BROWN HILL KESWICK CREEK CATCHMENT

STORMWATER MANAGEMENT PLAN 2016

MARCH 2016

THE CITIES OF ADELAIDE, BURNSIDE, MITCHAM, UNLEY AND WEST TORRENS

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Cover Photo: Ridge Park flood control dam – biofiltration basin and water injection and extraction bore housing for the managed aquifer recharge facility

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ABBREVIATIONS

AAD	Average annual damages
ACWS	Adelaide Coastal Waters Study
ACWQIP	Adelaide Coastal Water Quality Improvement Plan
AMLRNRMB	Adelaide and Mount Lofty Ranges Natural Resources Management Board
ANCOLD	Australian National Committee on Large Dams
ANZECC	Australian and New Zealand Environment Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AR&R	Australian Rainfall and Runoff
ARI	Average recurrence interval
ASR	Aquifer storage and recovery
AWE	Australian Water Environments
BCA	Benefit cost analysis
BCR	Benefit cost ratio
BHC	Brown Hill Creek (see note below)
BHKC	Brown Hill Keswick Creek
BHKC project	Brown Hill Keswick Creek Stormwater Project
BOD	Biological oxygen demand
BOM	Bureau of Meteorology
CDOM	Coloured dissolved organic matter
COD	Chemical oxygen demand
DEWNR	Department of Environment, Water and Natural Resources
DPA	Development Plan Amendment
DPTI	Department of Planning, Transport and Infrastructure
DTM	Digital terrain model
EPA	Environment Protection Authority
GAP	Glenelg to Adelaide Parklands
GIS	Geospatial information system
GPT	Gross pollutant trap
HTC	Hydro Tasmania Consulting
IFD	Intensity- frequency-duration
LGA	Local Government Association

MAR	Managed aquifer and recharge
MFS	Maloney Field Services
ML	Megalitres
NRM	Natural Resources Management
OSD	On-site detention
PCWMB	Patawalonga Catchment Water Management Board
PMF	Probable maximum flood
RRR	Rainfall Runoff Routing
PV	Present value
RAHS	The Royal Agricultural & Horticultural Society of South Australia
RCC	Roller compacted concrete
SAPPL	South Australian Planning Policy Library
SES	State Emergency Services
SMA	Stormwater Management Authority
SMF	Stormwater Management Fund
SMP	Stormwater management plan
SOCKET	Save Our Creek Environs and Trees
SOSCAG	Save Our Streets Community Action Group
W&G	Wallbridge and Gilbert
WBCM	Wood Bromley Carruthers & Mitchell
WSUD	Water sensitive urban design
UniSA	University of South Australia
URPS	Urban and Regional Planning Solutions
W&G	Wallbridge & Gilbert

Note: It is recognised that the name Brownhill Creek is often used instead of Brown Hill Creek – the latter is generally used in this SMP except where the former is used in the name of an organisation, business or document (or in a similar context).

REFERENCE TO STREETS AND ROADS

The content of Sections 11 and 12 of this SMP are mostly taken unchanged from the Part B Report (referred to in the Executive Summary and Section 7.4) in which the following street and road locations are referred to generally without reference to the suburb.

Angas Road	Hawthorn	Grove Street	Unley Park
Anzac Highway	Ashford	Hampton Street	Unley Park
Arundel Avenue	Millswood	Heywood Avenue	Unley Park
Avenue Street	Millswood	Hilda Terrace	Hawthorn
Ayr Avenue	Torrens Park	Jervois Street	Hawthorn
Belair Road	Hawthorn	Kent Street	Hawthorn
Charles Street	Forestville	King William Road	Unley
Chelmsford Avenue	Millswood	Leah Street	Forestville
Clifton Street	Millswood	Malcolm Street	Millswood
Cranbrook Avenue	Millswood	Mitchell Street	Millswood
Cross Road	Unley Pk. / Hawthorn	Muggs Hill Road	Torrens Park
Devon Street	Goodwood	Northgate Street	Unley Park
Devonshire Street	Hawthorn	Oakley Avenue	Millswood
Douglas Street	Millswood	Regent Street	Millswood
Ethel Street	Forestville	Unley Road	Unley
Fife Avenue	Torrens Park	Vardon Terrace	Millswood
Fisher Street	Fullarton	Victoria Street	Goodwood
Foster Street	Forestville	Windsor Street	Unley
George Street	Hawthorn	Wood Street	Millswood
Goodwood Road	Goodwood	Wurilba Avenue	Hawthorn

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Contributions by the following organisations to project investigations and the preparation of this stormwater management plan are acknowledged:

- Department of Planning, Transport and Infrastructure for hydrologic modelling (Section 8.2) and participation in the project Technical Group (Section 1.3.2)
- WorleyParsons for hydraulic modelling and analysis and resulting flood plain mapping (based on a floodplain model developed by others and upgraded by WorleyParsons), including flood damages and economic assessments (Sections 8, 9, 16.2 and 16.3)
- SMEC for concept designs of dams at Ridge Park and upper Brown Hill Creek (Sections 10.6 and 11.3.1)
- Maloney Field Services for easement and land acquisition costs and advice in relation to community concerns (Section 15.3.7)
- Kym Kelly for legislative advice regarding creek ownership and responsibilities (Section 12.3.2)
- Costplan for cost estimating based on feasible construction systems and practices (Sections 10.1, 11.3.1 and 15.2)
- The Adelaide and Mount Lofty Ranges Natural Resources Management Board for input on SMP objectives (Section 3.3), stormwater harvesting (Section 14.2), and advice regarding creek rehabilitation and maintenance (Section 12.3)
- Southfront for input on water quality (Section 14.1)
- Australian Water Environments for obtaining creek data to input the hydraulic modelling and miscellaneous advice regarding creek management (Sections 7.2, 7.4.1, 8.3, 8.5 and 8.6)
- Treevolution for arboreal advice in relation to Ridge Park flood control dam and potentially impacted trees along culvert routes (Section 11.6.2)
- Wallbridge and Gilbert on design and construction methodology for culvert crossing of Cross Road (Section 11.4.1)
- Civil Surveys and Design for engineering surveying along sections of upper Brown Hill Creek (Section 11.1.3)
- Tonkin Consulting for investigations and reporting of engineering concepts for the South Park Lands detention basins, upgrading of lower Brown Hill Creek and the Keswick Creek diversions (Sections 10.2, 10.3 and 10.4).
- URPS for advice in community engagement and consultation, and conduct of community consultation processes (Section 18)
- Natalie Fuller for advice and assistance in community engagement and consultation (Section 18)
- Parsons Brinckerhoff for risk assessment advice (Section 17.1)

Section 7.4.4 also summarises contributions by most of the above service providers to technical investigations of the Part B process of this SMP.

It is recognised that WorleyParsons has also used the trading name Advisian since 2015.

Stormwater flow in Glen Osmond Creek

EXECUTIVE SUMMARY

INTRODUCTION

The Brown Hill Keswick Creek (BHKC) Stormwater Project is a collaborative effort between the catchment councils of Adelaide, Burnside, Mitcham, Unley and West Torrens to mitigate significant flood risks and help safeguard properties across the catchment of Brown Hill and Keswick Creeks.

This document represents the Final stormwater management plan (SMP) for the four major watercourses in the Brown Hill Keswick Creek catchment (Brown Hill, Keswick, Glen Osmond and Parklands Creeks). It builds on the 2012 SMP (gazetted as the SMP in 2013) which, with the exception of flood mitigation works on upper Brown Hill Creek, was largely based on the 2006 Master Plan for the catchment (gazetted as the SMP in 2008).

The main objective of the Final SMP (as termed in the 2012 SMP) as well as the previous SMPs is to mitigate the risk and reduce the impact of major flooding from the four major watercourses on properties within the BHKC catchment, up to and including a 100 year average recurrence interval (ARI) flood. A 100 year ARI flood is also referred to as a 1 in 100 year event, and has a 1% chance of occurring in any given year. Other objectives are concerned with quality of runoff and effect on receiving waters, beneficial reuse of stormwater and effective complementary planning requirements.

The 2012 SMP groups works into two parts and includes a strategy which essentially comprises:

- Implementation of agreed Part A Works: Works to mitigate flooding generated from the mainly urban sub-catchments of lower Brown Hill Creek (downstream of Anzac Highway), Keswick Creek, Glen Osmond Creek and Parklands Creek; and
- A process to investigate and determine Part B Works (Part B process): Works to mitigate flooding from the upper Brown Hill Creek (upstream of Anzac Highway)

The strategy requires the catchment councils to consolidate the Part B outcomes, the Part A Works and other flood mitigation measures of the 2012 SMP into a whole of catchment (major watercourse) 'Final SMP'. This SMP of 2016 ('2016 SMP') is the result.

The strategy also reiterates the councils' recognition of community opposition at the time to a dam in the upper reaches of Brown Hill Creek and preference to pursue a feasible and whole of catchment community supported 'no dam' solution. Notwithstanding the councils' position, the Stormwater Management Authority (SMA), as a condition of its funding assistance, required dam options to be considered.

The Part B Report, publicly released in September 2014, summarises the Part B process. Following the favourable result of community consultation on the report conducted in May and June of 2015, the five catchment councils endorsed the recommended Part B Works for upper Brown Hill Creek in September 2015.

EXISTING FLOOD RISK

The catchments of both Brown Hill and Keswick Creeks arise on the western slopes of the Mount Lofty Ranges and flow westwards across inner south-eastern and western suburbs of Adelaide before discharging to the sea through the Barcoo Outlet (low flows) or the Patawalonga Lake outfall (high flows).

A majority of the Brown Hill Creek catchment consists of rural land in the Hills Face Zone, and storms that cause major flooding along Brown Hill Creek involve long periods of rainfall with relatively low intensity. Keswick Creek catchment (which includes Glen Osmond and Parklands Creeks) has a much greater proportion of urban and impervious area which contributes to increased runoff. Typically, short duration storms with intense rainfall cause flooding problems along Keswick Creek.

Urban infill development is resulting in increase of impervious area in urban catchments and, unless controls are introduced, will significantly increase the volumes and peak discharges of stormwater into the major watercourses over coming years.

A measure of the existing flood risk (without the benefit of Ridge Park flood control dam completed in 2015) is the number of properties in the catchment that would be affected by flooding from the major watercourses in the event of a major storm, as shown in the following table.

Table 1: Impacts of flooding for existing (base case) conditions

Design flood	Number of flood affected properties			Damages ($'000)
	Over-floor flooding	Under-floor flooding	Total	
10 year ARI	58	81	139	4,823
20 year ARI	158	239	397	10,622
50 year ARI	550	616	1,166	44,956
100 year ARI	1,172	917	2,089	122,220
500 year ARI	4,992	1,801	6,793	434,358
PMF*	Property data at this level could not be modelled			1,000,000

* Probable maximum flood (PMF)

PART A WORKS

The Part A Works are designed to mitigate flooding generated over the mainly urban sub-catchment of lower Brown Hill and Keswick Creeks through a combination of stormwater flow detention, diversion of high flows and watercourse upgrading for greater flow capacity. The Part A projects are:

- South Park Lands / Glenside detention basins (on Parklands Creek)
- Lower Brown Hill Creek capacity upgrade
- Flow diversions from Keswick Creek to Brown Hill Creek

- Brown Hill Creek upgrade between Forestville Reserve and Anzac Highway (also designated as Area 1 of upper Brown Hill Creek / Part B process)
- Ridge Park flood control dam (on Glen Osmond Creek) – constructed in 2015
- Brown Hill Creek diversion culvert at Goodwood railway junction – constructed in 2013 by the Department of Planning, Transport and Infrastructure (DPTI)
- Glen Osmond Creek minor upgrade works
- Mount Osmond interchange dam modification – constructed in 2008

The two largest and most significant projects in terms of cost and flood mitigation benefit are the above listed lower Brown Hill Creek upgrade and the flow diversions from Keswick Creek. The lower Brown Hill Creek upgrade caters for the combination of stormwater flow from upper Brown Hill Creek and flow diverted from Keswick Creek. The design rationale is that diverting some of Keswick Creek at times of high flow will mitigate the significant risk of flooding along Keswick Creek, particularly in the western suburbs of the catchment.

PART B PROCESS AND WORKS

Compared with the earlier investigations, the Part B investigation process benefited from:

- revised intensity-frequency-duration (IFD) rainfall data released in mid-2013 by the Bureau of Meteorology (BOM) and updated runoff estimates (hydrologic modelling);
- upgraded hydraulic modelling and floodplain mapping showing the extent and depth of stormwater inundation beyond the watercourse; and
- updated project cost estimates based on the revised technical information.

For the Part B Works, eight flood mitigation options were assessed which differed in how they combine three components: A detention dam (at one of two alternative sites); high flow bypass culverts; and creek capacity upgrade works (including bridge upgrade works).

In addition to those components, all of the Part B options included undertaking rehabilitation works along the full length of upper Brown Hill Creek towards achieving a state of 'good condition'. All eight options would provide approximately the same level of flood protection for the 100 year ARI storm.

Three of the eight flood mitigation options were short-listed on the basis of technical viability and estimated cost. These three options, which involved a detention dam and/or creek capacity upgrade works, were compared in detail. The remaining five options, which involved bypass culverts, were not investigated to the same extent as the short-listed ones as initial work undertaken in the Part B process indicated that they would be too costly.

Of the eight options, the five catchment councils endorsed a flood mitigation option referred to as Option D. This involves upgrading critical sections of upper Brown Hill Creek over 1.9 km of its total length of approximately 7 km, including critical bridges, to give the creek sufficient capacity to contain the peak flow of the 100 year ARI storm. Key factors in favour of Option D are:

- it has the lowest capital cost ($35.5 million) by a margin of about $5 million; the lowest annual maintenance cost and the lowest present value whole of life cost;
- for shorter duration storms it provides a higher than 100 year ARI level of flood protection;

- it satisfies the catchment councils' endorsed position to give preference to a feasible 'no dam' solution; and
- it does not require bypass culverts in suburban streets.

From an economic perspective all three options have an indicative benefit cost ratio (BCR) in the range of 0.3 to 0.4.

REHABILITATING UPPER BROWN HILL CREEK TO 'GOOD CONDITION'

Although maintenance of upper Brown Hill Creek is the property owners' responsibility, it is proposed that the BHKC project, in collaboration with creek property owners and the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB), will undertake:

- a 'one off' extraordinary creek maintenance to rehabilitate upper Brown Hill Creek towards achieving good condition, thereby assisting flow capacity for flood mitigation and improving the creek environment and geomorphology; and
- planned maintenance periodically through the life of the scheme, aimed at maintaining the creek in good condition after the initial one-off extraordinary creek maintenance is undertaken. This would typically include erosion control, bank stabilisation and clearance of major obstructive material.

Creek owners would still be responsible to undertake regular general site maintenance such as weed spraying and unplanned maintenance such as removal from the creek of fallen timber and objects which might cause flow blockages and consequent flooding.

FLOOD PROTECTION OUTCOMES

Floodplain mapping based on implementation of all the SMP flood mitigation works (mitigation case) compared with the existing conditions (base case) shows that the proposed works will reduce the number of properties affected by major watercourse flooding in the 100 year ARI event by over 98% (from 2,089 to 31). For properties subject to over-floor flooding, the reduction is almost 100% (from 1,172 to 6). The small number of properties still affected by flooding following implementation of the structural flood mitigation works of the SMP is shown in the following Table 27: Properties affected by flooding for mitigation case.

Design flood	Number of flood affected properties			Damages ($'000)
	Over-flood flooding	Under-floor flooding	Total	
10 year ARI	0	0	0	0
20 year ARI	0	0	0	0
50 year ARI	3	13	16	398
100 year ARI	6	25	31	814
500 year ARI	2,129	2,988	5,117	181,724
PMF	Data unavailable			1,000,000

Other measures which should assist (albeit to a small extent for major storms) in mitigating the impacts of stormwater runoff include water sensitive urban design (WSUD) and on-site detention (OSD) systems. These measures are being incorporated in strategies and implemented progressively by all the catchment councils.

In the review of planning policies, councils are forming Development Plans that are in accordance with the South Australian Planning Policy Library (SAPPL) in respect of flood risk reduction and which seek to ensure that new development does not reduce the capacity or functionality of the existing stormwater drainage network. Key elements include:

- planning policy measures which seek to limit stormwater discharge from new developments to predevelopment volumes and peak rates of discharge; and
- prohibition of new developments that would obstruct or interfere with a watercourse or is at high risk of flooding.

Informing people about the flooding risks they and their properties could be exposed to enables them to reduce their vulnerability to and increase their resilience against flood damage. It is therefore recommended that the State Emergency Services (SES) and the catchment councils continue to conduct the existing FloodSafe Program.

The SES in late 2015 carried out market research along the environs of Brown Hill Creek to survey property owners and businesses regarding levels of flood risk awareness and response preparedness, including flood insurance cover. The survey may serve to prompt further initiatives (at state or local government level with SES coordination) to complement any existing flood and storm response plans that are currently in use by the catchment councils.

MULTI-PURPOSE OUTCOMES

The SMP outlines measures for reducing adverse impacts of stormwater discharge to the environment, including marine receiving waters. Measures include installations such as gross pollutant traps (GPTs), trash racks and sedimentation basins. Currently, a large majority of the approximately 400 GPTs across the AMLRNRMB region are managed by local government councils.

The AMLRNRMB has identified the need for more GPTs across the BHKC catchment and actions to improve existing GPTs. The SMP provides an opportunity for catchment councils, through the BHKC project, to take a coordinated and collaborative approach to the management and maintenance of GPTs along the major watercourses of the BHKC catchment, including the installation of new GPTs (with AMLRNRMB funding assistance), in order to further reduce adverse impacts of stormwater quality on the environment.

Under the BHKC project, measures for improving quality aspects of stormwater include the stormwater detention facilities of Ridge Park dam and the proposed South Park Lands / Glenside detention basins. The proposed rehabilitation of upper Brown Hill Creek, as part of the Part B Works solution, would also improve the environmental and ecological condition of the creek.

Efforts have been made over the years to identify opportunities to include stormwater harvesting and reuse in flood management plans and a number of schemes have been identified that are complementary to flood mitigation, although their role in flood mitigation is minimal. Seven schemes, generating from 7 to 300 ML per year of reuse water have been implemented in the BHKC catchment. It is estimated that currently about 12% of flows (or about 16% of urban runoff) in the four major watercourses are or will be harvested for reuse applications.

FINANCIAL AND ECONOMIC ASSESSMENT

The following Table 34: Total estimated costs summarises estimated design and construction costs of proposed infrastructure of the SMP. The table compares the current estimated costs with estimated costs of the 2012 SMP (with the least cost Part B option). The table also shows the Part B estimated costs as reported in the Part B Report increased by 1.1% for cost escalation to current (2015/16) values. For Ridge Park dam and the DPTI culvert, final BHKC project costs are shown.

($'million)	Full BHKC project		Upper BHC	Upper BHC
	2012 SMP (dam option)	Current (2015/16)	Current (2015/16)	Part B Report [5]
Part A projects:-				
Ridge Park dam	1.1	2.8		
South Park Lands basins	17.6	17.4		
Diversions from Keswick Creek	31.9	43.1		
Lower BHC upgrade	49.1	39.1		
Glen Osmond Creek works [4]	4.5	0.8		
Forestville – Anzac Highway [1]	14.9	8.0	8.0	7.9
Part A sub-total	119.1	111.2	8.0	7.9
DPTI culvert	(Note 2)	5.0	5.0	5.0
Part B (excluding DPTI culvert)	28.5	22.8	22.8	22.6
TOTAL – flood mitigation works	147.6 [3]	139.0	35.8	35.5
Water quality works (GPTs)	0	1.0		
TOTAL – including GPTs		140.0		

Notes:

1. Identified as Area 1 in the Part B process / included as a component of Part A Works in the 2012 SMP
2. DPTI culvert built after the 2012 SMP was prepared
3. Other 2012 SMP options had estimated costs of $151 million and $154 million
4. Identified as 'Fisher Street bypass' in the 2012 SMP
5. Values of mid-2014

In the following Table 43: Summary of BCR for catchment-wide works (6% real discount rate) the benefit cost analysis (BCA) is presented in terms of upper and lower bound results to reflect a wide range of estimated flood damages for Adelaide Airport. The upper bound analysis (base case 1) uses the airport flood damages estimate of the 2012 SMP; whereas the lower bound analysis (base case 2) adopts a lower nominal estimate. The BCA includes estimated management and maintenance costs which rise progressively to about $500,000 per year after the full SMP works are constructed.

Table 43: Summary of BCR for catchment-wide works (6% real discount rate)

	Base case 1	Mitigation case 1	Base case 2	Mitigation case 2
AAD	$8.066 M	$2.130 M	$5.960 M	$1.924 M
PV benefits		$49.296 M		$33.528 M
PV costs		$98.369 M		$98.369 M
BCR		0.50		0.34
Net PV		-$49.073 M		-$64.841 M

AAD: Average annual damages

PV: Present value

BCR: Benefit cost ratio

COMMUNITY CONSULTATION

Stakeholder engagement and community consultation have been carried out at all stages of the BHKC project: 2006 Master Plan; Investigations 2008-1010; 2011 Draft SMP (formal consultation in November 2011): 2012 SMP (general consultation in 2013-2014); and the Part B process / Part B Report (general consultation in 2014-2015 and formal consultation in May/June 2015).

In relation to the recent formal consultation processes:

2011 Draft SMP: Overall there was general recognition of the importance of undertaking flood mitigation works to reduce the impacts of flooding across the catchment and support for the Draft Plan. Community feedback indicated high levels of support for all infrastructure components of the Draft Plan, with the exception of the proposed flood control dam at Brown Hill Creek for which there were both lower and more variable levels of support from respondents across the councils. During the process a 'no dam' petition of about 4,000 signatures was mobilised (it eventually reached over 11,000 signatures by May 2015).

Part B Report: The level of support for the preferred creek capacity upgrade works option varied markedly between creek property owners and members of the wider community, with creek property owners equally divided in their support or opposition, compared with overwhelming support (90%) by members of the wider community. Aggregating results, 85% of respondents favoured the preferred option.

IMPLEMENTATION AND FUNDING ARRANGEMENTS

In recognising that all spheres of government have an interest in reducing flood risk, the SMP reflects principles of cooperation and cost sharing in respect of implementation responsibilities.

The councils are proposing to establish a regional subsidiary in terms of the Local Government Act as the vehicle to meet their responsibilities under the SMP. Work has commenced on preparation of a charter which will be the basis of the legal agreement between the councils for operation of the regional subsidiary.

The regional subsidiary, working in partnership with or with the support of state government agencies, would be responsible for governance of the BHKC project, management of the SMP, and design, construction, operation and maintenance of SMP flood mitigation infrastructure.

The councils' preferred funding model for construction of the works is based on each sphere of government (Commonwealth, state and local) contributing a one third share of the overall project construction (capital) cost. The project councils will meet the ongoing management, maintenance and finance costs. The councils have agreed on cost apportionments between themselves in respect of the local government share of the overall project costs (construction, maintenance and administration).

The SMP flood mitigation works are proposed to be constructed over a 10-year program in accordance with the following order:

1st priority	South Park Lands / Glenside detention basins
2nd priority	Lower Brown Hill Creek upgrade Flow diversions – Keswick to Brown Hill Creeks
3rd priority	Brown Hill Creek upgrade – Area 1 of upper Brown Hill Creek
4th priority	Upper Brown Hill Creek – capacity upgrade works Upper Brown Hill Creek rehabilitation Glen Osmond Creek works

1. INTRODUCTION

1.1 FOREWORD

This Stormwater Management Plan (SMP) covers the four major watercourses in the Brown Hill and Keswick Creeks catchments. The combined catchment is referred to in the SMP as the Brown Hill Keswick Creek (BHKC) catchment. This SMP does not cover the various urban drainage systems that convey stormwater into the four major watercourses in the urban area.

The four major watercourses are: Brown Hill Creek (the most significant, particularly in terms of the potential volume of stormwater flow conveyance), Keswick Creek, and tributaries of Keswick Creek being Glen Osmond Creek and Parklands Creek. Collectively, Keswick, Parklands and Glen Osmond Creeks are referred to as Keswick Creek catchment. The catchments vary considerably from highly urbanised in the middle and downstream sections to predominantly rural in nature in the upper reaches of Brown Hill and Glen Osmond Creeks.

The combined Brown Hill and Keswick Creeks catchment is contained within the local government areas of Adelaide, Burnside, Mitcham, Unley and West Torrens (the ‘catchment councils’). A small part of the catchment also falls in the Adelaide Hills Council area, but for purposes of the SMP it is not included as one of the councils having catchment responsibilities.

The primary aim of the SMP, prepared in accordance with the Stormwater Management Planning Guidelines (July 2007) of the Stormwater Management Authority (SMA), is to recommend flood mitigation works and stormwater management strategies that will reduce the impact of flooding from the four creeks in the urban floodplain of the catchment and provide additional benefits where possible.

This SMP builds on previous SMPs – the 2006 Master Plan and the 2012 SMP, as outlined below and discussed further in Section 2:

- In 2006 a flood management report (‘2006 Master Plan’) was produced by lead consultant Hydro Tasmania Consulting (HTC) for the then Patawalonga Catchment Water Management Board (PCWMB). In 2008 the Stormwater Management Authority (SMA) conditionally approved the 2006 Master Plan as the SMP for the BHKC catchment. However, due to subsequent concerns about aspects of the 2006 Master Plan, particularly in respect of proposed flood control dams in the upper reaches of Brown Hill Creek, the catchment councils and the SMA agreed to prepare a revised SMP.
- The catchment councils subsequently developed the 2012 SMP as an update to the 2006 Master Plan. It was approved by the SMA and subsequently gazetted in March 2013. The 2012 SMP grouped works into two parts: Part A which specified endorsed works (comprising approximately 80% of the total SMP works) and Part B which specified a process for further work (‘Part B process’) to determine flood mitigation measures for upper Brown Hill Creek.

This SMP of 2016 presents a complete SMP for the major watercourses in the BHKC catchment, reporting on Part A Works as well as the outcomes of the Part B process and Part B Works endorsed by the catchment councils in September 2015. Development of this SMP based on the 2012 SMP is discussed in Section 7.

1.2 HISTORICAL CONTEXT

Brown Hill, Keswick, Parklands and Glen Osmond Creeks have a history of flooding and a low standard of flood protection, and therefore a relatively high flood risk. While widespread flooding has not occurred since the 1930s, there have been a number of times when flooding has threatened parts of the catchment; the most recent significant event being in November 2005 when flooding occurred along Brown Hill Creek in Mitcham and Unley due to heavy rains in the upper (rural) area of the Brown Hill Creek catchment.

Large scale channel improvement works were conducted by the State Government in the mid-1930s under the authority of the Metropolitan Drainage Act 1935. This work was confined to the lower reaches of Brown Hill and Keswick Creeks and followed major floods that occurred in 1925 and 1930. In the 1950s, as part of Adelaide Airport development works, Brown Hill and Keswick Creeks were relocated to their present alignments on the eastern and southern side of the airport.

Due to rapid post second world war development of the western suburbs, flooding remained a major issue. Since the 1950s, works to reduce the impact of flooding have largely been undertaken on an individual council basis, such as the Glenside detention basin and the Urrbrae wetlands.

As outlined in Section 2.1, a number of catchment-wide flood mitigation studies have been undertaken and a range of potential mitigation schemes have been considered. However, attempts to initiate and coordinate catchment-wide works were largely unsuccessful in the past because agreement could not be reached between the various catchment councils on the extent of the problem, works proposed, or cost sharing arrangements.

A notable exception was the installation of flood warning instrumentation for Brown Hill Creek and the lower reaches of Keswick Creek by the Bureau of Meteorology (BOM) and catchment councils during the 1990s with assistance from the State Government. More recently, the catchment councils' endorsement of the 2012 SMP has enabled Part A works to commence as discussed in Section 7.

1.3 GOVERNANCE

1.3.1 Stormwater Management Authority

In 2005 the State Government and the Local Government Association (LGA) released the Urban Stormwater Policy for South Australia. In 2006 they entered into the Stormwater Management Agreement which sets out the roles and responsibilities of state and local government and provides governance arrangements for stormwater management on a catchment basis throughout the state.

A key element of strategies described in the Urban Stormwater Management Policy is the development of stormwater management plans for catchments to ensure that stormwater management is addressed on a total catchment basis with the relevant Natural Resources Management (NRM) Board, local government authorities and relevant state government agencies working together.

The SMA was established in 2007 under the Local Government Act 1999 and is responsible for the operation of the Stormwater Management Agreement. The SMA has issued the Stormwater Management Planning Guidelines to provide a template for consistent management of stormwater through multi-objective planning, including reuse where feasible.

1.3.2 Brown Hill Keswick Creek Stormwater Project

In 2007 the five catchment councils took over responsibility for implementing the 2006 Master Plan and established the Brown Hill Keswick Creek Stormwater Project (BHKC project) for that purpose. The BHKC project is therefore a collaborative effort between the catchment councils to mitigate serious flood risks from the four major watercourses and help safeguard properties across the catchment of Brown Hill and Keswick Creeks.

Governance of the BHKC project is exercised through a Steering Group which includes the Chief Executives of the five catchment councils or delegates. A Memorandum of Agreement dated December 2008 provides terms of reference for the conduct of the project. Technical investigations are overseen by a Technical Group which includes a representative from each of the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB), Department of Planning, Transport and Infrastructure (DPTI) – as technical representative for the SMA, and the five councils.

1.4 LIMITATIONS

Flood mitigation works and other management measures proposed as part of this SMP have been generally developed to a level of detail suitable for concept planning and preliminary costing only. Subject to approval by the SMA and gazettal of this SMP, further concept designs will be prepared to define the proposed works in more detail, which may include investigation of technical and other aspects such as environmental, social and cultural heritage impacts. Those concept designs will then inform the detailed designs and documentation for the construction of works.

As the majority of the flood risk in the catchment is from flooding from the four major watercourses and as the 2006 Master Plan predates the formation of the SMA and the Stormwater Management Planning Guidelines, subsequent SMPs for the catchment including this one have continued to concentrate on this issue. It is recognised that at some stage another SMP is required that examines in more detail the urban drainage systems that convey stormwater runoff to the four major watercourses. It is considered that the design flows that have been identified in this SMP take sufficient account of the possibility that the urban drainage systems may be upgraded in the future.

2. BACKGROUND

This section summarises relevant studies undertaken prior to the 2006 Master Plan, the 2006 Master Plan and the 2012 SMP.

2.1 EARLIER STUDIES

Work in 1971 by consultants BC Tonkin and Associates identified a number of opportunities and barriers associated with reducing flooding in the catchment. They recommended a number of initiatives which included works and securing sections of watercourse into public ownership or the creation of easements. However, most of the recommendations were not implemented.

In the early 1980s, Wood Bromley Carruthers & Mitchell (WBCM) reported on the extent of flood risk from the four major watercourses and a preliminary flood mitigation strategy for the catchment, using computer modelling techniques unavailable in 1971, but further detailed investigations were not followed up.

In 2001, further investigations, this time involving the preparation of detailed floodplain inundation mapping and a comprehensive flood damages estimate for the first time, were undertaken by HTC for the PCWMB. That work was reported in the 2003 Floodplain Mapping Study.

2.2 2006 MASTER PLAN

Following its earlier work on the Floodplain Mapping Study, HTC, in association with Australian Water Environments (AWE), QED and the SA Centre for Economic Studies was appointed by the AMLRNRMB to undertake a flood mitigation study for the BHKC catchment.

The study was carried out in three stages. The first stage was documented in the Flood Mitigation Study for Brown Hill and Keswick Creeks Stage 1 Technical Report (2005). Stage 2 involved stakeholder and community consultation (discussed in Section 18.1) and Stage 3 was preparation of the 2006 Master Plan.

As part of the technical investigations:

- Hydrologic modelling of the catchment was undertaken by Dr David Kemp of DPTI using the Rainfall Runoff Routing (RRR) model. The hydrologic modelling was based on a projected 30 year catchment condition in which established trends in urban consolidation were expected to continue.
- Two dimensional floodplain modelling using the proprietary software system MIKE-FLOOD was completed in Stage 3 of the study to verify the effectiveness of the proposed flood mitigation works and enable flood damages (and avoided damages) to be estimated. The same hydraulic model had been used for previous floodplain mapping studies in 2001 to 2003.
- The watercourses were divided into approximately 30 reaches with similar characteristics which allowed catchment-wide flooding to be assessed on a larger scale.

Over 300 potential opportunities for flood mitigation works were identified in the study. These were checked for their technical and economic viability, which resulted in a short-list of around 80 viable options which could contribute to flood mitigation to varying degrees across the catchment.

While the primary focus was flood risk management, opportunities to include multi-purpose benefits were also identified. Those benefits included stormwater reuse, water quality improvements, improvements in biodiversity, passive recreational opportunities and improved amenity.

A multi-criteria analysis technique was used to rank the 80 options. The criteria were:

- expected cost of works;
- flooding reduction within the reach;
- flooding reduction across the catchment;
- potential for increasing open space and recreation opportunities;
- potential for improving water quality and providing reuse opportunities;
- opportunity to improve biodiversity; and
- degree of 'at source' management.

The process resulted in a further short-listing and combining of options resulting in about 20 works projects, which were evaluated in more detail by reviewing their expected costs and estimating the contribution they made individually to reducing flood damages and flood hazards.

The following short-listed projects were recommended in the 2006 Master Plan:

- Upgrade of Fullarton Road / Greenhill Road culvert (Parklands Creek)
- Series of detention basins in the South Park Lands (Parklands Creek)
- Modification of the Mount Osmond interchange dam outlet (Glen Osmond Creek)
- Inline flood detention system in Ridge Park Reserve (Glen Osmond Creek)
- Upgrade of culverts under Fisher Street (Glen Osmond Creek)
- 'Goodwood Road diversion culvert' from Keswick Creek to Brown Hill Creek
- 'Railway diversion culvert' from Keswick Creek to Brown Hill Creek
- Two flood control dams in the upper rural portion of the Brown Hill Creek catchment
- Brown Hill Creek channel upgrade between Hampton Street and Cross Road
- Upgrade of Brown Hill Creek channel downstream from Anzac Highway to the confluence with Keswick Creek.

The location of each of these works is shown in the map provided in Figure 1 (sourced from the 2006 Master Plan).

The 2006 Master Plan also incorporated non-structural management options, including community awareness and flood preparedness as well as improved planning policy involving the enhancement of development plans and assessment criteria.

A feasibility study of the two flood control dams in the upper reaches of Brown Hill Creek was undertaken by Gutteridge Haskins & Davey (report of October 2008) as a first stage in the design process (i.e. prior to undertaking detailed site investigations and detailed design as subsequent stages).

2.3 2012 STORMWATER MANAGEMENT PLAN

In 2010, the BHKC project engaged engineering consultant WorleyParsons to revise the 2006 Master Plan as the SMP for the catchment. The revision was required to meet the SMA Stormwater Management Planning Guidelines (specifically in relation to stormwater harvesting) and to reconsider the construction of flood control dams on Brown Hill Creek as proposed in the 2006 Master Plan.

WorleyParsons produced a report in August 2011 (the '2011 Draft SMP'), and community consultation was carried out on the 2011 Draft SMP in November 2011 (refer Section 18.3).

After further investigations and reporting in 2012, WorleyParsons produced a consolidated report, the 'Brown Hill Keswick Creek Stormwater Project Stormwater Management Plan 2012'. This was subsequently approved by the SMA as the SMP in February 2013 and gazetted on 5 March 2013; and is referred to as the 2012 SMP.

The 2012 SMP groups works into two Parts:

- Part A Works – designed to mitigate flooding generated from the mainly urban sub-catchments of lower Brown Hill Creek (downstream of Anzac Highway), Keswick Creek, Glen Osmond Creek and Parklands Creek
- Part B Works – designed to provide flood mitigation in the upper Brown Hill Creek catchment (upstream of Anzac Highway)

Development of this 'Final SMP' based on the 2012 SMP is discussed in Section 7.

2.4 STORMWATER PLANNING STRATEGY (SA GOVERNMENT)

In July 2011, the Government of South Australia released the 'Stormwater Strategy – The Future of Stormwater Management' which it says provides a 'road map' for future stormwater management in the state.

The Strategy, in referring to a changing climate in parts of southern Australia, warns that more intense and regular storms increase the potential for:

- more severe flooding, with consequent safety, economic and property impacts;
- a decrease in water quality within both watercourses and receiving waters (for example, Gulf St Vincent);
- channel erosion and increased sedimentation in watercourses;
- loss of vegetation through erosion and replacement by invasive species, and
- a reduction in the health of aquatic habitats, in both watercourses and receiving waters.

Key components of the Strategy which are relevant to this SMP include:

- transitioning Adelaide to a water sensitive city – the vision, in this context includes mandating in new developments sustainable water management features at an on-site, precinct and catchment scale (retrofitting, where possible, existing urban areas with water sensitive facilities);
- achieving targets for stormwater harvesting, where economically and technically feasible;

- addressing flood risk in existing and future developments and ensuring the state's planning system includes minimum risk standards for all types of developments;
- improving the management of flood risk by investing in flood preparedness, ensuring people are informed at the time of property purchase and evaluating adequate insurance cover; and
- recognising that, as watercourses often pass through private land, designing, implementing and managing appropriate flood mitigation measures can be problematic as private land is not always accessible for such purposes and ongoing responsibility for maintenance of watercourses on privately owned land has therefore been an issue.

3. STORMWATER MANAGEMENT OBJECTIVES

3.1 SMA PLANNING GUIDELINES

The SMP has been developed in accordance with the SMA Stormwater Management Planning Guidelines which specify the scope of content and process for preparation of SMPs in general. In particular, the following principles have been applied in developing the SMP:

- Development and implementation of the SMP and its objectives must ensure a 'whole of catchment' approach is achieved.
- Agreement should be gained from the relevant NRM board on the catchment area to be covered by the SMP.
- The objectives should provide measurable goals for the management of stormwater in the catchment.
- A coordinated and multi-objective strategy involving studies, works and any other actions is to be described in the SMP.
- Costs, benefits and funding arrangements for achieving the objectives are to be set out in the SMP. Benefits should include qualitative factors, including environmental improvements, as well as quantified benefits of reduced flood damage and stormwater use.
- Actions and strategies identified in the SMP should be prioritised and set out in a program of no more than a 10 year planning horizon.
- Responsibilities for actions in the SMP are to be clearly identified.
- Staff and elected members of catchment councils, the community, the AMLRNRMB and other government agencies are to be consulted.
- SMPs will be 'living documents' that are subject to periodic review to take account of current knowledge, changing conditions within the catchment and changing community attitudes to the management of stormwater and other water resources.

3.2 VISION

Regarding stormwater management, the Cities of Adelaide, Burnside Mitcham, Unley and West Torrens have a vision of becoming 'water sensitive cities' – by minimising flooding and harnessing the potential of stormwater to overcome water shortages, improve waterway health, enhance city landscapes and be utilised as a valuable community resource.

The vision is underpinned by the following six key objectives:

- Protection from flooding
- Quality of runoff and effect on receiving waters
- Beneficial reuse of stormwater runoff
- Protection of watercourses and riparian ecosystems
- Effective planning outcomes
- Management of stormwater infrastructure

The objectives are expanded in more detail below.

In developing the SMP a range of structural and non-structural flood mitigation measures have been considered. In addition to addressing stormwater management, these measures also seek to provide for multi-purpose benefits including passive recreation, pedestrian and cycle paths, water quality improvements, biodiversity improvements and stormwater reuse where practicable and economically and socially viable.

3.3 OBJECTIVES

In accordance with the Stormwater Management Planning Guidelines, a catchment-wide approach has been adopted to ensure that flood mitigation and stormwater management measures provide the most benefit across the entire catchment, irrespective of local government area boundaries.

3.3.1 Protection from flooding

The SMP seeks an acceptable level of protection from flooding for the community and its assets, both private and public. Major flooding is considered to be that resulting from a storm greater than a 10 year average recurrence interval (ARI) along the four major catchment watercourses, as distinct from localised flooding associated with the various stormwater drainage networks that feed into the major watercourses and which do not affect the wider community.

The four major watercourses form the backbone of what is referred to as the major drainage system. The major drainage system also includes roads, open spaces, other water courses and other overland flow routes which become engaged during a major storm when the capacity of the minor system (side entry pits and constructed underground drains) is exceeded.

The major system should be capable of preventing flooding that causes property damage or threatens people's safety except in very rare, extreme events. The minor system's primary function is to minimise nuisance flooding and ponding so as to allow properties to drain and to maintain the serviceability and safety of the road network.

In terms of the standard of protection that should be offered by the major system, it is considered that wherever possible this should be at least a 100 ARI year standard. The 100 year ARI is also referred to as a one in 100 year event, and is equivalent to a 1% chance of an event occurring in any year. There are numerous references in the existing Development Plans of each of the councils to reinforce the need for new development to be protected from the100 year ARI flood.

It is considered that a 1 in 5 year standard is an appropriate target standard for the minor system, noting that a lesser standard may well be acceptable when balanced against the cost to replace assets which still have a significant life ahead of them. While a 1 in 5 year standard may appear to be low, modelling and experience has shown that a minor system constructed to such a standard makes a significant contribution to limiting the extent of flows in the major system when more extreme events occur.

Both the minor drainage system and those parts of the major drainage system that are separate from Brown Hill, Keswick, Glen Osmond and Parklands Creeks, drain into the major creeks which, as the backbone, 'tie' the system together. As such there are numerous separate major and minor drainage systems across the catchment arranged in a fractal pattern typical of drainage systems. Those numerous separate major and minor systems, in terms of the SMA Stormwater Management Planning Guidelines, are outside the scope of this SMP and therefore have not been analysed or considered in respect of any specific objectives.

Objectives:

1.1 Provide an acceptable level of protection for the community and both private and public assets from flooding. Subject to economic justification, the objective is to provide a standard of flood protection equivalent to the 100 year ARI standard or better.

1.2 Enhance flood mitigation infrastructure with multi-purpose outcomes including visual, aesthetic and amenity improvements for the benefit of the wider community, where it is economically and socially feasible.

1.3 Provide flood forecasting and warnings and flood preparedness measures to help the community reduce any risk to life and residual damages to property during major flood events.

1.4 Ensure that new stormwater infrastructure does not increase the risk of flooding in downstream areas.

3.3.2 Quality of runoff and effect on receiving waters

The receiving water for stormwater runoff from the BHKC catchment is Gulf St Vincent at West Beach. The principal issues of concern for Adelaide coastal waters have been identified by the Environment Protection Authority (EPA) in its Adelaide Coastal Water Quality Improvement Plan (ACWQIP) as nutrient nitrogen, suspended solids and coloured dissolved organic matter (CDOM).

Targets in the ACWQIP for stormwater include a reduction from 2003 levels of 67% in nitrogen, 50% in suspended solids and a decrease in CDOM. The ACWQIP proposes that this issue be dealt with through the reuse of stormwater (noting the AMLRNRMB target of 75% reuse) and widespread adoption of water sensitive urban design (WSUD).

The EPA has also indicated that coastal waters would benefit from reduction in the number of runoff events. This could be achieved by providing retention devices at a regional, catchment-wide and allotment level throughout the catchment to capture the first 15 mm of smaller rainfall events. Options include rainwater tanks, rain gardens and under-driveway storage.

Secondary, but still important, issues associated with stormwater pollution include:

- pathogens that impact on recreational water quality;
- litter and debris that detracts from aesthetic qualities and contributes to CDOM; and
- toxicants (including pesticides) which must be kept away from stormwater.

Existing plans and policies provide support for programmes that lead to water quality improvements, particularly WSUD, street sweeping, enforcement of codes of practice and gross pollutant trap (GPT) construction and maintenance. Development Plans of councils also include objectives and principles which require that development does not contribute to pollution. These policies will be further strengthened with adoption of the South Australian Planning Policy Library (SAPPL) by all catchment councils.

Objective:

2.1. Stormwater discharged to the marine environment should meet targets that are set from time to time including targets in the EPA's ACWQIP.

3.3.3 Beneficial reuse of stormwater runoff

The AMLRNRMB's target for harvesting and reuse of stormwater is 75%. Considerable progress toward this target has already been achieved within the AMLRNRMB region, and there are further opportunities to utilise public open space to treat stormwater for aquifer storage. Increases in the price of mains water provide an incentive to encourage and increase reuse of stormwater runoff.

Larger scale opportunities include wetlands and stormwater harvesting schemes, including managed aquifer and recharge (MAR) schemes, for irrigation of large open spaces and other reuse applications. Options on a smaller scale include WSUD and on-site detention (OSD) techniques.

There are synergies between objectives for reuse and water quality, such as where WSUD techniques for water quality improvements for road runoff also provide water for street tree and streetscape improvement.

Objectives:

3.1. Maximise the reuse of stormwater for beneficial purposes including watering of community and private open spaces where feasible.

3.2. Where possible the drainage network should incorporate WSUD systems that aim to capture road runoff to replenish soil moisture for maintenance of street trees and plantings.

3.3. Encourage on-site use of stormwater by installation of rainwater tanks and detention and retention systems in order to minimise adverse runoff impacts of urban infill.

3.3.4 Protection of watercourse and riparian ecosystems

Stormwater runoff should be managed in a manner that protects and enhances biodiversity, sustainability and the natural environment.

Objectives:

4.1. Watercourses and creeks in public and private ownership should be managed to an acceptable standard.

4.2. Where practicable and economically feasible, watercourses should be preserved in as natural condition as possible and should be revegetated and managed to maximise their ecological and biodiversity values and functions and to minimise any potential for stream erosion.

4.3. Allow sufficient environmental flows to maintain water dependent ecosystems.

3.3.5 Effective planning outcomes

Land used for stormwater management purposes should be developed, where possible, to facilitate recreation use and to enhance amenity. Opportunities are generally associated with new development, open space and areas intended for recreation and amenity.

Floodplain mapping for the catchment shows that most flooding originating from overflows from the four major watercourses is less than 150 mm deep in the 100 year ARI storm. Water of this depth is less likely to cause above floor flooding (at which significant damages can occur). If flood prone allotments are redeveloped, this depth of water generally can be managed by setting floors at an appropriate level. Nevertheless, there are some areas in the floodplain where water depths are greater than 150 mm and flood mitigation works should be designed to mitigate major flood risk as far as possible up to the 100 year ARI flood event.

Urban infill development is resulting in increase of impervious area in urban catchments and will, unless controls are introduced, increase the volumes and peak discharges of stormwater significantly over the next 30 years. The need for source control must be addressed in order to achieve and maintain the required level of flood protection. Intensification of development is a feature of the BHKC catchment, as discussed in Section 4.3.

Objectives:

5.1. Open space should be utilised to achieve maximisation of permeable surfaces, on site retention and infiltration and stormwater reuse wherever possible.

5.2. All new development must be built at a level that ensures buildings are not subject to inundation in a 100 year ARI flood.

5.3. New development should be constructed so as not to cause an increase in 5 year ARI flow rates.

3.3.6 Management of stormwater infrastructure

Stormwater infrastructure should be managed and maintained on a sustainable basis. The cost of implementing flood mitigation works, including construction and ongoing operation and maintenance, needs to be spread across the community in a way that not only reflects the direct benefit to those who enjoy an increased level of protection, but also to those who already enjoy the benefit of the urban development that contributes to the quantity of stormwater flows.

Objectives:

6.1. Stormwater infrastructure is to be managed sustainably by development of asset management and other necessary plans for ongoing management, operation and maintenance of infrastructure.

6.2. A governance framework will be established based on having a single entity (nominally a regional subsidiary in terms of the Local Government Act) responsible for management of project infrastructure.

6.3. Financial budgeting and funding arrangements (as between councils and other potential funding contributors) necessary for the timely and effective implementation of the SMP (including construction and maintenance of infrastructure) will be established.

4. CATCHMENT DESCRIPTION

This section describes the geographical and land use characteristics of Brown Hill and Keswick Creek catchments as well as the drainage system provided by the four major watercourses of the BHKC catchment.

4.1 CATCHMENT AREAS

The Brown Hill and Keswick Creek catchments are shown in Figure 2. Both creeks arise on the western slopes of the Mount Lofty Ranges and then flow westwards across inner south-eastern and western suburbs of Adelaide towards the Adelaide Airport, before discharging into St Vincent Gulf through the Barcoo Outlet (low flows) or the Patawalonga Lake outfall (high flows). The BHKC catchment covers an area of 68.7 km^2. The general change in elevation across the catchment is shown in Figure 3.

Brown Hill Creek catchment

Brown Hill Creek flows through the suburbs of Crafers West, Brown Hill Creek, Mitcham, Torrens Park, Hawthorn, Unley Park, Millswood, Forestville, Ashford, Kurralta Park, Plympton, Netley and Adelaide Airport before flowing into the Patawalonga. It can be conveniently divided into two sections:

- lower Brown Hill Creek – which is downstream from Anzac Highway to its confluence with Keswick Creek at Adelaide Airport (which is also the western extent of the catchment study area); and
- upper Brown Hill Creek – being the section upstream of Anzac Highway to its source in the rural area of the Mitcham hills.

Brown Hill Creek has a catchment area of 32.0 km^2 (upstream from Adelaide Airport) of which about 18 km^2 is rural land.

Keswick Creek catchment

Keswick Creek is fed by:

- Glen Osmond Creek – which originates in the valley in which the South Eastern Freeway is located from the Heysen Tunnels to the Old Toll Gate and then passes through the suburbs of Leawood Gardens, Mount Osmond, Urrbrae, Myrtle Bank, Fullarton, Parkside, Unley and Wayville.
- Parklands Creek – which originates as several minor watercourses that flow off the hills face in the suburbs of Glen Osmond and Beaumont. These watercourses enter the minor (underground) drainage system and continue as underground drains on several routes down through the suburbs of Hazelwood Park, Linden Park, St Georges, Glenunga and Glenside. These drains come together at Conyngham Street, Glenside prior to becoming Parklands Creek as the drain enters the South Park Lands via a culvert under the Greenhill Road / Fullarton Road intersection. Parklands Creek leaves the South Park Lands near Peacock Road and flows through Unley before joining with Glen Osmond Creek to form Keswick Creek just downstream of Simpson Parade, Wayville.

Keswick Creek then flows through the suburbs of Wayville, Keswick, Mile End South, Richmond, Cowandilla, Brooklyn Park and Adelaide Airport prior to joining with Brown Hill Creek. The Keswick Creek catchment area is 36.7 km^2.

4.2 LAND USE AND STORMWATER RUNOFF CHARACTERISTICS

Despite having an overall similar catchment area, the overall land use characteristics of the Brown Hill and Keswick Creek catchments are different, which impacts the behaviour of the drainage system and the potential for flooding.

A majority of the catchment of Brown Hill Creek is in the Mount Lofty Ranges and consists primarily of rural land. As such, it is mainly pervious soil and in the drier half of the year (October to April) most of the rain falling on the catchment is expected to infiltrate into the soil. The rural part of the catchment is relatively steep with defined riverine channels which limit the spread of floodwaters.

The urban section of Brown Hill Creek has a defined channel of limited capacity, which can lead to overtopping of the channel and the spread of floodwaters across the floodplain. Downstream of Cross Road the channel gradually becomes increasingly ‘perched’ above the surrounding floodplain, which results in floodwaters spreading further and further away from the channel.

Due to the large pervious rural catchment, the storms that cause major flooding along Brown Hill Creek involve long periods of rainfall of relatively low intensity on a wet rural catchment. It is expected that these storms would last a day or longer with flood flows resulting from more intense rainfall bursts embedded in the longer storm duration. The runoff from longer durations storms has more volume than short duration storms and it is part of this increased volume, as it spreads out over the downstream urbanised floodplain, that is responsible for the majority of the flood damage.

The urban reaches of Glen Osmond, Parklands and Keswick Creeks are physically similar to Brown Hill Creek with Keswick Creek becoming increasingly ‘perched’ downstream of Anzac Highway. However, the Keswick Creek catchment has a much larger proportion of urban area. Development of land for residential housing and commercial development has increased the amount of impervious area, which contributes to increased runoff. These urban areas include a network of stormwater pits and pipes that collect runoff from roads and developed areas, and feed the water into the creek system.

As the majority of the Glen Osmond Creek catchment is urban, most of the creek is more susceptible to flooding from short duration storms. Parklands Creek is even more urbanised and is even more susceptible to flooding from such duration storms. As both creeks feed into Keswick Creek, the behaviour of Keswick Creek is the same. Peak flows along these creeks can be expected to occur within two hours of the onset of heavy rainfall.

Overall, most of the urban parts of the BHKC catchment are developed. Development is predominately residential closer to the hills and more a mix of commercial and residential closer to the airport.

4.3 INTENSIFICATION OF DEVELOPMENT

Urban development of the catchment area commenced in the Adelaide CBD and portions of Unley soon after the arrival of European settlers in 1836. Suburban growth spread out from the Adelaide centre during periods of prosperity following that time such that by World War II much of the urban catchment area upstream of Anzac Highway had been developed.

The older housing stock, and in particular that originating from the pre-World War II period established a 'character' for many areas across the catchment. In recent years, individual councils have revised Development Plan zones and policies in order to better protect local heritage and character. Notwithstanding this, there has been progressive redevelopment, associated particularly with division of larger allotments and extensions to existing dwellings.

Intensification of development (more buildings and less open space) can be expected over the foreseeable future given the market interest and the State Government's 30-Year Plan for Greater Adelaide which encourages urban regeneration, urban densification, transit oriented development and business and industry clustering.

The 30-Year Plan identifies areas that will be the focus of higher density development over the period to accommodate expected population growth. Amongst these areas are the inner south-west and inner west parts of metropolitan Adelaide, which fall within the urban catchment of Brown Hill and Keswick Creeks.

Higher density development could be expected to result in an increase in the impervious area within the catchment over time, as more buildings and paved areas replace private gardens and open space. The additional impervious areas created by redevelopment generate additional stormwater flows. This in turn increases the risk of flooding from both local stormwater flows and from the Brown Hill and Keswick Creeks. If left unchecked, redevelopment has the potential to progressively reduce the future performance standard provided by any proposed structural flood mitigation works.

Jensen Planning in its 'Coastal Catchment between Glenelg and Marino SMP' (2011) suggests that the impervious percentage is likely to increase to the order of 80% to 90% due to more intense development within each housing block. This effect is evident from inspections of such redevelopment. It is also evident from higher discharge rates during recent storms. Increases in impervious area of the scale indicated would lead to greater peak flows than are currently estimated, particularly for the more frequent flood events, unless counter measures are taken. There is further discussion on this matter in the context of flood modelling at Section 8.2.5.

4.4 THE DRAINAGE SYSTEM

The principal watercourses of the drainage system for BHKC catchment are shown in the plan at Figure 2.

4.4.1 Brown Hill Creek

The headwaters of Brown Hill Creek extend as far east as Crafers. The upper rural part of the catchment is relatively large and has an area of about 18 km^2. The creek is a natural channel before entering the urban area at Old Belair Road, Mitcham.

It then remains as mostly unlined but constrained (by adjacent development) channel until Mitchell Street, Millswood. Further downstream the majority of the channel is concrete lined until the airport is reached. Constrictions in the channel occur immediately upstream of Cross Road, at various locations in Millswood and Forestville and downstream of Daly Street in Kurralta Park.

Upper Brown Hill Creek (down to Anzac Highway) is privately owned for most of its length – the only exceptions being council and road reserves. For the section downstream of Anzac Highway to the airport (lower Brown Hill Creek), 95% of the length of the channel is contained in council or road reserves. The concrete lined section from Packard Street, Plympton down to the confluence with Keswick Creek is maintained by SA Water on behalf of the State Government under the Metropolitan Drainage Act 1935.

4.4.2 Parklands Creek

There is no defined creek channel upstream of the existing detention basin in the Glenside Development Site (managed by Renewal SA), formerly part of Glenside Hospital.

The various drains that join at Conyngham Street feed into two large diameter pipes which run under existing housing developments on the northern and eastern sides of the Glenside Development Site. At the downstream end the pipes discharge into the Glenside detention basin from where flow is conveyed through a culvert under the Greenhill Road / Fullarton Road intersection into the South Park Lands.

The creek is an unlined channel through the park lands before it exits through a culvert extending under Greenhill Road and for a short distance under Palmerston Road. The creek is then mostly concrete lined channel through Unley to its confluence with Glen Osmond Creek in Wayville.

Most of the length from Palmerston Road to King William Road is in council owned land, including a section through the North Unley Park, and is concrete lined to varying degrees. About two-thirds of the council owned land is in a very narrow drainage reserve. From King William Road (including the private property on the eastern side of the road) to the confluence with Glen Osmond Creek the creek is privately owned, and in poor condition.

4.4.3 Glen Osmond Creek

Glen Osmond Creek flows along the general alignment of the South Eastern Freeway as a semi-natural channel until it reaches Cross Road, from where it is piped underground into Ridge Park Reserve.

Leaving Ridge Park, the creek flows in a north-west direction through private properties and council reserves along a partly concrete lined channel until it reaches Fisher Street, Fullarton, where it is piped for a short section after which it is a concrete lined channel flowing west through private properties until reaching Fern Avenue, Fullarton.

From Fern Avenue the creek is conveyed through a long (2.65 km) culvert which runs north along Windsor Street to Henry Codd Reserve and then west to King William Road. Except for a short section upstream of Unley Road, all of the culvert is in council owned land. From King William Road the creek is a concrete lined channel in council reserve for a short distance to the confluence with Parklands Creek in Wayville.

4.4.4 Keswick Creek

Parklands and Glen Osmond Creeks combine to become Keswick Creek downstream of Simpson Parade in Wayville. Keswick Creek flows west through Wayville and then into a long twin cell box culvert under Goodwood Road and the Wayville Showgrounds. From the Showgrounds, the creek reverts to open channel under the railway corridor and through the Keswick Military Barracks, before flowing into a long culvert between Anzac Highway and Ashford Road, Keswick.

After the culvert section, the channel flows northwards through Keswick and Mile End South, and then westwards through Richmond before turning south along the eastern side of Adelaide Airport to its confluence with Brown Hill Creek.

Keswick Creek is concrete a lined channel for all of its length except for the culvert sections and the last 300 m (Adelaide Airport land) which is unlined. From Ashford Road, Keswick the culvert is maintained by SA Water on behalf of the State Government under the Metropolitan Drainage Act 1935.

Down to Goodwood Road, Keswick Creek is largely in private ownership. From Goodwood Road to Anzac Highway the creek is in public ownership (Commonwealth or State). Downstream of Anzac Highway before the creek enters Adelaide Airport, approximately 50% of Keswick Creek is in private property, mostly east of South Road. The section from Anzac Highway to South Road also includes the Adelaide City Council depot and the state owned land of the Office of the Rail Commissioner. Downstream of South Road before the airport most of the channel is in either road reserve or West Torrens Council reserve.

4.4.5 Concrete lining of creeks

Construction of most of the concrete lining along the above watercourses dates back to the 1930s. Some sections of lining may have been renovated since then, but now many sections are in a poor state of repair and, in places, significant undermining of the lining has become established. Those sections are at serious risk of failure under high flows. A concrete lined section of Keswick Creek failed in 2011 under high flow conditions caused by a storm of about a 10 year ARI.

A condition monitoring assessment of concrete lining along all four watercourses has not been undertaken as part of the SMP investigations and the SMP does not propose extraordinary maintenance works expressly for restoring concrete lining. However, in critical sections of lower Brown Hill Creek, concrete lining which is necessary in terms of hydraulic design would be replaced or repaired as part of necessary flood mitigation works, as outlined in Section 10.3. Similarly, Keswick Creek concrete lined channel through the Keswick Military Barracks would be improved under the proposed flood mitigation works of the SMP (refer Section 10.4).

5. EXISTING FLOOD PROBLEM

The current extent of flooding and the associated risk to properties and persons are discussed in this section enabling the cost of flood damages to be estimated for a range of design flood frequencies. Technical aspects of flood modelling and floodplain mapping, including terminology used below are outlined in Section 8.

5.1 FLOOD CHARACTERISTICS

The extent and depth of flooding that could occur for the range of design flood frequencies (10, 20, 50, 100 and 500 year ARIs) is provided in the floodplain mapping at Figure 6, Figure 7, Figure 8, Figure 9 and Figure 10 respectively.

In comparing the 20 and 10 year ARI maps, there is a marked increase in the extent and depth of flooding for the 20 year ARI flood map. As such, it is generally considered that the catchment has an indicative level of flood protection equivalent to about the 10 year ARI level under base case* conditions. (*refer Section 8.1)

As shown in the 100 and 500 year ARI mapping, a significant area through the Unley and West Torrens Council areas is at risk of flooding in those large storm events. In Mitcham Council area, it is mainly the relatively narrow riverine corridor along Brown Hill Creek that is at risk. In contrast, parts of Burnside and Adelaide would also be affected but to a lesser extent in terms of potential depth of inundation and number of properties at risk.

The following sections describe in more detail the potential base case flooding conditions across the catchment for the 100 year ARI flood. The descriptions are generally taken from the 2006 Master Plan and based on floodplain mapping included in the 2012 SMP. Descriptions have been updated since then to reflect known likely changes in flood characteristics. The relative impact of short and long duration storms in response to catchment characteristics is explained in Section 8.

5.1.1 Brown Hill Creek

A significant portion of the Brown Hill Creek catchment is in the rural area of the Adelaide Hills and therefore the catchment is expected to respond more significantly to longer duration storms.

Upstream of the Mitcham Shopping Centre (Torrens Park)

The flooding is typically less than 20 m wide, with the exception of the vicinity of Paisley and Fife Avenues, where flooding is up to 100 m wide. The box culvert beneath Mitcham Shopping Centre has capacity to convey more than the peak 100 year ARI flow.

Stormwater flow in Brown Hill Creek, Mitcham

Between Mitcham Square Shopping Centre and Hampton Street, Hawthorn

The flow is generally contained within Soldiers Memorial Park and the downstream reserve to George Street, with some minor flooding of some George Street properties. In the 2005 flooding, the Over 50s Club and houses in Durdin Avenue were affected. A breakout occurs between George and Kent Streets, with flow directed northward along Clifton and Kent Streets that continues over Cross Road and into Unley Park on the eastern side of the creek.

Hampton Street, Hawthorn to Victoria Avenue, Unley Park

Overflow is expected to spill out of the creek channel at Hampton Street and spread west along the roadway and then north along Denning Street and Hilda Terrace. This overflow will continue over Cross Road on the western side of Brown Hill Creek and travel further north along Whistler and Victoria Avenues, as well as along the railway line.

A significant depth of inundation is expected in the direct overbank area upstream from Cross Road at properties along Denning Street. Some localised breakouts will occur down to Heywood Park, but most of the overflow is expected to return to the creek channel at Victoria Avenue, apart from that which has been lost along the railway or on the floodplain further to the east.

Between Victoria Avenue, Unley Park and Ethel Street, Forestville

Breakout occurs from the channel in a number of locations due to insufficient capacity in the channel. Overflow along the western bank is generally contained within 100 m of the channel, whereas significant breakouts from the eastern bank are directed north along Regent Street and Goodwood Road towards the Showgrounds and Keswick Creek west of the railway.

Between Ethel Street, Forestville and Anzac Highway, Everard Park

A significant amount of flow is expected to spill from both the north and south side of the creek in this reach, due to several undersized bridge culverts as well as the undersized channel.

Breakout from the south bank of the channel flows to the west, inundating a large area of Forestville and Everard Park down to South Road. Overflow from the north bank flows in a north-west direction, inundating large areas between Brown Hill and Keswick Creeks before flowing across Anzac Highway and into the West Torrens Council area.

Daly Avenue, Kurralta Park to Marion Road, Plympton

Overtopping of the channel occurs to the north and south in this reach. Flow to the south joins overland flow that spreads west from Everard Park and then travels further west along Hawson and Kinkaid Avenues, North Plympton, towards the commercial area near the south-east corner of the airport.

Flow to the north of the channel spreads towards Netley through Plympton and Marleston and along Marion Road. It passes through the Netley Commercial Park, before most of the flow is fed back into the Brown Hill Creek channel or the Keswick Creek channel just upstream of their confluence.

Adelaide Airport

The airport is predominantly affected by Keswick Creek and to a lesser extent by Brown Hill Creek (refer Section 5.1.4).

5.1.2 Parklands Creek

The shorter duration storms are the primary cause of most flooding along Parklands Creek due to the responsive urban catchment.

Parklands Creek at Conyngham Street, Glenside

Twin 1950 mm diameter pipes from Conyngham Street, passing under housing on the northern side of the Glenside Development Site, discharge into the existing Glenside detention basin. The pipes have a 50 year ARI capacity. For larger events, flooding extends westward through the housing area, into the Glenside Development Site, and across Fullarton Road into Eastwood. There is also a small amount of flow through the business area on the north eastern corner of the Fullarton Road / Greenhill Road intersection.

The intersection of Fullarton Road and Greenhill Road, Eastwood

The constriction created by the culvert under this intersection causes water to back-up and overtop the road. Water flows down Greenhill Road until it reaches the intersection with Glen Osmond Road. Only minor flooding along the road goes beyond this intersection.

Parklands Creek, South Park Lands

Flooding occurs through the South Park Lands because of insufficient capacity in Parklands Creek. Flooding spreads out immediately downstream from the Fullarton Road / Greenhill Road culvert and extends either side of the channel such that most of the South Park Lands are inundated between Fullarton Road and Unley Road. Flooding extends as far north as South Terrace and as far west as King William Road / Peacock Road. Most of this overflow is eventually picked up by drains in the park lands and returned to Parklands Creek.

Between Greenhill Road and the confluence with Glen Osmond Creek

Floodwaters are contained within a strip approximately 50 m either side of Parklands Creek. The flow is expected to have significant depth, with an average of about 1.5 m increasing up to 2.5 m in some sections. Water ponds in the North Unley Play Park due to flow backing up from the culvert under King William Road. Flow is expected to overtop the roadway; however, it is typically confined to within 20 m of the channel.

5.1.3 Glen Osmond Creek

The uppermost section of the Glen Osmond Creek catchment is rural and therefore longer duration storms are critical. Further downstream, with increasing urban catchment, shorter duration storms become critical.

Glen Osmond Creek at Fisher Street, Fullarton

The culvert under Fisher Street at Wycliff Street (to the east of Fullarton Road) was historically a significant constriction to the flow in Glen Osmond Creek, causing floodwaters to break out from the creek and spread in a north-westerly direction through Fullarton to re-enter the creek in the vicinity of Unley Road. A 1500 mm diameter culvert was installed in 1996 that effectively removed this constriction.

Due to an oversight in the original modelling, this new culvert was not incorporated into the hydraulic model of the creek system for the 2012 SMP. This oversight was only identified late in the course of the 2012 SMP investigation. From latest modelling, the culvert has sufficient capacity to accommodate the 100 year ARI flow along Glen Osmond Creek with the Ridge Park flood control dam in place.

Between Fullarton Road and Windsor Street, Fullarton

The concrete lined open channel is in private (residential properties) ownership, except for road crossing culverts. Latest modelling (with Ridge Park dam in place) indicates a minor flooding breakout immediately upstream of the Windsor Street culvert at Fern Avenue and Torrens Avenue culverts.

Between Henry Codd Reserve and Unley Road, Unley

This section of creek was previously an inadequate capacity open channel which caused local flooding problems. The open channel was converted to an underground culvert by Unley Council in 2011 (to 100 year ARI standard – although based on different hydrological modelling to the 2012 SMP). However, there remains a likely constriction due to the potential of the twin cell layout of the old Unley Road culvert to catch debris. This old road culvert is now located within a long reach of single cell box culvert.

Flooding from Glen Osmond Creek in Culvert Street, Unley (April 2010)

Between King William Road and the confluence with Park Lands Creek

This area is subject to flooding from relatively frequent (low ARI) events; however, the flood extent is confined due to the riverine nature of the topography.

5.1.4 Keswick Creek

Shorter duration storms are the main cause of flooding along Keswick Creek, which collects additional runoff from urban areas downstream from the confluence between Parklands and Glen Osmond Creeks.

Downstream from confluence of Parklands and Glen Osmond Creeks

Floodwaters spread up to 50 m from the Keswick Creek channel between the confluence and the entry point to the culvert under the Showgrounds, affecting some residential housing.

Keswick Creek at Showgrounds

The Showgrounds culvert has insufficient capacity for very large flows and therefore flooding from the upstream channel inundates the area surrounding the Showgrounds. Flow then travels northwards along the railway line to the Keswick rail terminal or westwards along Maple Avenue and through the Keswick Military Barracks to meet up with overland flow that spills from the Brown Hill Creek channel to the south. The combined flow inundates large parts of Ashford, Keswick, Kurralta Park, Richmond and Marleston.

Between Richmond Road and South Road, Mile End South

Flow overtops the Keswick Creek channel for parts of this reach. The channel section between Scotland Road and South Road has insufficient capacity and is responsible for much of the overflow. These floodwaters combine with other flows coming from the Keswick rail terminal area to spill over South Road and flow west.

Keswick Creek in Mile End with high stormwater flow and localised flooding

Downstream from South Road, Mile End South

The creek channel is also overtopped at a number of locations between South Road and Brooker Terrace, Richmond. A constriction in the channel at Ellen Street contributes to the overflow.

Floodwaters spread out onto the floodplain to the north of the channel through the suburb of Cowandilla, with water depths of up to 1 m expected along this flow path as the plume of flow then curls back south towards the airport, to the west of Marion Road. Most of the flow is picked-up by either the Keswick Creek channel or by the Airport Drain which diverts water around the northern and western sides of Adelaide Airport.

Adelaide Airport

Water enters Adelaide Airport via two main locations; the first is at the western end of Lyons Street, Brooklyn Park. This inflow travels in a south-easterly direction once inside the airport. This water is expected to pool in the area where most of the terminal facilities are located. Flow also enters the airport at the south-east corner of the airport to the north of the Glenelg Golf Club.

5.2 FLOOD RISK

The risk to property and the safety of people living in the floodplain can be further investigated through comparison of the predicted flood extent with the location of roads, properties and other infrastructure that will be affected by this inundation.

The number of properties affected by flooding has been determined through comparison of the floodplain mapping with a properties database that has been compiled using information from the catchment councils' geographical information system (GIS) databases.

Coverage of the database of properties that have been included in the flood risk assessment is shown in Figure 4. A total of about 27,000 properties are included in the database, of which about 7,000 are identified within the 500 year ARI flood extent.

A summary of the number of properties at risk from flooding for the range of design flood scenarios is provided in Table 2. As shown, the information is separated into properties that are subjected to over-floor flooding (i.e. dwelling or structure damage) and those affected by under-floor inundation (i.e. peripheral property damage only).

Table 2: Properties affected by flooding – base case conditions

Design flood	Number of flood affected properties		
	Over-floor flooding	**Under-floor flooding**	**Total**
10 year ARI	58	81	139
20 year ARI	158	239	397
50 year ARI	550	616	1,166
100 year ARI	1,172	917	2,089
500 year ARI	4,992	1,801	6,793
PMF*	Data unavailable		

* Probable maximum flood (PMF)

The properties database was compiled as part of work to prepare the 2003 Floodplain Mapping Study and has not been fully updated since that time.

The BHKC project, through WorleyParsons, carried out a limited audit of the West Torrens Council portion of the properties database in 2011. It identified an approximate 20% increase in the number of properties in the 100 year flood extent compared with the original number. However, the scope of SMP investigations has not included updating the properties database; although adjustments have been made in terms of property valuations (refer Section 5.3.4).

The preparation of flood hazard mapping can also assist in determining the level of flood risk. Flood hazard mapping for the catchment was included in the 2012 SMP based on the hazard categories originally adopted for the 2006 Master Plan. The categories were based on the combination of the velocity and depth of flow at any location and in more practical terms can be expressed as:

- Low hazard – if necessary, children and elderly people could wade to safety with little difficulty
- Medium hazard – fit adults can wade to safety, but children and the elderly may have difficulty
- High hazard – fit adults have difficulty in wading to safety
- Extreme hazard – wading is not an option because of the rate of rise and depth and velocity

The creek channels are typically characterised as extreme hazard, which is to be expected due to the significant depth and velocity of flow. High hazard areas are typically limited to areas adjacent to the channel or along major flowpaths such as through the Showgrounds or up through the Keswick rail terminal.

Medium to high hazard areas are expected in riverine sections of creek and low lying areas such as Cowandilla, primarily due to high depths rather than high velocities. The remainder of the floodplain is typically characterised by low to medium hazard.

In 2011, the AMLRNRMB engaged Tonkin Consulting to do an assessment of the potential for severe and catastrophic outcomes from flooding along Brown Hill and Keswick Creeks. The assessment included interviews with residents who had been affected by the flooding that occurred in November 2005.

The following general observations were made in the assessment:

- Rapid response flash flooding is more likely to cause deaths and injury than slower response riverine flooding. This contrast was evident in the 2010/11 Queensland flooding where the flash flood that swept through the Lockyer Valley claimed a number of lives but the subsequent flooding of Brisbane, where sufficient time was available for evacuation, did not.
- There is risk of injuries both during a flood event and also during the recovery period as residents return to their homes to clean up and make repairs.

In reference to the BHKC catchment, the assessment included the following comments:

- The urban floodplain of Brown Hill and Keswick Creeks is densely populated. During a major flood there will be many people in close proximity to areas that are classified as high and extreme hazard. Many of these areas will have deep fast-flowing floodwaters and therefore flooding presents a serious risk to the safety of people in parts of the floodplain.

- During a major flood there will be a considerable amount of debris carried by floodwaters. This can originate from damaged structures such as fences, sheds, decks and other landscape features, in addition to fallen trees. This debris can alter the course of the floodwaters by blocking narrow sections of the creeks, culverts and bridges. This may cause rapid changes in the direction and level of floodwaters presenting further danger to people.
- There is no available evidence of any physical injuries caused by the 2005 flood event in Brown Hill Creek, although examples were given of near misses that could have had worse outcomes. These were the collapse of a bridge parapet, the risk of electrocution and the case of a council worker who was apparently saved from being swept away after stumbling into floodwaters.
- A major flood will cause significant erosion and scour of the existing creek banks. This has the potential to threaten the stability of structures built close to the creek and can also change the lie of the land that people are familiar with, causing them to become disorientated.
- The difference between life and death near fast-flowing floodwaters could be as simple as a slip or a poor decision to enter floodwaters. Serious injury or deaths during a major flood event in the BHKC catchment must be considered as possible, or even likely.

5.3 FLOOD DAMAGES

Flood damages are defined as adverse impacts to people, property and services as a consequence of flooding. They can be both tangible and intangible and are usually measured in terms of a dollar cost.

Tangible damages include direct damages such as the damage to property as a consequence of inundation (e.g. the cost of replacing carpets and removing mud from houses in the aftermath of a flood). Tangible damages can also be indirect damages such as the cost to the community of individuals being unable to get to work because they are isolated due to flooding. These costs can usually be measured and data has been gathered over many years by insurance and flood engineering consultants to provide a reliable indication of the likely damage costs that can be incurred by residential, commercial and industrial property owners.

It is more difficult to quantify intangible damages. Intangible damages include less readily measurable impacts such as the trauma felt by individuals as a result of a major flood and the associated health related impacts. Only limited data is available, but it is thought that intangible damages could be as much or more than the tangible damage cost.

5.3.1 Direct tangible damages

Direct tangible damages are those that arise from the destruction of, or damage to, physical assets. These include losses as a result of damage to buildings, be they residential, commercial or industrial. They can be:

- private or public buildings and the contents of buildings (e.g. furniture and fittings, retail stock, machinery and goods used for production of a commercial product);
- private or public infrastructure, such as roads, railway lines, telecommunications, pipelines, electricity generation and distribution systems; and
- vehicles and plant.

5.3.2 Indirect tangible damages

Indirect tangible losses are those incurred as a consequence of the flood, but are not related directly to the physical damage that has been incurred. These costs include such items as:

- the marginal cost incurred by emergency service organisations in responding to the flood;
- the equivalent cost of volunteers' time in assisting with the emergency response effort;
- costs incurred by landholders in cleaning up after the flood, including their time;
- emergency assistance grants given to people to help them deal with urgent situations (e.g. alternative temporary accommodation, replacing a fridge, fixing damaged windows); and
- disruption to business.

The first two points above have not been included in the quantification of damages.

5.3.3 Intangible costs

Intangible flood damages are those that are difficult to quantify in monetary terms. These damages are related to the physical and mental health of individuals, environmental impacts and disruption to essential community services and operations. They include:

- loss of life;
- personal injury and associated losses and expenses;
- destruction of memorabilia (e.g. family photos);
- loss of heritage and cultural features;
- increased medical costs and reduced life expectancy associated with increases in levels of sickness in a community following a disaster; and
- emotional stress and mental illness that can stem from experiences associated with damage to family homes and businesses, including:
  - replacement of damaged property, particularly if there is no flood insurance or it is insufficient;
  - living in temporary accommodation;
  - children attending a different school;
  - death of pets; and
  - loss of business goodwill.

Interviews undertaken by Tonkin Consulting in 2011 indicated that some emotional trauma had continued for residents in the City of Mitcham who were affected by flooding in 2005, and it is possible that other people affected by the flooding along Brown Hill Creek who have suffered emotionally as a result.

Although it was found that some creek-side residents are relatively at ease with the situation, other residents expressed fear of the flood risk and others are vigilant and prepare for a flood during periods of heavy rainfall.

Intangible costs are those for which no market exists and hence there is no agreed method in place to quantify them. Accordingly, these costs have not been included in the quantification of flood damages.

However, there is acceptance by flood management industry professionals that this type of intangible damage to the well-being of residents and the community could be significant – to the extent of matching or even exceeding the tangible damage cost.

5.3.4 Damages calculation method

A 'GIS Flood Cost Estimator Tool' was constructed by HTC as part of their original Floodplain Mapping Study (2003) for the Brown Hill and Keswick Creek catchments.

The damages estimator tool was peer reviewed by AWE as part of preparation of the 2005 Stage 1 Technical Report (precursor to the 2006 Master Plan). This incorporated a check on the methodology used and also the accuracy of the model compared to local and recent case studies of flood damages.

The flood damages model is GIS-based and allows the user to select any area or land use type in the catchment and obtain an estimate for the likely damage for any of the design flood events simulated through floodplain modelling.

Each property within the floodplain is assessed according to the land use type, specified as either residential, commercial retail, commercial office, industrial, institutional, public utility, recreational or vacant land.

The properties that have been included in the damages assessment are shown in Figure 4 overlaid upon flood modelling results for the specific base case scenario.

The GIS model calculates the damages for each property using information contained in the digital terrain model (DTM) for the catchment, survey information for building floor levels contained in the properties database and the flood model results.

An improved value was also assigned to each property, which represents the value of the structures or infrastructure that are susceptible to damage. This value also incorporates a portion of the damage costs to public utilities throughout the catchment, not just at the property itself.

The flood model results were used to determine the depth of flooding at each property and whether the inundation is above or below floor level. A depth curve consisting of damage multipliers was established for each property type, in which a multiplier is specified according to 'above' versus 'below' floor flooding and also subject to the depth of inundation, falling into the following ranges:

- 0 m - 0.1 m
- 0.1 m - 0.25 m
- 0.25 m - 0.5 m
- 0.5 m - 1.0 m
- 1.0 m - 1.5 m
- 1.5 m - 2.5 m
- 2.5 m - 5.0 m

Using this approach, an appropriate multiplier is applied to the improved value of each property to determine the expected damages. A copy of the original multiplier curves from 2003 is included in Appendix 1. These curves have since been updated to reflect an inflation factor of approximately 64%, based on the ABS building index increase up to September 2015.

As documented in the 2005 Stage 1 Technical Report, the original multipliers were determined from a number of sources and refined in the model by trial and error as follows:

- Chris Wright (2002) completed a comprehensive review of the impact of a flood in the Mile End/Keswick industrial/commercial zone. This study was an analysis of approximately 130 businesses in the area and determined the impact of a 1 in 100 year flood on their operations.
- The Insurance Council of SA provided insight into flood damages on residential and commercial properties. This information was used to develop the damages curves for the corresponding multipliers.
- Councils provided improvement values for each property and these were correlated with DPTI valuation data. The property values were based on the then current 2000 valuation records.
- Real estate agents and valuers provided assistance and knowledge with respect to the value of residential land institutional properties.
- Interviews with stakeholders in the areas affected by recent floods (residential, commercial, industrial and government).

From this information, the likely damages for properties were determined at various flood depths and these were applied to the damages model. Adjustments to the various land uses and depths were made by empirical trials until a reasonable match was achieved (PCWMB, 2005). The validity of the damages estimator tool developed by HTC was demonstrated by AWE through comparison of the damages results with per-lot damage estimates derived from actual flood events.

This method of flood damages calculation has been adapted by WorleyParsons for use with its proprietary floodplain analysis software called waterRIDE™. The software is GIS based and has been developed over a number of years. It is commonly adopted as the industry standard in NSW for the presentation and interpretation of flood modelling results. State agencies often request that the results of flood modelling investigations be provided in waterRIDE compatible format.

The method of damages analysis using waterRIDE adopts the same approach used in previous studies, in terms of the damage multiplier curves being applied to the improved value of each property according to the depth of flooding. Verification of waterRIDE damages results was carried out by matching the damages for base case mapping with that reported in previous studies for the catchment.

Adelaide Airport has been considered separately.

Airport damages for the 2005 Stage 1 report were determined separately as one single lot through interviews with airport owners, West Torrens Council, the then PCWMB and other stakeholders. For the 2012 SMP an inflation factor was applied to the previously estimated airport damages amount to update it to 2011 dollars ($56 million).

It was recognised that the airport has undergone extensive redevelopment since the early to mid-2000s, which may reflect a greater amount of damages in real terms of late, compared with 2005; however, this was not incorporated into the updated analysis primarily because of the likelihood that new developments since 2005 have been built above the 100 year ARI flood level.

In 2013, Adelaide Airport Limited provided information to the BHKC project about potential airport flood damages to the airport. As a result, an alternative estimate of flood damages ($15 million), lower than the 2012 SMP estimate, has also been used in the economic assessment (refer Section 16).

5.3.5 100 Year ARI flood damages

The waterRIDE software has been used to determine that the tangible flood damages cost associated with 100 year ARI flooding is approximately $122 million using the lower Adelaide Airport damages estimate. Full results are presented in Table 3.

This estimate is considered to be a lower bound amount, because intangible damages are not included. If intangible damage costs are as high as the tangible damages (as is likely), the total 100 year ARI damages cost could be in the order of $250 million.

Also, as discussed in Section 5.2, the number of properties being assessed may be understated in the existing properties database dating from 2003, and therefore the damages are likely to be underestimated.

The results of the 100 year ARI flood damages analysis were interrogated further to estimate the damages on an area-by-area basis for each of the catchment councils (refer Table 4).

Table 3: 100 year ARI base case flood damages by property type

Property type	Number of flood affected properties			Damages ($'000)
	Over-flood flooding	Under-floor flooding	Total	
Residential	917	837	1,754	31,026
Commercial retail	64	21	85	38,386
Commercial office	92	33	125	19,350
Industrial	41	12	53	6,705
Institution	34	11	45	9,829
Public utility	22	2	24	1,874
Recreation	2	1	3	50
Airport				15,000
TOTAL	1,172	917	2,089	122,220

Table 4: 100 year ARI base case flood damages by council area

Council area	Number of flood affected properties			Damages ($'000)
	Over-floor flooding	Under-floor flooding	Total	
Adelaide	0	0	0	
Burnside	74	7	81	6,071
Mitcham	17	13	30	2,507
Unley	539	315	854	51,309
West Torrens	542	582	1,124	47,333
Airport				15,000
TOTAL	1,172	917	2,089	122,220

5.3.6 Flood damages for other ARIs

A summary of total tangible damages cost for a range of design ARI is provided in Table 5.

Table 5: Base case flood damages

Design flood	Damages ($'000)
10 year ARI	4,823
20 year ARI	10,622
50 year ARI	44,956
100 year ARI	122,220
500 year ARI	434,358
PMF	1,000,000

PMF damages are an approximate estimate based on original estimates contained in the Floodplain Mapping Study (HTC, 2003)

Compared with the 100 year ARI damages estimate, the $4.8 million damages for the 10 year ARI event is less than 4%, and the $10.6 million damages for the 20 year ARI is less than 9%. These comparisons indicate that about 95% of properties across the catchment would be unaffected by flooding up to about the 10 year ARI event. This is confirmation that generally the existing creek system has, as a minimum, about a 10 year ARI level of flood protection. It is also apparent that over 90% of properties would be unaffected by about a 20 year ARI event.

Expected damages for the PMF have not been calculated using the waterRIDE software and the value of $1 billion is based on original estimates contained in the 2003 Floodplain Mapping Study.

5.3.7 Average annual damages

The relative cost of the potential flood damages is typically expressed in terms of the average annual damages (AAD). The AAD is the average damage per year that would occur from flooding over a very long period of time. In understanding this concept, there may be periods where no floods occur or the floods that do occur are too small to cause significant damage. On the other hand, some floods will be large enough to cause extensive damage.

In calculating the AAD, the probability of damages occurring is plotted against the expected value of damages for that probability of event occurring (e.g. a 100 year ARI event has a probability of 0.01 in any given year). In Figure A below, the area under the curve effectively represents the AAD. It provides a measure for comparing the economic benefits of potential flood damage reduction options.

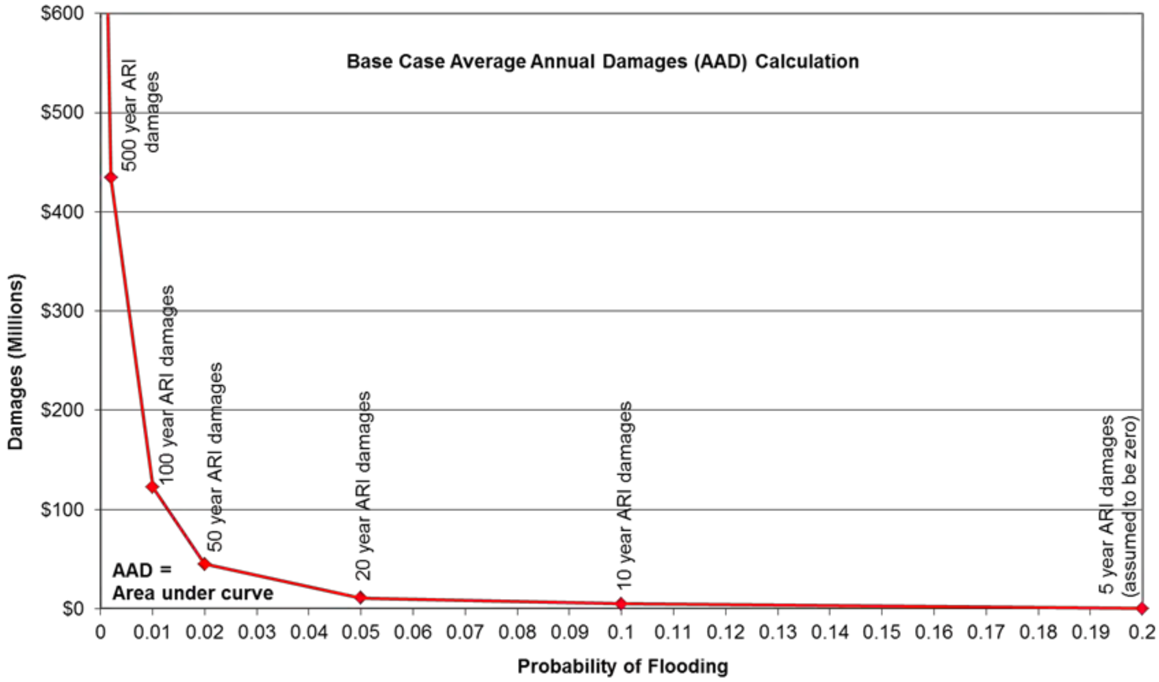

Figure A: Base Case AAD Calculation

The AAD for the catchment under existing (base case) conditions was determined to be $5.96 million (lower bound assessment).

6. OPPORTUNITIES FOR FLOOD MITIGATION AND STORMWATER MANAGEMENT

This section considers potential flood mitigation measures as well as other stormwater management measures. Types of generic measures are described.

Potential flood mitigation measures are considered in the following two categories:

- Structural measures – 'on-ground' works that aim to physically modify existing flood behaviour or reduce the flood impact on properties within the catchment.
- Non-structural measures – typically planning measures and flood emergency response actions that can be implemented to prevent or reduce the risk to safety and property.

Other stormwater management measures typically include stormwater harvesting, water sensitive urban design and on-site detention. Whilst these necessarily involve structural works, their effectiveness in terms of flood mitigation on the scale of 100 year ARI events is limited.

Flood management measures can be implemented separately or in combination with other measures to achieve a catchment-wide benefit.

Types of generic measures are described below.

6.1 STRUCTURAL FLOOD MITIGATION MEASURES

6.1.1 Flood control dams

Flood control dams provide for the temporary storage of floodwaters during a major storm event and act to reduce the peak flow downstream of the dam, thereby reducing the potential for channel breakouts and subsequent floodplain inundation.

The relatively flat and highly urbanised nature of the urban parts of Brown Hill and Glen Osmond / Parklands / Keswick Creek catchment generally precludes the use of flood control dams, which typically require deep, well defined watercourses and large areas of land to provide sufficient volume for temporary water storage.

The rural catchment of Brown Hill Creek is better suited to flood control dams as it is characterised by relatively steep-sided valleys cut by narrow creeks. Flood control dams in the upper Brown Hill Creek catchment have been considered in previous studies. The 2006 Master Plan recommended two flood control dams from four sites investigated. Other sites were considered for the 2012 SMP, as discussed in Section 11.1.1.

In the (rural) upper reaches of the Glen Osmond Creek catchment there is the existing Mount Osmond Interchange flood control dam, which was modified in 2008 in accordance with a recommendation of the 2006 Master Plan. The Plan also recommended a flood control dam in Ridge Park dam on Glen Osmond Creek which, with a modified design, was included in the 2012 SMP. The dam has since been constructed (refer Section 10.6).

6.1.2 Detention basins and wetlands

In the context of this SMP, detention basins operate in a similar way to flood control dams, but are of smaller scale and/or are located within the urban areas of the catchment, typically in parks, reserves and open spaces.

They provide temporary storage for floodwaters during a storm event and reduce peak channel flows downstream. They can be implemented as either on-line structures (through which all flow would pass) or as off-line structures (which might only capture a portion of the flow).

Detention basins located further upstream can be more effective in reducing peak flow for all downstream areas and have a greater cumulative effect in reducing downstream flooding.

For the 2006 Master Plan, potential detention basin locations were investigated across the whole catchment, with the emphasis placed on the ability to capitalise on any existing open space. As a result, a series of detention basins were recommended at locations along Parklands Creek in the South Park Lands and, following concept design modification, included in this SMP (refer Section 10.2).

6.1.3 Overland flow interceptor culverts

The impact of overland flows that originate from upstream breakouts from a creek could be mitigated to some degree by directing these overland flows into underground conduits laid transversely to the flow. These ‘interceptors’ would feed the flow back into the channel at a suitable location downstream.

Interceptors in the vicinity of the tramline were investigated as part of the 2012 SMP investigations but not recommended. The use of interceptors may be perceived as inequitable in terms of the enhanced flood protection provided to properties downstream as compared with no protection provided to properties upstream of the interception line. An interception system also presents additional operational risks (blockage, public safety) compared with measures that prevent channel breakouts in the first place.

6.1.4 Flow diversions

In the context of this SMP a flow diversion is defined as the transfer of flow away from one watercourse system into another. Assessment of a diversion needs to ensure that any existing flooding risk in the receiving watercourse system is not exacerbated by the transfer of additional stormwater flow.

Opportunities for diversion of flows have been considered at various locations across the catchment (Tonkin Consulting, 2002). Potential diversions investigated were typically sized to transfer a required magnitude of flow such that the residual downstream flow can be contained within the channel and thereby avoid breakouts.

A diversion system from Keswick Creek to Brown Hill Creeks in order to reduce peak flows in Keswick Creek downstream of Anzac Highway was recommended in the 2006 Master Plan and is included in this SMP, albeit based on an updated concept design (refer Section 10.4).

6.1.5 Flow bypasses

A flow bypass is defined as a diversion of flow away from the main creek channel to reduce downstream breakouts, which is returned to the same creek system further downstream beyond the problem area. Underground conduit systems along roadways may be required due to the lack of alternative locations in urban areas to construct additional open channels. The use of bypasses is limited by constraints on the downstream flow capacity of the creek so as to not transfer potential breakout areas to downstream locations. Flow bypasses were included in options for upper Brown Hill Creek in the 2012 SMP (refer Section 7.4.3).

6.1.6 Channel upgrades to increase capacity

Channel upgrades typically involve channel widening or modification of the cross-sectional channel shape to provide additional flow conveyance. A significant issue with this option is the potential to transfer breakouts to downstream locations, hence the general need to undertake such works on a whole of creek basis. A further consideration is the need for bridges and culverts along the creek to be upgraded to the same capacity.

For the 2006 Master Plan, the downstream reaches of Brown Hill and Keswick Creeks were identified as significant problem areas; that is, downstream of Anzac Highway to the airport for Brown Hill Creek, and Richmond Road to the airport for Keswick Creek. Upgrading of the shorter channel length only (lower Brown Hill Creek) in conjunction with diversion of flow from Keswick to Brown Hill Creeks was recommended in the 2006 Master Plan and adopted for the 2012 SMP. Further investigations since then have resulted in a modified concept design (refer Section 10.3).

6.1.7 Bridge / culvert upgrades

A number of bridges and culverts along creeks (mainly road crossings) provide a constriction to flow, typically where the adjacent channel sections have a higher capacity. At these locations it is expected that flow will 'back-up' against the upstream side of the bridge and breakout from the channel. Similar to channel upgrades, an issue with bridge upgrades is the potential to transfer breakouts to downstream locations unless the entire creek is considered in the hydraulic analysis. Public road bridge upgrades have been identified principally along Brown Hill Creek (refer Sections 10.3, 10.5 and 12.2).

6.1.8 Other miscellaneous measures

Other mitigation measures considered in developing the original 2006 Master Plan and this SMP are:

Under-grounding or covering

While it would be technically possible to convey the estimated 100 year ARI flows within an underground culvert system placed in the creek (as has been done for a large proportion of Glen Osmond Creek), long sections of the creeks, especially between the railway and the foothills are in private ownership and relatively inaccessible in individual owners' backyards.

Whilst this option could be accompanied by some form of community benefit above ground, such as a linear park, property acquisitions or easements would be required. Furthermore, the under-grounding of creeks is inconsistent with good practice natural resource management and may not readily allow major overland flows (i.e. flows in excess of the capacity of the existing underground drainage network) to enter such a creek system.

Channel lining (no increase in cross-section area)

Unlined sections of channel can be concrete lined to decrease the hydraulic roughness of the channel and thereby increase flow capacity. Whilst this is not an ideal policy approach from a natural resource management perspective, it may be appropriate for those sections of channel where space is limited and the banks of the channel are overly steep, or where no other mitigation options are feasible where capacity is limited and overtopping occurs.

Channel maintenance

Channel maintenance is a contentious issue due in part to misunderstanding about the responsibilities of councils, the AMLRNRMB and private landowners. To maintain the modelled hydraulic characteristics of the creek system it is essential that the creek system be well maintained to reduce the risk of obstructions caused by debris accumulating along the channel or at bridge structures. Channel maintenance is further identified as a non-structural flood mitigation measure in Section 6.3.4.

Flow containment – levees and walls

This type of flood mitigation measure assumes that the design flow is to be contained wholly within the existing channel by raising the sides of the channel above their existing level. The practicality of flow containment depends on both the required height of the structure and the ease of construction (including available space to accommodate the structure). Such structures can be constructed as earthen embankments or as concrete or reinforced blockwork retaining walls. These types of works are included in proposed channel upgrades along upper Brown Hill Creek (refer Section 12.1).

Road diversions

In flood events, the road network in the catchment provides some storage of flood water. Water would be partially contained within the road reserve along existing kerb and gutters according to the natural fall of the land. This option, to increase the amount of storage offered by roads by artificially creating areas capable of storing additional volumes of water, was investigated in development of the 2006 Master Plan.

However, whilst this is potentially an effective option, it would not be possible to achieve significant storage gains without major structural works and lowering of roads, which in turn might increase localised stormwater problems and pose a significant safety hazard.

Raising floor levels

Providing floor levels above the design flood level is typically a non-structural option as it is more suited to planning policy for new or upgraded properties. In the case of Brown Hill and Keswick Creeks it was not considered cost-effective to raise floor levels for existing properties compared with other structural works or reliance on flood preparedness measures to reduce damages during times of flooding.

New developments should be constructed with floor levels above the peak 100 year ARI flood level to reduce the risk of flooding and damage. This is currently a requirement for a number of the councils and is seen as a best practice flood damage reduction measure (refer Sections 6.2.1 and 13.2.3).

6.2 NON-STRUCTURAL FLOOD MITIGATION MEASURES

6.2.1 Planning policy

Planning policy can contribute to flood mitigation and stormwater management outcomes by applying restrictions or specific requirements to new development. For example, planning policy may:

- prohibit development that would obstruct or interfere with a watercourse;
- prohibit development, or particular types of development in areas where the risk of flooding is high;
- require new buildings to be designed and constructed to prevent the entry of flood waters to a specified standard (e.g. 100 year ARI); and
- require development to be set back a specified distance from a watercourse.

The South Australian Planning Policy Library (SAPPL) is a set of Development Plan policies developed by DPTI that deal with issues common to most councils, including stormwater management and flood risk management. The SAPPL policies are consistent with the current State Planning Strategy. All councils when updating their Development Plan must have regard to the suite of policy modules contained in the SAPPL, however this is occurring over time and different councils are at different stages of the process.

Neighbourhood planning in strategic areas of concern along watercourses at identified areas of infill development and urban renewal is a means of addressing potential future flooding and stormwater management issues through targeting actions at the regional, neighbourhood and property level.

As the inner suburbs of Adelaide undergo further infill and urban renewal, there may be opportunities to address stormwater management issues through developing neighbourhood plans that cover particular regions of risk, rather than at a local government area level.

While planning policy can influence how new development contributes to stormwater management and flood risk management, it cannot have an impact where buildings and structures have already been constructed in areas subject to flood risk.

Planning policy proposals in relation to flood mitigation are discussed in Section 13.2.3.

6.2.2 Flood awareness and preparedness

Experience shows that informing people about the flooding risks they and their properties could be exposed to enable them to reduce their vulnerability and increase their resilience against flood damage.

Community awareness of flood risk and potential for flood damage in the catchment has been elevated in recent years with major flooding events in Queensland, New South Wales and Victoria. This has likely boosted the interest that was originally shown when the floodplain mapping was originally published for the catchment (2003) and the interest shown after the flood of November 2005. However, public interest tends to focus on recent events and diminishes rapidly thereafter, unless a concerted effort is made to maintain a high level of awareness.

The South Australian community does not, by and large, have any experience of flood. Many houses have changed ownership since previous flooding and many people who could be affected by an extreme flood along Brown Hill or Keswick Creeks are likely to be ill-prepared and taken by surprise (Tonkin Consulting, 2011).

It is considered, in general, that through effective community awareness and flood warning, flood damages can be reduced by up to 50% in particular cases assuming individuals or businesses are able to invest in substantial work and have the capability to respond at critical times. However, it is unlikely that such a reduction could be achieved on a catchment-wide basis. The warning time for Brown Hill and Keswick Creeks is relatively short compared to larger river systems and so the reduction in damages may not be so high (Tonkin Consulting, 2011).

In addition to the financial and economic benefits from reduced damages are intangible benefits of flood warning and flood preparedness. An informed community is likely to be more resilient to flooding; simple actions like relocating valuable items to a higher cupboard or second storey are easily implemented and could significantly reduce the longer-term trauma of a flood event. A community that understands the dangers of floodwaters will likely be safer than a community that is ill informed about flood behaviour (Tonkin Consulting, 2011).

Flood awareness proposals are discussed in Section 13.2.4.

6.2.3 Flood warning and emergency response

In South Australia the Bureau of Meteorology (BOM) issues formal Flood Warnings only for the Gawler, Torrens and Onkaparinga Rivers (Tonkin Consulting, 2011). The BOM has developed technology that automatically collects rainfall and river flow information and generates SMS and e-mail messages for distribution to staff from BOM, SES and councils. It has been historically known as the ALERT system. It is now called the Enviromon system. The BOM (in conjunction with state agencies) maintains and operates the network of rain gauges and river level gauges within these catchments.

The BOM also issues generalised Flood Watches, which indicate on a regional scale that predicted rainfall could cause flooding. These are issued up to three days ahead of the weather and are updated as more accurate forecasts are made. These are not official Flood Warnings and severe flooding may occur only once for every 10 Flood Watches that are issued. Severe Thunderstorm or Severe Weather Warnings are issued up to six hours before the onset of bad weather that could potentially lead to flooding.

However, the BOM does not have responsibility for issuing official Flood Warnings in catchments that are subject to flash flooding, which is defined as any catchment where the time from the onset of rain to the onset of flooding is less than six hours (Tonkin Consulting, 2011). The rationale behind this is that six hours would be the minimum time that is required to undertake monitoring and modelling of a flood situation and then issue warnings in order to provide any worthwhile warning time.

Brown Hill and Keswick Creeks are regarded by the BOM as falling within the category of flash flooding and therefore, it is not responsible for issuing official Flood Warnings for the catchment. Notwithstanding this, there are 13 rainfall and river level stations within the catchment that form part of the ALERT system. These stations are an asset of local government who are financially responsible, with assistance from the SMA, for maintenance and replacement as necessary.

The BOM is currently undertaking the operation and maintenance of these gauges on a fee basis for the councils. Although it does not issue official Flood Warnings based on the gauged data, it is understood that the data is available in near real-time on the BOM's external website.

Due to the relatively quick response time of the BHKC catchment it is likely that by the time an alarm from the Enviromon system is triggered by water depths or rainfall, flooding may be imminent or may already have commenced in some areas of the catchment. The alarm would have some benefit, but in terms of reducing flood damages it is expected to be limited (Tonkin Consulting, 2011).

Accordingly, the use of meteorological predictions for rainfall as part of the BOM's Flood Watches and Severe Weather Warnings will be the only way to provide sufficient time to allow flood preparations to be made. Due to the difficulties in predicting extreme rainfall, in many cases there will be false alarms and possibly even a failure to predict a flood event.

Currently the alarms generated by the Enviromon system, based on measured rainfall, only go to the emergency response agencies and do not get distributed to the communities that might be at risk. During a major flood event it may give emergency response personnel some warning time, which could be up to a few hours, depending on the pattern of rainfall (Tonkin Consulting, 2011).

There is also benefit in receiving Enviromon alerts during smaller, more frequent events that do not pose significant damages but may require action from the councils, such as clearing of blocked drains or monitoring their performance.

Flood warning and emergency response proposals are discussed in Section 13.2.4.

6.2.4 Flood insurance

Major Queensland flooding in 2011/12 and in other areas of Australia since then has attracted debate about flood insurance. It is recognised that there may be calls from some sections of the community for flood insurance to be considered as a valid flood management measure, to be implemented in lieu of hard structural mitigation works or other non-structural measures.

This approach is not considered appropriate, primarily because the purchase of flood insurance will not reduce the flood hazard and risk that residents are exposed to. It is also likely to lead to an increase in flood damages as existing properties in hazardous locations are further enhanced. Accordingly, it has not been included as a valid non-structural flood management measure for the SMP.

6.2.5 Supporting policies and programs

There may be further opportunities to develop policies and programs related to open space and road reserve management, with the intent of providing detention of stormwater within a neighbourhood precinct. Works could be incorporated during the construction of roads and footpaths or at the time of development of open spaces. However, as a retrofit, such work is more likely to fall into the category of WSUD with enhanced environmental outcomes but with little or no flood mitigation benefits.

6.3 OTHER STORMWATER MANAGEMENT MEASURES

6.3.1 Stormwater harvesting

The 2012 SMP outlined the extent of stormwater harvesting across the catchment in terms of its overall potential and projects being considered. Under the Part B process no additional stormwater harvesting initiatives were identified in respect of upper Brown Hill Creek flood mitigation options; although, the BHKC project gave in-principle support for a private proposal being put to the CSIRO to research the potential for stormwater harvesting from a flood control dam in upper Brown Hill Creek. However, the proposal was not approved for funding (poor geotechnical conditions for aquifer storage in the vicinity of a dam was a factor). The current application of stormwater harvesting across the BHKC catchment is outlined in Section 14.2.

6.3.2 Water sensitive urban design

Water sensitive urban design provides for the sustainable use and reuse of water from various sources, including stormwater. WSUD is essentially a system for retaining stormwater for use on site, usually by recharging soil moisture and thereby reducing flow rates and volumes of stormwater discharged into or managed by stormwater infrastructure. WSUD provides an opportunity to manage the risk of flooding in the context of new development and urban consolidation.

WSUD focuses on on-site and built environment scales such as allotment, sub-division, and precinct scales and includes:

- integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- storage, treatment and beneficial use of runoff;
- treatment and reuse of wastewater;
- using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non-drinking water supplies.

The South Australian Government's position on WSUD is expressed in the publication 'Water sensitive urban design – creating more liveable and water sensitive cities in South Australia' (DEWNR, August 2013). This publication provides state-wide WSUD performance principles and targets and their areas of focus across the full range of urban settings, including residential, commercial, institutional, industrial and open space, particularly in respect of new developments and roads, streets and thoroughfares.

A key objective of Government is the transitioning South Australia and Adelaide to a water sensitive state and city respectively, and this is articulated in the state's water security plan, 'Water for Good'. It is also an inherent objective in the 30-Year Plan for Greater Adelaide and the regional volumes of the Planning Strategy which guide South Australia's future urban and regional development (Department for Water, 2012).

The South Australian Government is seeking to integrate WSUD into all urban development and buildings to achieve a more secure and sustainable future for Greater Adelaide. WSUD is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process (Stormwater Strategy – Government of SA, 2011). Such a definition recognises WSUD as a valid approach for urban design for both 'development' (as defined in South Australia's Development Act 1993), and for other urban land uses such as streets and thoroughfares constructed or altered by the state, local council or other public authority.

Implementing WSUD in neighbourhood level planning through a master planning process provides the opportunity to incorporate stormwater management at an early stage of design and development. Good practice management of stormwater at that level reduces the risk of flooding throughout the catchment, particularly in downstream areas of the floodplain.

Implementation of WSUD by BHKC catchment councils, together with expected the benefits, is discussed in Section 13.2.1.

6.3.3 On-site detention

On-site detention refers to the collection of stormwater, usually on an individual property or development, storing it temporarily and then releasing it slowly so that it does not worsen downstream flooding. OSD is applied locally and interstate where, typically, it is a mandatory requirement of all new development where impervious areas are increased beyond a certain threshold.

An objective of OSD is to reduce any increase in downstream flooding resulting from future development. It is not generally a measure for reducing existing flood risk as it would require retrofitting OSD into situations that are not suitable for it. Reduction in existing flood risk is achieved by the provision of stormwater infrastructure including pipes, detention dams and major flow paths such that property has up to a 100 year ARI level of protection from flooding.

In NSW for example, OSD typically is provided by large underground concrete tanks (e.g. beneath a residential driveway) or as a bunded open land area around a house that can act as a temporary storage pool. To be reasonably effective against increased runoff from increased impervious area due to new development, individual installations typically have to have a capacity of about 10,000 litres. In terms of design and construction, they have to be 'engineered' (they are not rainwater tanks) and costs can be in the order of tens of thousands of dollars.

On-site detention through the compulsory fitment of rainwater tanks to residential properties is a potential WSUD measure. While it has other benefits, hydrologic analysis of the catchment confirmed the conclusions of work elsewhere that rainwater tanks for on-site detention on their own have little effect in reducing peak flows during large flood events (Pezzaniti, 2003), with the effect diminishing with increasing size of the flood event.

In South Australia, the OSD experience of Campbelltown Council was reported by the University of South Australia (UniSA) in 2006, based on a sample of 300 installations approved by the council over a five year period. These installations have storage capacity designed around typical suburban rainwater tanks of about 2,000 litres.

UniSA in conjunction with the then Torrens Catchment Water Management Board (now the AMLRNRMB) reported that the council's policy did not reduce flows sufficiently to pre-redevelopment peak flows for the critical 5 year ARI event, and advised caution in expecting "long term effectiveness of a policy that relies on allotment scale management". It also recommended that the council "invest resources in the continual inspection, education and maintenance of such systems".

Across the BHKC catchment, OSD should reduce the impact of development on local stormwater networks due to runoff from the urban area of the catchment, particularly for shorter duration storms. However, OSD has not been investigated as an alternative flood mitigation measure (for Part A or Part B Works) for a number of reasons:

- For upper Brown Hill Creek, OSD could only be a component of an option involving a dam, not a 'stand-alone' option because it could not mitigate rural runoff.
- In respect of the Part B Works, the cost of any option including OSD as a component would be much greater than the viable Options B1, B2 and D (refer Section 7.4.3).
- For OSD to be effective, it would have to be a mandatory condition of new developments (probably over a threshold value in terms of percentage impervious area). Any notion of retrospective application for existing development would require state government legislation which is very unlikely.
- The potential construction and maintenance cost per installation that are large enough to be effective for ARI events greater than five years would probably impose significant social and economic impacts within the relevant council areas if applied as a direct cost to individuals as distinct from a BHKC project cost.
- Because of the potential social and economic impacts, mandatory OSD would require significant investigation and consultation before being recommended to the community.
- If OSD were applied as a BHKC project cost, the administrative arrangements, as between council, property owner, designer and constructor, would potentially be complex and a subject of investigation and consultation in its own right.
- The size of OSD required to make it an effective flood mitigation measure for the 100 year ARI event may be impracticable for both new and existing developments.

Implementation of OSD by BHKC catchment councils, together with the expected benefits, is discussed in Section 13.2.2.

6.3.4 Creek maintenance

The flood capacity of the creek system is directly affected by the presence of vegetation within the creek channels. Where creeks are in the form of natural channels, both native and exotic trees and shrubs become established, and this can reduce their capacity to convey high flows. In an urban environment, where natural flows are augmented by urban stormwater, it is necessary to manage the channel and the vegetation in it, in order to ensure adequate flood capacity and to prevent erosion of banks and the stream-bed.

Private ownership of the watercourse is particularly relevant to upper Brown Hill Creek because of the way in which the creek, particularly in its 'natural' or unkempt condition has become or is perceived to be an aesthetic feature of some properties. Such a condition in fact presents potential flooding risk (either due to limited channel cross-section, vegetation overgrowth and lack of maintenance or a combination of these factors) and may not realise the full environmental, biodiversity and amenity potential of the watercourse.

An indication of public and private ownership along the creek system is given in Section 4.4.

Where the creeks are in public ownership, and for those sections that come under the 1935 Metropolitan Drainage Act, maintenance is undertaken by public authorities. Where the creeks are in private ownership, responsibility for maintenance is not well understood and creek conditions are generally unsatisfactory, particularly in terms of maintaining flood carrying capacity (refer Section 12.3).

6.4 OPPORTUNITIES FOR MULTI-PURPOSE OUTCOMES

There are numerous examples where flood mitigation works have been expanded or adapted to provide benefits other than reducing flood damages. Opportunities for multi-purpose outcomes include the following:

- Flood mitigation works are typically designed to deal with large and infrequent flows and therefore only operate to their full design capacity on rare occasions. If a proposed detention system requires large areas of land that go unused for the majority of the time, then it would be worthwhile to incorporate other benefits such as increased recreational amenity.
- Similarly, flood detention works provide an opportunity to incorporate permanent bodies of water in the base of the basins which provide opportunities for stormwater use, quality improvements and enhanced amenity.

Flood mitigation works can involve the use of large amounts of public funds, much of which is sourced directly or indirectly from the community (taxpayers and ratepayers) many of which may not receive any direct benefit from the works. Incorporating multiple use benefits provides the opportunity to share the benefits more widely in the community.

Achieving a wider array of multi-purpose outcomes from the works also offers the opportunity to attract a wider range of funding partners in the works and therefore the costs can be distributed over a larger funding base.

In preparing the 2006 Master Plan, opportunities for achieving multiple outcomes were considered on both a reach-by-reach and a catchment-wide basis. However, any multi-purpose works firstly had to be associated with a practical flood mitigation measure.

Each flood mitigation and stormwater management option considered in development of the SMP was considered in terms of its potential to provide one or more of the following additional benefits:

- water quality improvement;
- improved biodiversity;
- passive recreational opportunities;
- formal recreational opportunities;
- water harvesting and reuse opportunities;
- natural infiltration and replenishment of local shallow groundwater;
- transport corridors; and
- visual amenity.

Multi-purpose opportunities that have been incorporated within proposed flood mitigation works of this SMP are outlined in Sections 13.2 and 14.

7. DEVELOPMENT OF THE SMP

This section describes the incremental development of this SMP through the following stages:

- the 2011 Draft SMP;
- supplementary investigations undertaken in response to feedback on the 2011 Draft SMP;
- the 2012 SMP, which identified agreed Part A Works and outlined a process for further investigations for Part B Works;
- the Part B Report (September 2014); and
- this Final SMP ('2016 SMP'), which is an update of the 2012 SMP including an update on the Part A Works as well as reporting on outcomes of the Part B process and agreed Part B Works.

7.1 2011 DRAFT SMP

In accordance with their brief, WorleyParsons developed the 2011 Draft SMP to include the following deliverables:

- review of the economic justification of the 2006 Master Plan works that were proposed for upper Brown Hill Creek (i.e. two flood control dams upstream from the Brown Hill Creek Recreation Reserve and the Hampton Street to Cross Road channel upgrade works);
- assessment of potential alternative mitigation options for upper Brown Hill Creek, involving qualitative and quantitative filtering methods;
- further detailed assessment of the effectiveness of priority mitigation options for upper Brown Hill Creek using the existing hydrologic and hydraulic flood modelling tools for the catchment;
- an economic analysis of the selected stormwater management strategy involving the comparison of benefits versus cost;
- an independent peer review of the economic assessment method used; and
- incorporation of stormwater harvesting information provided by the AMLRNRMB.

Apart from those requirements, flood mitigation and stormwater management measures proposed in the 2006 Master Plan were to be retained for the other creeks in the catchment. Where appropriate, documentation of those measures was updated based on concept design work carried out by others subsequent to the 2006 Master Plan (mainly flow diversions from Keswick Creek to Brown Hill Creek and the South Park Lands detention system).

WorleyParsons' role therefore focused on stormwater management options for the upper part of Brown Hill Creek, and much of the content of the SMP and associated strategies, particularly in respect of other creeks across the wider catchment, were necessarily adapted from the work of others. Also, general background information on catchment conditions and the flooding characteristics were adapted from the 2006 Master Plan. As such, due acknowledgement is given to the authors of the 2006 Master Plan.

The 2011 Draft SMP included recommendations for structural flood mitigation works on upper Brown Hill Creek, including a flood control dam in Brown Hill Creek Recreation Park and high flow bypass culverts in streets of Unley, as well as the recommended works for other parts of the catchment based on the 2006 Master Plan.

The methodology, investigations and outcomes of that upper Brown Hill Creek assessment are the subject of Sections 9, 10 and 11 of the 2012 SMP. However, that information is not included in this SMP as it has effectively been superseded by the Part B process (refer Section 7.4).

The 2011 Draft SMP was the subject of community consultation carried out around November 2011. A report was prepared on the consultation outcomes (Brown Hill Keswick Creek Stormwater Plan Project – Community Consultation Report, by Urban and Regional Planning Solutions (URPS), March 2012) (refer Section 18.3).

7.2 SUPPLEMENTARY INVESTIGATIONS

Following the consultation process on the 2011 Draft SMP:

- Mitcham Council, in response to community concerns about the proposed dam in Brown Hill Creek Recreation Park, engaged WorleyParsons to investigate other flood mitigation options for the upper Brown Hill Creek part of the catchment. The study investigated variations to the flood mitigation scheme presented in the 2011 Draft SMP, including extension of proposed flow bypass culverts in lieu of a flood control dam, and the potential impact of further reducing the size of the dam. ('Brown Hill Keswick Creek Stormwater Management Plan – Preliminary Assessment – Enhancement of flood Mitigation Options' WorleyParsons, November 2011).
- Subsequent to the above report, the BHKC project engaged WorleyParsons to further investigate the feasibility of installing large flow bypass culverts through Mitcham and Unley council areas, with a focus on hydraulic design of the culverts and their potential to conflict with existing underground services, particularly sewer and water supply mains. ('Brown Hill Keswick Creek Stormwater Project – Bypass Culvert Feasibility Assessment (Hampton Street to Forestville Reserve)' WorleyParsons*,* April 2012).
- Unley Council submitted a 'Discussion Paper on the Brown Hill Keswick Creek Draft Stormwater Management Plan 2011' which had been endorsed by Council on 28 May 2012 (included at Appendix 2). The paper identified several additional flood mitigation works in its council area which it sought to have included in the SMP ('Unley Special Works'). From the Part B process, the works were found to be unnecessary and have not been included in the SMP.

In addition to the above studies:

- The AMLRNRMB in 2011 commissioned AWE to carry out a survey of the major watercourses of the BHKC catchment. The previous detailed survey of the creeks had been undertaken in the 1980s.

Key findings of the report by AWE ('Brown Hill Keswick Creek Survey and Hydraulic Assessment – Channel Capacity Assessment', April 2012) were:

"It is to be expected that there have been significant changes to the creeks over those 30 years and (it) is intended to collect the necessary information so that the current channel capacities can be determined and mapped. This information will also enable the existing condition (in terms of channel roughness / obstructions) to be mapped, along with the flood conveyance capacity at each surveyed cross section. This will provide a reference point from which the Board and Councils can work with landholders to ensure flood capacities are not further compromised in the future."

7.3 2012 SMP

7.3.1 Strategy

Subsequent to the 2011 Draft SMP and its associated community consultation, the five catchment councils were able to reach agreement on the preferred flood mitigation works for most of the catchment (Part A Works); however, they could not finalise a preferred flood mitigation solution for upper Brown Hill Creek (Part B Works) within the project timeframe.

In May 2012, the catchment councils endorsed a strategy for completion of the SMP which, as communicated to the SMA by letter dated 30 April 2012, is included at Appendix 3.

The strategy (subsequently included in the 2012 SMP at Section 3.3) essentially comprises:

- Implementation of agreed Part A Works: Works to mitigate flooding generated from the mainly urban sub-catchments of lower Brown Hill Creek (downstream of Anzac Highway), Keswick Creek, Glen Osmond Creek and Parklands Creek (refer Section 7.3.3)
- A process to investigate and determine Part B Works: Works to mitigate flooding from the upper Brown Hill Creek (upstream of Anzac Highway) (refer Section 7.4.1)
- Production of a Final SMP encompassing the Part A and B Works, together with:
    - any other flood mitigation measures that may be identified; and
    - information required to satisfy the SMA Stormwater Management Planning Guidelines.

The strategy also reiterates the councils' recognition of community opposition to a dam in the upper reaches of Brown Hill Creek and preference to pursue a feasible and whole of catchment community supported 'no dam' solution. Notwithstanding the councils' position, the SMA, as a condition of its funding assistance, required dam options to be considered.

7.3.2 Objectives

Overall vision and objectives for the 2012 SMP are as discussed in Sections 3.2 and 3.3. The key objective was a 100 year ARI standard of flood protection to provide an acceptable level of protection for the community and private and public assets generally across the catchment, accepting that in some relatively small areas it may not be economically feasible to achieve that standard. As distinct from the 2006 Master Plan, the 2012 SMP was prepared in accordance with the SMA's Stormwater Management Planning Guidelines.

7.3.3 Part A Works

Part A Works comprise structural flood mitigation works as follows (together with subsequent progress):

- South Park Lands / Glenside detention basins – concept design completed
- Lower Brown Hill Creek capacity upgrade – concept planning carried out
- Flow diversions from Keswick Creek to Brown Hill Creek – concept planning carried out
- Brown Hill Creek upgrade between Forestville Reserve and Anzac Highway (also designated as Area 1 of the upper Brown Hill Creek / Part B works)

- Ridge Park flood control dam (Glen Osmond Creek) – constructed in 2015
- Brown Hill Creek diversion culvert by DPTI: A section of Brown Hill Creek in Forestville and Goodwood was diverted in 2013 by a creek diversion culvert and associated works as part of the Goodwood Junction rail project undertaken by DPTI. A section of the previous creek remains to take local runoff and (via a spillway aqueduct over the lowered railway) rare high flows beyond the capacity of the diversion culvert.
- Glen Osmond Creek minor upgrade works (this item supersedes the Fisher Street bypass included in the 2012 SMP)
- Mount Osmond interchange dam modification (on Glen Osmond Creek) – carried out in 2008 as a minor item of work under the BHKC project.

Progress on the Part A Works is discussed in detail in Section 10.

7.3.4 Part B Works

Following construction of the Brown Hill Creek diversion culvert in Forestville/Goodwood (Goodwood Junction rail project), the Part B Works area now effectively extends upstream from the new diversion culvert entrance near Victoria Street, Goodwood. The diversion culvert discharges back into the creek in Forestville Reserve (with reference to the plans at Appendix 4).

The process for determining Part B Works is discussed in detail in Section 7.4. This built on work already undertaken in the 2012 SMP which identified the following three potential flood mitigation scenarios for upper Brown Hill Creek (with reference to the plans at Appendix 4):

- No Dam Extended Bypass Culvert (Route 3 – via Grove Street):
  - Minor creek channel works in Mitcham
  - Creek channel upgrade between Hampton Street and Cross Road
  - Bypass culvert between Malcolm Street and Forestville Reserve
  - Extended bypass culvert between Hampton and Malcolm Streets
- No Dam Extended Bypass Culvert (Route 3A – via railway reserve):
  - Minor creek channel works in Mitcham
  - Creek channel upgrade between Hampton Street and Cross Road
  - Bypass culvert between Malcolm Street and Forestville Reserve
  - Extended bypass culvert between Hampton and Malcolm Streets
- Flood control dam in Brown Hill Creek Recreation Park (Site 1):
  - Minor creek channel works in Mitcham
  - Creek channel upgrade between Hampton Street and Cross Road
  - Bypass culvert between Malcolm Street and Forestville Reserve.

The final determination of the Part B Works is discussed in Sections 11 and 12.

7.3.5 Other stormwater management measures

Other stormwater management measures considered in the 2012 SMP were stormwater harvesting, water sensitive urban design, and on-site detention (structural measures); and planning policy and development assessment process, flood awareness and preparedness, flood warning and emergency response, supporting policies and programs and channel maintenance and clearing (non-structural measures). Those measures are discussed in later sections of this SMP.

7.4 PART B PROCESS

7.4.1 Strategy for determining Part B Works

The 2012 SMP (Section 3.3 paragraphs 5 to 12) outlines the strategy for determination of Part B Works. The strategy includes the following key components:

- The councils, recognising community opposition to a dam in the upper reaches of Brown Hill Creek, commit to a preference to pursue a feasible and whole of catchment community supported 'no dam' solution
- Investigations (of the 2012 SMP) centred on structural mitigation works as outlined in the Bypass Culvert Feasibility Assessment report by WorleyParsons of April 2012 and the channels assessment by the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB), these being:
  - Channel improvement works to Brown Hill Creek along sections of the creek in Mitcham and Unley
  - High flow bypass culvert from Hampton Street to Malcolm Street (considering two routes – one via Grove Street and the other adjacent to the Belair railway line)
  - Upgraded high flow bypass culvert between Malcolm Street and the Glenelg tramway (Forestville Reserve).

The following extracts from Section 13.3 of the 2012 SMP are also relevant to the strategy:

- The Part B Works process will be informed by the Supplementary Investigations (of 2012 SMP Section 3.2), including the Bypass Culvert Feasibility Assessment (Section 11.3 of 2012 SMP) and the Channel Capacity Assessment study by AWE (refer Section 7.2)
- Investigations will include a preliminary concept design and costing for the flood control dam option (to enable a more detailed comparison with other options) and measures to increase the conveyance capacity of Brown Hill Creek channel through the suburbs of Torrens Park, Hawthorn, Unley Park and Millswood.

The 2012 SMP outlined an overall approach to finalise the selection of preferred flood mitigation measures for upper Brown Hill Creek. The process included:

- focus to be on a 'no dam' solution;
- further investigation of channel capacity;
- a more detailed bypass culvert feasibility assessment;

- investigation of measures to increase conveyance capacity of Brown Hill Creek through Torrens Park, Hawthorn, Unley Park and Millswood; and
- the development of a concept design and costing for flood control dam options (to enable a more detailed comparison with other options).

The 2012 SMP also required the project to advance other issues during the Part B process including:

- ‘Unley Special Works’ (refer Section 7.2) which address the capacity of culverts at Windsor Street, Unley Road and King William Road, which all relate to Glen Osmond Creek;
- quality of stormwater discharge to receiving waters of St Vincent Gulf;
- WSUD systems;
- planning controls (Development Application process); and
- private creek maintenance.

Private creek maintenance in relation to upper Brown Hill Creek is discussed in Section 12.3. The other four matters have been partially progressed and will be addressed more fully in the full implementation phase of the SMP.

7.4.2 Upper Brown Hill Creek

Upper Brown Hill Creek is approximately 7 km in length from downstream of Brown Hill Creek Caravan Park to Anzac Highway. For the purposes of this SMP, it is categorised into sections of private and public ownership:

- Privately owned (primarily residential) sections are identified by numbered Areas (1 to 7)
- Publicly administered sections are identified by their known names.

Exception: The ‘Leah to Ethel Street council channel’ traverses two private properties at the Ethel Street end.

Table 6: Sections of upper Brown Hill Creek

Ownership	Descriptor	Location
Private	Area 1	Anzac Highway to Leah Street
Public & private		Leah to Ethel Street council channel
Public		Forestville Reserve
Public		Forestville Reserve to Victoria Street diversion culvert
Private	Area 2	Victoria to Mitchell Streets Area 2A: Victoria Street to Cranbrook Avenue Area 2B: Cranbrook Avenue to Goodwood Road Area 2C: Goodwood Road to Mitchell Street
Public		Orphanage Park
Private	Area 3	Douglas to Malcolm Streets
Private	Area 4	Malcolm Street to Cross Road
Private	Area 5	Cross Road to Belair Road Area 5A: Cross Road to Hampton Street Area 5B: Devonshire to Kent Street Area 5C: George Street to Angas Road
Public		Soldiers Memorial Gardens, JWS Morris Park and Delwood Reserve
Private	Commercial	Mitcham shopping centre and other commercial properties
Private	Area 6	Mitcham shopping centre to Muggs Hill Road Area 6A: Ayr Avenue to Paisley Avenue Area 6B: Paisley Avenue to Muggs Hill Road
Private	Area 7	Muggs Hill Road to Brown Hill Creek Caravan Park

These sections of the creek are described in Section 11.2.

Area 1 through to Victoria Street, Goodwood, is technically within the Part A Works of the 2012 SMP (noting that construction of the DPTI culvert post-dates the 2012 SMP). The other sections of creek categorised in the table are within the scope of the Part B Works.

7.4.3 Options investigated

The following eight flood mitigation options for the Part B Works were assessed in terms of technical feasibility, non-technical aspects and financial considerations, as discussed in Sections 11 and 12.

Table 7: Part B flood mitigation options

Option	Detention dam	High flow bypass culvert	Creek capacity upgrade
A1	Site 1: Brown Hill Creek Recreation Park	Malcolm Street to Victoria Street	Anzac Highway to Leah Street; Cross Road to Hampton Street
A2	Site 2: Ellisons Gully	Malcolm Street to Victoria Street	Anzac Highway to Leah Street; Cross Road to Hampton Street
B1	Site 1: Brown Hill Creek Recreation Park		Anzac Highway to Leah Street; sections between Mitchell and Malcolm Streets; Cross Road to Hampton Street; Fife Avenue
B2	Site 2: Ellisons Gully		Anzac Highway to Leah Street; sections between Mitchell and Malcolm Streets; Cross Road to Hampton Street; Fife Avenue
C1		Hampton Street to Victoria Street via the railway corridor with Malcolm Street leg (Route 3A)	Anzac Highway to Forestville Reserve; sections upstream of Hampton Street
C2		Hampton Street to Victoria Street via suburban streets (Route 3)	Anzac Highway to Forestville Reserve; sections upstream of Hampton Street
C3		Hampton Street to Victoria Street via the railway corridor without Malcolm Street leg	Anzac Highway to Forestville Reserve; sections between Douglas and Malcolm Streets; sections upstream of Hampton Street
D			Anzac Highway to Forestville Reserve; sections between Victoria and Mitchell Streets; Orphanage Park; Douglas to Malcolm Streets; Cross Road to Hampton Street; sections upstream of Hampton Street to Muggs Hill Road

Notes:

1. The above options all include works to upgrade Brown Hill Creek between Anzac Highway and Forestville Reserve. This section of the creek, technically, is an item of the Part A Works. However, in comparing options, this section has been included in the assessment of the Part B Works as the extent of works in this section varies between the eight options and its cost therefore impacts on the overall cost of the Part A Works as well as the Part B Works.

2. All of the above options include undertaking maintenance works along the full length of upper Brown Hill Creek in order to rehabilitate the creek towards achieving a state of good condition. Under the NRM Act, creek owners have the responsibility to maintain the creek in ‘good condition’.

3. Under all options, some bridges and culverts at road crossings of the creek would be upgraded to give increased flow capacity as required.

7.4.4 Part B Report

Technical aspects of the Part B process were based mainly around the following investigations carried out by the service providers identified:

- Access to the railway corridor between Cross Road and Vardon Terrace:
  - studied for the extended high flow bypass culvert options (Options C1, C2 and C3)
  - required seeking in-principle agreement with DPTI for the culvert route
  - included agreement with DPTI for concept design of culvert under Cross Road next to the railway crossing
  - carried out by Wallbridge & Gilbert (W&G)
- Construction cost estimates and constructability factors:
  - carried out by Costplan
- Flow conveyance capacity of upper Brown Hill Creek:
  - based on the 2012 study for AMLRNRMB
  - identified critical sections and works required to improve the flow capacity of upper Brown Hill Creek
  - obtained additional survey information along the creek particularly relating to constrictions (particularly bridge culverts) and low capacity reaches
  - included investigations of hydraulic modelling and estimated construction costs
  - carried out by AWE
- Impact of culvert construction on roadside and nearby vegetation:
  - involved identification and assessment of all trees within impact range of culvert construction
  - considered impact of construction methodology
  - carried out by Treevolution
- Preliminary concept design of detention dam(s) in Brown Hill Creek:
  - focussed principally on dam at Site 1 (Brown Hill Creek Recreation Park)
  - extended to include basic concept of dam at Site 2 (Ellisons Gully)
  - carried out by SMEC
- Land acquisition and easement costs:
  - involved preliminary desktop assessment
  - based on a nominal common width of easement and compensation provisions of the Land Acquisition Act
  - provided by Maloney Field Services
- Hydrology:
  - used updated IFD rainfall data issued by the Bureau of Meteorology (BOM) in 2013
  - involved review hydrologic modelling
  - carried out by DPTI

- Upgrading of floodplain model/modelling simulations:
  - incorporated data from the Brown Hill Creek reinstatement investigation (by Australian Water Environments) and physical changes over the BHKC catchment since 2003
  - incorporated updated hydrologic modelling inputs (2013 hydrology)
  - carried out by WorleyParsons
- Creek engineering surveys:
  - clarified the creek location in relation to property boundaries (non-cadastral surveys)
  - located the position of principal trees, bridges, retaining walls and other key features along the creek in areas identified for capacity upgrade works
  - carried out by Civil and Surveys and Design
- Field inspections:
  - covered most of the length of upper Brown Hill Creek and evidence considered in order to validate results of floodplain modelling
  - involved on-site meetings with a number of creek owners
  - carried out by the project team including consultants

The above investigations comprised the technical content of the Part B process which is the subject of the Part B Report released in September 2014. Key results of the above investigations are discussed in Sections 11 and 12.

8. FLOOD MODELLING

This section outlines technical aspects of flood modelling and floodplain mapping. Results of floodplain modelling are reported in Section 9.

8.1 OVERVIEW

In respect of this SMP (as well as the 2011 Draft and the 2012 SMP), design of the BHKC project is based on flood estimating using computer simulation (or modelling).

Much of the engineering analysis of the BHKC project is based on flood modelling using computer based hydrologic and hydraulic models followed by damage assessments based on the estimated extent and depth of flood inundation.

This process can be followed both for the catchment 'as it is' and for various future scenarios including more intensive development and/or proposed flood mitigation solutions. For the purpose of this SMP, the existing conditions flood scenario is referred to as the 'base case' and a flood management scenario is referred to as a 'mitigation case'.

The modelling process follows a number of stages:

- estimating 100 year ARI rainfall across the catchment (as input into the hydrologic modelling – see Section 8.2)
- assessing likely runoff behaviour of the catchment through analysis of recorded flood events and/or likely runoff from impervious and pervious surfaces in urban areas (hydrologic modelling)
- converting rainfall to runoff across each sub-catchment and modelling how these catchments feed their runoff into the main creek system (hydrologic modelling)
- modelling the movement of flood water down the main creek channels (hydraulic modelling – refer Section 8.3)
- modelling where floodwater both remains in and can overflow out of the creek channel and flows across the floodplain causing flooding (hydraulic modelling)
- mapping the extent and depth of inundation (floodplain mapping)
- flood impact analysis which determines the likely damage resulting from that flooding (damage assessment).

A critical element in the flood modelling process is to determine various design ARI rainfalls across the catchment. In Australia, the BOM is responsible for preparing estimates of design rainfall events of varying ARIs across Australia.

Rainfall varies significantly. Some storms are short and intense; others are less intense but last longer. Both can produce significant floods. A 100 year ARI storm could be a short, high intensity storm or a longer, lower intensity storm (which could potentially result in greater runoff) or anything in between.

Rainfall variability is reflected in rainfall intensity-frequency-duration (IFD) data published by the BOM. This data varies from location to location across Australia. How to determine IFD data at any location, together with other information which may modify the IFD data, depending on circumstances, is published in a national design guide known as the Australian Rainfall and Runoff (AR&R).

As part of the hydrological assessment for the BHKC project, the catchment was studied to determine which combination of intensity and duration of storm produces the peak stormwater runoff flows for the nominal 100 year ARI. In the case of upper Brown Hill Creek, there are two critical storm durations (90 minutes and 36 hours). Over the whole BHKC catchment the critical storm durations are 90 minutes, 6 hours and 36 hours.

Projected flooding at any point in the catchment is the composite (producing the worst case) of three critical storm durations (90 minute, 6 hour and 36 hour) applied over the whole area of the catchment. The resultant flood map does not represent any one particular flood event, but rather it shows the greatest of the three extent maps for the modelled storm durations.

For the 100 year ARI, the 36 hour event produces the highest stormwater flows out of the rural area of the catchment and the 90 minute storm produces highest flows off the urban areas. However, the 6 hour storm produces a greater extent of flooding over much of the urban area (concentrated along Keswick Creek), than does the 90 minute storm. The 36 hour storm produces a significant flood extent over most of the catchment. For modelling purposes, the storms (90 minute, 6 hour and 36 hour) are applied across all of the catchment.

8.2 HYDROLOGIC MODELLING

Hydrologic modelling is based on the transformation of rainfall data into estimated flood flow hydrographs at various locations along the catchment watercourses for various ARI events.

DPTI is the developer and operator of the RRR hydrologic model for the catchment (refer Section 2.2). The hydrologic model is used to determine the rate and volume of runoff that is expected to travel down through the catchment and onto the floodplain. The RRR model is not its own computer package as such, but is a structure designed to be applied using the industry standard XP-RAFTS graphical user interface.

A further description of the RRR model is provided in Appendix 5, along with a map to show the location where flow hydrographs have been extracted from the hydrologic model for use in the hydraulic modelling.

8.2.1 Hydrology

For the purposes of this SMP, key hydrology concepts and terminology are explained in this section.

Runoff or *stormwater runoff* occurs when rainfall, beyond the capacity of the ground to absorb, runs freely off an area of ground surface. It can be expressed as an instantaneous rate of flow (in litres/s or m^3/s) or as a volume of stormwater produced over the duration of a storm event in megalitres (litres x 10^6) (ML) or cubic metres (litres x 10^3).

In urban areas, runoff enters a watercourse either directly over the ground surface (the major system) or enters via local underground drainage systems (the minor system). For most storm events the majority of stormwater enters the watercourse via the minor system. Runoff and the subsequent flow along creeks can occur due to any combination of rainfall intensity, storm duration and catchment losses prevailing at the time of the storm.

The term *overland flow* can be used to describe flow that *breaks out* of a watercourse and spreads over the floodplain. The spread (or *extent*) and depth of *inundation* is what is represented in *floodplain mapping*.

The *critical storm* is the duration of storm that gives the maximum flow when the various design storm parameters are applied (rainfall intensity, loss values, storage and routing parameters).

Within the urban part of the catchment, where there are large impervious surfaces (roads, roofs etc.), a fixed percentage of the rainfall runs off quickly and this process does not vary much from storm to storm. The rural parts of the catchment are dominated by pervious surfaces. The response of these surfaces to rainfall is much more variable. Significant factors in this variability are the intensity of the rainfall itself and the amount of rain that has fallen previously (related to *catchment saturation*).

These runoff characteristics, together with other information for the urban and rural catchments, have been incorporated into the hydrologic model. Key outcomes are:

- The *90 minute storm* is the critical duration storm for peak runoff for most locations where the upstream catchment consists largely of urban area.
- The *36 hour storm* is the critical duration storm for peak runoff where the majority of the catchment is rural.
- The *6 hour storm* is the critical duration storm for peak runoff in some limited areas along Parklands Creek downstream of the South Park Lands.

As Glen Osmond Creek and Brown Hill Creek emerge from the foothills and as the percentage of urban area in the total catchment becomes progressively larger, there is a transition from where the 36 hour storm produces the peak flow to where the 90 minute storm produces the peak flow.

For Glen Osmond Creek, that transition occurs at Fullarton Road, Fullarton. For Brown Hill Creek, it occurs downstream of the confluence between Brown Hill and Keswick Creeks on the east side of the airport.

Temporary storage (*detention*) in the rural part of the Brown Hill Creek catchment effectively removes that part of the rural catchment above the storage such that the transition point from the 36 hour to a 90 minute critical duration storm moves upstream (i.e. closer to the foothills).

8.2.2 Hydrology review

As noted previously, hydrologic modelling for the 2006 Master Plan and earlier investigations was carried out by DPTI. The RRR model used was calibrated on rainfall and streamflow data collected for all four creeks since 1989.

In 2010 Mitcham Council commissioned VDM Consulting to investigate the hydrology of the catchment of upper Brown Hill Creek. VDM used standard AR&R methods to determine flood flows for a range of average recurrence intervals. The VDM estimates of peak flows are greater than the DPTI estimates.

Under the BHKC project, Sinclair Knight Merz (specifically Mr Peter Hill) was engaged to carry out a peer review of both the DPTI and VDM hydrology assessments and to make recommendations regarding the appropriate set of design flows to be adopted for the purposes of flood analysis, and provide comment on any further hydrological analysis that could or should be undertaken before design flows are finalised.

The key conclusions by Hill are:

"The theoretical basis of the RRR model used in Transport SA studies (DPTI approach) appears sound and from the reporting provided the model has been carefully configured to account for the complex flow paths and control structures such as the freeway, various detention basins and piped sections.

On the basis of the results from at-site and regional flood frequency analysis, a 1 in 100 AEP peak flow at Scotch College of between 25 and 30 m^3/s would appear reasonable and this supports the peak flows from the Transport SA study which are considered suitable for design. The VDM values are somewhat higher than this which is consistent with their stated intention of being conservative.

The flows from the urban areas are likely to be highly sensitive to the assumptions regarding directly connected impervious fractions. The generally good calibration to the recorded hydrographs achieved in the Transport SA study provides some assurance that the values of directly connected impervious, and hence peak flows at Cross Road, are appropriate. On this basis they are recommended for design, however it would be desirable if the approach and adopted values were further documented."

The BHKC project accepted the assessment by Hill and confirmed that the RRR hydrology would be used in investigations for the SMP. Subsequently, all additional hydrologic information required for the SMP study was provided by DPTI / Kemp through the BHKC project to WorleyParsons.

8.2.3 Revised hydrology

When the SMP was produced in 2012, it was based on the latest available IFD data from the BOM as contained within the most recent AR&R guideline updated in 1987. For the purposes of this SMP, application of the 1987 data is referred to as the 2012 hydrology.

In mid-2013, the BOM published revised IFD data for the whole of Australia, which updated the 1987 data used previously by the BHKC project. Based on advice from the hydrology advisors to the BHKC project (the Stormwater Group of DPTI), the updated data was applied to the BHKC catchment hydrologic analysis.

In conjunction with the new IFD data, DPTI also revised the hydrologic modelling for the shorter duration (90 minute) critical storm to recognise that in the lower reaches of the BHKC catchment (and downstream from Victoria Street, Goodwood in the case of upper Brown Hill Creek), the street drainage system has only a limited capacity to convey stormwater into the creeks and the higher 'perched' banks of the creeks prevent direct entry of stormwater into the creeks.

Other minor adjustments were also made, in line with recent findings from other Adelaide urban catchments which showed that runoff that fell on a local sub-catchment was slower to reach the main stormwater channel than previously estimated.

The impact of these changes (the ‘2013 hydrology’) has been to reduce the peak 100 year ARI design flows in the order of 10 - 15%, and up to 25% depending on location in the catchment. This has resulted in a reduction in the scale of some flood mitigation infrastructure compared with the 2012 SMP.

The letter of advice by DPTI’s Principal Stormwater Engineer regarding these matters is included at Appendix 6.

It is understood that other information regarding the use of the new IFD data will be released in future years and it is possible that new information in the future may result in further adjustments to the BHKC catchment hydrology. However, any such modification is unlikely to be on a scale that would change the general form and scope of the works proposed in the SMP.

8.2.4 Climate change

As part of the hydrology review outlined above (Section 8.2.2) Hill, as an independent expert advisor in hydrology matters, was also asked to comment on climate change. His opinion was that: “There is currently a lack of quantitative information on the potential impacts of climate change on factors that affect flood magnitude. Any increase in design rainfall intensities may be partially offset by higher losses resulting from the drier antecedent conditions. Given the uncertainty in the projections it is recommended that the flood estimates are derived using the existing design information”.

However, the issue takes on more currency with the release of the new IFD data. It is understood that changes in the IFD data from 1987 reflect the much greater amount of recorded data upon which the IFD predictions are based. On release of the new IFD data, the BOM made no mention of the data being adjusted up or down for predictions of future trends due to climate change. On further enquiry, the BOM advised (23/1/2014) that “the new IFDs are for current climatic condition and do not incorporate climate change”.

DPTI (via the Principal Stormwater Engineer) has advised that there is still a lack of quantitative information on the potential impacts of climate change on factors that affect flood magnitude and accordingly the flood estimates do not make any allowance for climate change.

8.2.5 Urban in-fill

Intensification of development across the catchment in general terms is outlined in Section 4.3.

The hydrologic modelling allows for small increases in the percentage of impervious surface over the estimated existing percentage. The increase is up to 10% of the existing impervious percentage (i.e. for an existing impervious percentage of 40%, the modelling allows 44%). The allowance varies in different parts of the catchment depending on zoning and existing development.

The level of impervious site coverage adopted in the hydrological modelling is presented by local government area in Table 50. These figures were taken from the 2006 Master Plan. This is broken down further into sub-catchment areas, as shown in Figure 5.

Given changes to planning policies as outlined in Section 6.2.1, such an allowance may now be regarded as too low. However, the SMP recognises that in order to contain the scope of flood mitigation infrastructure, councils and other planning control bodies have to require means for reducing additional runoff from new developments through WSUD and OSD.

8.3 HYDRAULIC FLOOD MODELLING

Hydraulic flood modelling takes the hydrographs from the hydrologic modelling and estimates the extent and depth of inundation in the channel and across the floodplain for each event. The hydraulic modelling of flows in the watercourse is normally along the flow direction only and is referred to as one dimensional (1D), while modelling of flow on the floodplain is often in more than one direction and is referred to as two dimensional (2D) modelling.

The hydraulic model has been developed using the MIKE-FLOOD proprietary software system. The model was developed by HTC in 2003 and subsequently updated in 2006, including calibration of the model to flooding that occurred in November 2005. A summary describing the development and use of the MIKE-FLOOD model since 2000 was prepared by HTC and is included at Appendix 7.

In developing the 2012 SMP, WorleyParsons, in accordance with its brief and terms of engagement, subcontracted the floodplain modelling, using the MIKE-FLOOD model developed by HTC, to AWE (for analysis and presentation of results) who, in turn, subcontracted to HTC for the 'hands on' operation.

In mid-2013, the BHKC project had the model transferred to WorleyParsons. The role specified for WorleyParsons in the Part B process – as an extension of their existing contract – was to upgrade and operate the model for purposes of floodplain mapping and analysis of base case and flood mitigation options.

Since the model was created, changes have occurred along particular sections of the watercourses, as well as to other physical characteristics of the catchment. At a local level in some relatively small areas the flood mapping may still need to be updated.

In upgrading the model, WorleyParsons made or incorporated a number of enhancements, including:

- use of an up to date digital terrain model (DTM) for the West Torrens Council area of the catchment (produced by Aerometrex) provided by the council;
- use of an up to date DTM for the upper Brown Hill Creek area of the catchment obtained from Aerometrex;
- an up to date channel cross-section survey for upper Brown Hill Creek carried out by AWE (for AMLRNRMB in 2012) supplemented with additional cross-sections measured as part of the 2013 work by AWE (for the BHKC project), was incorporated;
- roughness factors (Manning 'n') in the model were updated using data adopted for the 2013 AWE study;
- the 'as constructed' Goodwood Junction rail project diversion culvert (DPTI culvert) was incorporated; and
- physical characteristics of other watercourses of the catchment were validated against measurements recorded by AWE in 2012 and corrections made to the model as necessary.

Whilst the upgrade focused on the upper Brown Hill Creek part of the model, enhancements also applied to the full catchment model.

8.4 MODELLING SYSTEMS

Both hydrologic and hydraulic computer modelling tools have been used to define the base case flood characteristics. Outputs from the hydrologic model are used as inputs to the hydraulic model, which enables the characteristics of the runoff to be modelled across the topography of the floodplain and thereby determine the extent, depth and velocity of flow.

In the SMP investigations, the following forms of hydrologic and hydraulic modelling have been used to analyse flood risk and flood mitigation measures:

- hydrologic modelling using the Rainfall Runoff Routing (RRR) model operated by DPTI;
- channel (hydraulic) modelling using a one dimensional (1D) model (HEC-RAS);
- floodplain (hydraulic) modelling using a two dimensional (2D) model (MIKE-FLOOD); and
- channel (hydraulic) modelling using MIKE 11 (1D) component of MIKE-FLOOD.

The RRR model and MIKE-FLOOD models are discussed earlier (Sections 2.2 and 8.2). HEC-RAS (as with MIKE-FLOOD) is a proprietary software system.

Hydrologic modelling underpins the hydraulic modelling and floodplain mapping.

The HEC-RAS and MIKE-FLOOD hydraulic models can be operated independently of one another and can be used to verify or compare one another's results. All of the models rely on the same set of inflow hydrographs for the basic input data (at the locations shown in Appendix 5).

The RRR hydrologic model provides a less rigorous level of flood routing through the catchment compared with the hydraulic models. More reliance is placed on assumed information than the other models and it is therefore considered to give the least reliable results in terms of the estimated peak flow reaching the lower parts of the catchment (which is not to say the results are not fit for purpose). The RRR model is primarily used to derive local inflow hydrographs down through the catchment for input to the hydraulic modelling.

The 1D hydraulic models for the BHKC project use the same set of surveyed field measurements of cross-sections and the same assumed roughness factors applied to the cross-sections. The HEC-RAS modelling has been targeted towards assessment of the capacity of in-channel areas and therefore, the model results have reduced reliability in cases where the flow exceeds the capacity of the channel and overflows onto the floodplain.

The storage and conveyance effects of overbank areas can be under-estimated in the HEC RAS modelling, or simply not considered as part of the channel capacity assessment. By contrast, the MIKE 11 model is linked to the floodplain as part of the MIKE-FLOOD model and therefore the interaction between in-channel and overbank flow is better represented during higher flows.

There is also a difference in terms of the 'dynamic' capability between the 1D HEC-RAS and MIKE 11 models. The HEC-RAS simulations modelled flow only in steady state mode, (i.e. the flow remains constant) which means the dynamic behaviour caused by an interaction of flows from various parts of the catchment is not taken into account. By contrast, the MIKE-FLOOD model (incorporating the MIKE 11 1D channels) is used to perform dynamic simulations to capture the full inflow hydrographs (i.e. as flows increase and then decrease during a storm).

Consequently, where there are conflicting results between the HEC-RAS and MIKE-FLOOD modelling, greater reliance is put on the hydrodynamic MIKE-FLOOD results.

The limitations of modelling systems, in terms of the floodplain mapping and associated data (typically for flow and depth, and numbers of affected properties), are outlined at Section 8.7.

8.5 CREEK ROUGHNESS

Flow conveyance in a watercourse will vary according to the roughness condition of the base and sides. In hydraulic modeling, roughness is expressed as a Manning 'n' number. The extent of flooding breakout, if flow exceeds channel capacity, will also depend on the level and roughness of the overbank area.

In the 2D floodplain model domain, Manning 'n' numbers are also applied to the different types of area across the wider catchment as outlined in the MIKE-FLOOD model summary at Appendix 7. Floodplain roughness will affect the extent and depth of flooding breakout across the floodplain.

Roughness factors (Manning 'n') were critically reviewed following the results of the Channel Capacity Assessment study by AWE for the AMLRNRMB (refer Section 7.2) and carried through into a subsequent study of upper Brown Hill Creek by AWE for the BHKC project in 2012/13 (refer Section 8.6).

The Manning 'n' values (base and sides of the creek) for the existing condition of upper Brown Hill Creek were agreed between the BHKC project (technical representatives) and AWE, and subsequently specified for use by WorleyParsons in the MIKE-FLOOD hydraulic modelling.

In 2012 the AMLRNRMB commissioned Water Data Services to monitor flows in upper Brown Hill Creek for the purpose of calibrating the Board's flow measurement models. The investigation included an assessment of channel roughness for comparison with the 'n' values in the floodplain model. Twelve months of data was collected (September 2012 to September 2013) at six stations in the Mitcham section of creek and five stations in the Unley section. The calculated 'n' values ranged from 0.02 to 0.03 for a wetted perimeter of the bed and small way up the banks.

As the maximum flow rate at Scotch College gauging station during that time was slightly less than 5 m^3/s compared with a full creek flow of about 20 m^3/s, no firm conclusion could be drawn in terms of the accuracy of modelled values. Nevertheless, these values compare favourably with the modelled 'n' values (base case condition) of about 0.035, implying that if the model is erring, it is doing so on the side of caution.

Due to the relative complexity of Brown Hill Creek, the impact of different 'n' values on the creek's flow capacity is not readily assessed from the hydraulic modelling. In general, the creek has irregular alignment, dimensions and shape. Also, it is intersected by many culverts and bridges along its length which act as hydraulic controls, and determine conditions of subcritical and supercritical flow along different reaches. In the 2D modelling, overall creek flow capacity is more sensitive to those factors than it is to roughness.

Furthermore, creek roughness, in practice, is not constant. The modelling (in terms of roughness) is configured to simulate the general conditions that exist along the creek (e.g. sections of modified channel versus natural creek channel). However, the modelling does not capture every feature such as eroded banks or individual retaining walls and boulders that, in places, form the banks. Nor does the modelling simulate choke points that may form along the creek due to loose material being washed down in high flows and caught up in trees and vegetation growing in the creek bed and banks.

Due to those variables, modelling the effect of a reduction in roughness is not conclusive. However, it can be demonstrated that, in theory for ideal conditions, flow is increased by about 10% by reducing 'n' on the channel sides from 0.031 to 0.028. It is reasonable to assume that such a reduction in 'n' may correspond to the improvement that would be achieved by rehabilitating the creek to good condition. Also, in improving the flow path by pruning and removing unsuitable vegetation and generally removing flow constraints, there is less chance that choke points and blockages at culverts will form in high flows. Choke points decrease flow rate and increase the risk of flooding.

8.6 CREEK CAPACITY – UPPER BROWN HILL CREEK

The need to improve the capacity of upper Brown Hill Creek is discussed in the 2012 SMP at Section 13.3.1. Key points are:

- As discussed in Section 7.2, AWE assessed the hydraulic capacity of the major watercourses of the catchment in the Channel Capacity Assessment report of April 2012.
- The Channel Capacity Assessment study indicated that channel capacity was reduced significantly in places since the time of the last assessment in 1983 (by WBCM who modelled the capacity of Brown Hill Creek in 1984 – referred to in the 2012 SMP at Section 2.1), mainly along the privately owned sections of Brown Hill Creek upstream of Anzac Highway.
- Based on the HEC-RAS analysis by AWE for the AMLRNRMB in 2012, the capacity of the creek varies from less than 10 m^3/s to greater than 30 m^3/s.
- Reasons for deterioration in capacity include encroachment of structures (typically bridges and walls) and increased trees and vegetation within the channel due to lack of maintenance.
- The floodplain model produced by HTC for the 2006 Master Plan and used in subsequent modelling for the SMP incorporates channel capacities that were verified by HTC against the capacities determined by WBCM in 1983. It is therefore assumed that in terms of the channel capacity the HTC model was based closely on the 1983 WBCM analysis.
- In respect of upper Brown Hill Creek, the AWE findings indicated that in many areas the previously accepted capacity of the existing channel and bridges/culverts may have been overestimated.

Investigations of creek capacity were carried out over two phases – based initially on 1D modelling by AWE and subsequently on 2D modelling by WorleyParsons.

The BHKC project engaged AWE in early 2013 to develop high level concept design information for increasing the flow conveyance capacity of upper Brown Hill Creek from Forestville Reserve for two alternative design flow rate options, being:

- restoration of WBCM flow capacity over the full study length of the creek; and
- provision of 100 year ARI peak flow capacity ('no dam' situation) over the length of creek upstream of Hampton Street, Hawthorn.

The study used the existing HEC RAS (1D) model developed for Brown Hill Creek under the Channel Assessment carried out by AWE for AMLRNRMB in 2012. However, in order to achieve more accurate dimensional accuracy, additional cross-sections were surveyed along the creek and incorporated into the model. Channel roughness values (Manning's 'n' values) were also reviewed (as described in Section 8.5).

The AWE findings and costs, based on HEC-RAS (1D) modelling, gave a preliminary indication of the potential extent of creek widening and vegetation clearance work to enable peak flows to be conveyed. But the 1D modelling results did not reflect the full potential of the creek to convey flow in the overbank area as well as the channel itself.

It was judged that in many of the reaches the creek where the 1D modelling indicated channel capacity would be exceeded, the cross-sectional area for assessing flow capacity could be extended out from the channel to include over-bank width in addition to the channel itself. In these reaches, flows greater than channel capacity would still be contained to what is effectively the immediate creek floodplain without causing what would reasonably be regarded as significant property damage.

At the time that the initial results by AWE were being reviewed, new IFD data became available which, when applied to revised hydrological modelling, presented the opportunity for investigating the upgrading of the creek as an alternative 'no dam' solution for the Part B Works.

Also, at about the same time the 2D floodplain model (MIKE-FLOOD) was upgraded by WorleyParsons in combination with the revised hydrological modelling, and so became available for analysing the flow conveyance capacity of the creek.

Consequently, the AWE findings of required works and estimated costs were effectively superseded by more reliable 2D modelling results by WorleyParsons.

The 2D floodplain model (MIKE-FLOOD) together with analysis using the WaterRide program by WorleyParsons have been used to study performance of the creek under various flow conditions and the scope of works required to mitigate significant breakouts and flood extents, particularly in terms of:

- flood extents emanating from the creek which impact on a significant number of houses and buildings; and
- breakouts from the creek where its flow capacity is exceeded which cause localised minor flooding with low risk of material damage.

Upgrade works are proposed to mitigate breakouts which extend over relatively large areas and consequently impact on a significant number of houses and buildings, as distinct from minor breakouts which cause localised minor flooding and do not produce material damages.

8.7 LIMITATIONS OF FLOODPLAIN MAPPING

The resulting floodplain maps have certain limitations:

- The mapping delineates areas of the catchment that are assessed as being subject to inundation by floods of various magnitudes from upper Brown Hill Creek catchment.
- The mapping does not show flooding from local drainage systems which can occur as a result of localised heavy rainfall.
- The data contained is based on survey, hydraulic and hydrologic modelling to an accuracy sufficient for broad scale flood risk management and planning.
- The modelling reflects current practice but there are uncertainties associated with the data on which the modelling is based and therefore on the flood extents shown on the maps.
- Actual flood extents will vary from one storm event to another, being affected by earthworks, blockages of structures (e.g. due to debris), further development within the catchment and other factors.
- The limit of flooding is not a boundary between flood prone and flood free areas. Larger floods could inundate areas outside the areas shown.

Concept design of creek capacity upgrades is limited by the relative accuracy of results possible from the floodplain model in its current configuration. In particular, the DTM of the floodplain model is configured on a 5 m grid spacing for data points. The 2D model is designed for 'broad acre' flooding over the full catchment and not for the relatively fine detail required to measure flooding impact at individual property scale, where there can be significant changes in creek topography and conditions in a distance of less than 5 m.

9. FLOODPLAIN MODELLING RESULTS

Floodplain modelling was carried out by WorleyParsons based on upgrades to the MIKE-FLOOD model as outlined in Section 8.3.

Floodplain mapping produced from the MIKE-FLOOD model shows the predicted extent and depth of flood inundation over the catchment for a given ARI. As with all floodplain mapping presented in this SMP, the thematic mapping indicates where the depth ranges between zero to 0.5 m (white to blue shading) and where depths are expected to be greater than 0.5 m (darkest blue areas).

As outlined in Section 8.1, the mapping is a composite of the storm durations that are modelled for each simulation. Generally for the BHKC catchment, the critical storm durations used to simulate the resultant floodplain modelling for any given ARI are 90 minutes, 6 hours and 36 hours. The resultant flood map shows the greater of the three extent maps for the modelled storm durations. It does not represent any one particular flood event.

Potential flooding impacts based on the 2003/2006 version of the model as updated in 2014 and assessed on a catchment-wide basis, are considered fit for purposes of the SMP. It is proposed that the catchment-wide model be updated as part of detailed design.

The main focus of this section is on floodplain modelling carried out to analyse base case flooding impacts and potential flood mitigation solutions. Resulting flood mitigation solutions are described in Sections 10 and 12 for Parts A and B respectively. Floodplain modelling results for the implementation of all the proposed flood mitigation works are referred to in Section 13.1.

9.1 BASE CASE – ENTIRE CATCHMENT

As explained in Section 8.1, 'base case' is the existing situation with no flood mitigation works in place. For this SMP, base case modelling results are for the scenario in which Ridge Park flood control dam is not in place. Floodplain mapping for the entire catchment was carried out for the following base case simulations:

- 10 year ARI (refer Figure 6)
- 20 year ARI (refer Figure 7)
- 50 year ARI (refer Figure 8)
- 100 year ARI (refer Figure 9)
- 500 year ARI (refer Figure 10)

Each simulation is a composite of the three critical storm durations (90 minute, 6 hour and 36 hour) based on the 2013 hydrology (refer Section 8.2.3) and applied to the upgraded floodplain model (refer Section 8.3).

For comparison purposes, the base case condition was also modelled on the upgraded floodplain model for the 2012 SMP hydrology. That simulation is discussed in Section 9.3.1, together with base case simulations relevant to the Part B Works.

Note that the 500 year ARI base case mapping includes an inherent assumption that the full 500 year ARI flow from the upper Glen Osmond Creek catchment is contained by the Glen Osmond Creek channel until Myrtlebank in the vicinity of Ferguson Avenue. This area represents the upstream boundary of the 2D domain of the MIKE-FLOOD model on Glen Osmond Creek, as limited by the eastern extent of the available topographic data.

The mapping therefore is considered to provide an over-estimate of the breakout from the channel in this area, as it is expected that a significant portion of the 500 year ARI stormwater flows arriving at the intersection of Glen Osmond Road and Cross Road will be diverted along Cross and Glen Osmond Roads due to the flow capacity of the creek culvert immediately upstream of Ridge Park (refer Section 10.6). This constraint would reduce the 500 year ARI peak flow in the downstream channel of Glen Osmond Creek. The extent of the MIKE-FLOOD model is such that the hydraulics of this intersection are not captured by the model.

9.2 PART A WORKS

9.2.1 Modelling simulations

Modelling simulations were carried out for base case flooding impacts on lower Brown Hill and Keswick Creeks and for analysing the mitigation case interaction of lower Brown Hill Creek, Keswick Creek and the Keswick to Brown Hill Creek diversions.

A number of simulations were analysed in order to arrive at an optimal solution between the transfer of peak flow from Keswick Creek (via diversions), the resulting peak flow in lower Brown Hill Creek, and minimisation of residual flooding along Keswick Creek downstream of Anzac Highway.

The preliminary diversions design resulted in a peak flow in lower Brown Hill Creek of 37.1 m^3/s compared with a peak flow of 46.9 m^3/s in the final concept solution (discussed in Section 10.3 and Section 10.4).

Simulations also assessed the impact on lower Brown Hill and Keswick Creeks without the lower Brown Hill Creek upgrade works (i.e. base case conditions) but with the other Part A Works (incorporating a preliminary design for the Keswick to Brown Hill Creek diversions) and Part B Works in place.

To appreciate the impact of diverting flow from Keswick Creek into lower Brown Hill Creek (without capacity upgrade works), two floodplain maps are included at Appendix 8 for the following hypothetical simulations:

- 100 year ARI / lower Brown Hill Creek base case condition / all other mitigation works in place including diversions from Keswick Creek (refer Figure (i) of Appendix 8)

  This simulation shows the worst case breakout points along lower Brown Hill Creek if no capacity upgrade works are carried out along the creek.

- 100 year ARI / lower Brown Hill Creek base case condition / all other mitigation works in place except diversions from Keswick Creek (refer Figure (ii) of Appendix 8)

This simulation shows:

- flooding along Keswick Creek with upstream mitigation works in place (South Park Lands and Ridge Park) and without the diversions in place to transfer high flows into lower Brown Hill Creek; and
- flooding along lower Brown Hill Creek without upgrade works or flow diverted from Keswick Creek and with upper Brown Hill Creek upgrade works in place.

A scenario in which only the Part A Works are in place is discussed in Section 10.10 with reference to the floodplain map at Figure 17.

Modelling for the South Park Lands was carried out by Tonkin Consulting separately from the MIKE-FLOOD modelling by WorleyParsons (refer to Section 10.2).

9.2.2 Peak flows – Part A Works

The volume of stormwater runoff reaching any point along a watercourse is a function of the flow rate (or, more specifically, the flow hydrograph) in the watercourse assuming 100% containment of flow to the watercourse.

Flood mitigation measures of this SMP aim to achieve 100% containment of peak flow (generated by runoff from the critical duration storm for the 100 year ARI) to each watercourse, by means of peak flow reduction (via detention facilities) and/or creek capacity upgrades.

In respect of the base case scenario, theoretical peak flows, assuming 100% containment of the full runoff flows along the full length of each watercourse, have been determined using the RRR model. This has enabled the impact of the revised hydrologic modelling to be compared with modelling used for the 2012 SMP.

As a reality check of the mitigation case, peak flows have been compared between the RRR model and the MIKE 11 (1D) component of MIKE-FLOOD.

Peak flows for watercourses of the catchment, including mitigation case peak flows resulting from the Part A Works, are given at Appendix 9. Assessment of peak flows specific to the Part B Works is discussed in Section 9.3.3.

In comparing the 2013 hydrology with the hydrology previously applied (2012 hydrology), based on the RRR model of base case predicted flows:

- Maximum flow in lower Brown Hill Creek for the 90 minute storm is reduced from 35.5 to 28.0 m^3/s (21% reduction).
- Over the full length of lower Brown Hill Creek the 90 minute peak flow reduction is the same (21%).
- With the Part A Works in place the maximum peak flow in lower Brown Hill Creek results from the 90 minute storm. Otherwise – i.e. for the base case – the 36 hour peak flow is higher.
- Maximum flow in lower Keswick Creek for the critical 90 minute storm is reduced from 68.1 to 61.3 m^3/s (10% reduction).

- Over the length of lower Keswick Creek the 90 minute peak flow reduction varies from 14% at Anzac Highway to 10% at Adelaide Airport.
- For lower Brown Hill and Keswick Creeks, reduction in peak flow for the 36 hour storm (2012 to 2013 hydrology) is similar in proportion to that for the 90 minute storm.

Conclusions drawn from the peak flow data (RRR model / 100 year ARI) in relation to the Part A Works are:

- Without the proposed diversion flows from Keswick Creek, lower Brown Hill Creek is dominated by flow entering from the upper creek. The increase in peak flow between Anzac Highway and Adelaide Airport is only 2 m^3/s.
- Peak flow reduction in Glen Osmond Creek as a result of Ridge Park flood control dam (critical 90 minute storm) varies from 30% at Windsor Street to 15% at Unley Road. Historically, this has been the worst section for flooding problems. Peak flow entering Keswick Creek (critical 90 minute storm) is reduced by 2 m^3/s.
- The South Park Lands detention basins would have a significant impact in reducing peak flow along Parklands Creek in north Unley and consequent flow entering Keswick Creek. Peak flow reduction at Greenhill Road is reduced from 22.8 m^3/s to 6.6 m^3/s with similar reductions at the start of Keswick Creek.
- As a result of the Part A Works, maximum peak flow in Keswick Creek (at Adelaide Airport) is reduced from 61.3 to 28.4 m^3/s (54% reduction). At Anzac Highway the percentage reduction is greater due to the immediate influence downstream of the diversion off-takes into lower Brown Hill Creek.

9.3 PART B WORKS

9.3.1 Modelling simulations

Modelling simulations were run to analyse impacts for various base case and mitigation conditions as listed in the following table. Explanatory notes regarding the table:

- For ‘Upper Brown Hill Creek’ simulations, upper Brown Hill Creek was modelled in isolation of the other watercourses.
- The 90 minute peak flow for upper Brown Hill Creek is unaffected by a detention dam. The flooding impact for Options B1 and B2 is therefore represented by the base case simulation (No. 3).
- All simulations are based on 2013 hydrology except No.1, which is based on hydrologic modelling used for the 2012 SMP.

Floodplain maps for simulations listed in the following and Table 9 (except Simulation No. 4) are at Appendix 10.

Table 8: Part B flood modelling simulations

No.	Simulation	Catchment	ARI (yrs)	Storm event
1	Base case 2012 hydrology	Full BHKC	100	Composite
2	Base case 2013 hydrology	Full BHKC	100	Composite
3	Base case	Upper BHC	100	90 minutes
4	Base case	Upper BHC	10	36 hour
5	Base case	Upper BHC	20	36 hour
6	Base case	Upper BHC	50	36 hour
7	Base case	Upper BHC	100	36 hour
8	Base case	Upper BHC	500	36 hour
9	Dam at Site 1 without creek upgrade (1)	Upper BHC	100	36 hour
10	Option B1	Upper BHC	100	36 hour
11	Option B1	Upper BHC	500	36 hour
12	Dam at Site 2 without creek upgrade*	Upper BHC	100	36 hour
13	Option B2	Upper BHC	100	36 hour
14	Option B2	Upper BHC	500	36 hour
15	Option D	Upper BHC	100	36 hour
16	Option D	Upper BHC	500	6 hour

Notes:

1. Simulation No. 9 was run on a superseded version of the model
2. Simulations 10, 13, and 15 show the flood mitigation outcomes for Options B1, B2 and D respectively.

The following screenshots show localised flooding in key areas under simulations 10, 13 and 15.

Table 9: Part B flood modelling – localised flooding in key areas

No.	Simulation	Catchment	ARI (yrs)	Storm event
10A	Option B1 – Areas 4 and 5A	Upper BHK	100	36 hour
10B	Option B1 – Area 5B	Upper BHK	100	36 hour
10C	Option B1 – Area 6	Upper BHK	100	36 hour
13A	Option B2 – Areas 4 and 5A	Upper BHK	100	36 hour
13B	Option B2 – Area 5B	Upper BHK	100	36 hour
13C	Option B2 – Area 6	Upper BHK	100	36 hour
15A	Option D – Areas 4 and 5A	Upper BHK	100	36 hour
15B	Option D – Area 5B	Upper BHK	100	36 hour
15C	Option D – Area 6	Upper BHK	100	36 hour

Modelling simulations for Options C1, C2 and C3 were not carried on the upgraded model, nor for the 2013 hydrology. Options C1 and C2 were analysed for the 2012 SMP and were not repeated in the Part B process because they were unlikely to be short-listed for further detailed consideration. Key points of analysis from the simulations are outlined below.

Table 10: Analysis of Part B simulations

No.	Analysis of simulation
1	• Similar flood extent as 2012 SMP mapping for Glen Osmond and Parklands Creeks • Slightly reduced flood extent along upper Brown Hill Creek down to Forestville Reserve • Reduced breakout along Wilberforce Walk, probably due to better definition along roadways • Reduced breakout at Showgrounds travelling north, which is partly due to upgraded modelling of Showgrounds culverts with correct size and roughness • To the west of Anzac Highway floodwaters appear to travel towards the north more than previously, resulting in less extent of floodwaters either side of lower Brown Hill Creek, and increased extent past the airport
2	• Similar to 2012 SMP mapping, except for: - reduced breakout along Glen Osmond Creek because 1997 culvert works at Fisher Street are now in the model - breakout from Glen Osmond Creek now primarily at Torrens and Fern Avenues - reduced westerly spread of breakout from Brown Hill Creek at Hampton Street - less breakout at Forestville Reserve • Spreading flow through West Torrens is fed along streets rather than fanning out evenly across the floodplain
3	• Minimal breakout upstream from Orphanage Park • Some breakout at Orphanage Park into Mitchell Street and down Goodwood Road, but less than 0.5 m^3/s • Some breakout at First and Second Avenues, but peak flow is less than 2 m^3/s across Anzac Highway
4	• No significant breakout from upper Brown Hill Creek
5	• Only very minor breakout at Second Avenue, resulting in less than 0.5 m^3/s across Anzac Highway
6	• Reduced breakout at Hampton Street, but contained within the roadway and down Denning Street in the road • About 2 m^3/s is breaking out at Regent Street, with about 1 m^3/s breaking out at Goodwood Road • Some breakout at First and Second Avenues, with about 4 m^3/s passing over Anzac Highway to the north of the creek, spreading west as far as Keswick Creek as it passes the east side of the airport
7	• Breakouts at: - Kent Street due to private access bridges - Between Hampton Street and Cross Road - About 7 m^3/s is breaking out at Regent Street, with about 1 m^3/s breaking out at Goodwood Road - Some breakout at First and Second Avenues, with about 6 m^3/s passing over Anzac Highway to the north of the creek - Flow across Anzac Highway to the south of the creek is about 1 m^3/s

No.	Analysis of simulation
8	• Localised but high flow breakouts down to Kent Street • Significant breakout begins at Kent Street, travelling north and west • Continuous flow/breakout either side of the creek down to DPTI culvert • Breakouts between Forestville Reserve and Anzac Highway • About 28 m^3/s passing over Anzac Highway to the north of the creek • Flow across Anzac Highway to the south of the creek is about 8 m^3/s
9	• Some localised riparian flooding upstream from Cross Road • About 1 m^3/s breakout at Regent Street • Very minor breakout at Orphanage Park into Goodwood Road • Breakout from Second Avenue, leading to about 3 m^3/s passing over Anzac Highway to the north of the creek
10	• Some localised riparian flooding upstream from Cross Road
11	• Significant reduction in riparian flooding upstream from Kent Street • Some breakouts at Kent Street and Hampton Street • Continuous breakout and flow either side of the creek from Victoria Avenue to DPTI culvert • Breakout at Ethel and Charles Streets • Flow across Anzac Highway to the north of the creek is 8 m^3/s
12	• Some localised riparian flooding upstream from Cross Road • Very minor breakout at Orphanage Park into Goodwood Road • Breakout from Second Avenue, leading to about 1.5 m^3/s passing over Anzac Highway to the north of the creek • 90 minute storm also tested and shows similar flood characteristics as the 36 hour storm
13	• Some very localised riparian flooding upstream from Cross Road
14	• Not completed due to lack of hydrograph for dam 2
15	• Some localised riparian flooding upstream from Devonshire Street
16	• Localised but high flow breakouts down to Kent Street • Significant breakout begins at Kent Street, travelling north and west • Continuous flow/breakout either side of the creek down to DPTI culvert • Breakout at Ethel and Charles Streets • About 16 m^3/s passing over Anzac Highway to the north of the creek • Flow across Anzac Highway to the south of the creek is about 3 m^3/s
10A	• Localised breakout between Heywood Avenue and Cross Road does not impact above floor level • Proposed creek capacity upgrade works between Cross Road and Hampton Street (not modelled in this simulation) will reduce the localised breakout shown in this area
10B	• Localised breakout does not impact above floor level of houses
10C	• Localised breakout does not impact above floor level of houses
13A	• Same comment as 10A above
13B	• Same comment as 10B above
13C	• Same comment as 10C above
15B	• Localised breakout between Heywood Avenue and Cross Road does not impact above floor level
15B	• Same comment as 10B above
15C	• Same comment as 10C above

9.3.2 Conclusions from floodplain mapping

Conclusions from the floodplain mapping are:

- Results of floodplain mapping confirm the nearly complete flood mitigation effectiveness of each of Options B1, B2 and D.
- Options B1, B2 and D provide approximately the same level of flood protection for the 100 year ARI event (see simulation No. 7 compared with Nos.10, 13 and 15). The number of potential flood impacted properties along upper Brown Hill Creek in the Mitcham and Unley Council areas is reduced from over 400 to about 25 properties; and none of the 25 properties are likely to suffer above floor flooding.
- Flooding from upper Brown Hill Creek extends across Anzac Highway and as a result of any of the proposed flood mitigation Options B1, B2 or D, approximately 400 properties in West Torrens previously prone to flooding would also be protected from upper Brown Hill Creek flows.
- Comparison of simulations Nos. 3 and 7 shows that the 90 minute storm has less flooding influence compared with the 36 hour storm than reported in the 2012 SMP. This finding is confirmed by the peak flows obtained from the MIKE 11 analysis (discussed below).
- Simulation No.13 indicates that a dam at Site 2 alone would reduce significant flooding for all areas except downstream of Forestville Reserve. However, analysis of peak flows and 1D modelling indicates that existing creek capacity may be exceeded in the area of Regent Street and Orphanage Park. To determine the impact of such flooding, further modelling and analysis at a more detailed level would be required.

The 10, 20, 50 and 500 year ARI simulations for the composite storm events were undertaken for the purpose of obtaining economic assessments.

The effect of applying the 2013 hydrology and updating the floodplain model has reduced the extent of flooding compared with previous modelling results (as assessed for the SMP), and this is reflected in the reduced number of flood affected properties, as follows:

Table 11: Flood affected properties for the whole of the BHKC catchment

100 year ARI	**Number of flood affected properties**		
	Over-floor flooding	**Under-floor flooding**	**Total**
2012 SMP	1,712	5,209	6,921
2013 hydrology	1,163	914	2,077

A reduction of approximately 1,100 properties is due to a correction made in the model for existing infrastructure on Glen Osmond Creek.

Table 12: Flood affected properties for upper Brown Hill Creek

100 year ARI	Number of flood affected properties		
	Over-floor flooding	Under-floor flooding	Total
2012 SMP	726	323	1,049
2013 hydrology	147	270	417

* These numbers are not readily obtained from the 2012 modelling. An estimate has been made but, in reality the numbers are likely to be lower than shown.

The 2013 hydrology and upgraded floodplain model have significantly altered the flood risk profile of upper Brown Hill Creek. Flooding for both the 90 minute and 36 hour storm durations are significantly reduced in places. Previously, about 80 houses in Mitcham were at risk and 969 in Unley. Now the respective numbers are 30 and 387.

Scaling down the size of the dam (either at Site 1 or Site 2) in response to the 2013 hydrology would not produce equivalent flood mitigation benefits (i.e. elimination of 100 year ARI flood impact, particularly in the top half of upper Brown Hill Creek).

Although modelling simulations were not carried out in the Part B process for Options A1, A2, C1, C2 and C3, there is data from the 2012 SMP investigations to verify that these options could all be designed to provide the same level of flood protection as for Options B1, B2 and D.

9.3.3 Peak flows – upper Brown Hill Creek

The rationale for examination of peak flows is explained in Section 9.2.2.

Based on the RRR model, the impact of 2013 hydrology compared with that used for the 2012 SMP, in respect of upper Brown Hill Creek, is summarised in the following predicted peak flows (100 year ARI):

Table 13: Peak flows for upper Brown Hill Creek – 36 hour storm

Storm duration	36 hour (no dam)		36 hour (dam 1)		36 hour (dam 2)	
Hydrology	2012	2013	2012	2013	2012	2013
Location	Peak flow (m^3/s)					
Scotch College	26.1	26.5	19.5	19.3	15.9	16.0
Belair Road	30.2	27.7	21.7	20.4	20.0	17.4
Cross Road	36.4	30.0	27.7	22.2	26.3	19.8
Goodwood Road	37.1	30.2	28.2	22.4	26.9	20.1
Anzac Highway	38.9	31	29.7	22.9	28.7	20.9

Peak flows for 2013 hydrology under ‘no dam’, ‘dam 1’ and ‘dam 2’ are applicable to Options D, B1 and B2 respectively.

The following 90 minute peak flows for the 2013 hydrology are the same for Options D, B1 and B2.

Table 14: Peak flows for upper Brown Hill Creek – 90 minute storm

Storm duration	90 minute	
Hydrology	**2012**	**2013**
Location	**Peak flow (m^3/s)**	
Scotch College	3.7	6.4
Belair Road	18.7	13.8
Cross Road	27.8	21.9
Goodwood Road	29.4	23.2
Anzac Highway	33.9	26.8

The 90 minute and 36 hour flows assume 100% containment of flow to the creek.

In comparing peak flows based on the 2013 hydrology with the 2012 modelling, the 90 minute peak flows along upper Brown Hill Creek are reduced by a relatively constant factor. However, the 36 hour peak flow at Scotch College under the 2013 hydrology is about the same as in the 2012 hydrologic modelling. This is because the methodology for determining the 36 hour peak from the rural part of the catchment relies on the measured flow at Scotch College weir. It is not until downstream of Cross Road that the 36 hour peak flows along Brown Hill Creek for the previous 2012 hydrology and the 2013 hydrology diverge significantly from one another.

The following predicted peak flows in upper Brown Hill Creek are extracted from the MIKE 11 part of the MIKE-FLOOD model (upgraded and based on the 2013 hydrology for 100 year ARI). Governing flows for each option are highlighted.

Table 15: Peak flows for upper Brown Hill Creek – mitigation case options

Option	Option D		Option B1		Option B2	
Duration	**90 min**	**36 hr**	**90 min**	**36 hr**	**90 min**	**36 hr**
Location	**Peak flow (m^3/s)**					
Scotch College	6.4	26.3	6.4	19.3	5.0	15.9
Belair Road	6.4	26.5	6.4	19.3	5.0	15.9
Cross Road	12.1	27.3	12.1	20.4	12.1	17.1
Goodwood Road	20.6	29.9	20.1	22.4	20.0	19.1
Anzac Highway	24.8	30.8	24.0	23.0	24.0	19.9

Options D, B1 and B2 relate to 'no dam', 'dam 1' and 'dam 2' respectively of the RRR peak flow table.

Until the floodplain model (MIKE-FLOOD) was upgraded late in 2013, design criteria of the Part B process relied on peak flows of the RRR model. Peak flows resulting from the upgraded floodplain model (MIKE-FLOOD) generally corroborate the RRR flows.

Conclusions from the peak flow data are:

- In all modelling, peak flows from dam Site 2 are less than from dam Site 1 and this is reflected in the flood mapping simulations Nos. 9 and 12.
- For Option B1 (RRR model results) the reduced 36 hour peak flow governs down to about the Avenue Street area from where the 36 hour and 90 minute peak flows are about the same until the section downstream of Forestville Reserve where the 90 minute peak flow governs.
- For Option B1 (MIKE 11 model results) the reduced 36 hour peak flow governs along the full length of upper Brown Hill Creek except downstream of Forestville Reserve. This is different from the analysis in the SMP (for which 2012 hydrology applied).

In the 2012 SMP analysis:

- The dam, in reducing peak flows generated mainly in the rural part of the catchment under the 36 hour event, would only be effective in preventing breakout down to about Avenue Street, no matter how large the dam or at what site; and
- therefore, downstream of Avenue Street, peak flows off the urban area of upper Brown Hill Creek under the 90 minute storm produced flooding which was designed to be mitigated by the Malcolm Street high flow bypass.

Under the 2013 hydrology, with a dam (either at Site 1 or Site 2), the reduced 36 hour peak flow governs (or is about the same as the 90 minute flow) for all of upper Brown Hill Creek except downstream of Forestville Reserve where the 90 minute flow governs.

- For the RRR data applied to Option B2, the reduced 36 hour peak flow governs only down to about Cross Road, after which the 90 minute peak flow governs.
- For the MIKE 11 data applied to Option B2, the 90 minute and reduced 36 hour peak flows below Cross Road are closer to one another than for Option B1.
- For Option D, the 36 hour peak flow is higher than the 90 minute peak flow (100 year ARI). Therefore by expanding creek capacity to accommodate the 36 hour peak flow, the creek will be able to accommodate shorter duration storms of greater ARI than 100 years.
- In the revised hydrologic modelling, peak flows along critical reaches of the creek downstream of Malcolm Street are about 7 to 8 m^3/s less than those of the 2012 SMP (based on RRR data). This created the opportunity to re-assess upgrading creek capacity as a feasible flood mitigation option for upper Brown Hill Creek.

Creek capacity is assessed as the minimum flow at which, from the floodplain modelling, significant breakout occurs and causes flooding which extends beyond the immediate environs of the creek. For example, from analysis of the MIKE 11 flows, the capacity of the creek through Orphanage Park is about 18 m^3/s based on simulations 3, 12 and 13 which show little or no breakout from the creek through the park. From HEC-RAS analysis, creek capacity through the park was assessed to be about 16 m^3/s.

Also, from the modelling data it is possible to estimate the approximate volume of water in excess of existing channel capacity down to any point in the system (i.e. the theoretical breakout volume along the channel upstream of the nominated point). For upper Brown Hill Creek, the estimated approximate flood volume upstream of Goodwood Road (36 hour peak flow/100 year ARI) is 193 ML. To put this volume into perspective, an Olympic size swimming pool is about 2 ML capacity.

A range of peak flow velocities have been obtained from the MIKE 11 model (100 year ARI), as follows:

Table 16: Range of peak flow velocities in upper Brown Hill Creek – mitigation case options

Option	**Option D**		**Option B1**		**Option B2**	
Duration	**90 min**	**36 hr**	**90 min**	**36 hr**	**90 min**	**36 hr**
Location	**Peak flow velocity (m/s)**					
Scotch College	2.4	3.4	2.4	3.2	2.2	3.0
Belair Road	2.4	3.8	2.4	3.4	2.2	3.2
Cross Road	1.6	3.3	1.6	2.5	1.6	2.2
Goodwood Road	3.4	3.9	3.7	3.8	3.7	3.6
Anzac Highway	2.8	3.6	3.7	3.6	3.7	3.5

The maximum velocity of flow for each of the three options generally occurs in the 36 hour storm (100 year ARI), as follows:

Table 17: Summary of peak flow velocities in upper Brown Hill Creek

Option	**Average velocity (m/s)**	**Maximum velocity (m/s)**
D	3.6	3.9
B1	3.3	3.8
B2	3.2	3.6

In general, any flow of velocity greater than about 2 m/s has the potential to cause erosion in a creek. For creek flows in the 100 year ARI event, the difference in velocity between Options B2 and D is only marginal in terms of any damaging impacts on the bed and banks of the creek. Any difference also has to consider that with Option D, for the sections of creek subject to capacity upgrade works, stabilised creek banks are likely to be better protected against erosion than ‘natural’ banks. Erosion is also a factor of the alignment and smoothness of the flow surface (bed and banks). Irregularities in the creek geometry are more likely to result in turbulence induced erosion than where the creek is modified to an appropriate design.

9.3.4 Lower Brown Hill Creek

The 2012 SMP reported that the design flow of lower Brown Hill Creek upgrade is governed by the 90 minute peak flows in both upper Brown Hill and Keswick Creeks. The design therefore is not dependent on a ‘with dam’ or ‘no dam’ outcome for upper Brown Hill Creek. That conclusion was verified for Option D through RRR and MIKE 11 modelling carried out in the Part B process.

Peak flows (100 year ARI) from MIKE 11 modelling (90 minute, 6 hour and 36 hour storms) for upper Brown Hill, Glen Osmond, Parklands and Keswick Creeks, based on mitigation works in place along those watercourses – principally Ridge Park detention dam, South Park Lands detention basins and flow diversions from Keswick to lower Brown Hill Creek – are shown at Figure 11.

10. PART A FLOOD MITIGATION WORKS

10.1 OVERVIEW

The Part A Works are designed to mitigate flooding generated over the mainly urban sub-catchment of lower Brown Hill and Keswick Creeks through a combination of stormwater flow detention, diversion of high flows and watercourse upgrading for greater flow capacity. The Part A projects are:

- South Park Lands / Glenside detention basins (on Parklands Creek)
- Lower Brown Hill Creek capacity upgrade
- Flow diversions from Keswick Creek to Brown Hill Creek
- Brown Hill Creek upgrade between Forestville Reserve and Anzac Highway (also designated as Area 1 of the upper Brown Hill Creek / Part B process)
- Ridge Park flood control dam (on Glen Osmond Creek)
- Brown Hill Creek diversion culvert by DPTI
- Glen Osmond Creek minor upgrade works
- Mount Osmond interchange dam modification

The two largest and most significant projects in terms of cost and flood mitigation benefit are the above listed lower Brown Hill Creek upgrade and the flow diversions from Keswick Creek to Brown Hill Creek. The lower Brown Hill Creek upgrade caters for the combination of stormwater flow from upper Brown Hill Creek and flow diverted from Keswick Creek. The design rationale is that diverting some of Keswick Creek at times of high flow will mitigate the significant risk of flooding along Keswick Creek, particularly in the western suburbs of the catchment.

Past studies have shown that upgrading each of the creeks separately would be a less economic solution, particularly as Keswick Creek has a longer length through the western suburbs than lower Brown Hill Creek and more of the creek is located in private properties compared with lower Brown Hill Creek.

Descriptions of each of the above Part A projects are outlined in the following eight sections with the locations shown in the plan at Figure 12.

Some of the above works were originally components of the 2006 Master Plan for which further work or concept designs have been carried out:

- South Park Lands flood detention basins: The originally planned six basins have been reduced to three and the proposed culvert upgrade beneath Fullarton and Greenhill Roads intersection has been superseded by enlarging the existing basin in Glenside Development site (formerly part of Glenside Hospital) as one of the three basins.
- Flow diversions from Keswick Creek to lower Brown Hill Creek: The configuration has been revised twice – originally by moving the railway off-take downstream to Anzac Highway and moving the Showgrounds offtake upstream to Le Hunte Street, and more recently avoiding the culvert route along Leader Street by utilising more of the Showgrounds and the existing creek in Keswick Barracks.

- Lower Brown Hill Creek capacity upgrade: Scope of works reduced as a result of revised hydrologic modelling (2013 hydrology).
- Ridge Park flood control dam: Constructed in 2015 with a modified design to also allow for stormwater harvesting by means of a MAR scheme.
- Brown Hill Creek upgrade between Forestville Reserve and Anzac Highway: Planning design included in the Part B process.
- Glen Osmond Creek minor upgrade works: This supersedes the Fisher Street bypass culvert proposed in the 2012 SMP which was in lieu of the original Fisher Street culvert upgrade included in the 2006 Master Plan.
- Mount Osmond interchange dam modification: Completed in 2008.

As outlined in Section 8.3, computer modelling which underpins the flood mitigation analysis of all the works has undergone significant change since the 2012 SMP. The effects of revised computer modelling, particularly in terms of peak flows for establishing design criteria, vary from project to project and the resulting changes from the 2012 SMP to this SMP are identified in the following sections.

In particular, the lower Brown Hill Creek upgrade (Section 10.3) and Keswick Creek diversions (Section 10.4) have involved creek and channel capacity upgrade solutions derived from modelling analysis by WorleyParsons using the MIKE-FLOOD, MIKE 11 and WaterRide systems, as follows:

- Peak flows as the basis for design are derived from hydrologic modelling by DPTI and subsequent floodplain hydraulic modelling carried out by WorleyParsons, as summarised in Appendix 9.
- Creek capacity upgrade works involve widening the creek bed and/or modifying the creek banks at critical sections, including bridges, to give sufficient capacity for 100 year ARI peak flows. Minor deepening of the creek may also be required at certain sections by removing sediment build up in order to lower the creek bed to a consistent grade line.
- Cross-sectional dimensions for proposed creek widening and deepening (mitigation case), as applied to the hydraulic modelling, are based on analysis of MIKE-FLOOD and MIKE 11 modelling results by WorleyParsons (refer Appendices 13, 16 and 21).
- Where significant flow breakouts are evident, the approximate channel dimensions have been adjusted in the model so that breakouts are eliminated (i.e. flows are therefore contained to the ‘modified’ creek).
- The cross-sectional dimensions are indicative only and would need to be verified or modified by more accurate modelling carried out in detailed design. In general, the investigations relating to creek capacity works are based on ‘whole of catchment’ modelling and the related design is at concept level only.

Cost estimates in the 2012 SMP for works derived from the 2006 Master Plan were updated by ABS indexing. All the design and construction cost estimates for this SMP have been re-estimated from first principles by the specialist construction planning and estimating resource (Costplan) to give consistency across the cost estimates of each project. An overall financial summary is provided at Section 15.

10.2 SOUTH PARK LANDS / GLENSIDE DETENTION BASINS

Currently, predicted peak stormwater flows in Parklands Creek are about double the creek capacity downstream of Greenhill Road. The South Park Lands detention basins will reduce peak stormwater flows along Parklands Creek and reduce the flooding risk to mainly residential areas downstream of Greenhill Road as well as areas bordering to the park lands.

Parklands Creek flows east to west through a number of parks within the South Park Lands. The 2006 Master Plan proposed six temporary storage basins in the South Park Lands between Fullarton Road and Peacock Road. Those proposals were constrained by the use of Victoria Park for horse racing.

Since then, horse racing has ceased at Victoria Park and the Adelaide City Council has produced a master plan to redevelop Victoria Park which includes the establishment of wetlands on the northern side of Parklands Creek in the southern precinct of Victoria Park. This has allowed for the original proposal of six detention basins to be reassessed.

In recent years the State Government has been preparing the former Glenside Hospital of SA Department of Health for redevelopment. As part of the current Glenside Development Site (initiated by Renewal SA in 2015) a significant area has been set aside for community open space including extension of the current stormwater detention basin in the north western part of the site. It is understood from informal liaison with Renewal SA that the open space layout will take into account requirements of the BHKC project.

In 2009 Tonkin Consulting was engaged by the BHKC project to undertake investigations and design development for a series of flood mitigation storages, wetlands and MAR potential in the South Park Lands. In their two reports 'Stormwater Management in the South Park Lands; Stage 1 – Feasibility Study' (January, 2010) and 'Stormwater Management in the South Park Lands; Stage 2 – Concept Design' (November, 2014) Tonkin indicates that required flood mitigation measures can be achieved by the establishment of temporary flood detention basins in three areas, being:

- enlargement of the existing Glenside basin from a storage capacity of 18 ML to 37 ML, to limit flow to the existing capacity of the culvert under the Fullarton and Greenhill Roads intersection (leading into the South Park Lands);
- creation of a storage of up to 115 ML incorporating a wetland in Victoria Park (identified in the Victoria Park Master Plan of Adelaide City Council); and
- construction of a levee to create storage of up to 47 ML in the southern and western part of Park 20 which is located between Peacock and Unley Roads.

The Tonkin concept design report addresses a range of issues more fully, including:

- flood detention;
- landscaping;
- water quality improvement;
- water harvesting;
- environmental flows;
- approvals;
- access to Glenside campus;
- geotechnical conditions;

- contaminated soils (Glenside site, Victoria Park and Park 20);
- cultural heritage; and
- community consultation.

In 2009/10 consultation on a feasibility design was carried out with relevant authorities and community and park lands user groups, and outcomes were used to inform the subsequent stage of concept design. Key elements of the concept design were outlined in information produced for stakeholders and the community in March 2011.

Tonkin carried out a further stage of design ('detailed concept design') in 2014 which comprised general arrangement drawings for civil engineering structures and earthworks for Victoria Park and Park 20. The designs to this level of detail would enable the project to quickly advance to the 'shovel ready' stage if required by funding or political imperatives brought on at short notice.

The proposed layout of works and concept design sketches for the detention system are included in Appendix 11.

Key features of the concept design are:

- diversion of stormwater flow out of Parklands Creek and through a series of ephemeral wetlands in the southern portion of Victoria Park;
- operation of the wetlands to slow down stormwater flow and provide further treatment prior to returning water of improved quality back into Parklands Creek;
- improvement in the biodiversity of each site through the inclusion of native vegetation and habitat opportunities;
- provision of an alternative flow path in Park 20 to reduce erosion and control the release of water under Greenhill Road;
- enhanced amenity, recreational and educational opportunities for the South Park Lands;
- utilisation of the existing GPT at the Glenside site and construction of an enlarged sedimentation basin to improve the quality of water entering the South Park Lands;
- operation of the wetlands within a range of water levels under normal conditions to ensure environmental integrity (re-seeding of ephemeral plants, reduced potential for nutrient release in the sediment substratum and minimisation of nuisance insects); and
- potential for harvesting of stormwater through a MAR facility, should aquifer capacity be suitable and reuse water prove to be in demand.

The flood detention basins will reduce the flow of stormwater in Parklands Creek from about 23 m^3/s to 6.9 m^3/s downstream from Park 20. The estimated capacity of the culvert under Greenhill Road downstream from Park 20 is 8 m^3/s. As a tributary of Keswick Creek, peak stormwater flow reduction in Parklands Creek will also contribute to flood mitigation along Keswick Creek (refer Section 9.2.2).

The estimated cost of the three South Park Lands detention basins is $17.4 million (refer Section 15.2.1 and details at Appendix 26).

The flood extent in the South Park Lands for the 100 year ARI mitigation case, produced by Tonkin in their concept design report, is reproduced at Figure 13. This flood extent has been 'clipped' into the floodplain map at Figure 18 (refer Section 13.1). Flood extents for other ARIs were not produced by Tonkin.

10.3 LOWER BROWN HILL CREEK UPGRADE

Lower Brown Hill Creek extends for a length of 3.3 km from Anzac Highway to its confluence with Keswick Creek on the eastern side of Adelaide Airport.

For much of its length the creek consists of a concrete lined channel within a 12 m wide council owned reserve. In areas where the creek remains unlined, it typically consists of an incised earth channel devoid of native vegetation. The capacity of the channel varies considerably from 15 m^3/s to 40 m^3/s due to localised obstructions and varying channel cross-section geometry.

Bank stabilisation works have been constructed in places along the creek at different times, some up to about 50 years ago. The photo below shows a gabion retaining wall constructed by West Torrens Council in 2012. Existing characteristics of the creek are outlined at Appendix 12.

Gabion retaining wall constructed by West Torrens Council in 2012

Brown Hill Creek channel needs to be upgraded in flow capacity to take both the existing stormwater flows from the upstream creek together with additional flows diverted from Keswick Creek (refer Section 10.4).

The original concept for the proposed lower Brown Hill Creek channel upgrade, as documented in the 2012 SMP, was based on having a peak flow capacity of 60 m^3/s to accommodate:

- a diversion flow of 24 m^3/s (Le Hunte Street diversion: 14 m^3/s and Anzac Highway diversion: 10 m^3/s) combined with a flow from upper Brown Hill Creek of approximately 34 m^3/s – for the 90 minute storm; and
- a diversion flow at the peak of the 36 hour storm of 18 m^3/s combined with a peak flow from upper Brown Hill Creek of 39 m^3/s.

Further concept planning work based on the 60 m^3/s capacity was carried out in 2012 and 2013 by Tonkin Consulting as documented in the report 'Lower Brown Hill Creek Channel Upgrade / Stage 1 – Engineering Feasibility Report – Interim Report' (February 2014).

The nominal design was a concrete lined channel for the entire length of upgrade, with vertical walls of 2 m average depth and a base width of 5.5 m, together with bridge upgrades. Other concepts were also considered for preliminary estimated cost ranking, including a gabion sided channel (either vertical or stepped) and underground culvert. The final design was expected to involve a combination of designs for different sections of the creek.

The Tonkin Interim Report (February 2014) also addressed non-engineering considerations including heritage, biodiversity, environmental assessment and local community opportunities; and alternative design options to a concrete lined channel, together with estimated construction costs.

In the latter stage of the Interim Report preparation by Tonkin, the release of revised IFD data by the BOM initiated the revision of the catchment hydrology (refer Section 8.2.3). Following this revision, further investigations were based on the peak flow in lower Brown Hill Creek being about 50 m^3/s maximum.

The Interim Report therefore also includes a preliminary assessment of an alternative concept involving construction of a culvert under roads extending from Keswick Creek at Anzac Highway to near the end of lower Brown Hill Creek to convey the diversion flow. Only minor upgrading of lower Brown Hill Creek would then be required to accommodate its peak flow alone, except for capacity upgrading of a short length at the end to convey the combined flow. Variations of this theme were also considered but were seen to be less viable and cost-effective (and therefore not reported).

As a result of floodplain modelling work carried out by WorleyParsons during the Part B process, concept planning for lower Brown Hill Creek and the associated Keswick to lower Brown Hill Creek diversions has been refined by Tonkin since its 2014 Interim Report. Furthermore, as established in the Part B process, the BHKC project commissioned Costplan to produce all construction cost estimates for the Parts A and B Works, including lower Brown Hill Creek upgrade.

As indicated in Section 10.1, the concept design is based on hydraulic modelling carried out and analysed by WorleyParsons. Key points are:

- Peak flows are derived from hydrologic modelling by DPTI and subsequent floodplain hydraulic modelling carried out by WorleyParsons, as summarised in Appendix 9.
- Cross-sectional dimensions for proposed creek widening and deepening (mitigation case), as applied to the hydraulic modelling, are shown Appendix 13.
- The cross-sectional dimensions are indicative only and would need to be verified or modified by more accurate modelling carried out in detailed design.

The current planning concept design is documented in the draft report 'Lower Brown Hill Creek and Keswick Creek Upgrades – Concept Report' (Tonkin Consulting, March 2016 draft). The following key extracts from that report are included in the SMP:

- The plan at Figure 14 shows the overall scope of the project.
- To inform investigations, the creek was divided into segments as detailed in the plans at Appendix 12. That information assists in putting into perspective the variability of the creek in terms of its existing condition, relative capacity and related factors.

- Proposed works for a cost-effective capacity upgrade of lower Brown Hill Creek, as described in the draft Tonkin Concept Report (March 2016) and based on cost estimating by Costplan, are outlined in Appendix 14.

Proposed works include structural upgrades of the following bridges and pedestrian walkways:

- Farnham Road
- Daly Street
- Marion Road
- Harvey Avenue
- Beare/Watson Avenue
- Pedestrian bridges (Beauchamp Street, Warwick Street, Packard Street and Gray Street)

The concept design is outlined in Appendix 14. The concept design is not intended to necessarily represent likely final design. The aim of the channel upgrade works is to retain as far as possible a natural creek environment. Where this is not possible, or the creek banks need to be stabilised, the type of treatment that could be used includes gabions as shown in the image on page 88. Generally, where the creek is already fully or partly concrete lined any upgrading is assumed to be based on the same type of construction.

The exact scope of creek capacity upgrade works and the degree to which individual properties are protected would be an outcome of detailed design. It is expected that final designs will involve consultation with the local community and collaboration with individual property owners where works impact on their properties.

Existing GPTs, including trash racks, floating litter booms and silt basins to aid rubbish removal and reduce maintenance costs, will be kept at existing locations and facilities of this type may be installed at additional locations (refer Section 14.1.3).

An allowance in the cost estimate for property acquisitions and/or creation of easements has been made in respect of the following locations, generally due to insufficient creek corridor width:

- Private property on either the northern or southern side of the creek fronting Anzac Highway
- Approximately a 10 m wide strip of land from up to 11 private properties between Daly and Gray Streets
- Boundary correction where the creek has encroached into the property at Warwick Avenue
- Approximately a 2 m strip of land from two private properties between Marion Road and Harvey Avenue (the estimate conservatively allows for full acquisition less residual value)
- Disruption to properties due to works within existing easements and creation of new easements – downstream side of Harvey Avenue
- Other potential boundary corrections between the creek corridor (creek reserve) and private and state owned properties

The properties identified for acquisition and precise land areas need to be confirmed following further investigations and detailed design. Most of the land areas involved are part of the existing creek and are of little benefit to the properties concerned.

In addition to the flood mitigation objective, upgrading lower Brown Hill Creek would present an opportunity to enhance the environment and amenity of the creek corridor which is mostly council owned reserve.

- Between Anzac Highway and Farnham Road a viable option to increase channel capacity is to convert the creek into an underground culvert system and utilise the open space created along the corridor as a linear park concept.
- In the Grassmere Reserve integration of the creek and surrounding open space could be enhanced.
- Where Brown Hill Creek crosses the disused railway corridor in Plympton, there is a significant area that could be utilised for a wetlands, thus improving the amenity of that part of the railway corridor open space.
- Associated with upgrading, the creek corridor can be revegetated with appropriate indigenous species, and exotic and pest plant vegetation removed.

The estimated cost to upgrade lower Brown Hill Creek is $39.1 million (refer Section 15.2.2 and details at Appendix 27).

10.4 FLOW DIVERSIONS FROM KESWICK CREEK TO BROWN HILL CREEK

Keswick Creek extends for a length of 7.5 km, starting at the confluence of Parklands and Glen Osmond Creeks in Wayville. For most of its length Keswick Creek has insufficient capacity for large stormwater flows, including the culvert sections of Goodwood Road / Showgrounds and Anzac Highway / Ashford Road.

The State Government owns the Showgrounds site and is therefore responsible for the Showgrounds culvert. The Royal Agricultural & Horticultural Society of South Australia (RAHS) leases the site.

The culvert under Goodwood Road and the Showgrounds (in effect, twin culverts 1,520 mm high x 2,320 mm wide) has a capacity of approximately 25 m^3/s, compared with the predicted 100 year ARI peak flow of 43 m^3/s. At high flows the constriction leads to flooding of areas through the Showgrounds, down into Keswick and along the railway line and into the commercial areas of Mile End South.

The existing culvert from Anzac Highway to Ashford Road also has a capacity of approximately 25 m^3/s. Higher flows at this point lead to flooding in areas through the suburbs of Ashford, Keswick and Mile End South.

Downstream of Anzac Highway the channel capacity varies between 20 m^3/s and 25 m^3/s compared with predicted peak flows which range from 44 m^3/s up to about 61 m^3/s. Keswick Creek continues to pick up further inflows downstream, significantly exceeding its maximum capacity. This results in substantial flooding in the commercial area of Mile End South and residential suburbs further to the west.

In 2001, in response to regular flooding events, the (then) Department of Defence commissioned consultants to investigate the condition of the Keswick Creek open channel where it traverses the Keswick Military Barracks. Relevant conclusions of the report 'Investigation of Keswick Creek – Keswick Barracks, South Australia – Condition Assessment Review Draft Report' (Brown & Root, September 2001, for Haden Facilities Management) are that:

- flooding appears to have resulted from inadequate capacity of the channel – noting that capacity was considered to be about 25 m^3/s;
- the poor structural condition of the Showgrounds tunnel at the western end was "alarming"; and
- no decision be made in regard to any increase in the capacity of the channel until after completion of the then PCWCB investigations (the forerunner of the 2006 Master Plan process).

Diverting a proportion of stormwater flow from Keswick Creek upstream of the Anzac Highway / Ashford Road culvert into Brown Hill Creek allows the remaining flow to be largely within the existing channel capacity downstream. This provides substantially less flood risk immediately downstream and in the commercial district of Mile End South and areas further west.

Furthermore, it provides an additional benefit as the effect of transferring flows into Brown Hill Creek avoids the need for channel capacity upgrades along Keswick Creek downstream, more of which is in private ownership and would cause greater community disruption and involve higher cost than the proposed scheme.

The concept documented in the 2012 SMP was based on culverts to divert high flows from Keswick Creek into lower Brown Hill Creek, as follows:

- Le Hunte Street culvert – from the intersection with Keswick Creek, via the Showgrounds, Leader Street and Anzac Highway to lower Brown Hill Creek – to convey 14 m^3/s
- Anzac Highway culvert – along the highway from Keswick Creek to lower Brown Hill Creek – to convey 10 m^3/s

The proposed concept was based on upgrading lower Brown Hill Creek to accommodate a maximum flow of about 60 m^3/s, combining the 24 m^3/s with a 90 minute storm peak flow from upper Brown Hill Creek of 34 m^3/s. For the 36 hour storm the diversion flow of 18 m^3/s would have combined with a peak flow from upper Brown Hill Creek of 39 m^3/s. The following reports informed on concept planning of the diversions at the time:

- Stage 1 Report – Feasibility & Alignment Selection – Diversions from Keswick Creek to Brown Hill Creek (Tonkin Consulting, November 2009)
- Environmental Site History – Diversions from Keswick Creek to Brownhill Creek (Tonkin Consulting, January 2010)
- Stage 2 Report – Preliminary Design – Keswick Creek to Brown Hill Creek Diversions (Tonkin Consulting, December 2010)
- Keswick Creek Diversion – Options Report (Tonkin Consulting, March 2013)

As discussed in Section 10.3 (lower Brown Hill Creek upgrade), concept planning for the diversions and lower Brown Hill Creek has been taken further since the 2012 SMP through subsequent investigations by Tonkin and WorleyParsons based on the 2013 hydrology.

The current planning concept design is documented in the draft report 'Lower Brown Hill Creek and Keswick Creek Upgrades – Concept Report' (Tonkin Consulting, March 2016 draft). For background, characteristics of Keswick Creek between Le Hunte Street and Anzac Highway are provided in the information at Appendix 15.

With reference to the plan at Figure 15, it is now proposed to:

- divert 13.8 m^3/s of high stormwater flow around the section of Keswick Creek between Le Hunte Street and the railway corridor to discharge back into the section of Keswick Creek immediately downstream of the railway and in the Keswick Barracks ('Le Hunte Street diversion');
- expand the capacity of the open channel in the Keswick Barracks to accommodate the 100 year ARI peak flow; and
- divert up to 25.1 m^3/s of high stormwater flow from Keswick Creek into lower Brown Hill Creek via twin culverts under Anzac Highway.

Peak flows and culvert dimensions (both Le Hunte Street and Anzac Highway) used as the basis for design are derived from hydrologic modelling by DPTI and subsequent hydraulic modelling carried out by WorleyParsons (refer Figure 11). The hydraulic modelling design assumes the insertion of a 'choke' in the existing Keswick Creek culvert immediately downstream of the diversions take-off point. The modelled choke is a 2 m diameter orifice. In practice, the orifice could be a short length of pipe cast into a block with streamlining of the entry and exit ends.

The proposed concept of works as described in the draft Tonkin Concept Report (March 2016) is reproduced in Appendix 14.

Features of Le Hunte Street diversion:

- The feasibility of the route along Le Hunte Street, across Goodwood Road and through part of the Showgrounds was established in the 2009 and 2010 reports by Tonkin Consulting. The current revised route has not been investigated to the same level of detail, but the preliminary investigations indicate that it is a viable option of lower cost.
- Extending the route along Leader Street is regarded as more problematic than previously considered. Adverse factors include working around existing utility services, likely community opposition (reflecting community opposition to constructing culverts in suburban streets experienced during the Part B process) and the high cost to DPTI in laying the Brown Hill Creek (Goodwood Junction rail project) diversion culvert.
- Investigations by DPTI of a road underpass at the Leader Street railway crossing presented a further risk in terms of feasibility and risk – as discussed in the 2013 Options Report by Tonkin.
- The culvert will therefore have to cross under the railway corridor as shown approximately in the plan at Figure 15 (also Figure 9 of Appendix 14). Whilst construction will involve complexities in respect of meeting the requirements of DPTI and Australian Rail Track Corporation (ARTC) for the railway infrastructure and operations, a crossing point at Leader Street would probably present greater difficulties.
- The diverted flow of about 14 m^3/s is modelled on having a single 3.3 m (W) x 1.5 m (H) culvert, approximately 1,200 m in length.
- The exact culvert alignment and size are subject to detailed design and are expected to vary marginally, particularly if changes are made to underground services in the meantime.
- Structural works at each end are required to transition flow from Keswick Creek into the culvert inlet at Le Hunte Street, and flow transition from the culvert into Keswick Creek channel. Preliminary concept layout designs are shown in Appendix 14.

- The railway crossing is conceptualised as nominally three parallel pipes of 1.8 m or 1.5 m diameter. Hydraulically, anything other than a single conduit is not ideal, but jacking pipes under the railway tracks would probably be necessary to satisfy DPTI and ARTC requirements.
- Limited property acquisition may be required at the Le Hunte Street inlet, and an easement or similar legal arrangement created for the culvert through the Keswick Barracks.

Informal discussions have been carried out with the RAHS (for the Showgrounds) and the Commonwealth Government property office (for the Barracks). No adverse issues arose concerning the potential culvert route through the Showgrounds and potential capacity upgrading of Keswick Creek concrete lined channel through the Keswick Barracks.

It is noted that a report 'Keswick Barracks and Surrounds / Urban Design Framework' (Alba and Woodhead, 2010) commissioned by West Torrens and Unley Councils identifies opportunities to enhance the creek through this area by landscaping it in more natural form to achieve desirable social and environmental objectives. A design of this nature would have to recognise that during a flood water will be flowing at high velocity and the available cross-section to convey the flow may be limited.

Features of the Barracks channel upgrade:

- The majority of the channel is trapezoidal shaped and concrete lined, with construction dating from the late 1930s. There is a short section of new channel construction leading away from where the channel crosses under the railway corridor.
- Peak flows and upgraded channel dimensions used as the basis for design are derived from hydrologic modelling by DPTI and subsequent hydraulic modelling carried out by WorleyParsons.
- Cross-sectional dimensions for proposed channel widening (mitigation case), as applied to the hydraulic modelling, are shown in Appendix 16. The dimensions are indicative only and would need to be verified or modified by more accurate modelling carried out in detailed design.
- The implications in terms of land tenure and access rights and responsibilities of constructing channel infrastructure works on Commonwealth land at the Keswick Barracks have not been addressed. However, it is expected that satisfactory legal arrangements would be reached when necessary.

Features of the Anzac Highway diversions:

- The diverted flow of about 25 m^3/s is modelled on having twin 3.6 m wide x 1.5 m high culverts, approximately 500 m in length.
- Based on the 2009 and 2010 Tonkin reports and to avoid other utility services, the preferred alignment within the road reserve is generally under the central median strip. There are established trees in the strip which would have to be removed, but they are not in the significant category.
- The exact alignment and culvert dimensions are subject to detailed design and are expected to vary, particularly if changes are made to underground services in the meantime.
- Structural works at each end are required – to transition flow from Keswick Creek into the twin culverts, and transition flow from the culverts into lower Brown Hill Creek in conjunction with the existing Brown Hill Creek culvert under Anzac Highway. Preliminary concept layout designs are shown in Appendix 14.

The estimated cost of for the Keswick Creek diversions is $43.1 million (refer Section 15.2.3 and details at Appendix 27).

If at a later time the Barracks channel upgrade is found to be unsuitable, another alternative would be to extend the Le Hunte Street / Showgrounds culvert along Maple Avenue. With more detailed investigations, the Maple Avenue alternative may be found to be more cost-effective than upgrading the Barracks channel. For example, one of the Anzac Highway diversion culverts could be shortened by the distance between Maple Avenue and Keswick Creek. Preliminary indications are that a Maple Avenue culvert alternative could result in an overall cost for the diversions project of about $44 million.

Between them, the diversions will provide significant flood protection to Wayville (including the Showgrounds), Keswick, Ashford, the commercial district of Mile End South, and suburbs further west.

10.5 UPPER BROWN HILL CREEK UPGRADE – AREA 1

In the 2012 SMP it was determined that Brown Hill Creek between Anzac Highway and Forestville Reserve, including the tramway ramp culvert, would have to be upgraded in capacity, with or without a detention dam at the top end of Brown Hill Creek. For cost estimating purposes, the 2012 SMP assumed a concept design to accommodate an undetained peak flow of 39 m^3/s, corresponding to the (then) critical 36 hour peak flow.

As noted in Section 7.4.3 in relation to the eight options investigated for Part B, this section of the creek was included in the investigations of the Part B process. It is noted that '…in comparing options, this section has been included in the assessment of the Part B Works as the extent of works in this section varies between the eight options, and its cost therefore impacts on the overall cost of the Part A Works as well as the Part B Works.

In the Part B Report, Area 1 is defined as the length of creek within the private properties between Anzac Highway and Leah Street. However, for the purposes of this SMP, Area 1 is assumed to also extend along both drainage reserve and private land between Leah Street and Forestville Reserve.

Consequently the scope of works was revisited during the course of Part B investigations. The resulting proposed works in Area 1 (of Option D) are outlined in this SMP at Sections 12.1.1 (Anzac Highway to Leah Street), 12.1.2 (mainly Unley Council channel between Leah and Ethel Streets), 12.1.3 (Forestville Reserve) and 12.2 (bridge upgrades).

A majority of the channel widening is within the council reserve of Wilberforce Walk on the northern side of the channel. However, the channel is largely located within privately owned properties extending from the southern side of the channel. As the proposed capacity upgrade works should not require further encroachment into the private properties, the open aspect of this section of Brown Hill Creek presents an opportunity for Unley Council to acquire this section of creek and improve the recreational amenity of Wilberforce Walk, typically with landscaping and more effective use of the open space (refer Section 11.2.1).

The estimated cost of the Area 1 creek capacity upgrade works is $8 million (refer Section 15.2.4 and details at Appendices 33 and 34).

10.6 RIDGE PARK FLOOD CONTROL DAM

Ridge Park dam is on Glen Osmond Creek at the western end of Ridge Park, Myrtle Bank (Unley Council area). The dam was constructed in 2014/15 and serves the dual purpose of flood mitigation and stormwater harvesting.

The dam is a gravity structure comprising a concrete corewall supported on both sides by rock-filled gabion baskets. The maximum height of the dam is six metres above the existing (unmodified) creek level and the maximum length of the wall at crest level is 65 m. A stilling basin spillway energy dissipator is of reinforced concrete construction. The storage capacity (to spillway level) is 9.45 ML.

Unley Council undertook the stormwater harvesting component as a MAR scheme. Investigations for the council confirmed that the hydrogeology of the area is suitable for MAR for extraction of water during average flow events and subsequent reuse for irrigation of the park and other nearby council reserves. The harvesting component of the dam’s storage capacity is approximately 0.65 ML. It is planned to harvest 60 ML per year which represents about 30% of annual creek flow. Stormwater is harvested from the creek baseflow that originates in the nearby upstream semi-rural hills catchment. The harvesting process makes no contribution to flood mitigation.

Design of the dam (including geotechnical assessment) was by SMEC as described in their design report ‘Ridge Park Dam Design Report’ (February, 2014). Unley Council was the client for both design and construction, and will own and maintain the asset until such time as alternative governance arrangements are agreed by the five catchment councils (refer Section 17.3).

The dam is designed to reduce the 100 year ARI flood downstream of Ridge Park to a maximum 8 m^3/s flow rate. Peak inflow from upstream of Ridge Park is estimated to be approximately 8.9 m^3/s which is governed by the modification made to Mount Osmond interchange dam outflow in 2008 and the capacity of the pipe through which the creek flows under Cross Road and properties (Glen Woodley Estate and Carmelite Convent) immediately upstream of Ridge Park.

Due to the time delay and outflow hydrograph modification caused by the Ridge Park dam, the more significant flood mitigation benefit provided by the dam is a 30% reduction in the 90 minute peak flow at the lower end of Glen Osmond Creek, which in turn reduces peak flows in Keswick Creek. In addition, the dam provides multi-purpose benefits in terms of recreation, reduced scour velocities immediately downstream and biodiversity enhancement.

The cost of the dam was $2.8 million (not including the MAR component which was funded by Unley Council with Commonwealth Government assistance). Construction was by York Civil under supervision by MAPS Consulting. Other service providers were involved in other aspects of the project, including dam concept design and the MAR facility.

Ridge Park flood detention dam (October 2015)

10.7 BROWN HILL CREEK DIVERSION CULVERT BY DPTI

As described in Section 7.3.3, a section of Brown Hill Creek in Forestville was diverted in 2013 by a creek diversion culvert and other works as part of the Goodwood Junction rail project undertaken by DPTI (the 'DPTI culvert'). A section of the previous creek remains to take local runoff and (via an aqueduct over the lowered railway) rare high flows beyond the capacity of the diversion culvert. The general location and layout of the culvert and associated spillway aqueduct is shown in Figure 16.

The combination of culvert and aqueduct has been designed to accommodate a 'no dam' peak flow of 38 m^3/s which is in excess of the revised (2013 hydrology) peak flow of 30 m^3/s. The culvert capacity is 28 m^3/s. The culvert is approximately 360 m long from the inlet on the southern side of Victoria Street to the end outlet in Forestville Reserve. Its size varies from 4.2 m wide x 1.8 m high to 5.8 m wide x 1.4 m high.

A benefit to the BHKC project is that the diversion culvert bypasses a section of Brown Hill Creek which is under capacity for the 100 year ARI standard and would be particularly difficult to upgrade due to private ownership and the confined corridor which it traverses, including a length of culvert under a commercial building.

Private properties along Devon Street South and on the southern side of Victoria Street were acquired by DPTI to enable construction access. With the completion of the project most of the Devon Street South properties were to be sold back into the market with easements over the culvert corridor. Part of the former Devon Street South privately owned land and the Victoria Street property have been transferred to Unley Council.

Design and construction details (including land acquisition), cost sharing, and ongoing ownership and maintenance responsibilities were agreed with DPTI to the satisfaction of the BHKC project and the SMA. Each of the catchment councils gave common endorsement on the commercial matters including cost contribution. The ongoing responsibilities are legally documented in registered easements on the certificates of title for the railway corridor, Forestville Reserve and other land parcels in which the culvert is located.

DPTI has accepted responsibility for ownership of the asset (including structural maintenance) and Unley Council is responsible for operational maintenance (keeping it free of rubbish and materials which could block or restrict flow).

The BHKC project, with the support of the SMA, contributed $5 million towards the cost of the DPTI culvert project.

DPTI culvert outlet into Brown Hill Creek in Forestville Reserve (February 2014)

10.8 GLEN OSMOND CREEK MINOR UPGRADE WORKS

The 2006 Master Plan recommended the upgrade of the Fisher Street culvert at Wycliff Street, Fullarton to increase its capacity from approximately 3.5 m^3/s to 8 m^3/s (equivalent to the 100 year ARI flow with Ridge Park flood control dam upstream).

It was later realised that a new 1,500 mm diameter pipe had been installed in 1996 that effectively bypasses this culvert. The new culvert was configured with a design capacity of about 8 m^3/s. Hence there is no longer a risk of significant 100 year ARI flow breakout to the east of Fullarton Road (with the 1996 culvert construction, the modified outlet at Mount Osmond interchange dam and Ridge Park dam now in place) and therefore the Fisher Street culvert proposed as part of the 2006 Master Plan is no longer required.

For the section of creek further downstream, the 2012 SMP recommends that a bypass culvert be installed along Fisher Street between Wycliff and Windsor Streets to alleviate breakouts on Glen Osmond Creek between Fullarton Road and Windsor Street and effectively reduce reliance on the creek within private properties where maintenance of the creek is problematic.

The updated modelling (post-2013), with all previous and recently completed works (including Ridge Park dam), indicates that the risk of breakout along the full length of Glen Osmond Creek is greatly reduced. However, for the 100 year ARI event a small amount of breakout would still occur along the section of channel between Fern Avenue (effectively the entrance to the Windsor Street culvert) and Torrens Avenue, Fullarton as well as from the channel between Braeside Avenue and Burnham Avenue, Myrtle Bank.

Modelling for the 100 year ARI mitigation case (refer Figure 18) is based on:

- upgrading Fern Avenue bridge culvert from 2.4 m wide x 0.9 m high to 2.5 m x 1.5 m (estimated cost $164,000);
- upgrading Torrens Avenue bridge culvert from 1.8 m wide x 1.3 m high to 2.5 m x 1.35 m (estimated cost $151,000); and
- other potential minor works, including widening of the creek channel between Braeside Avenue and Burnham Avenue (cost not estimated).

Further investigation would be required to more confidently identify the extent of mitigation works and their estimated cost. A nominal amount of $0.8 million is allowed for the two bridge upgrades and other minor works (refer Section 15.2.7 and details at Appendix 28).

10.9 MOUNT OSMOND INTERCHANGE DAM MODIFICATION

Investigations for the 2006 Master Plan determined that the original flood control dam at the Mount Osmond Interchange was over-designed for the 100 year ARI event.

It was proposed that the diameter of the existing orifice plate on the dam outlet could be reduced from 610 mm to 475 mm to achieve a reduction in the outflow from 3.2 m^3/s to 1.9 m^3/s, while not compromising the dam's safety and stability. This reduction in the outflow benefits downstream flood mitigation, watercourse stability and water quality for small storm events.

The proposed works were completed in 2008 at minimal cost. This measure is included in the SMP for the record, but no further works are required for this relatively minor project.

10.10 PART A WORKS IMPLEMENTATION

In the context of risk assessment, the implications of implementing the Part A Works without Part B Works have been considered as follows.

10.10.1 Viability

The Channel Capacity Assessment findings (AWE, 2012) raised concerns about reduced flow conveyance capacity of watercourses of the catchment, particularly in terms of upper Brown Hill Creek, and that, in turn, this would adversely affect the Part A / Part B strategy (refer Section 7.3.1). This matter was discussed in correspondence between the BHKC project, the AMNRNRMB and the SMA when the 2012 SMP was submitted for approval.

A flood mitigation solution for the overall catchment requires completion of both Parts A and B Works. However, the Part A Works collectively can stand alone in terms of flood mitigation benefit, if necessary. Moreover, the South Park Lands detention basins and the lower Brown Hill Creek upgrade would each provide benefit in their own right, as does the completed Ridge Park dam. However, the diversions from Keswick Creek rely on the completion of the lower Brown Hill Creek upgrade to be fully effective.

10.10.2 Flood protection and residual flood risk

For implementation of the Part A flood mitigation works only, floodplain mapping is provided in Figure 17 for the 100 year ARI event. Other ARI events for the Part A mitigation case were not modelled.

The number of properties affected by flooding following implementation of the Part A Works is shown in Table 18. For events other than the 100 year ARI, the numbers of flood affected properties are estimated using previous modelling results as a guide. This is considered appropriate due to the limited breakouts that are expected to occur during the lesser events. It is assumed that for the 500 year ARI event the Part A Works mitigation impacts would not differ markedly from the Part A and B Works mitigation case condition.

Comparison of these numbers with that for existing base case conditions (refer Table 2) shows that implementation of the Part A Works alone would provide the required level of flood protection (100 year ARI) to approximately 71% of the approximately 2,100 properties over the entire catchment that are currently at risk of flooding. It would also reduce by about 67% the estimated catchment-wide flood damages resulting from a 100 year ARI storm. The area protected by the Part A Works includes the bulk of industrial, commercial and public utilities properties at risk across the BHKC catchment.

Table 18: Properties affected by flooding – Part A Works mitigation case

Design flood	**Number of flood affected properties**			**Damages ($'000)**
	Over-floor flooding	**Under-floor flooding**	**Total**	
10 year ARI	0	0	0	0
20 year ARI	0	0	0	0
50 year ARI	(110)	(120)	(230)	(9,000)
100 year ARI	261	343	604	30,515
500 year ARI	(2,000)	(3,000)	(5,000)	(182,000)
PMF	Data unavailable			

(Estimated approximate figures – not based on specific floodplain mapping)

Table 19: 100 year ARI flood affected properties by council area – Part A Works mitigation case

Council area	Number of flood affected properties			Damages ($'000)
	Over-floor flooding	Under-floor flooding	Total	
Adelaide	0	0	0	0
Burnside	0	0	0	0
Mitcham	7	20	27	1,009
Unley	190	195	385	23,959
West Torrens	64	128	192	5,547
Airport				0
TOTAL	261	343	604	30,515

It is difficult to clearly define the level of protection on an area-by-area basis. However, if only the Part A Works are implemented, it is expected that the effects of flood protection would be as follows:

- The level of protection along Glen Osmond and Parklands Creeks would be the same as for the full scheme (Parts A and B).
- The level of protection along upper Brown Hill Creek down to Forestville Reserve would remain at base case conditions (i.e. approximately a 20 year ARI level of protection).
- The level of protection along Brown Hill Creek downstream from Forestville Reserve would generally be increased to the 100 year ARI level. However, breakouts from further upstream would permeate down through the floodplain and cause low-depth inundation to the north of Brown Hill Creek between Anzac Highway and South Road (refer Figure 17).

For comparison, Section 13.1 discusses results for the mitigation case in which all SMP flood mitigation works (Parts A and B) are implemented.

11. PART B FLOOD MITIGATION OPTIONS

As listed in Section 7.4.3 eight flood mitigation options were identified for Part B Works. All options provide approximately the same level of flood protection for the 100 year ARI event.

This section commences with an overview of the eight options followed by a description of the various sections of upper Brown Hill Creek. It goes on to detail the seven non-selected options (A1, A2, B1, B2, C1, C2 and C3). Option D – the preferred option – is discussed in detail in Section 12.

11.1 WORKS COMPONENTS

The eight options differ in how they combine the following three components:

- detention dam (at one of two alternative sites):
- high flow bypass culverts: and
- creek capacity upgrade works (including bridge upgrade works).

Each of these components is initially described, followed by the level of works required for each option. Works for specific areas of the creek use the categorisations outlined in Section 7.4.2.

In addition to these components, all of the options include undertaking maintenance works along the full length of upper Brown Hill Creek with the aim of achieving, as far as possible, a creek in good condition (refer Section 12.3).

11.1.1 Detention dam

In the case of upper Brown Hill Creek, a detention dam will reduce the flow of stormwater in the creek which is generated from the rural area of the catchment. A dam will not reduce the flow of stormwater generated from the urban area of the catchment.

As detailed in the 2012 SMP, a number of dam sites in the rural reaches of Brown Hill Creek were identified for detention of runoff from that part of the catchment, but only two were considered feasible – Site 1 in the Brown Hill Creek Recreation Park and Site 2 in Ellisons Gully.

A detention dam is a component of Options A1, A2, B1 and B2. Options A1 and B1 include a dam at Site 1 (Brown Hill Creek Recreation Park); while Options A2 and B2 include a dam at Site 2 (Ellisons Gully).

Given that a detention dam (at either site) would not mitigate flooding generated off the urban part of the catchment, the following additional works are required:

- Options A1 and A2 – a high flow bypass culvert from Malcolm Street to Victoria Street and creek capacity upgrade works in Areas 1 and 5A
- Options B1 and B2 – creek capacity upgrade works in Areas 1, 3, 5A and Orphanage Park

11.1.2 High flow bypass culverts

A high flow bypass system, in the form of underground box culverts of precast and insitu concrete construction, conveys stormwater flows that are greater than the creek capacity and then returns the flow back into the creek further downstream from where the flow can be contained in the creek. This bypasses existing low capacity sections of the creek and avoids creek overflows at those locations.

A bypass system increases the rate of stormwater transfer downstream. Therefore, laying of any bypass system would have to be progressed from downstream to upstream to ensure there is always sufficient downstream channel capacity to contain the flow.

High flow bypass culverts are a component of Options A1 and A2.

Options C1, C2 and C3 primarily rely on high flow bypass culverts (along different routes) supplemented by creek capacity upgrade works.

11.1.3 Creek capacity upgrade works

Creek capacity upgrade works involve widening the creek bed and/or modifying the creek banks at critical sections, including bridges, to ensure there is sufficient capacity for 100 year ARI peak flows. Minor deepening of the creek may also be required at certain sections by removing sediment build up in order to lower the creek bed to a consistent grade line. All eight options require creek capacity upgrade works, but to different extents as explained in the sections for each option.

Note that investigations relating to creek capacity works are at a concept level based on ‘whole of catchment’ modelling. Indicative concept designs are described in the later Sections 11.3, 11.4 and 12. The designs are based on analysis of MIKE-FLOOD modelling results (both in terms of the floodplain mapping and MIKE 11 flows). Where significant breakouts are evident, the approximate channel dimensions have been adjusted in the model so that breakouts are eliminated (i.e. flows are therefore contained to the ‘modified’ creek).

In describing creek capacity upgrade works required for Options B1, B2 and D, the locations of properties where works are required are identified. However the exact scope of creek capacity upgrade works and the degree to which individual properties are affected would be an outcome of detailed design. It is expected that final designs would be the result of professional landscaping and engineering advice based on consultation and collaboration with individual property owners.

Importantly, it is not proposed to create a concrete lined channel. Instead, the aim is to retain as far as possible a natural creek environment. Where this is not possible, or the creek banks need stabilisation, the type of materials that could be used include dry stone walling or gabions.

Sketch diagrams and artistic impressions at Appendix 18 show possible treatments for bank stabilisation. These include (but are not limited to):

- Vertical support (retaining wall) for full depth
- Vertical support for bottom depth with top part of the bank sloping back
- Stepped support (over full or partial depth)
- Bank laid back on a relatively flat batter.

These are not intended to represent likely final design solutions. Rather they indicate technically feasible and aesthetic concepts, and serve as the basis of cost estimates. The cost estimates generally are based on a full depth bank support (either vertical or stepped) which would generally be the highest cost treatment.

Any creek capacity upgrade works, like bypass culverts, need to be progressed from downstream to upstream to always ensure there is sufficient downstream channel capacity to contain the flow.

Private properties identified for creek capacity upgrade works under Options B1, B2 and D are listed below. All properties are residential with the exception of one amalgamated commercial property.

Table 20: Properties in Area 1 (Unley Council)

B1	B2	D	Address
1	1	1	28 Anzac Highway, Everard Park
2	2	2	13 Grove Avenue, Forestville
3	3	3	16 Third Avenue, Forestville
4	4	4	13A Third Avenue, Forestville
5	5	5	18A Second Avenue, Forestville
6	6	6	13A Second Avenue, Forestville
7	7	7	12A First Avenue, Forestville
8	8	8	7A First Avenue, Forestville
		9	16 Ethel Street, Forestville (2 units)
		10	18 Ethel Street, Forestville

Table 21: Properties in Area 2 (Unley Council)

B1	B2	D	Address
		11	35 Victoria Street, Goodwood
		12	33 Victoria Street, Goodwood
		13	27 Victoria Street, Goodwood (10 units)
		14	25 Victoria Street, Goodwood
		15	39 Clifton Street, Millswood
		16	37 Clifton Street, Millswood
		17	35 Clifton Street, Millswood
		18	33 Clifton Street, Millswood
		19	86 Mitchell Street, Millswood
		20	84A Mitchell Street, Millswood
		21	84 Mitchell Street, Millswood
		22	169 - 173 Goodwood Road, Millswood (commercial property)

Table 22: Properties in Area 3 (Unley Council)

B1	B2	D	Address
9		23	1 Douglas Street, Millswood
10		24	1A Douglas Street, Millswood
11		25	3 Douglas Street, Millswood
12	9	26	18 Regent Street, Millswood
13	10	27	20 Regent Street, Millswood
14	11	28	22 Regent Street, Millswood
15	12	29	5A Regent Street, Millswood
16		30	3 Heathcote Crescent, Millswood
17		31	4 Heathcote Crescent, Millswood
18		32	10 Avenue Street, Millswood
19		33	14 Avenue Street, Millswood
		34	15 Avenue Street, Millswood
		35	14 Malcolm Street, Millswood
		36	10 Malcolm Street, Millswood

Table 23: Properties in Area 5 (Mitcham Council)

B1	B2	D	Address
20	13	37	113 Cross Road, Hawthorn
21	14	38	1 Denning Street, Hawthorn
22	15	39	3 Denning Street, Hawthorn
23	16	40	5 Denning Street, Hawthorn
24	17	41	11 Denning Street, Hawthorn
25	18	42	13 Denning Street, Hawthorn
26	19	43	15 Denning Street, Hawthorn
		44	6 Jervois Street, Hawthorn
		45	27A Hampton Street, Hawthorn
		46	27 Hampton Street, Hawthorn
		47	40A Kent Street, Hawthorn
		48	42 Kent Street, Hawthorn
		49	34 George Street, Hawthorn
		50	1 Cameron Road, Hawthorn
		51	30 George Street, Hawthorn
		52	26 George Street, Hawthorn
		53	13 Durdin Road, Hawthorn
		54	14 Angas Road, Hawthorn

Table 24: Properties in Area 6 (Mitcham Council)

B1	B2	D	Address
27	20	55	17B Fife Avenue, Torrens Park
28	21	56	19 Fife Avenue, Torrens Park
29	22	57	22A Fife Avenue, Torrens Park
		58	22B Fife Avenue, Torrens Park
		59	22C Fife Avenue, Torrens Park
		60	22D Fife Avenue, Torrens Park
		61	15 Paisley Avenue, Torrens Park
		62	18 Paisley Avenue, Torrens Park
		63	16 Paisley Avenue, Torrens Park
		64	17 Inverloch Avenue, Torrens Park
		65	18 Leonard Terrace, Torrens Park
		66	19 Lochness Avenue, Torrens Park

Surveying firm Civil Surveys and Design did an engineering survey along critical sections of the creek to establish a survey control traverse, identifying where the creek is in relation to property boundaries, measuring creek widths and bank heights and identifying features along the creek such as prominent trees, bridges and retaining walls. The survey was carried out for Areas 1, 2 and 3, while in Area 6 only a survey control traverse of the creek was established. In other Areas, sufficient information already existed or, as in the case of Area 4 where no creek capacity upgrade works have been identified, detailed survey information was not required.

11.2 SECTIONS OF BROWN HILL CREEK

As outlined in Section 7.4.2, upper Brown Hill Creek can be categorised into sections as follows (with reference to maps at Appendix 19).

11.2.1 Area 1

The creek has a trapezoidal shape with earthen banks, with a concrete lined trapezoidal section about 2 m wide along the base. The creek alignment is straight.

In this Area the property owners generally do not use the creek (e.g. for any amenity value) or recognise the creek as part of their property, as evident from the fence line which separates the creek (and the public thoroughfare Wilberforce Walk) from the usable area of each property. For some residents the creek provides a buffer between their usable property area and Wilberforce Walk. However it also presents a risk in terms of erosion which is prevalent along the southern bank.

A number of alternative concepts for upgrading the creek were discussed with property owners at an Area meeting held in April 2014, including:

- Widening the creek on the northern side (i.e. into Wilberforce Walk)
- A public authority (e.g. council or BHKC project entity) purchasing the creek land from the current owners

- Installing an underground culvert in place of the creek (in public or private ownership):
  - With retention of private ownership, installing an underground culvert would free up the land above the culvert for private use, albeit within an easement
  - With public ownership, installing an underground culvert would enable the creation of a linear park environment to enhance the existing Wilberforce Walk which runs alongside the creek
- As a variation to the linear park theme, flow capacity could be achieved by a design incorporating a floodway overlying an underground culvert

11.2.2 Council and privately owned channel – Leah to Ethel Street

The channel is fully concrete lined (base and sides) with a nearly rectangular shape. The lining is old, but with proper maintenance it could be expected to last at least another 20 years.

11.2.3 Forestville Reserve

Following its upgrading about 10 years ago, and with subsequent maturing of its vegetation, Forestville Reserve is a highly valued amenity by the surrounding community. Further landscaping is planned by Unley Council and it is recognised that the design of any flood mitigation works in the reserve, particularly involving widening the creek, would have to be sympathetic to concepts that have been and continue to be developed in consultation with the local community in recent years.

Over the upstream (southern) half of its length, the creek banks have been laid back and landscaped through work undertaken by Unley Council in about 2004. The downstream (northern) half retains its original design comprising a small concrete trapezoidal channel set in a larger earth sided channel.

11.2.4 Diversion culvert

The new culvert, combined with overflow provisions to convey flows greater than 28 m^3/s into the bypassed section of Brown Hill Creek, has sufficient capacity for flows in excess of 30 m^3/s. Therefore no further creek capacity upgrade works are required.

11.2.5 Area 2

The creek in this area is considered in three sub-sections:

- Area 2A: Victoria Street to Cranbrook Avenue. The section consists of a small concrete lined trapezoidal channel set in a larger earthen trapezoidal channel. In one property, the creek is integrated with the amenity area at the side and rear of the house. Other properties in this section do not appear to recognise ownership of and use the creek and generally maintenance is lacking.
- Area 2B: Cranbrook Avenue to Goodwood Road. This section consists of a small trapezoidal channel set in the base of a larger earthen channel. Generally, the creek is fenced off from properties, ownership is not recognised and consequently is poorly maintained.

- Area 2C: Goodwood Road to Mitchell Street. This section is a steeply sided trapezoidal channel which is concrete lined for the bottom two-thirds. Again, it is substantially fenced off from the private properties through which it traverses and ownership is not recognised. For a length of 50 m upstream of Goodwood Road, the creek flows through a culvert under a building and car park on privately owned commercial use property fronting the road (termed the 'approach culvert' to Goodwood Road).

In all three sections the concrete lining, thought to be more than 75 years old, is significantly deteriorated in places but not beyond repair. Generally, the creek through Area 2 is in a corridor defined by fence lines on either side with ownership not recognised and with little or no maintenance undertaken. There is an exception to this, where the creek is landscaped into an owner's property and is readily accessible.

11.2.6 Orphanage Park

Orphanage Park (the eastern portion, comprising mainly the park area) was acquired by Unley Council in 1999/2000 for community recreation.

Brown Hill Creek bisects the park for a length of about 230 m. Although the alignment is straight, the creek width and depth vary due mainly to erosion which in several places has left the creek banks and bed exposed to further and more accelerated deterioration.

Any SMP works would have to be sympathetic to the park's recreational, amenity, environmental and heritage features, particularly the stone lining of part of the creek bed and banks. The lining, completed in about 1901, is in varying condition and currently extends for about 40% of the creek length.

The historical relevance of the lining is documented in a November 2011 report by Donovan & Associates ('history and historic preservation consultants') commissioned by Unley Council. The report notes that the lining is of "evident local heritage value", but is of "insufficient heritage value to be considered a State Heritage place".

The report also notes that the "extant lining has deteriorated under the influence of heavy flows" and recommends that a "conservation plan should be completed to conserve the existing stone lining to the creek while enhancing the amenity of the area through which it flows".

11.2.7 Area 3

For the most part, the creek in this area is an unlined natural channel with a rocky base and steep earthen (natural) banks generally up to about 2 to 2.5 m high, although lower in places. Ground cover and manly exotic vegetation and trees feature along the banks; however, some trees are growing in the creek bed and banks in a way that would impede high flows.

In a number of properties there are retaining walls on one or both sides of the creek that have been previously built by the land owners. The walls are built in a range of construction types, including concrete, mortared block work, mortared stone and dry-stacked stone. In Malcolm Street, there is a short length of gabion construction, installed to facilitate the construction of a pedestrian footbridge.

In a number of properties, the creek is readily accessible and/or is a landscaping and amenity feature. In other properties the creek is fenced off or defined by high retaining walls on one or both sides of the channel and ownership of the creek is not recognised.

11.2.8 Area 4

From Malcolm Street to Victoria Avenue, the creek in terms of geomorphology is similar to the preceding downstream section (Area 3) but has sufficient capacity for the estimated peak flow. The creek in Area 4 is more heavily overgrown, but subject to removal of excessive vegetation in the channel and banks, this section of creek is not identified as requiring capacity upgrade works. Generally, between Malcolm Street and Victoria Avenue Park, the creek is similar to Area 3 in terms of amenity, usage and lack of recognition of ownership.

Upstream of Victoria Avenue, the creek is less confined but becomes more sinuous with several acute angle bends. There is also a short channelised length (concrete base and mortared stone sides) with a series of vertical drops which would act to slow down the flow of water. Upstream of Victoria Avenue to Cross Road, ownership of the creek is recognised with the result that the creek is more integrated with the surrounding private open space.

Peak flows break out along this section of creek but are contained to the relatively wide and low overbank area. Localised inundation occurs for a distance of up to approximately 30 m either side of the channel, but this is not considered to have significant consequences, and any adverse impact on buildings or structures would be minimal.

11.2.9 Area 5

There are three critical reaches of creek in this area:

- Area 5A: Cross Road to Hampton Street
- Area 5B: A length of about 50 m approximately mid-way between Devonshire and Kent Streets (two private driveway bridges are 'bottlenecks' to stormwater flow in addition to a narrow width of creek upstream of the bridges)
- Area 5C: Properties between George Street and Angas Road affected by the proposed JW Morris Reserve upgrade project by Mitcham Council

In Area 5C, parts of the creek are heavily eroded and the banks are failing. The proposed upgrade by Mitcham Council in conjunction with the BHKC project will stabilise the creek and include beautification enhancements.

Otherwise, the creek has a well-defined alignment with regular width and depth (less depth than downstream of Cross Road). The bed is natural with stones. Between Cross Road and Hampton Street there are natural banks mainly on the western side of the creek which are earthen and steeply battered, as well as several sections of retaining wall (either stone or 'post and panel').

A section of creek between Devonshire and Kent Streets is closely integrated into some of the properties with landscaping on both sides of the creek and mortared boulders forming the base and sides.

11.2.10 Soldiers Memorial, JW Morris and Delwood Reserves

In 2011, Mitcham Council endorsed the preparation of a master plan to improve and link the three adjoining reserves of Soldiers Memorial Gardens, JWS Morris Park and Delwood Reserve. As part of the master plan, it is proposed to re-establish a more natural creek environment, improve the surrounds and link the reserve areas as a community feature, as well as ensure sufficient creek capacity for peak 100 year ARI flows – in conjunction with the BHKC project.

Other aspects of the plan, including the future development of a linear park, provision of recreational facilities, additional landscaping and redevelopment of the library and carpark areas, would be funded separately by the Mitcham Council.

11.2.11 Mitcham shopping centre

Brown Hill Creek enters a culvert on the upstream (eastern) side of the shopping centre and, except for about a 55 m length of open creek channel in the middle section, exits a culvert at the rear of commercial property on the western side of Belair Road. The culvert (total length approximately 300 m) and open channel section can convey the peak flow (i.e. no dam) without requiring creek capacity upgrade works.

11.2.12 Area 6

The creek generally is on a steep grade with a gently meandering alignment. In its natural condition, it has a rocky base and earthen, low vegetated banks. A short distance downstream of Fife Avenue (over a short radius 180 degree bend) the creek has been significantly landscaped with boulders and the sides engineered with retaining walls of mortared stone and concrete construction.

In random modified sections between Fife Avenue and Muggs Hill Road, stone and concrete sides and bases have been constructed. Significant bank erosion is occurring for a length of about 100 m upstream of Paisley Avenue.

11.2.13 Area 7

The creek is similar to the preceding Area 6. It is generally on a steep grade with a gently meandering alignment. It is generally in a natural state with rocky base and earthen, low vegetated banks.

11.3 NON-SELECTED OPTIONS A1, A2, B1 & B2

Options A1, A2, B1 and B2 incorporate a dam and creek capacity upgrade works; as well as high flow bypass culverts for Options A1 and A2.

11.3.1 Dam component

Of the two feasible sites for a detention dam in the rural reaches of Brown Hill Creek:

- Site 1 is located in the Brown Hill Creek Recreation Park
- Site 2 is located in Ellisons Gully

The Site 1 dam in the Brown Hill Creek Recreation Park (110 ML capacity and 12 m height to spillway) is in the optimum location from a hydrological point of view because it is located downstream of the confluence of the two main waterways of the area and therefore can detain nearly all the runoff from the rural part of the catchment. A greater reduction in peak flow could be achieved if the dam were higher. However, a higher dam would have more visual impact, require that more of Brown Hill Creek Road be relocated and require the acquisition of one or more houses as they would then be located in the temporary water storage area created by the dam.

The Site 2 dam is located in Ellisons Gully, the main northern tributary of Brown Hill Creek. Due to its location further upstream on a tributary, the Site 2 dam needs to be much larger in size (355 ML capacity with wall height of 19.5 m) to achieve a comparative flood protection performance as a dam at Site 1. The increased capacity of a dam at Site 2 would ensure that runoff from its catchment area when combined with runoff from the remainder of the rural catchment produces the same or better peak flow reduction as the Site 1 dam.

The 2012 SMP outlines at Section 11.2.1 that under the 2012 hydrology, the 90 minute peak flow causes flooding from the creek downstream of Avenue Street, for which the Malcolm Street high flow bypass was designed to provide mitigation. The dam at Site 1 was designed to reduce the 36 hour peak flow so that it would be accommodated by the combined capacity of the creek and the Malcolm Street bypass. That situation has changed as a result of applying the 2013 hydrology and upgrading the floodplain model as explained in Sections 8.2.3 and 8.3.

Engineering consultant SMEC was engaged early in the Part B process to develop preliminary concept designs for the detention dam at Site 1 based on performance criteria established in the 2012 SMP. A number of potential design concepts were considered. The consultancy was extended to include a dam at Site 2, such that four concepts were investigated:

- Site 1: Zoned (earth and rock) fill with concrete core wall
- Site 1: Roller compacted concrete (RCC) gravity dam
- Site 1: RCC gravity dam with architectural treatment (earth and rock fill) on the upstream and downstream faces
- Site 2: RCC gravity dam

Concept sketches of the dams are included at Appendix 20.

For Site 1, two additional detention dam concept designs were identified (concrete buttress dam and gabion structure with concrete core wall) but were discounted due to technical considerations and cost. For the Site 2 dam, SMEC considered that the RCC gravity design was the only cost-effective option for this site.

SMEC's study utilised information from a previous investigation undertaken by consultants GHD in 2008 and was based on a 'desktop' assessment in order to avoid any test digging or other invasive investigation on the site. The assessment included application of Australian National Committee on Large Dams (ANCOLD) guidelines.

SMEC's brief included estimates of construction. However, in accordance with other estimates of the Part B process, the SMEC estimates were superseded by those of Costplan as part of their overall construction planning and cost estimating peer review role. The adopted estimated costs are outlined in Section 15.3.2, including the cost of land and easement acquisitions at dam Site 2 as assessed by Maloney Field Services.

11.3.2 High flow bypass culverts

The 2012 SMP (Section 11.2.1) outlines that, under the 2012 hydrology, the 90 minute peak flow caused flooding downstream of Avenue Road, Millswood irrespective of the size or location of any dam constructed in the upper catchment.

A supplementary high flow bypass culvert therefore was designed from Malcolm Street to Victoria Street. Starting from the creek in Malcolm Street, Millswood the route is along Vardon Terrace and Arundel Avenue to just south of Victoria Street, Goodwood to then connect into the DPTI creek diversion works.

The dam at Site 1 was sized to reduce the 36 hour peak flow so that it would be accommodated by the combined capacity of the creek and the Malcolm Street bypass. If a dam at Site 2 had been recommended in the 2012 SMP, it would have been sized on the same basis.

The Malcolm Street to Victoria Street culvert is incorporated in Options A1 and A2, supplemented with creek capacity upgrade works between Anzac Highway and Leah Street (Area 1) and between Hampton Street and Cross Road (Area 5A).

Applying the 2013 hydrology and upgrading the floodplain model identified that with a dam (either at Site 1 or Site 2), the reduced 36 hour peak flow governs (or is about the same as the 90 minute flow) for all of upper Brown Hill Creek except downstream of Forestville Reserve where the 90 minute peak flow governs (refer Section 9.3.3).

Given the reduced flows, creek capacity upgrade works between Mitchell and Malcolm Streets (including Orphanage Park) are now more viable to consider. This is the scenario for Options B1 and B2.

11.3.3 Creek capacity upgrade works

As identified above, creek capacity upgrade works are a component of Options A1, A2, B1 and B2.

The cost of Options B1 and B2 is significantly less than for Options A1 and A2 (refer Section 15.3.1). For this reason, Options A1 and A2 were not analysed in terms of the 2013 modelling. Nevertheless, floodplain mapping results for Options A1 and A2 are anticipated to be the same as for Options B1 and B2 respectively.

The extent of creek capacity upgrade works below therefore relate only to Options B1 and B2. Based on a concept level of investigation, the number of properties requiring creek capacity upgrade works is estimated to be 29 for Option B1 and 22 for Option B2 (refer Section 11.1.3). It should be noted for both Options B1 and B2, eight properties are in Area 1 which is within the Part A Works.

Approximate channel dimensions applied to the hydraulic modelling for Option B1 and B2 (together with Option D) are shown in cross-sections at Appendix 21.

Area 1 – Anzac Highway to Leah Street

For both Options B1 and B2, the following creek capacity upgrade works are proposed which would affect an estimated eight properties (28 Anzac Highway, 13 Grove Avenue, 16 Third Avenue, 13A Third Avenue, 18A Second Avenue, 13A Second Avenue, 12A First Avenue and 7A First Avenue) as identified in the plan at Appendix 19:

- Streamline the transition on both sides of Leah Street culvert – to match the existing bridge width of 4.5 m
- Streamline the transition on both sides of First Avenue culvert – based on the proposed bridge upgrade width of 6 m

- Streamline the transition on both sides of Second Avenue culvert – based on the proposed bridge upgrade width of 6 m
- Streamline the transition on both sides of Third Avenue culvert – to match the existing bridge width of 6 m
- Between Second and Third Avenues, widen the base to 5 m (existing width is about 1.5 m at the concrete base to 2.5 m at the lower bank)
- Between Second and Third Avenues raise both bank heights by 0.5 m in places to achieve minimum 2.5 m channel depth
- Between Third Avenue and Anzac Highway, raise both bank heights by about 0.5 m to achieve minimum 2.5 m channel depth.

Orphanage Park

Preliminary concept plan options have been prepared for Orphanage Park for Option D as outlined in Section 12.1.6. A modification of these concepts based on a lesser scope of works could be developed to gain the additional capacity required under Options B1 and B2.

Area 3 – Douglas Street to Malcolm Street

For Option B1, proposed creek capacity upgrade works would affect an estimated 11 properties (1, 1A and 3 Douglas Street, 5A, 18, 20 and 22 Regent Street, 3 and 4 Heathcote Crescent, 10 and 14 Avenue Street) as identified in the plan at Appendix 19:

- Between Douglas and Regent Streets, achieve 4 m base width (from the existing width of about 1.5 – 2.5 m) and 2.5 m depth of channel (similar to Option D at Section 12.1.7)
- Between Regent and Avenue Streets:
  - Raise the northern/eastern bank as required in places to achieve 2.5 m depth of channel (generally a raising of about 0.5 m)
  - Widen the base to about 4 m for a length of about 70 m upstream of Regent Street (existing base width is about 1.5 – 2.5 m)
- Between Avenue and Malcolm Streets:
  - Raise the northern/eastern bank as required in places to achieve 2.5 m depth of channel (generally a raising of about 0.5 m)
  - A length of about 35 m of creek bed (approximately 65 to 100 m downstream of Malcolm Street) is up to about 600 mm above the general grade line – take this 'hump' down to grade
- Streamline the transition on both sides of Regent Street bridge – based on the proposed bridge upgrade width of 4 m
- Existing retaining walls would be retained.

For Option B2, proposed creek capacity upgrade works would affect an estimated four properties (5A, 18, 20 and 22 Regent Street) as identified in the plan at Appendix 19:

- The general cross-sectional profile of the creek is satisfactory over the full length if the banks are raised, as follows:
  - Between Douglas and Regent Streets raise the northern/eastern bank in places to achieve 2.5 m depth of channel (generally a raising of about 0.5 m)

- Between Regent and Avenue Streets, raise the eastern bank as required in places to achieve 2.5 m depth of channel (generally a raising of about 0.5 m)

- Streamline the transition on both sides of Regent Street bridge – based on the proposed bridge upgrade width of 4 m
- Existing retaining walls would be retained.

Area 5A – Cross Road to Hampton Street

Floodplain mapping for Options B1 and B2 shows localised flooding along the creek between Cross Road and Hampton Street. Given the close proximity of houses and recreational facilities to the creek, the following creek capacity upgrade works are proposed which would affect an estimated seven properties (1, 3, 5, 11, 13, 15 Denning Street and 113 Cross Road) as identified in the plan at Appendix 19:

- Widen the creek channel (existing base varies from about 1.5 to 2.5 m) predominately on the eastern side of the creek to about 3.5 m which is a lesser extent than for Option D (Section 12.1.9).

Area 5B – Devonshire Street to Kent Street

Although floodplain mapping shows private driveway bridges would cause some localised flooding, no works are proposed as buildings are above (or raised above) potential water level.

Area 6A – Ayr Avenue to Muggs Hill Road

Floodplain mapping for Options B1 and B2 shows reduced localised flooding along the creek mainly between Ayr and Fife Avenues. The following creek capacity upgrade works are therefore proposed for both Options B1 and B2 that would affect an estimated three properties (17B, 19, and 22 Fife Avenue):

- Replace two private driveway bridges at 17B and 19 Fife Avenue
- Streamline the creek upstream and downstream of the culvert under the house at 22A Fife Avenue – less extent of works than for Option D (Section 12.1.12).

11.3.4 Public road bridge upgrades

For Options B1 and B2, the following public road bridge upgrades are required.

Table 25: Public road bridges – Options B1 and B2

Bridge	Current form (dimensions in metres)	Proposed upgrade (dimensions in metres)
Second Avenue, Forestville	Irregular concrete 3.1 (max) x 2.4	Rectangular culvert 6 x 2.1
First Avenue, Forestville	Irregular concrete 3.2 (max) x 2.3	Rectangular culvert 6 x 2.1
Orphanage Park (internal road)	5.25 m bridge span across trapezoidal channel	This is dependent on the preferred concept design for Orphanage Park
Regent Street, Millswood	Rectangular concrete 3.1 x 2.5	Rectangular culvert 4 x 2.5

11.4 NON-SELECTED OPTIONS C1,C2 & C3

Options C1, C2 and C3 incorporate high flow bypass culverts and creek capacity upgrade works.

11.4.1 High flow bypass culverts

In addition to the Malcolm Street to Victoria Street culvert discussed above in Section 11.3.2, the 2012 SMP outlines two other culvert routes which incorporate and extend onto the Malcolm Street to Victoria Street culvert:

- Extended culvert along Route 3A

  Along Hampton Street / Hilda Terrace / Wurilba Avenue / under Cross Road / railway reserve to Malcolm Street / Malcolm Street to DPTI culvert

- Extended culvert along Route 3

  Starting from Hampton Street / along Jervois Street / under Cross Road / Grove Street / Northgate Street / Wood Street / Malcolm Street / Malcolm Street to DPTI culvert

Option C1 incorporates Route 3A while Option C2 incorporates Route 3. A third option, C3, was considered along the same route as C1 (route 3A) but excluding Malcolm Street.

The proposed routes, approximate sizes and design flow capacities of all three high flow bypass culverts are shown in Appendix 4. The culvert sizes and capacities are based on peak flows derived from the 2012 hydrologic modelling.

A major consideration in Route 3A was to obtain in-principle agreement with DPTI regarding access along the railway reserve between Cross Road, Unley Park and Vardon Terrace, Millswood. For the route to be viable, the culvert crossing of Cross Road has to be close to the railway crossing and this is a critical issue for DPTI.

Consequently, in 2013 the BHKC project engaged engineering consultant Wallbridge and Gilbert (W&G) to liaise with DPTI regarding a satisfactory design solution. Whilst the matter was not formally resolved between the BHKC project and DPTI, it is understood that the W&G design of a viable culvert crossing meets DPTI's design conditions.

Similarly, in project liaison with DPTI, there were no significant impediments regarding access along the railway reserve; although constraints caused by existing underground rail communications services have a significant cost impact.

It is likely that the bypass culverts, as proposed in the 2012 SMP for Malcolm Street and Routes 3 and 3A, could be scaled down in size as a result of applying the 2013 hydrology. Downsized culverts have not been investigated in the Part B investigations because any culvert systems would still have to follow the same routes, the smaller sizing would be marginal and their costs would still be relatively high compared with other options.

11.4.2 Creek capacity upgrade works

Options C1 and C2 require creek capacity upgrade works from Anzac Highway to Leah Street (Area 1) as well as upstream of Hampton Street.

By excluding the culvert along Malcolm Street, Option C3 also requires increased creek capacity upgrade works downstream of Malcolm Street in Area 3.

11.5 SELECTED OPTION D

Option D was endorsed by all five catchment councils in September 2015 as the preferred Part B flood mitigation works option.

Key factors in favour of Option D are:

- it has the lowest capital cost ($35.5 million) by a margin of about $5 million; the lowest annual maintenance cost and the lowest present value whole of life cost;
- for shorter duration storms it provides a higher than 100 year ARI level of flood protection;
- it satisfies the catchment councils' endorsed position to give preference to a feasible 'no dam' solution; and
- it does not require bypass culverts in suburban streets.

From an economic perspective all three options have an indicative BCR in the range of 0.3 to 0.4 (refer Section 16.3.3). Part of the assessment process involved consideration of environmental impacts, as discussed in Section 11.6.

Option D is described in detail at Section 12.

11.6 ENVIRONMENTAL IMPACTS

Environmental assessment of the Part B investigations has largely focused on the likely impact on trees of constructing a dam (at either site), installing high flow bypass culverts or undertaking works along the creek either as part of increasing the capacity of the creek or rehabilitating the creek.

The aim is to preserve as many trees as possible. However, under all eight mitigation options some trees would need to be removed. As described below, trees would need to be removed to construct a dam, to install culverts or in undertaking creek capacity upgrade works. The nature and condition of trees vary depending on the particular flood mitigation component: from exotic trees in the creek bed that would need to be removed under creek capacity upgrade works to manicured street trees that could be damaged if culverts were installed. Where trees need to be removed, the project would replant new trees and vegetation where appropriate.

When the works for upper Brown Hill Creek are determined in more detail, it will be possible to assess if there is a need for more detailed environmental studies. Generally, such studies are carried out when there is sufficient design detail in place to enable any potentially adverse impacts to be mitigated, reduced or managed. Sometimes such studies are required under legislation (including planning legislation), but at this stage those conditions have not been identified for the works being considered along Brown Hill Creek.

11.6.1 Dams

Based on general site inspections and photographic records, a preliminary desktop estimate has been made of the number of trees that would need to be removed if dams were constructed at either Site 1 or Site 2.

For Site 1, approximately 30 trees would need to be removed; excluding any trees that might need to be removed to create a work area/compound. In addition, the construction of a flood detention dam at Site 1 would adversely impact on one of the old Stone Pine trees, known locally as the Seven Pines, which are listed on the National Trust of South Australia's Register of Significant Trees and are regarded as several of the largest and oldest living Stone Pines in the world.

For Site 2, approximately 10 trees would need to be removed from the dam site and a further 20 to allow for construction of an access road. Additional trees might need to be removed to create a work area/compound.

11.6.2 High flow bypass culverts

In relation to the impact of high flow bypass culverts on street trees, arborist Colin Thornton (Treevolution) was engaged by the BHKC project to assess the potential impact of laying culverts along the routes of the high flow bypasses (Malcolm Street bypass, Route 3 bypass and Route 3A bypass) identified in the 2012 SMP.

The Treevolution report (August 2013) describes all trees located within or adjacent to the road reserves for the culvert routes, with an assessment of potential impacts that the associated excavation works may have on the overall health and appearance of the trees. The report outlines the following key factors:

- In planning the construction, issues will have to be addressed with regard to the type and size of machinery required to undertake the works.
- There are also implications with regard to sewer relocations, new rider sewer construction, sewer re-connections and stormwater pipes that still have to be addressed.
- In general there are significant site constraints that need to be considered prior to undertaking works, but to avoid potential damage to trees the preferred option would be to locate the culvert centrally in the road where possible.
- Excavation is shown to extend into the structural root zone for a large percentage of the trees.
- Loss of structural roots will impact on both tree health and structural stability.
- The potential to cause significant damage to tree rooting systems and canopy structures is considered to be high.

The Treevolution report highlights the loss of amenity as a result of the laying of the culverts, stating: "There could be severe impact on the visual amenity of the local streetscape by reducing tree health and vigour to the point at which some trees may need to be removed". The report identified that approximately 200 trees would be impacted by these culvert options, 20 to 40 of which are 'significant' or 'regulated' depending on the bypass option chosen. Appendix 22 lists the summary tables from the Treevolution report detailing the number of structural root zone impacted trees.

11.6.3 Creek capacity upgrade and creek rehabilitation works

Based on general site inspections and photographic records, a preliminary desktop estimate initially was made of the number of trees that would need to be removed resulting from a combination of both creek capacity upgrade works and creek rehabilitation works (only for Options B1, B2 and D, for the privately owned sections of creek).

A survey of trees along upper Brown Hill Creek (and other creeks of the BHKC catchment) carried out independently by the AMLRNRMB has also been studied and is likely to provide the more reliable data, although none of the data can be precise. The number of unsuitable trees affected under Option D is likely to number several hundred (all options affect about the same number of trees). However, removal of trees would be compensated by appropriate replanting of native trees on top of the creek banks.

In addition, 16 significant or regulated trees have been identified in Areas 1, 2, 3 and 5 where creek capacity upgrade works are required under Option D. It is assumed that the proposed creek capacity upgrade works can be designed to ensure that all of these trees are retained.

12. PART B FLOOD MITIGATION WORKS (OPTION D)

Option D, also referred to the 'creek capacity upgrade' concept essentially involves upgrading the capacity of approximately 1.9 km of the creek at critical sections over the approximately 7 km full length of upper Brown Hill Creek, as well as upgrading specific creek choke points including public and private bridges. It does not require a flood detention dam or high flow bypass culverts.

Upgrading the creek's capacity as a feasible flood mitigation option for upper Brown Hill Creek became evident when the 2013 hydrologic modelling (refer Section 9.3.3) identified that peak flows along the critical sections of the creek downstream of Malcolm Street are about 7 to 8 m^3/s less than those of the 2012 SMP (based on RRR data).

Option D is designed to mitigate flooding at a catchment scale. The exact scope of creek capacity upgrade works and the flood protection given individual properties would be determined during the detailed design phase.

12.1 CREEK CAPACITY UPGRADE WORKS

Proposed capacity upgrade works for each section of upper Brown Hill Creek (refer Section 7.4.2) are outlined below. In total, capacity upgrade works are proposed on 66 private properties: 36 in the Unley Council area and 30 in the Mitcham Council area (refer Section 11.1.3). It should be noted that the Unley Council number includes 10 properties in Area 1 which is within the Part A Works of the BHKC project.

Approximate channel dimensions applied to the hydraulic modelling for Option D (together with Options B1 and B2) are shown in cross-sections at Appendix 21.

12.1.1 Area 1 – Anzac Highway to Leah Street

Proposed creek capacity upgrade works would affect an estimated 10 properties as identified in the plan at Appendix 19:

- Between Anzac Highway and Third Avenue (28 Anzac Highway, 13 Grove Avenue, 16 Third Avenue), the base of the creek has to be widened to about 4 to 5 m (at existing invert level) from the existing concrete channel width of about 1.5 m. The banks would be re-formed to about the same batter as currently exists. The channel is required to have a depth of about 3 m and therefore the tops of the banks may need to be raised about 0.5 to 0.75 m in places, which could be achieved as a levee or bund embankment.
- Between Third Avenue and Leah Street (13A Third Avenue, 18A and 13A Second Avenue, 12A and 7A First Avenue) the base of the creek has to be widened to about 4 to 5 m (from about 1.5 m) at the existing invert level, with banks re-formed to about the same batter as currently exists. The existing channel depth of about 2.5 m would be retained.
- Either side of the road culverts at Leah Street, and First, Second and Third Avenues, the creek needs to be transitioned for a length of about 20 m to suit the culvert width (First and Second Avenue culverts are proposed to be widened).
- Between Anzac Highway and Leah Street, it is likely that works would have to be carried out on both sides of the creek and existing gabion structures (supporting banks) replaced. However, on the southern side of the creek it is unlikely that the existing top of bank would have to be moved any further south than its current line.

- The significant tree (eucalypt variety) along this reach could be retained.
- Two private properties, at 16 and 18 Ethel Street, are traversed by a section of the concrete lined channel referred to in the following Section 12.1.2. The same capacity upgrade works to the channel as described in Section 12.1.2 apply to the section of channel through the two properties.

12.1.2 Area 1 – Council and privately owned channel – Leah Street to Ethel Street

The channel has to be increased in capacity by about 20%. It is proposed that the increased capacity is achieved by increasing the height of the walls (about 2 m existing) by up to 0.5 m.

12.1.3 Area 1 – Forestville Reserve

Proposed creek capacity upgrade works:

- Do minor re-shaping of the channel base and sides through the southern half of the reserve.
- Widen the base of the northern half of the creek to about 2.5 m (with removal of the concrete channel with a width of about 1.5 m) and re-form the banks to achieve a uniform batter.

12.1.4 Area 1 – Diversion culvert – Forestville Reserve to Victoria Street

No works are required.

12.1.5 Area 2 – Victoria Street to Mitchell Street

Area 2A: Victoria Street (DPTI culvert) to Cranbrook Avenue

Proposed creek capacity upgrade works would affect an estimated four properties (35, 33, 27 and 25 Victoria Street) as identified in the plan at Appendix 19:

- From the DPTI culvert for a length of about 100 m upstream, raise the banks by about 0.5 to 1 metre to achieve a channel depth of about 2.5 m and widen the channel base to about 5 m from the existing base width of about 2 m.
- Recognising that residential buildings are close to the northern bank, widen the bank on the southern side with the bank being fully or partially battered (i.e. vertical, stepped or laid-back – as described at Section 11.1.3).
- It is likely that a significant River Red Gum tree near the boundary of 33 and 27 Victoria Street (southern side of the creek) can be retained.
- Raise, replace or remove four private footbridges depending on their existing condition and required usage.

Area 2B: Cranbrook Avenue to Goodwood Road

No creek capacity upgrade works are proposed.

Area 2C: Goodwood Road to Mitchell Street

Proposed creek capacity upgrade works would affect an estimated eight properties as identified in the plan at Appendix 19:

- Widen the channel base (1.5 to 2 m existing width) to about 4.5 m within the creek width as defined by the existing fences on either side of properties at 39, 37, 35 and 33 Clifton Street.

- Streamline the channel from Mitchell Street through properties at 84, 84A and 86 Mitchell Street to transition the channel into the 4.5 m width required for the remaining length.
- Widen and re-form the southern side bank with a (near vertical) reinforced concrete wall or similar treatment subject to detailed design.
- A large River Red Gum tree in No. 84A Mitchell Street could be retained.
- Subject to detailed design, lay a supplementary culvert under the car park and entrance of the property at 169-173 Goodwood Road, from the start of the existing culvert to connect back into the main culvert under Goodwood Road.

12.1.6 Orphanage Park

In order to mitigate flooding from this section of the creek under Option D, creek capacity upgrade works would be required to increase existing capacity (approximately 17 m^3/s) to convey the required 30 m^3/s (36 hour storm).

It is technically feasible to achieve the required stormwater conveyance through the park by increasing the creek's capacity by widening the base or sides and/or diverting high flows through a culvert.

A preliminary community consultation process was conducted in June 2014 to present and seek feedback on five concept plan options for managing stormwater flows through Orphanage Park under a 'creek capacity upgrade' option:

- Increasing the capacity of the creek to take 100% of the flows:
  - Option 1: Widen the creek bed
  - Option 2: Widen the creek banks
  - Option 2A: Lay back the creek banks
- Partially increase creek capacity and install smaller culvert (Option 3)
- Do not increase creek capacity and install larger culvert (Option 4).

These concept plan options are included in Appendix 23 together with a summary of community feedback.

Based on the feedback received, no preferred option emerged with mixed support expressed for all of the concept plan options:

- A few respondents, including one representing the Unley Residents' Association and the Orphanage Park Concerned Residents Group, indicated strong opposition to any works being undertaken. Concerns primarily related to the removal of vegetation, especially olive trees, as well as the impact on the character, amenity and heritage aspects of the creek and park.
- In contrast, many respondents indicated support for some works to be undertaken, recognising the current poor state of the creek and a desire to protect and enhance the character including the heritage stone lining of the creek.

The least supported options were Option 1 (widening the creek bed) and Option 2A (laying back the creek banks) on the basis of loss of vegetation and useable open space. This is consistent with views previously expressed by the local community.

Option 2 (widening the creek banks) received the strongest support with comments indicating this option is seen as increasing stormwater capacity while largely maintaining open space, safe access to the creek, and maintaining the character and heritage aspects of the creek environment. While some existing vegetation would be lost, some respondents identified this as an opportunity to improve the creek environment, while those opposed voiced concerns about the loss of vegetation and the impact on the heritage and character of the creek.

Option 3 (partially increase creek capacity and install smaller culvert) and Option 4 (do not increase creek capacity and install larger culvert) received mixed responses. Option 3 was seen by some as a good compromise in achieving additional stormwater capacity with minimal disruption to the creek, while others were concerned about the additional expense and disruption caused by the installation of a culvert. While Option 4 attracted similar comments, some respondents supported this option because it does not involve any creek works whereas others opposed this option because they want something done to restore the creek.

As can be seen from the above summary, there are mixed views between respondents and any option is unlikely to satisfy all members of the community. Unley Council has considered the above community feedback, and while no decision is required at this stage, Council has recommended that Option 1 (widening the creek bed) and Option 2A (laying back the creek banks) be discarded as potential options.

12.1.7 Area 3 – Douglas Street to Malcolm Street

Proposed creek capacity upgrade works would affect an estimated 14 properties (1, 1A and 3 Douglas Street, 5A, 18, 20 and 22 Regent Street, 3 and 4 Heathcote Crescent, 10, 14 and 15 Avenue Street, 10 and 14 Malcolm Street) as identified in the plan at Appendix 19:

- In general, the creek over the full length of this area requires cross-sectional dimensions having a base width of about 4 m and a depth of about 2.5 m. The existing base width is generally about 1.5 – 2.5 m and depth is generally about 2 – 2.5 m. Where the bank height is less than 2.5 m and the creek is roughly trapezoidal in shape (i.e. banks are not vertical but on a slope), the necessary flow capacity may be achieved if there is sufficient width between the top of the two banks.
- Generally the creek bed is on a uniform grade over the full length but over a length of about 35 m (approximately 65 to 100 m downstream of Malcolm Street) the base is raised by up to about 600 mm above the grade line. The raised section of base should be brought down to grade (in addition to widening). Otherwise, the existing creek bed would be retained.
- Existing retaining walls would be retained.
- Prominent trees close to the creek that should be able to be retained are:
  - four regulated English Elms in No. 15 Avenue Street (one may be in No. 17 Regent Street);
  - one significant River Red Gum in No. 10 Avenue Street;
  - one significant River Red Gum in No. 4 Heathcote Crescent;
  - two significant River Red Gums in No. 3 Douglas Street; and
  - two significant River Red Gums in No. 1 Douglas Street.
- Raise, replace or remove five private footbridges.

12.1.8 Area 4 – Malcolm Street to Cross Road

No creek capacity upgrade works proposed.

12.1.9 Area 5 – Cross Road to Belair Road

Area 5A: Cross Road to Hampton Street

Proposed creek capacity upgrade works would affect an estimated 10 properties (113 Cross Road, 1, 3, 5, 11, 13 and 15 Denning Street, 6 Jervois Street, 27A and 27 Hampton Street) as identified in the plan at Appendix 19:

- In general, the channel base needs to be widened to about 4.5 m (the existing base varies from about 1.5 to 3 m).
- Subject to a detailed design, a feasible design for providing greater creek width (whilst retaining existing invert level) is to:
  - widen the creek channel predominately on the eastern side of the creek along properties at 1, 3, 5, 11, 13, 15 Denning Street and 113 Cross Road;
  - widen western side of the creek at the southern boundary of 15 Denning Street; and
  - raise the western bank by about 0.5 m through 11, 13 and 15 Denning Street.
- In properties at 27A and 27 Hampton Street and 6 Jervois Street, the southern bank of the creek may have to be increased in height to 2 m to match the existing retaining wall along the northern side of the creek (in 6 Jervois and 15 Denning Streets).
- A significant River Red Gum in the middle of the creek bed at 11 Denning Street should be removed or, alternatively, if there is enough area, the creek could be widened around one or both sides of the tree.
- A significant River Red Gum adjacent to the creek at the rear of the properties on Hampton Street could be retained.
- Five private footbridges have to be raised, replaced or abandoned, depending on their existing condition and required usage.

Area 5B: Devonshire Street to Kent Street

Proposed creek capacity upgrade works would affect an estimated two properties (40A and 42 Kent Street) as identified in the plan at Appendix 19:

- Replace two driveway bridges at 40A and 42 Kent Street
- Near the southern boundary of 42 Kent Street, the creek narrows for about 10 m, forming a constriction. Subject to detailed design, a feasible design to widen the creek to about 4 m (whilst retaining existing invert level) is to:
  - retain the large tree if necessary; and
  - excavate the creek bank under the tennis court to obtain the required creek width and support the court with a cantilevered structure of reinforced concrete.

Area 5C: George Street to Angas Road

This section of the creek runs through the Soldiers Memorial Gardens and JWS Morris Park. Over the years there has been considerable erosion of the existing creek bank, particularly on the western side causing slippage of the bank into the creek bend, hence compromising the available waterway area. Although the general alignment of the creek is within council owned land, within this section there are six private properties at 26, 30, 34 George Street, 1 Cameron Road, 13 Durdin Road and 14 Angas Road, Hawthorn, which are affected along one of their boundaries by the creek.

In order to increase the waterway area to be able to accommodate the peak flood flows, it will be necessary to construct retaining walls approximately 2 m in height on the western side of the creek adjacent to the six properties, commencing from 34 George Street, upstream to the southern boundary of 14 Angas Road. The eastern side of the creek over this section will also require creek capacity upgrade works involving channel widening to 4 – 4.5 m where possible, construction of some low level retaining, flood walls and levees, creek bed and bank grading improvements and bank stabilisation.

12.1.10 Soldiers Memorial Gardens, JW Morris and Delwood Reserves

In addition to the creek capacity upgrade works on adjoining private properties (discussed above in relation to Area 5C), works on the reserve that are included in the BHKC project include laying back the creek banks where possible, installing 'softer' creek stabilisation measures such as gabions and natural stone wall, and replanting the banks with native vegetation.

12.1.11 Mitcham shopping centre

No creek capacity upgrade works are proposed.

12.1.12 Area 6 – Mitcham shopping centre to Muggs Hill Road

Area 6A: Between Ayr Avenue and Paisley Avenue

Proposed creek capacity upgrade works would affect an estimated seven properties (17B, 19, 22A, 22B, 22C and 22D Fife Avenue, 15 Paisley Avenue) as identified in the plan at Appendix 19:

- Replace two private driveway bridges at 17B and 19 Fife Avenue.
- In general, the creek for a length of about 80 m upstream of 22A Fife Avenue to about 20 m of Blakissoch Road footbridge needs to have a cross-sectional area equivalent to a base width of about 4 m and a depth of about 2 m (based on vertical banks). Creek capacity works are therefore required at 22A, 22B, 22C and 22D Fife Avenue:
  - Retain existing retaining walls along this length
  - Retain the prominent trees close to the creek at 22D Fife Avenue and the adjacent stone building
- The house at 22A Fife Avenue is built over the creek. The channel opening under the house is considered to have sufficient capacity (subject to further detailed modelling). Widen and streamline the base of the creek upstream and downstream of the house, which has been modified with concrete channelisation of irregular shape, to about 4 m wide base.

- From the Blakissoch Road footbridge to Paisley Avenue, the creek traverses the property of 15 Paisley Avenue over a distance of about 35 m. The house at 15 Paisley Avenue is built over the creek. Creek widening under the house should be possible without significantly altering or putting the house or its foundations at risk.

Area 6B: Between Paisley Avenue and Muggs Hill Road

Proposed creek capacity upgrade works would affect an estimated five properties (18 and 16 Paisley Avenue, 17 Inverloch Avenue, 18 Leonard Terrace and 19 Lochness Avenue) as identified in the plan at Appendix 19:

- The upstream transition of the creek from the under-house section extending into public land (Betty Long Reserve) at the end of Paisley Avenue needs to be streamlined by generally widening the creek base and undergrounding an exposed water main.
- For a length of 60 m immediately upstream of the footbridge at the end of Paisley Avenue, the creek is generally in public reserve but, subject to a detailed survey, part of the creek may be in adjoining private properties on the western side (18 and 16 Paisley Avenue and 17 Inverloch Avenue). The banks along this reach are heavily eroded and should be stabilised in conjunction with widening of the creek base to about 4 m.
- There is a critical section of creek (flooding breakout) about 180 m downstream of Muggs Hill Road where the creek turns in a south westerly direction (18 Leonard Terrace and 19 Lochness Avenue). Flow in this section could be improved by smoothing the directional alignment of the creek for a length of about 50 m.

12.1.13 Area 7 – Muggs Hill Road to Brown Hill Creek caravan park

No creek capacity upgrade works are proposed.

12.2 PUBLIC ROAD BRIDGE UPGRADES

For Option D, public road bridge upgrades are required as follows.

Table 26: Public road bridges – Option D

Bridge	Current form (dimensions in metres)	Proposed upgrade (dimensions in metres)
Second Avenue, Forestville	Irregular concrete 3.1(max) x 2.4	Rectangular culvert 6 x 2.1
First Avenue, Forestville	Irregular concrete 3.2 (max) x 2.3	Rectangular culvert 6 x 2.1
Charles Street, Forestville	Trapezoidal concrete 5 (max) x 2.2	Rectangular culvert 4 x 2.2
Ethel Street, Forestville	Rectangular culvert 3.9 x 2.3	Rectangular culvert 4.8 x 2.4
Approach to Goodwood Road, Millswood	Rectangular culvert 4 x 2.1	Additional rectangular culvert 2 x 1.5

Bridge	Current form (dimensions in metres)	Proposed upgrade (dimensions in metres)
Orphanage Park (internal road)	5.25 m bridge span across trapezoidal channel	This is dependent on the preferred concept design for Orphanage Park
Regent Street, Millswood	Rectangular concrete 3.1 x 2.5	Rectangular culvert 5 x 2.5
Northgate Street, Unley Park	Rectangular concrete 3.3 x 2.4	Rectangular culvert 4.8 x 2.4
Hampton Street, Hawthorn	Half round concrete and brick 5 x 2.25	Rectangular culvert 5 x 2.25
Fife Avenue, Torrens Park	Rectangular concrete 2.5 x 2.0	Rectangular culvert 4 x 2

12.3 MAINTAINING THE CREEK IN GOOD CONDITION

12.3.1 Watercourse health

All eight flood mitigation options for the Part B Works include undertaking rehabilitation and maintenance works along the full length of upper Brown Hill Creek to return the creek to a state of 'good condition'. As discussed further in Section 12.3.3, the AMLRNRMB is currently preparing a recommended practice to define 'good condition' for urban creeks.

The AMLRNRMB has previously prepared an advisory brochure entitled 'A Property Owners Guide to Managing Healthy Urban Creeks' *(*NRM Board 2008*)* which provides guidance as to the geomorphology, vegetation and management of urban creeks to balance creek capacity, bank stabilisation, creek habitat and environment, aesthetics and native vegetation. The brochure is included at Appendix 24.

Under current legislation, creek owners have a legal responsibility to maintain the creek in good condition within their properties, and the AMLRNRMB has powers to direct property owners to undertake works to ensure the creek is maintained in, or returned to good condition. The responsibilities are outlined further in the following Section 12.3.2.

Although the care of the watercourse is the responsibility of the property owner, the significant cost of periodic erosion protection, vegetation control and flow capacity upgrades (as proposed under the Part B process) is potentially beyond the financial capacity of most private owners.

To achieve a consistent level of maintenance works, the BHKC project is therefore proposing to undertake certain creek rehabilitation works on behalf of the private property owners as well as on behalf of the councils who are also creek owners in their own right. The nature of works and proposed cost sharing arrangements are discussed in Section 12.3.4.

12.3.2 Responsibility for creek maintenance

This subject was discussed in the 2012 SMP at Sections 13.7.6 and 13.7.7. In the Part B process, further information was obtained which supersedes relevant content in the 2012 SMP.

The legal framework which governs flood mitigation, creek rehabilitation and establishes the responsibilities of creek owners is set out in the NRM Act 2004, the Local Government Act 1969 and Schedule 1A under that Act, and in some circumstances the Metropolitan Drainage Act 1935.

Under those Acts, the corresponding and respective bodies (regional NRM Boards, councils, the SMA and the Minister) may exercise a range of powers relating to the clearing, removal of obstructions or widening or deepening of creeks within the boundaries of private landowners.

The NRM Act makes it clear that for the purposes of the duties under the Act, the owner of a watercourse, as well as the owner of land that adjoins a watercourse, is responsible for the watercourse. In some circumstances, the owner of an interest in land (such as the beneficiary of an easement) may also attract responsibilities under one or more of these Acts.

Property owner responsibilities in relation to watercourses as set out in the NRM Act include:

- to not undertake water affecting activities (outlined below) without a permit or contrary to the relevant NRM Plan;
- a general duty to act reasonably in relation to watercourses (a very broad obligation in relation to the management of natural resources);
- preventing damage to a watercourse; and
- liability to maintain the watercourse in ‘good condition’.

Water affecting activities include:

- placing any object on the floodplain to control flooding;
- building structures in a watercourse or on its floodplain or obstructing a watercourse in any other way;
- excavating material from a watercourse; and
- destroying vegetation or growing inappropriate vegetation in a watercourse or floodplain.

Under section 131 of the NRM Act, the AMLRNRMB has the power to direct the owner of land on which a watercourse is situated to take action to maintain the watercourse in good condition. However, the AMLRNRMB has not previously used its section 131 powers without strong reason and only does so principally to uphold the objects of the NRM Act, which are orientated to natural resources management and ecological sustainability.

Section 31 of the NRM Act also provides powers to the AMLRNRMB to enter onto private land for the purposes of undertaking stormwater management or flood mitigation works.

Similar powers exist for local government under section 21, Schedule 1A of the Local Government Act. The Local Government Act also provides powers for local government to access any part of the watercourse for undertaking any work consistent with a SMP. The SMA can require a council to use the powers available under section 21 by issuing an order under section 16 of the Local Government Act Schedule 1A.

Powers and responsibilities in relation to creeks are summarised at Appendix 25.

12.3.3 Defining ‘good condition’

The AMLRNRMB in consultation with the BHKC project, the LGA and the Department of Environment, Water and Natural Resources (DEWNR) is currently preparing a recommended practice for maintenance of urban watercourses.

The recommended practice will clarify ‘good condition’ for urban creeks in the context of natural resources enhancement as well as stormwater conveyance, and include:

- vegetation management;
- planting vegetation;
- removing problem vegetation;
- improving biodiversity and habitat; and
- erosion repair and control.

In terms of routine maintenance, particularly for stormwater conveyance, general principles incorporated into Option D (and applied to all of the other Part B flood mitigation options) are:

- clearing exotic and invasive species of vegetation from the watercourse channel and banks;
- removing trees and branches that may have fallen into the channel;
- removing or raising bridge structures that are too low and do not provide sufficient capacity for the passage of floodwaters;
- removing rubbish such as tyres, discarded whitegoods, building materials and general refuse which have the potential to contribute to flooding problems; and
- avoiding any installation or construction within the watercourse, and ensuring that if anything has to be constructed the necessary NRM Board consent is obtained beforehand.

Other natural resource management principles applicable to maintenance are:

- avoiding removal of natural material such as rocks and gravel, submerged logs and water plants which act to prevent erosion or scour;
- planting native riparian plants (e.g. grasses, sedges and rushes) in the banks as they lay flat and allow water to flow freely during floods;
- replanting native vegetation along the creek corridor using plants and trees of local provenance and typically with narrow or clear stemmed trunks – trees will typically not be planted in or close to the main channel; and
- stabilising and/or flattening steep bank slopes where possible to reduce bank collapse and/or erosion potential and to increase safety along the edge of the watercourse.

Example of creek rehabilitation – First Creek in Burnside (2011)

12.3.4 Proposed creek rehabilitation works

Although maintenance and rehabilitation of the creek is the property owners' responsibility, it is proposed that the BHKC project in partnership with the creek property owners and the AMLRNRMB will undertake:

- a 'one off' extraordinary creek maintenance to rehabilitate the creek towards achieving good condition, thereby assisting flow capacity for flood mitigation and improving the creek environment and geomorphology; and
- planned maintenance thereafter, aimed at maintaining the creek in good condition after the initial one-off extraordinary creek maintenance is undertaken. This work could include erosion controls, bank stabilisation and clearance of major obstructive material.

Creek owners would still be responsible to undertake:

- regular general site maintenance such as pruning vegetation, weed spraying and removing rubbish, litter and leaf build-up from within the creek; and
- unplanned maintenance such as removal from the creek of fallen timber and objects which might cause blockages and consequent local flooding.

In relation to the 'one off' extraordinary creek maintenance, it is proposed that this would entail progressive removal of exotic trees and introduced plant species from the creek bed and banks, and the re-planting of native vegetation.

In areas of the creek already affected by erosion and/or bank instability, stabilisation works such as flattening the creek banks, stabilising with matts or dense planting may be required. These measures would be designed to suit the specific location and conditions and with the objective of establishing as natural a creek environment as practicable.

Where stabilisation or other creek rehabilitation works are required within private property, and particularly where any proposed creek rehabilitation may interact or impact on existing vegetation or landscaping, the BHKC project in partnership with the AMLRNRMB will work individually with property owners to develop a site specific plan which meets the reasonable requirements of the project and the property owner.

Costs for both capital and planned maintenance works have been incorporated in the estimated costs for each of the eight flood mitigation options (refer Section 15.3).

Maintenance of retaining walls and other privately constructed features which have been installed by property owners either for flow protection or landscaping would continue to be the responsibility of the property owner.

12.4 REQUIREMENTS FOR AN EASEMENT OR AGREEMENT

Both the NRM Act (section 31) and the Local Government Act (Schedule 1A, section 21) provide identical powers to the AMLRNRMB or a council respectively to enter onto private land for the purposes of undertaking stormwater management or flood mitigation works. The powers in section 21 may only be exercised by councils where there is an SMP approved by the SMA and gazetted.

Provided the proposed works do not entail the construction of permanent infrastructure (e.g. undertaking creek rehabilitation or maintenance clearing), no formal agreement or easement is necessary for the works to be undertaken apart from a standard notice of intention to enter the property.

However, both the NRM Act and the Local Government Act are more specific if permanent infrastructure or works are proposed (such as creek capacity upgrade works or bank stabilisation work). In those circumstances, the following requirements apply:

- Works can be carried out under an agreement with the property owner subject to that property owner's consent, and if the property owner agrees to undertake ongoing care, control and management of the works; and
- Where the property owner wants the AMLRNRMB or council to retain ongoing responsibility for care, control and management of the permanent works, then the NRM Board or council must acquire an easement or other appropriate interest over the land (e.g. acquisition of land).

The choice of whether a property owner wants an easement or to have works undertaken under an agreement is largely a decision for the property owner. The difference between the two choices (easement or agreement) is that if the property owner wishes the NRM Board or council to retain responsibility for construction and ongoing maintenance for any works constructed on their property, then they need to do so through an easement. If however, the property owner would prefer to take care, control and management of the infrastructure after it has been constructed by the NRM Board or council, then the works can be undertaken by an agreement to that effect with the property owner.

From the BHKC project's perspective, the creation of an easement to cover the bank to bank area of the creek provides a higher level of certainty over the works and ensures that the issues of ongoing maintenance responsibilities have been addressed and determined. As an easement is also attached to the property title, it continues after a property has been transacted and is essentially perpetual unless revoked by agreement of both parties.

It is not proposed to seek easements along the entire length of upper Brown Hill Creek. Nor is it planned to acquire land or create a creek reserve through private property.

An easement is unlikely to impose any more limitation on the property owner's access and use of the creek than already apply under legislation of the NRM and Development Acts. Existing responsibilities (and associated limitations) under the NRM Act are summarised in Section 12.3.2. Development Plans under the Development Act 1993 designate certain areas, including flood prone areas, watercourse zones and floodplain zones which are subject to special consideration and restrictions in respect of development.ther key points:

- An individual property owner will be able to choose the form of arrangement – either an agreement or easement.
- It would be a condition of the agreement that as part of any transfer of the land, the vendor must require the purchaser to agree to be bound by the terms and conditions of the management agreement. Alternatively, the agreement could be registered as an encumbrance on the title.
- An easement will generally transfer a requirement onto the council to be responsible for and/or undertake certain things (e.g. maintenance works) that would otherwise reside with the property owner.
- There would be a number of standard conditions which all easements would generally include, but otherwise conditions would be designed to suit specific local conditions.
- An easement can be granted over an individual property without affecting the rights of adjoining properties. This so called 'landlocked' easement does not contravene the Land Acquisition Act nor impose any restriction on the council in terms of access (in either the practical or legal sense).
- Under the legislation, an easement or alternative form of interest in the land must be in place before any infrastructure work is carried out by the council.
- Under the Land Acquisition Act, Ministerial approval is required for the creation of an easement.
- The landowner is entitled to seek compensation for the creation of an easement; with the amount of compensation being determined in accordance with the Land Acquisition Act.

In respect of compensation for the creation of an easement, the following principles have been advised by specialist land management consultants Maloney Field Services:

- Section 25 (1)(a) of the Land Acquisition Act includes the following overarching requirement that (for property owners impacted by acquisition) "the compensation payable to a claimant shall be as such as adequately to compensate him for any loss that he has suffered by reason of the acquisition of the land".
- The best test of loss under such a scenario is the difference in value (if any) of a property 'before and after' the acquisition, however compensation can also reflect such factors as the actual value of the land taken, severance, disturbance and injurious affection.
- Whilst the actual value of the land taken is self-explanatory, severance and injurious affection deal with any loss in value to the balance of the land not being acquired.
- Disturbance on the other hand is not related to property value, but to other matters arising as a result of the acquisition which may cause financial and/or non-financial disturbance to an owner.

- Section 25 of the Act also recognises the concept of enhancement associated with the development of the land after its acquisition, with any such enhancement needing to be taken into consideration in determining the overall compensation package.
- Some examples of enhancement in the context of creek capacity upgrade works may include increased property protection from flooding, release from previous obligation to maintain the waterway, and improved landscaping and amenity.

Assumptions regarding estimated costs of compensation for easements are outlined in Section 15.3.7.

Councils have access to powers under the Land Acquisition Act which allow for the compulsory acquisition of easements to enable the implementation of any approved SMP. Whilst these powers exist, it is the strong preference of the catchment councils (through the BHKC project entity) to liaise with property owners to secure either an agreement or the creation of an easement.

Whilst it is not proposed to purchase full properties as part of this project, there are previous schemes in other council areas where this has been undertaken and then only to place an easement on the title and then resell the property. However, this is rare, and relying on the purchase of properties when they come up for sale or where permanent works are to be undertaken as a means of exercising public control over the maintenance of watercourses would take many decades to fully implement based on the normal turnover of properties.

A consultative strategic approach would draw from the following range of options for which implementation details would be subject to consultation with and general support by watercourse property owners:

- Where creek channel capacity needs to be increased through works, apply the LGA Act section 21 powers to deepen or widen the watercourse in accordance with good practice measures and landowner consultation, particularly in seeking to achieve a suitably landscaped form.
- Works would be carried out at the expense of the catchment councils (through the BHKC project), subject first to either acquisition of an easement over the works or entering into an agreement.
- The BHKC project entity or relevant council is to regularly inspect the watercourse condition with results to be shared with watercourse landowners.
- Use results of cooperative watercourse inspections to identify any necessary maintenance actions to be undertaken by either the council (through the BHKC project entity) or landowner.

13. STORMWATER MANAGEMENT STRATEGIES

This section discusses the expected outcomes of the flood management measures described in Sections 10 and 12 in terms of residual flood extent and numbers of properties impacted. Section 16 provides an economic assessment of flood mitigation measures.

13.1 FLOOD MITIGATION AND RESIDUAL FLOOD RISK

Floodplain mapping (extent and depth of inundation) based on implementation of the full suite of structural works as identified in Sections 10 and 12 is provided in Figure 18 and Figure 19 for the 100 and 500 year ARI events, respectively. A floodplain map for the 50 year ARI event is not included as the residual flooding extent is minimal and barely discernible at normal mapping scale.

Further to the limitations of the 500 year ARI mapping as outlined in Section 9.1, note that the benefit afforded by the proposed South Park Lands detention system during the 500 year ARI event has not been specifically captured in detailed modelling as part of the South Park Lands concept design. Accordingly, the benefit of the detention system has been approximated in the 500 year ARI event by applying the base case 100 year ARI hydrographs at inflow points to the MIKE-FLOOD model upstream from the South Park Lands outlet at Greenhill Road.

The small number of properties still affected by flooding under the 100 year ARI event following implementation of the structural flood mitigation works of the SMP is provided in Table 27.

Comparison with the base case conditions (refer Table 2) shows that the proposed works will reduce the number of affected properties in the 100 year ARI event by over 98% (from 2,089 to 31). For properties subject to over-floor flooding, the reduction is almost 100% (from 1,172 to 6).

Table 27: Properties affected by flooding for mitigation case

Design flood	Number of flood affected properties			Damages ($'000)
	Over-flood flooding	Under-floor flooding	Total	
10 year ARI	0	0	0	0
20 year ARI	0	0	0	0
50 year ARI	3	13	16	398
100 year ARI	6	25	31	814
500 year ARI	2,129	2,988	5,117	181,724
PMF	Data unavailable			1,000,000

The level of flood protection varies across the catchment due to the varying capacity of the watercourses and differing flowpaths that originate from each creek system. Therefore, although it is difficult to clearly define the level of protection within all specific areas of the catchment a general assessment has been made on a sub-catchment scale and the results are presented in Table 28.

Table 28: Indicative level of flood protection

Reach	Level of flood protection (ARI standard)	
	Base case	Mitigation case
Parklands Creek: Conyngham St to Glenside	50 year	50 year
Parklands Creek: downstream of Greenhill Rd	10 year	100 year
Glen Osmond Creek: Ridge Park to Windsor St	10 - 20 year(1)	100 year(1)
Glen Osmond Creek: culvert section to King William Rd	100 year	100 year(2)
Glen Osmond Creek: downstream from King William Rd	10 year	50 year(3)
Keswick Creek: downstream to Le Hunte St	20 year	50 year(4)
Keswick Creek: Le Hunte St to Richmond Rd	10 year	100 year
Keswick Creek: Richmond Rd to South Rd	10 year	100 year(5)
Keswick Creek: downstream from South Rd	10 year	100 year
Brown Hill Creek: downstream to Cross Rd	20 year	100 year(6)
Brown Hill Creek: Cross Rd to Anzac Hwy	20 year	100 year(7)
Brown Hill Creek: downstream from Anzac Hwy	20 year	100 year

Notes:

1. The base case condition of Glen Osmond Creek is assumed to be without Ridge Park dam in place.
2. It is assumed that the Unley Road constriction (refer Section 5.1.3) will be rectified outside the scope of the SMP.
3. A small extent of residual flooding is evident along Simpson Parade for the 50 year ARI event (mitigation case).
4. A small extent of residual flooding is evident near the tramway culvert.
5. Parts of Mile End South may still be prone to localised flooding due to local area runoff rather than flow from upstream.
6. Some nuisance flooding is expected during events greater than 20 year ARI, but flooding would be limited to the channel overbank area.
7. Small number of properties could experience inundation during the 100 year ARI flood in the vicinity of Heywood Park, but there is unlikely to be significant damages.

Discussion of the residual 100 year ARI flood risk along each of the watercourses follows.

13.1.1 Parklands Creek

- Enlargement of the existing detention basin in the Glenside Development Site confines the 100 year ARI flood extent mainly to areas within the Site.
- Some residual breakout will occur upstream at Conyngham Street where the stormwater pipes leading down to the detention basin have a 50 year ARI capacity. The existing masonry wall fronting Greenhill and Fullarton Roads would assist in containing the spread of inundation into the area of Eastwood.

- The existing culvert beneath the intersection of Fullarton and Greenhill Roads has sufficient capacity to pass the mitigated 100 year ARI peak flow from the enlarged Glenside basin.
- Flow detention in the South Park Lands reduces 100 year ARI flow inundation mainly to the designated basin areas (Victoria Park and Park 20). The 100 year ARI flow out of the detention basins is reduced to less than 8 m^3/s which can be accommodated in the stormwater culvert under Greenhill and Palmerston Roads.
- Capacity of the open channel between Greenhill Road and the confluence with Glen Osmond Creek is considered to be about 8 m^3/ or marginally less. Extraordinary maintenance work may be required on this section of channel to restore all the channel capacity to 8 m^3/s.

13.1.2 Glen Osmond Creek

- Mount Osmond interchange dam modifications and the Ridge Park flood control dam assist in reducing breakouts further downstream, including Keswick Creek. However, the small residual breakout at Fern Avenue (the entrance to the Windsor Street culvert) is expected to be overcome by enlarging the bridge culverts at Fern Avenue and Torrens Avenue, Fullarton.
- The open channel from King William Road down to the start of Keswick Creek is estimated to have a capacity of about 15 m^3/s compared with the peak mitigation case flow (100 year ARI) of about 19 m^3/s. Hence this part of the system has less than the 100 year ARI level of protection. The extent of residual flooding (i.e. mitigation case / 100 year ARI) is shown in the following Figure B. The level of protection is estimated to be at about the 50 year ARI (mitigation case).

Figure B: Residual flood extent along Glen Osmond Creek downstream of King William Road (mitigation case / 100 year ARI)

13.1.3 Keswick Creek

- From the start (confluence of Parklands and Glen Osmond Creeks) to Le Hunte Street, localised flooding will continue to occur immediately upstream of the tramway crossing.
- As a result of the Le Hunte Street diversion, the channel upgrade works in the Military Barracks and the diversion to lower Brown Hill Creek, no flooding is expected downstream from Le Hunte Street through as far as Mile End.
- Minor breakout may still occur at Manchester Street as flow builds up due to continuing local urban runoff.

13.1.4 Brown Hill Creek

- Along upper Brown Hill Creek in Mitcham Council area between Fife Avenue and Mitcham shopping centre and between Belair Road and Cross Road, small localised breakouts would have minimal impact.
- Proposed works by Mitcham Council (on Council's forward program) at George Street bridge would assist in reducing the risk of minor localised flooding in the vicinity.
- Along upper Brown Hill Creek, small localised breakouts between Heywood Avenue and Cross Road (Unley Park) would not impact houses at above-floor level.
- Downstream from Anzac Highway any breakout will be localised and minimal.

13.1.5 Summary

While it would be technically possible to provide a higher level of flood protection at all locations, the social impacts and capital costs would likely outweigh the benefits. The proposed flood mitigation works have been prioritised with a view to minimising social impacts and ensuring the costs of works are largely offset by the benefits.

In the case of Keswick Creek downstream from Richmond Road, there is significant runoff from local urban areas which exceeds the existing channel capacity. Further investigation of how this flow is being conveyed to the creek would better define the local flood risk and identify local mitigation strategies.

Further reduction of the likelihood of flooding in these areas may require the acquisition of land to either increase the capacity of the channel or to provide enough open space to provide adequate flood storage. Such an approach is unlikely to be justified economically nor is it likely to be socially acceptable.

13.2 SUPPORTING MEASURES

13.2.1 Water sensitive urban design

Background to WSUD is provided at Section 6.3.2.

In respect of stormwater management, WSUD related elements are being implemented across the catchment in order to achieve water quality and water reuse objectives of the SMP. In recent years BHKC catchment councils have been pro-active in adopting WSUD applications and this trend is expected to continue.

The Adelaide City Council Strategic Plan (2016-2020) includes water related strategies for improving the ecological value of watercourses and biodiversity in the Park Lands, reducing stormwater runoff and pollution through integrated catchment management and WSUD, increased use of recycled water and landscape and streetscape designs that include WSUD principles. WSUD principles are also contained within Council action plans including the Biodiversity and Water Quality Action Plan 2011-2016 and the Water Security Action Plan 2011-2016. Applications include:

- bioretention and passive irrigation systems installed along a number of prominent streets and roads;
- a ‘green streets’ program incorporating permeable paving and other WSUD systems; and
- development of ‘green infrastructure guidelines’ incorporating WSUD principles.

At Burnside Council, WSUD and sustainable water use practices are featured in a number of strategic initiatives in the form of water conservation, reuse and capture designed to enhance streetscapes for improved amenity, character and environmental outcomes. Applications include:

- installation of rain gardens and Bpods along a number of streets (Bpods are infiltration systems which collect runoff from houses for subsurface storage and infiltration within road verges to support street tree health); and
- a car park with permeable paving provides infiltration to supply a small wetland from which treated stormwater is reused for site irrigation of sustainable vegetation.

Mitcham Council has nine operational applications in streets and open spaces (parks and ovals) within the catchment. Their primary function includes first flush infiltration, bioremediation, street tree irrigation (or a combination) and they involve techniques of infiltration trench, rainwater collection, rain garden and aquifer storage and recovery (ASR). These applications harvest relatively small volumes, but would provide significant benefits if applied more generally.

Unley Council has an overall strategy to improve and maintain its green urban environment by striving to be a water sensitive city. The strategy will be achieved via a number of programs including this SMP and a specific stormwater harvesting / WSUD strategic plan. Council has implemented four significant WSUD applications.

Significant applications of WSUD by Unley Council at Wattle Street, Fullarton and Hamilton Boulevard, Wayville have been developed in conjunction with road reconstruction (Hamilton) and a stormwater drainage system (Wattle). Those applications are also regarded as stormwater harvesting schemes because of the relatively large volumes of stormwater being collected. More extensive stormwater harvesting has been established in Ridge Park and Heywood Park (refer Section 14.2).

West Torrens Council has established WSUD applications at over 20 sites across the city and another seven are currently in design. Many of those are in the form of streetscape rain gardens and ‘treepit’ installations.

The above applications comply with the South Australian Government’s position on WSUD (as expressed in ‘Water sensitive urban design – creating more liveable and water sensitive cities in South Australia’).

Table 29: WSUD applications in terms of aims and principles

Performance principle	Intent	Performance target	Primary focus
Water conservation	Sustainable use of water resource	Promotion of water efficient technique in urban setting	Residential and commercial areas
Runoff quality	Help protect receiving water environment	Reduction of pollutant loads compared with untreated stormwater runoff	Roads, streets and thoroughfares within residential and commercial areas
Runoff quantity	Help protect waterways	Reduction in the peak flow of runoff entering waterways	Roads, streets and thoroughfares within residential and commercial areas
Runoff quantity	Help manage flood risk	Reduction in the volume of runoff entering waterways	Roads, streets and thoroughfares within residential and commercial areas
Integrated design	Establishment of 'green infrastructure' – with related beneficial outcomes	Stakeholder engagement is satisfied (council processes / local community consultation)	Roads, streets and thoroughfares within residential and commercial areas

Table 30: The value of WSUD applications in terms of benefits

Economic	Environmental	Social
• Cost savings in other measures designed to improve waterway quality • Cost savings in reduced sizing of other stormwater management infrastructure • Improved market value of residential areas due to the environmental and social enhancements	• Helps maintain hydrological balance by using natural processes of storage, infiltration and evaporation • Minimised impact of urban development (roads) on the environment • Enhancement of natural habitats • Groundwater recharge	• Provides amenable urban and residential landscapes • Provides high value visual amenity • Helps ameliorate urban heat island effects

In mid-2012, AMLRNRMB initiated development of a business case, in partnership with other organisations including the LGA, Department for Water and the EPA, to support implementation of a local WSUD capacity building program (i.e. knowledge and skills). The BHKC catchment councils are potential stakeholders in the program and would seek to be involved.

Fundamental stormwater reuse applications including WSUD and the use of rainwater tanks remain important actions to promote and where possible mandate and regulate in planning and building policies. Further adoption of this measure by BHKC catchment councils for increased capture of rainfall runoff is recommended.

However, whilst WSUD (which may include OSD) is beneficial in reducing the impact of increased runoff due to urban in-fill development, it is not a complete solution to the existing risk posed by large storm events, particularly in the 100 year ARI range.

Typical rain garden (WSUD application) in West Torrens Council area

13.2.2 On-site detention

An introduction to OSD is provided at Section 6.3.3.

The level of flood protection provided by the proposed works will be reduced over time if higher density redevelopment is permitted without appropriate controls in place. This reduction is potentially very large. Individual councils currently implement a variety of approaches to manage this issue, ranging from arbitrary property peak discharge limits, to no limitation on impervious site coverage.

It is necessary that a catchment-based on-site detention policy, or other policy providing a similar outcome, is applied to appropriately manage this issue. The policy will need to be tailored such that future development will have appropriate guidance on measures by which the peak flows within the creek system are maintained to those adopted for the design of the new works.

It should be noted that the policy may vary from council to council, and between areas within a council area, based on the different hydrological impacts of development in different areas. For example, the proposed South Parklands and Glenside detention storages would need to be taken into consideration in scoping a policy that would be relevant to the Adelaide City Council and Burnside Council catchment areas, in order to achieve a balance between OSD and publicly funded stormwater infrastructure.

Further work is proposed to be undertaken as part of a collaborative effort between the planning and infrastructure departments of the catchment councils. This work would include:

- identification of catchment development trends;
- assessment of the likely catchment impervious site coverage levels at the end of the current planning period;
- adoption of policies within each council to limit the discharge of stormwater from any new development (large or small scale) to pre-development volumes and peak discharges;
- verification of the effectiveness of the proposed policy response in managing future development; and
- formulation of policies for inclusion in a future revision of the SMP.

13.2.3 Development Plans

The Development Plans of each council within the BHKC catchment currently contain policies relating to stormwater management and flood risk mitigation, however not all Development Plans have adopted the SAPPL.

Those councils within the catchment which have not adopted the SAPPL policies are required to do so in the future, and by doing so will incorporate standardised Development Plan policies including:

- a Development Plan overlay showing high and medium flood hazard areas and 100 year ARI flood levels;
- general policies that recommend all new development including land division, change of land use, and building works to incorporate WSUD techniques; and;
- policies to ensure that new development does not reduce the capacity or functionality of the existing drainage network, or have any adverse impact on flooding across adjacent properties.

The Unley Council Development Plan already incorporates the Natural Resources module from the SAPPL. Amongst other things, this module introduces to the Development Plan requirements for developments to incorporate WSUD, to ensure water discharge from a development site does not exceed the predevelopment rate of discharge, and to incorporate stormwater management systems to mitigate peak flows and maintain clean stormwater runoff.

The Development Plan states that stormwater management systems should:

(a) maximise the potential for stormwater harvesting and re-use, either on-site or as close as practicable to the source; and

(b) utilise, but not be limited to, one or more of the following harvesting methods:

  (i) the collection of roof water in tanks;

  (ii) the discharge to open space, landscaping or garden areas, including strips adjacent to car parks;

  (iii) the incorporation of detention and retention facilities; and

  (iv) aquifer recharge.

Unley Council is developing the relevant information sheets and incorporation of stormwater management systems will eventually become a requirement of new dwellings and major redevelopments.

Mitcham Council mitigates the impacts of floodwaters on development and other property adjacent to watercourses through its Development Plan. The Development Plan contains specific design techniques relating to stormwater management together with mapping that identifies land within the vicinity of a watercourse. The Development Plan requires all development application for properties within the vicinity of a watercourse to be assessed on merit, rather than being a complying development, which provides Council with the opportunity to assess potential flood/watercourse impacts that may arise and to ensure that development mitigates the potential loss of life and property damage, as well as not impeding the flow of water.

Mitcham Council is proposing to undertake a future Watercourse Development Plan Amendment (DPA) that will introduce policy amendments relating to mitigating the impacts of floodwaters on development and property adjacent to watercourses. This DPA is particularly investigating the floodplains associated with Brown Hill Creek, Minnow Creek and Sturt River. A further longer term change is to consider subsequent DPAs identified to introduce Hazards-Flooding and Natural Resources-Water Sensitive Designs policies into the Development Plan.

The Building Code of Australia mandates the installation of a 1,000 L (minimum size) rainwater tank to be installed with each new dwelling built in South Australia and plumbed into a toilet, a water heater or all laundry cold water outlets. The Building Code also states that the rainwater tank must be fitted with an overflow device that disposes of overflow from the rainwater tank in accordance with any specific requirements of the relevant authority.

A report prepared for Unley Council in 2010 recommended that Council consider a streamlined approach to assessment of development applications according to a classification of high, mid or low categories of flood risk. The categories relate to the predicted depth of flooding at the development site during a 100 year ARI storm event, and correspond to three levels of flood risk assessment:

- High category
  - If any part of the property is subject to 100 year ARI flood depths greater than 500 mm, or if the property is adjacent to or within a watercourse;
  - an engineering report is to be prepared by a suitably qualified chartered professional engineer with experience in floodplain management and hydraulic modelling; and
  - the report is to include recommended minimum floor levels and an assessment of potential flood impacts.
- Mid category
  - If the property is subject to 100 year ARI flood depths between 100 and 500 mm;
  - a detailed engineering report is not required; however, the flood depth information provided by council is to be used to demonstrate that requirements for minimum floor levels have been met (i.e. in terms of freeboard allowances).
- Low category
  - If the property is subject to 100 year ARI flood depths less than 100 mm;
  - the floor level must be at least 150 mm higher than the top-of-kerb level – for properties higher than the adjacent road level; or
  - the floor level must be at least 150 mm higher than the finished site levels around the perimeter of the proposed structure – for properties lower than the adjacent road level.

Other councils within the catchment may consider adoption of similar assessment guidelines to those under consideration by Unley Council. In considering assessment guidelines, the different categories do not represent different flood-related design standards, but rather represent differences in the approach to assessment.

13.2.4 Community awareness and emergency response

Flood maps provide the best available estimate of flood flows and extent, indicating where water is most likely to travel and what depth it might reach. This is vital information for helping property owners and residents to understand the scale of the flood problem, and therefore be able to mitigate potential damages.

The 100 year ARI flood map for Brown Hill and Keswick Creeks shows that much of the flooded area is affected by shallow water (less than 150 mm) (refer Figure 9). In most cases the flow will not be deep or fast enough to break through glass doors or windows, meaning that blocking door seals and wall vents by sand bagging may be sufficient to alleviate the problem. Raising furniture and belongings to well above floor level or to upper storeys would also help alleviate flood damages.

In New South Wales and Victoria, catchment management authorities and councils have the authority to issue a flood report or certificate when a property is in a flood-prone area. Agents, owners or potential purchasers can obtain a report or certificate as part of property enquiries. The content of the certificate is limited and basically advises that the property is within the calculated flood-prone area.

An opportunity exists to incorporate similar advice in South Australia on Section 7 searches required as part of the Real Property Act 1886. The purpose of providing such advice would be to inform owners and occupiers of flood-prone land so they can make informed decisions.

To help residents manage the impact of flooding and reduce damages to their property, the 2006 Master Plan indicated that an ongoing awareness program was needed to achieve a reasonable and sustainable level of community awareness and raise levels of awareness in emergency management and response procedures.

The FloodSafe Program has since been established across a number of councils in partnership with the SES, including councils of the BHKC catchment, which is beneficial for raising community awareness of flooding and helping residents in planning for a flood emergency.

The program is designed to:

- provide people with an understanding of whether they live or work within a floodplain area;
- provide information on ways landholders can flood-protect their houses and businesses;
- provide information on effective ways to respond during a flood emergency; and
- Work with landholders at a neighbourhood level to provide advice on developing individual emergency response and recovery plans.

A key communication tool used as part of the FloodSafe Program is a 'Flood Pack', which is distributed to at-risk residents and contains information on methods for flood-proofing dwellings and properties, in addition to advice on flood preparation, safety and recovery.

In addition to any financial benefits, there are significant intangible benefits to a flood preparedness program. It can increase the safety of residents during a flood and help them to be more resilient in the aftermath of a flood. It is considered that the FloodSafe program can be justified on the basis of personal safety alone.

Accordingly, it is recommended that the SES and the catchment councils continue to operate and develop the FloodSafe Program. In light of comments made by some residents affected by flooding in 2005, it is also recommended that the program consider a door-knock approach by SES volunteers for the most flood prone areas to advertise any upcoming FloodSafe events or provide assistance and advice in preparing a household or business Emergency FloodSafe Plan.

Under the Agreement on Stormwater Management (2013) between DEWNR and the LGA, it was agreed that South Australian councils would "communicate floodplain mapping and associated risk information to the community, and allow the State Government full and free access to also disseminate the floodplain mapping to improve community resilience to flood hazard". The BHKC project is providing flood mapping data to DEWNR for a flood awareness website which would also be informed by the following initiative.

A project is being undertaken jointly by DEWNR and the SES in 2015/16 to improve flood warning and flood hazard management. The project is expected to build capacity and expertise in flood behaviour, risk and impact mitigation, flood warning and community resilience. Outcomes of the initiative will include:

- collection of flood information to inform a flash flood warning capability (adding to the value of river flood warnings provided by the BOM) and inform emergency response activities (including evacuation) and long-term flood response planning;
- capability building by SES (with DEWNR support) to issue flash flood warnings, provide information on flood impacts and actions to the community, and provide flood advice to emergency response units;
- improved flood response planning for at-risk areas; and
- advice to the community on flood risk and flood warnings.

(DEWNR, February 2016)

In late 2015 the SES carried out market research along the environs of Brown Hill Creek to survey property owners and businesses regarding levels of flood risk awareness and response preparedness, including flood insurance cover. Results of the survey are expected to be submitted to the State Government in the first quarter of 2016. If necessary, the survey may prompt further actions (involving the SES) to complement any existing flood and storm response plans that are currently in use by the councils. (SES, February 2016)

13.2.5 Creek maintenance

Creek maintenance, as discussed in Section 12.3, is considered to be an integral supporting measure to the proposed flood mitigation infrastructure works for upper Brown Hill Creek. The same principles of creek maintenance should be applied to other creeks of the BHKC catchment, particularly Parklands Creek downstream of Greenhill Road, Glen Osmond Creek between Ridge Park and Windsor Street, and lower Brown Hill Creek.

14. MULTI-PURPOSE STRATEGIES

Following on from the initial discussion of opportunities for multi-purpose outcomes in Section 6.4, this section outlines proposed multi-purpose strategies for implementation as part of the SMP. The strategies cover stormwater quality, particularly in terms of impact on receiving waters, and stormwater harvesting and reuse.

14.1 WATER QUALITY

14.1.1 Existing water quality

Urban stormwater runoff contains common contaminants including suspended solids, nutrients, biological oxygen demand (BOD), chemical oxygen demand (COD) and bacteria which are usually considered to have the most significant ecological impact on receiving waters (Engineers Australia, 2006). Oils, surfactants and litter have aesthetic impacts in addition to their ecological impacts, and are more renowned for generating community concern.

Contaminants within stormwater runoff are generally higher than nationally accepted levels (ANZECC and ARMCANZ, 2000) for discharge into marine environments, with respect to both aquatic ecosystems and recreational use.

The transfer of contaminants from metropolitan Adelaide to Gulf St Vincent has been described by the Adelaide Coastal Waters Study (ACWS) (Wilkinson et al., 2004). A brief summary of the median values for a range of physical and chemical parameters reported for Brown Hill Creek are presented below.

Table 31: Contaminants for reporting

	EC[1] (µs/cm)	Suspended Sediments (mg/L)	Total nitrogen (mg/L)	TKN[2] (mg/L)	Nitrate (mg/L)	Total Phosphorous (mg/L)
Brown Hill Creek (1996-2005)	437	17	1.01	0.80	0.165	0.134
Urban Average[3]		150 (50-450)	2.5 (1.4-5)			0.35 (0.15-0.85)

Based on (Wilkinson et al 2004)

[1] The EC unit microsiemen/cm (µs/cm) can be converted to mg/L by multiplying by 0.64.

[2] TKN – Total Kjeldahl Nitrogen is the sum of organic nitrogen; ammonia and ammonium.

[3] 'All Urban' mean value, (± 1 Standard Deviation) (Duncan, 2005)

The AMLRNRNB operates a flow and water quality monitoring gauge on Brown Hill Creek (Site No A5040583), located immediately upstream of the Morphett Road sedimentation basin. This gauge records water quality data for a number of flow constituents listed in the table above, as well as copper, zinc and lead.

14.1.2 Stormwater marine impacts

Stormwater from the BHKC catchment discharges directly into Gulf St Vincent within the ACWS zone. The ACWS determined that nutrients, particularly nitrogen from wastewater and stormwater are likely to be responsible for broad scale seagrass loss along the Adelaide metropolitan coast, with turbidity from sediments carried by stormwater possibly contributing, especially in the near-shore zone (Fox et al., 2007). Nutrients and sediment loads are also implicated in the loss of large brown canopy algae from temperate reefs, and a shift to turf-dominated assemblages (Gorgula and Connell, 2004; Turner, 2004).

The Adelaide Coastal Water Quality Improvement Plan (ACWQIP) has adopted the targets recommended by the ACWS, specifically, a 50% reduction in sediment loads and a 75% reduction in nitrogen from 2003 levels (McDowell and Pfennig, 2011) from all flow inputs (wastewater, stormwater and industrial).

Heavy metals and other contaminants potentially carried in stormwater have periodically exceeded levels of concern in Adelaide waters; although not considered an important factor in historical seagrass decline (Fox et al., 2007), these may pose a risk to receiving environments if present in sufficient concentrations (Mills and Williamson 2008; Gaylard, 2009).

14.1.3 Water quality treatment measures

The PCWMB (since superseded by the AMLRNRMB) was established in 1995 to manage the water resources of the catchment through the implementation of its comprehensive Catchment Water Management Plan. The focus of the Board in the first five years was water quality improvement, largely driven by the polluted and unsustainable condition of the Patawalonga Basin (PCWMB, 2002).

Up until the early 1970s waters of the Patawalonga Basin were used extensively for recreation, including water skiing, swimming and other water sports. These activities were banned when it became apparent from the results of testing that the quality of the water was unacceptable for primary contact. Water quality declined as the upstream stormwater drainage network was improved and local streets were kerbed and sealed (disappearance of roadside grassed swales resulting in more runoff and less local treatment), increased roadside vegetation (more leaf and bark litter), increased use of motor vehicles (more oils, heavy metals, etc) and increased commercial activity (more gross pollutants).

The PCWMB was active in promoting improved practices in the catchment and facilitating works such as wetlands and GPTs to improve water quality. It established an extensive network of GPTs that, as reported in the 2012 SMP, are estimated to collect about 1,000 tonnes per year of mainly organic (vegetation debris) and silt material. The existing (off-stream) Urrbrae wetlands also collects gross pollutants from a significant source of stormwater inflow to upper Brown Hill Creek. As reported in the 2012 SMP, it is estimated that a total of up to 5,000 tonnes of stormwater pollutants per year could ultimately be discharged from the BHKC catchment.

Currently, a large majority of the approximately 400 GPTs across the AMLRNRMB region are managed by councils. In a small number of cases the AMLRNRMB has agreements with councils regarding responsibilities and cost sharing in relation to individual GPTs, typically for their establishment, routine clearing and unplanned maintenance.

The SMP provides an opportunity for catchment councils, through the BHKC project, to take a coordinated and collaborative approach to the management and maintenance of GPTs along the major watercourses of the BHKC catchment, including the installation of new GPTs, in order to further reduce adverse impacts of stormwater quality on the environment. It is expected that the AMLRNRMB would continue to provide oversight in the context of resources management and ecological sustainability, and assist in funding the cost of new GPTs. An amount of $1 million is included in the project cost estimate for GPTs and related works ('water quality works').

Details of the five principal GPTs on watercourses of the BHKC catchment are summarised in Table 32 (source: AMLRNRMB). The AMLRNRMB has carried out a gap analysis and identified the need for 11 more GPTs across the BHKC catchment, and identified actions to improve the performance of three of the principal existing GPTs. Operational and proposed GPTs across the catchment are shown in the plan at Figure 20.

Table 32: Gross pollutant traps

Creek	Location	Catchment area	GPT type	Status
Brown Hill	Downstream of confluence with Keswick Creek	332 ha	Trash rack / nets / sediment basin	Fair performance / actions identified
Brown Hill	Watson Avenue / confluence with Keswick Creek	2841 ha	Trash rack / nets	Good performance
Brown Hill	Watson Avenue / confluence with Keswick Creek	2841 ha	Floating boom / screen / sediment basin	Good performance
Glen Osmond	Simpson Parade, Goodwood	910 ha	Trash rack	Poor performance / actions identified
Parklands	South Park Lands – park 20	309 ha	Trash rack	Fair performance / actions identified

The rated good performance by the Watson Avenue GPT (including the trash rack and floating boom) is the result of a major upgrade undertaken in 2014 and 2015. It is expected that improvement actions identified on other operational GPTs will be implemented by AMLRNRMB.

In recent years, the AMLRNRMB has also rehabilitated Brown Hill Creek below the junction with Keswick Creek, which involved laying back the banks and establishment of appropriate vegetation. These works have resulted in further water quality improvement through this creek section.

As discussed in Section 13.2.1, individual councils are contributing to improving stormwater runoff quality by incorporating WSUD measures into road reconstruction and drainage construction projects. This has taken a number of forms, including bioretention swales and pods; tree pits, designed to receive street runoff; and street verge stormwater pods. Some of these works support small scale stormwater harvesting and reuse for irrigation of local street trees.

Overall, the state-wide performance target of stormwater runoff quality is to achieve the following minimum reductions in total pollutant load, compared with untreated stormwater runoff (from the developed part of a site, including roads and hard stand areas):

- Total suspended solids by 80%
- Total phosphorous by 60%
- Total nitrogen by 45%
- Litter / gross pollutants by 90%.

Other non-structural works that have been undertaken in the past by the PCWMB and AMLRNRMB, in collaboration with the councils include:

- public awareness and education campaigns incorporating Waterwatch, Our Patch and best practice promotion;
- stormwater pollution prevention projects (Mitcham, West Torrens, Adelaide, Unley and Eastern Health Authority – serving Burnside and other councils);
- modifications to work practices (Service Authorities, councils);
- Local Agenda 21 plans in conjunction with councils;
- promotion of EPA Codes of Practice for Stormwater and Guidelines for Urban Stormwater Management; and
- street sweeping, building site management, retail sector site management improvements.

The street sweeping programs of councils are considered to be a significant source control component. Data collected indicates that 10-20 kg per ha per month of material (mainly vegetation and sediment) is generated in urban areas. Trials and investigations have shown that the generation of gross pollutants, especially vegetation, is dominated by the urban sector over the rural sector by a ratio of around 25:1. The reason for this difference is the very efficient urban drainage network (PCWMB, 2002).

Stormwater harvesting schemes across the BHKC catchment, as discussed in Section 14.2, also contribute to reducing adverse impacts of stormwater quality on the environment by reducing the volume of stormwater discharged into marine receiving waters.

14.1.4 Water quality targets

Preparation of the SMP has not included investigations that would enable specific runoff quality targets to be established. Management of the quality of runoff and its effect on receiving waters will be pursued with the AMLRNRMB during the full SMP works implementation phase.

Glen Osmond Creek, Simpson Parade trash racks

Brown Hill Creek, Watson Avenue trash rack, floating boom and sediment basin

14.2 STORMWATER HARVESTING AND REUSE

14.2.1 AMLRNRMB Report

In 2010 the AMLRNRMB produced a report 'Stormwater Harvesting Plan' which informed the 2012 SMP regarding stormwater harvesting and reuse actions and opportunities within the catchment and to be regarded as a complementary component of the SMP.

The Stormwater Harvesting Plan was informed by a number of supporting studies at the time, the principal ones being:

- Urban Stormwater Harvesting Options Study (Wallbridge and Gilbert et al, July 2009): This study was commissioned by the SMA in collaboration with the AMLRNRMB and other State Government agencies. The study looked at the technical feasibility of stormwater harvesting, rather than the broader viability of schemes. The opportunities identified in the study represent the upper limit of stormwater harvesting opportunities in Adelaide.
- Brown Hill and Keswick Creeks Aquifer Capacity and Water Demand Study (Design Flow, December 2009): This desktop study was commissioned by the AMLRNRMB. The scope included the viability of aquifer storage along Brown Hill and Keswick Creeks and potential demands for stored water.

In terms of further opportunities, the Urban Stormwater Harvesting Options Study included the following comments:

- Areas to the east of the city have limited ASR potential as the target aquifers are in bedrock, which typically have limited injection rates and low recovery efficiency.
- The aquifers further to the west are generally more favourable for ASR, providing greater storage and yield characteristics.
- Additional demands identified within the upper catchment at Waite and Urrbrae could be served by more economical harvesting from local catchments.
- The opportunity for harvesting up to 1500 ML per year from Brown Hill Creek at Plympton and transfer to the disused railway corridor at Plympton for treatment and aquifer injection.

The Stormwater Harvesting Plan outlines a review of existing projects, including major opportunities identified by the above studies and the State Government's Water for Good Strategy, as well as examining reuse opportunities from any proposed upper Brown Hill Creek catchment flood detention storage and possible harvesting and reuse opportunities in the eastern suburbs.

The report outlined the critical success factors in the development of any successful stormwater harvesting scheme, being:

- availability and reliability of stormwater supply;
- demand for recycled stormwater;
- storage (such as suitable aquifers);
- space for collection and treatment;
- risk management;
- identification of owners/operators; and
- availability of funding.

The report also took into account technical viability, demand for water, the impact that the availability of recycled effluent from the Glenelg to Adelaide pipeline has on demand for harvested stormwater and the other practical issues.

The Stormwater Harvesting Plan concludes as follows:

- Existing stormwater harvesting projects (identified below) should be considered part of the BHKC project, even though their role in flood mitigation is minimal.
- Flood detention storage (as proposed at the time) for the upper reaches of Brown Hill Creek could be modified to provide a steady yield from the rural catchment of up to 1.5 GL per year. However, likely demand and water treatment per MAR options reveal that at present there is insufficient justification for such an option. Also, such flow is not regarded as stormwater, but rather rural runoff.
- Fundamental stormwater reuse activities including WSUD and the use of rainwater tanks remain important actions to promote and where possible mandate and regulate in planning and building policies. However, those measures will not have a measurable impact on reducing the flood risk and hazards in the Brown Hill Keswick Creek catchment in the medium to long term.
- In regard to water quality and watercourse amenity stormwater management objectives, significant measures have been implemented in the catchment. There is a network of trash racks and silt trap facilities that remove litter, debris and sediment from the system before discharging to the marine receiving waters. There are also rural and urban watercourse restoration sites established. In addition, as part of the catchment management plan, there has been an industry, community and local government stormwater pollution control awareness program implemented. Importantly, there will be opportunities to incorporate further water quality improvement measures (e.g. GPTs and wetlands) as part of the physical works associated with the SMP.
- Stormwater harvesting opportunities are based on the regular stormwater flows that occur throughout the winter period. Flood management options are founded on addressing the rare, large and potentially catastrophic events that might happen once or twice in a lifetime. Opportunities that meet both of these water management objectives may not be readily available or may involve uneconomically high cost.
- Projects within the scope of the BHKC project that should be considered for stormwater harvesting and reuse are Glenelg Golf Club, Adelaide Airport, South Park Lands (subject to review), Ridge Park and Orphanage Park.

In addition to two of the above sites, the Design Flow report also identified Urrbrae Agricultural High School / Waite Institute and Soldiers Memorial Gardens (Mitcham Council) as key ASR sites for investigation. Subsequent to the above studies, sites that have been investigated and implemented are identified in the following section.

14.2.2 Existing schemes

The current status of identified stormwater harvesting schemes in the catchment is summarised below, including discussion of six of the schemes. Several of these schemes have been advanced from their status at the time of the AMLRNRMB report. Seven schemes, generating from 7 to 300 ML per year of reuse water have been implemented in the BHKC catchment.

Based on the total estimated capacity of existing schemes (780 ML per yr) it is estimated that currently about 12% of flows (or about 16% of urban runoff) in the four major watercourses are or will be harvested for reuse applications.

Table 33: Stormwater harvesting schemes

Scheme	Status	Harvest capacity (ML/yr)	Proponents
Urrbrae wetland / Heywood Park MAR	Investigated / not proceeding	60	Cities of Mitcham and Unley
Heywood Park MAR	Operational	35	Unley Council
Claremont dam	Operational	10	University of Adelaide / Mitcham Council
Orphanage Park	Not proceeding at this stage / harvested stormwater is piped from Heywood Park MAR system	30	Unley Council
South Park Lands / Victoria Park	Investigated / limited demand at this stage (refer Section 14.2.3)	100	BHKC project
Plympton railway corridor	Preliminary assessment / funding application rejected	1500	BHKC project
Glenelg Golf Club	Operational	300	Glenelg Golf Club
Adelaide Airport	Operational	300	SA Water / Adelaide Airport Ltd
Ridge Park	Operational	60	Unley Council
Scotch College	Operational	60	Scotch College
Hamilton Boulevard WSUD	Operational	10	Unley Council
Wattle Street WSUD	Operational	3	Unley Council

Locations of the above schemes are shown in the plan at Figure 21.

14.2.3 Scheme descriptions

South Park Lands

Construction of wetlands in the South Park Lands as part of the proposed stormwater detention system presents an opportunity to harvest approximately 350 ML per year of stormwater for reuse. However, the capacity of a reuse scheme is limited by the capacity of aquifers in the area to store water. The suitability of aquifers in the vicinity for MAR has been investigated and is considered to be of low potential from a hydrogeological perspective, with capacity to store and recover a maximum of 100 ML per year.

Whilst 100 ML per year would be sufficient to irrigate about 15 ha, which is about the area of playing fields proposed for the southern half of Victoria Park, the area is able to be irrigated much more economically using the existing Glenelg to Adelaide Parklands (GAP) pipeline supply (treated wastewater from Glenelg wastewater treatment plant). An alternative demand and a potential owner and operator have not been identified at this stage. Construction of the stormwater detention and wetlands system will not preclude the retro-fitting of a stormwater harvesting scheme at a later date.

Ridge Park

The Ridge Park scheme is designed as a MAR system based on harvesting average seasonal (largely rural runoff) flow from Glen Osmond Creek. The facility is designed to enable yield from the creek to be increased by use of some of the storage volume available in Ridge Park flood control dam.

Multi-purpose objectives include reduction of potable water irrigation demand, improvement of stormwater quality, encouragement of plant biodiversity, overall environmental improvement and enhanced recreational benefits at Ridge Park and other reserves, including Fraser Reserve, Ferguson Avenue Reserve, Scammell Reserve and Fullarton Park Community Centre.

Glenelg Golf Club

The MAR scheme, which can harvest up to 300 ML per year for golf course irrigation enables the club to demonstrate a 100% recycled water rating. It is beneficial in terms of maintaining sustainability of the aquifer by utilising stormwater in place of the natural underground supply and decreasing salinity in the aquifer by 'refreshing' with wetland filtered stormwater.

Adelaide Airport

SA Water, in collaboration with Adelaide Airport Limited, designed and installed a MAR scheme which commenced operation in 2014. The current harvest capacity of 300 ML per year from Brown Hill Creek is used for on-airport facilities.

Heywood Park

In the 2012 SMP it was reported that Unley and Mitcham Councils were collaborating in a stormwater harvesting scheme involving the diversion of up to 60 ML per year of stormwater from Urrbrae Wetlands for storage in a MAR facility at Heywood Park, Unley Park. The scheme did not eventuate for economic reasons.

In the meantime, Unley Council proceeded with the MAR system in Heywood Park. Water is extracted from Brown Hill Creek and given ultra violet disinfection before being pumped into the underlying aquifer. The stored groundwater, after extraction, is used for irrigation in Heywood Park and Orphanage Park via a pipeline. The scheme became operational in mid-2014. The scheme currently is providing 35 ML per year of water for irrigation.

Plympton railway corridor

The land is owned by the Commissioner of Highways and is licensed to the West Torrens Council for open space purposes, with restrictions currently in place for certain activities which might prejudice future access for transport purposes.

Biofiltration has been proposed by Wallbridge and Gilbert in the Urban Stormwater Harvesting Options Study (2009) to minimise the footprint needed for a wetlands system to service the size of a stormwater harvesting and reuse system proposed.

In December 2011 the BHKC project applied to the Commonwealth Government for funding assistance of $20 million under the National Urban Water and Desalination Plan: Stormwater Harvesting and Reuse Grants (Round 3) to develop a MAR scheme in the disused railway corridor in proximity to lower Brown Hill Creek. The project concept was supported in-principle by key stakeholders including DPTI.

Meetings with DPTI officials in 2011 revealed that there are no current plans for use of the land for transport purposes, but the intention is to investigate likely future needs prior to agreeing to release the land. It was acknowledged by the officials that the proposed use of the land has significant community, business and resource use benefits and that the proposed use may not preclude its use for transport purposes. However its use as proposed would be subject to formal approval by the State Government.

14.2.4 Brown Hill Creek flood control dam

Further to the Urban Stormwater Harvesting Options Study, W&G was engaged by the AMLRNRMB in 2011 to review the practical opportunities of optimising stormwater harvesting from the two Brown Hill Creek flood control dams proposed in the 2006 Master Plan. It is noted that subsequent to this study the catchment councils in September 2015 endorsed a 'no dam' solution for the upper Brown Hill Creek (rural) catchment as part of SMP considerations. The following discussion is therefore hypothetical, but is provided for the record.

W&G considered the following stormwater harvesting options for flood control dams:

1. Direct harvest from an active / permanent storage in the dams:

   This option would require additional storage to be added to the dams in order to achieve the same flood mitigation potential. Height of dam is a critical factor in order to minimise visual impact, which detracts from this option.

2. Diversion of flows to a local MAR using a small active storage:

   This option is not envisaged to have any impact on flood mitigation effectiveness of the dams. However, the MAR potential in the upper catchment is poor to moderate and extremely variable. Due to the lower yield and recovery efficiency of fractured rock aquifers, the scheme establishment costs in the upper catchment are likely to be double of an equivalent scheme in the lower catchment.

3. Temporary detention of water:

   This would provide a slow release to increase yields at downstream sites and may require an increase in the volume of the dams to achieve the same flood mitigation potential.

Modelling indicates that total catchment yield is only marginally increased by harvesting at the dam sites. Throttling of flows from the dams provides an increased yield at the downstream sites in the order of 5%. Furthermore, harvesting in the lower catchment provides water supply closer to the demand points and hence at decreased reticulation cost.

Wallbridge and Gilbert made the following conclusions:

- Approximately 1.5 GL – 1.7 GL per year of median flow is generated from the rural part of the Brown Hill Keswick Creek catchment, compared with 6.5 GL per year for the whole catchment.
- Approximately 75% of the identified potential yield is from the lower end of the catchment, where MAR potential in the aquifer is high.
- It is not recommended that large scale harvesting be undertaken at the (then) proposed dam sites – subject to local demand for non-potable water in the region.
- If early throttling of flow rates from dams increases the required storage volumes of dams, then it is unlikely to be worthwhile due to the relatively small increase that this achieves in total catchment yield.
- A flood detention storage for the upper reaches of Brown Hill Creek could be modified to provide a steady yield from the rural catchment of up to 1.5 GL per year. However, with limited demand and requirements involving water treatment and MAR, there is at present insufficient justification for such an option.

14.2.5 Stormwater reuse goals

As outlined in the Stormwater Management Planning Guidelines, (refer Section 3.1) a stormwater management plan objective is to set goals for the "extent of beneficial use of stormwater runoff".

A detailed review of all the potential MAR schemes, water demands and the key flood management requirements in the catchment has not revealed any stormwater harvesting options that would significantly change, improve or enhance the key flood mitigation components of the stormwater management plan.

Stormwater harvesting opportunities are based on the regular stormwater flows that occur throughout the winter period. Flood management options are founded on addressing the rare, large and potentially catastrophic events that might happen once or twice in a lifetime. Opportunities that meet both of these water management objectives may not be readily available or may involve uneconomically high cost.

The Stormwater Strategy (refer Section 2.4) states that "harvesting for reuse contributes to our water security….however, the end use, location of schemes, amounts harvested, storage options and prevailing hydro-geological conditions must be carefully considered when proposing harvesting schemes, as other sources of water may be available to better fit the need".

Fundamental stormwater reuse activities including WSUD and the use of rainwater tanks remain important actions to promote and where possible mandate and regulate in planning and building policies. However, those measures will not have a measurable impact on reducing the flood risk and hazards in the Brown Hill Keswick Creek catchment in the medium to long term.

It is noted that the GAP pipeline, with lateral connections in the Cities of Unley and West Torrens, provides non-potable water to a number of areas within the catchment area that could otherwise be considered for supply from stormwater reuse. As a consequence, any remaining demand opportunities for stormwater harvesting and reuse are more likely to be at a smaller scale.

Preparation of this SMP has not included investigations that would enable specific strategies or targets for increasing the volume of reuse to be established. Such strategies and targets would be negotiated with the AMLRNRMB during the full project implementation phase.

14.2.6 Summary

The detailed review carried out as part of the AMLRNRMB report did not reveal any stormwater harvesting options that would significantly change, improve or enhance the key components of flood management.

Whilst many stormwater harvesting schemes have merit in their own right, the conflicting factors of managing stormwater for flood control compared with harvesting the regular stormwater flows from winter storms means that synergy between the two objectives does not readily exist within this catchment.

Efforts have been made over the years to look at opportunities for the BHKC project to include stormwater harvesting and reuse in flood management plans and a number of schemes have been identified that are complementary to flood mitigation, but in that context the role of stormwater harvesting is minimal.

It should be noted that should circumstances change in the future and further harvesting becomes practicable and viable there is no apparent reason why it could not proceed, since there would be nothing done as part of the flood mitigation works of this SMP that would be detrimental to the cost and/or viability of increased stormwater harvesting.

Overall:

- Seven schemes, generating from 7 to 300 ML per year of reuse water have been implemented in the BHKC catchment.
- Based on the total estimated capacity of existing schemes (780 ML per year) it is estimated that currently about 12% of flows (or about 16% of urban runoff) in the four major watercourses are or will be harvested for reuse applications.
- Harvesting has been examined at a preliminary level for other potential applications when there is demand.
- Harvesting would play a minimal role in any flood mitigation scheme whether or not the scheme, for upper Brown Hill Creek, is based on a detention solution or creek capacity upgrade.

15. FINANCIALS

Costplan was engaged to review and update cost estimates in the 2012 SMP. The objectives sought for all cost estimates include consistency of risk and overheads, greater rigour and transparency, local knowledge, and updating to 2015/16 dollar values. This section presents revised costings for both Part A and Part B Works.

15.1 TOTAL COST ESTIMATES

The following Table 34 summarises estimated design and construction costs of flood mitigation infrastructure for Part A Works (Section 10) and Part B Works / Option D (Section 11.5). The table compares the current estimated costs with estimated costs of the 2012 SMP (with the least cost option of Part B). The table also shows the Part B estimated costs as reported in the Part B Report increased by 1.1% for cost escalation to current (2015/16) values.

Table 34: Total estimated costs

	Full BHKC project		**Upper BHC**	**Upper BHC**
($'million)	**2012 SMP (dam option)**	**Current (2015/16)**	**Current (2015/16)**	**Part B Report (5)**
Part A projects:-				
Ridge Park dam	1.1	2.8		
South Park Lands basins	17.6	17.4		
Diversions from Keswick Creek	31.9	43.1		
Lower BHC upgrade	49.1	39.1		
Glen Osmond Creek works (4)	4.5	0.8		
Forestville – Anzac Highway (1)	14.9	8.0	8.0	7.9
Part A sub-total	119.1	111.2	8.0	7.9
DPTI culvert	(Note 2)	5.0	5.0	5.0
Part B (excluding DPTI culvert)	28.5	22.8	22.8	22.6
TOTAL – flood mitigation works	147.6 (3)	139.0	35.8	35.5
Water quality works (GPTs)	0	1.0		
TOTAL – including GPTs		140.0		

Notes:

1. Identified as Area 1 in the Part B process / included as a component of Part A Works in the 2012 SMP
2. DPTI culvert built after the 2012 SMP was prepared
3. Other 2012 SMP options had estimated costs of $151 million and $154 million
4. Identified 'Fisher Street bypass' in the 2012 SMP
5. Values of mid-2014

15.2 COST ESTIMATES – PART A WORKS

15.2.1 South Park Lands / Glenside detention basins

Tonkin Consulting provided an opinion of cost in their design report (refer Section 10.2). Costplan was engaged to peer review the estimate based on subsequent preliminary detailed designs by Tonkin. The Costplan estimate of cost has been adopted for the purposes of the SMP (refer Appendix 26). The estimates for Victoria Park and Park 20 are dated February 2015. The total of those amounts ($13,728,679) has been escalated by $138,000. The Glenside estimate dated February 2016 ($3,491,319) is in current dollar values. The total is therefore $17,357,998.

15.2.2 Lower Brown Hill Creek upgrade

Tonkin Consulting provided an opinion of cost in their interim report of February 2014. The interim report has been superseded by the 2016 concept report which includes revised cost estimates provided by Costplan (refer Section 10.3). The Costplan cost estimate of $39,070,196 dated March 2016 has been adopted for the purposes of the SMP (refer Appendix 27).

15.2.3 Flow diversions from Keswick Creek to Brown Hill Creek

Tonkin Consulting provided an opinion of cost in their 2009 reporting which was adopted for the 2012 SMP. In terms of configuration of the diversions, the 2009 report has been superseded by the 2016 concept report which includes revised cost estimates provided by Costplan (refer Section 10.4). The Costplan cost estimate of $43,079,097 dated March 2016 has been adopted for the purposes of the SMP (refer Appendix 27).

15.2.4 Upper Brown Hill Creek upgrade - Area 1

This section of upper Brown Hill Creek was assessed under the Part B process (refer to Section 10.5). The estimates (refer Appendix 29 and Appendix 33) are dated July 2014. The total amount of $7.9 million (rounded) has been escalated by 1.1% as advised by Costplan to arrive at the current estimate of $8 million.

15.2.5 Ridge Park flood control dam

Actual cost of construction was $2.8 million, which compares favourably with the pre-construction estimated cost provided in the design report by SMEC (refer to Section 10.6).

15.2.6 Brown Hill Creek diversion culvert by DPTI

The BHKC project negotiated with DPTI to contribute $5 million towards the cost of the culvert design and construction (including the net cost of land acquisition and disposal). The contribution, less $2.5 million provided by the SMA, was approved through common resolutions by each of the five catchment councils (refer to Section 10.7).

15.2.7 Glen Osmond Creek minor upgrade works

The estimated cost of upgrading two bridge culverts ($315,000) is dated February 2016 (refer Appendix 28). For the bridge upgrades together with other potential minor works, including widening of Glen Osmond Creek between Braeside and Burnham Avenues, a nominal amount of $0.8 million has been allowed in the SMP. These works are proposed in lieu of the Fisher Street bypass culvert identified in the 2012 SMP (refer to Section 10.8).

15.3 COST ESTIMATES – PART B WORKS

15.3.1 Total costs – Part B options

Construction costs of all Part B options, as presented in the Part B Report, are summarised in the following Table 35:

Table 35: Estimated costs for all Part B options

		Estimated costs ($'million)							
Component	**Options**	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**	**C3**	**D**
Dam		24.1	28.8	24.1	28.8				
High flow bypass culvert		19.2	19.2			43.4	46.4	28.6	
Creek capacity upgrade works		4.4	4.4	6.3	5.4	10.0	10.0	11.0	17.0
Public bridge upgrades		0.9	0.9	1.6	1.6	2.8	2.8	4.0	8.5
Creek rehabilitation		2.9	2.9	2.7	2.7	2.5	2.5	2.3	1.8
Easements		0.4	0.4	1.2	0.6	1.2	1.2	1.4	3.2
BHC diversion by DPTI		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Estimated total cost		56.9	61.6	40.9	44.1	64.9	67.9	52.3	35.5

The DPTI culvert is included in the above table for purposes of comparison of upper Brown Hill Creek estimated costs between 2012 SMP and the Part B process.

The above costs do not include an amortised amount for depreciation and maintenance over the asset lives. Present value whole of life costs for Options B1, B2 and D are compared in Section 16.1.2.

Each of the component costs are described in more detail in the following Sections 15.3.2 to 15.3.7 as well as Appendix 29.

15.3.2 Brown Hill Creek detention dam

The estimated cost of a dam at Site 1 (Brown Hill Creek Recreation Park) reported in the 2012 SMP was $10.8 million (2011/12 dollar values). However, design details available for the 2012 SMP assessment were very preliminary and essentially restricted to size, capacity and location. As discussed in Section 11.3.1, SMEC was engaged to produce concept designs suitable for obtaining cost estimates of better accuracy, and to include a dam at the alternative Site 2 (Ellisons Gully). No estimate was made in the 2012 SMP for a dam at Site 2.

In the Part B process, Costplan produced construction cost estimates based on the SMEC report of four dam options. Estimated costs, together with the superseded estimates reported by SMEC are ($'million):

Table 36: Brown Hill creek detention dam options

Type of dam	SMEC	Costplan
Site 1: Zoned fill (earth and rock) with concrete core wall	18	22.7
Site 1: Roller compacted concrete (RCC) gravity dam	16	20.9
Site 1: RCC gravity dam with architectural treatment (earth and rock fill) on the upstream and downstream faces	Not costed	24.1
Site 2: RCC gravity dam – excluding land acquisition costs	26	28.6
Site 2: RCC gravity dam – including land acquisition costs	26.2	28.8

The full cost estimates by Costplan, in detail, are included at Appendix 30.

The estimated costs of Options A1 and B1 include the RCC gravity dam with architectural treatment ($24.1 million) because if a dam were constructed at Site 1 this design is assumed to be the likely selection in terms of having least adverse environmental and social impact.

Site 2 would involve acquisition of privately owned land and impact on an unmade road reserve. The cost of land acquisition, as assessed by Maloney Field Services, is estimated to be $179,000. That amount takes into account an arrangement to enable legal road frontage to be maintained to affected properties and an area of easement for periodic filling of the dam. The extent of land potentially affected by the dam and watershed for the 100 year ARI event is shown in plans at Appendix 31.

15.3.3 High flow bypass culverts

The estimated costs of culvert options of the 2012 SMP (Section 7.3.4 and with reference to Appendix 4) were re-estimated as follows ($'million):

Table 37: Revised estimated costs of bypass culverts

Culvert	2012 SMP	Part B review*
Malcolm Street culvert (with dam)	14.1	24.2
Extended culvert – Route 3A (no dam)	26.6	48.4
Extended culvert – Route 3 (no dam)	30	51.4

* Includes $5 million BHKC project cost for the DPTI culvert

These are not strictly 'like for like' comparisons:

- The culverts were re-estimated based on culvert sizes detailed in the 2012 SMP, but with the modified (shorter) route resulting from installation of the DPTI culvert which occurred post-SMP.
- The scope of work defined in the 2012 SMP assumed that all three culverts would be routed from the intersection of Cranbrook and Arundel Avenues through streets on the western side of the railway corridor (Chelmsford, Oakley, Victoria and Foster Streets).

- The culverts were not re-designed to take account of the revised hydrology. A re-design with the modified peak flows of the 2013 hydrology would enable the culvert sizes to be of smaller size.
- 2012 SMP costs are in 2012 dollar values compared with the Part B review in 2014 values.

Details of the cost estimates are included at Appendix 32.

15.3.4 Creek capacity upgrade works

For the purpose of establishing a preliminary budget cost estimate, assumptions have been made regarding potential creek capacity upgrade treatments. Treatments are described in two forms:

- Cross-sectional dimensions for creek widening and/or deepening
- Form of bank stabilisation associated with creek widening.

For creek capacity upgrade works, the following elements of cost are included:

- Base construction cost
- Engineering survey
- Landscaping
- Fencing
- Negotiations with landowners – separate from easement costs
- Legal fees – separate from easement costs
- Detailed design, project and construction supervision
- Risks during construction, including weather interruptions, latent conditions, and heritage and environmental issues.

Estimates are based on the extent of creek widening evident from the floodplain modelling results as well as detailed site inspection along all the areas identified for creek capacity upgrade works. In some places, engineering survey information obtained along the creek was made use of. Estimates assume that access to the creek for construction can be obtained generally from nearby street crossings or public land, as distinct from using each property's street access. Allowance is made for the cost of compensation for and restoration of any private areas that may be disturbed by having to work on or gain access through private property.

Details of the cost estimates are included at Appendix 33.

15.3.5 Public road bridge upgrades

Public bridges need to be replaced under Options B1 and B2 (refer Section 11.3.4) and Option D (refer Section 12.2). In terms of the scope of works, the estimates are based solely on the required waterway dimensions estimated (from MIKE-FLOOD modelling) for the passage of peak flows. For 'upgrades', it is assumed that, in general, existing bridges will be replaced using standard size or specially designed culverts. Concept designs for individual bridges were not considered to be warranted at this stage of the BHKC project.

Details of cost estimates are provided at Appendix 33.

15.3.6 Creek rehabilitation

The estimate is necessarily a general assessment and is not specific to particular conditions in individual properties. The estimate is based on inspection of the creek over most of its length between Anzac Highway and Muggs Hill Road. Note was made of the extent of light as distinct from heavy vegetation along the creek channel and banks. For the BHKC project costings, creek rehabilitation costs are only applied to areas of the creek for which creek capacity upgrade works are not proposed. Any creek rehabilitation required in areas of creek capacity upgrade works are included in the upgrade costs.

Details of cost estimates are provided at Appendix 33.

15.3.7 Easements

Maloney Field Services (MFS) provided advice in relation to the process and cost of acquiring easements. The assessment was specified to be at ‘desktop’ level, for use only in the feasibility stage of the BHKC project, and not to involve site inspections or interaction with property owners (which would happen if and when any easements have to be acquired).

The first MFS report, produced in August 2013, was based on initial results from a creek upgrade assessment by AWE. Following the finalisation of concept plans for creek capacity upgrades based on the 2D modelling by WorleyParsons, MFS produced an updated report in June 2014.

Estimated costs of easements comprise allowance for:

- property compensation;
- disturbance compensation (general and construction disturbance);
- property owner professional fees;
- survey, statutory and legal costs associated with easement registration; and
- contingency at 10%.

Assumptions by MFS include:

- Acquisitions are for easements rather than complete acquisition for freehold tenure.
- Assessments of compensation are only in respect of the property owner’s interest and do not extend to any other interest in the land such as leases and licences.
- All costs associated with acquisition will be borne by the BHKC project and are included in the assessment.
- Any fencing and/or other property infrastructure affected by construction will be reinstated by the BHKC project but estimated costs are not included in the easement costs.
- In the event that the project pursues an acquisition, individual assessments of compensation will need to be prepared with the benefit of survey plans, access to properties to undertake site inspections, and the opportunity to interview affected property owners.
- Estimated property compensation is based on 20% of current site value applied pro rata to the easement area assuming a width of 8 m over the estimated creek length through the property.

- Estimated compensation also includes likely losses arising from injurious affection, severance and disturbance, for which a percentage is applied to the balance of the property area based on improved value. The percentage varies but is about 1.5% on average.
- Estimates include allowance for basic professional fees to be incurred by the property owner, but do not include any allowance for litigation.
- Estimates do not include property reinstatement (which are included in construction cost estimates) and costs associated with negotiating with property owners.

The estimated costs included in the Part B capital costs (Section 15.3.1 and in Appendix 33) allow for easements on all the properties identified for creek capacity upgrade works. However, it is likely that many of those property owners would elect to enter into an agreement for the maintenance of infrastructure works on their property rather than have an easement over the works. The estimated costs for easements in the BHKC project costings therefore are likely to be conservative (i.e. high) estimates.

Estimated easement costs are detailed at Appendix 34.

15.4 MAINTENANCE AND MANAGEMENT COSTS

Annual maintenance costs of civil engineering assets, including culverts, dams, retaining walls and earthworks are assumed to be 0.3% of the accumulated asset construction cost taken to the previous two years. Two years after completion of the full works program of nominally 10 years, the annual works maintenance cost ‘plateaus’ at about $420,000. In addition, management costs are assumed to be about $100,000 per year. Table 38 shows the annual amounts of maintenance and management up to year 10.

15.5 EXPENDITURE PROGRAM

Applying the estimated costs detailed in the preceding Sections 15.1 to 15.4, expenditure for a 10 year works implementation program is shown in the following Table 38.

The 10 year program is based on the rationale outlined in Section 17.2 which, in summary, is:

- to complete projects in the optimal order for flood mitigation effectiveness;
- maintain continuity of works for overall efficiency of project management;
- spread the works so as to avoid too many simultaneous active work-faces; and
- maintain a relatively flat spread of expenditure (thus minimising annual budgetary instability due to severe cash flow peaks and troughs).

The expenditure program may not correspond to the budgetary program of individual catchment councils.

Table 38 Proposed SMP works funding program

(All amounts in $'000)	Previous expenditure	1	2	3	4	5	6	7	8	9	10	
		2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	Totals
South Park Lands	566	-	1,000	5,000	5,000	5,000	834					17,400
Lower BHC capacity upgrade	315	100	100	5,000	12,000	12,000	9,000	585				39,100
Flow diversions	141	-				2,300	10,000	12,000	9,500	9,159		43,100
BHC upgrade - Area 1	-	-					400	6,000	1,600			8,000
Glen Osmond Creek minor works	-	-									800	800
Ridge Park detention dam	2,634	171										2,805
BHC diversion culvert by DPTI	5,000	-										5,000
Part A Works sub-total	8,656	271	1,100	10,000	17,000	19,300	20,234	18,585	11,100	9,159	800	116,205
Upper BHC - capacity upgrade								700	8,000	8,000	6,100	22,800
Other	184											
Part B Works sub-total								700	8,000	8,000	6,100	22,800
Total design & construction	8,656	271	1,100	10,000	17,000	19,300	20,234	19,285	19,100	17,159	6,900	139,005
Maintenance		-	26	27	30	60	111	169	230	288	345	
Management & SMP development	3,807	100	100	150	150	150	150	150	150	150	100	
Total operating costs	3,807	100	126	177	180	210	261	319	380	438	445	

Sunk 'Management' previous expenditure of $3,807k and $360k in 2015/16 are not included in the economic assessment
Sunk 'Other' previous expenditure of $184k (BHC dams design in 2008) is not included in the economic assessment
Water quality works ($1 million) not shown - funding program subject to further investigation

16. ECONOMIC ASSESSMENT

This section outlines the benefit cost analysis (BCA) used to assess the economic viability of implementing the proposed SMP flood mitigation works. The resulting benefit cost ratio (BCR) involves the comparison of the cost of the flood mitigation works with the expected benefit that will result from their implementation. The benefit is typically estimated as the reduction in flood damages that will be provided by constructing the proposed works.

Additional multi-purpose benefits associated with the works are difficult to quantify and therefore have not been incorporated into the BCA (e.g. increased recreational opportunities and visual amenity). Also, any financial benefits of any stormwater management initiatives such as stormwater harvesting and quality improvements have not been included due to the difficulties in quantifying such benefits in monetary values.

In addition to the overall BCA for the full flood mitigation works, analyses in relation to each of Part A and B Works are discussed. A limited analysis has been made of the impact of the Part Works alone. As discussed in Section 17.2, it is unlikely, principally for engineering reasons (but also in terms of economics and social equity), that Part B Works would be carried out before major elements of the Part A Works. It is therefore assumed that at some stage the Part A Works alone could be completed and functioning. In respect of the Part B Works, BCAs were carried out to compare Options B1, B2 and D (as distinct from a BCA of the Part B Works in isolation of the Part A Works).

BCRs have been assessed in terms of capital costs (construction, land and easement costs) by applying the methodology outlined generally in Section 5.3 and particularly in Section 5.3.7 regarding the AAD concept. The BCA methodology was independently reviewed as part of the 2012 SMP process (Evans & Peck, 2011).

16.1 WHOLE OF LIFE COST

Whole of life costs were assessed in the form of a present value (PV). PV is defined as the current worth of the stream of expenditure flows (construction and ongoing maintenance) at a specified discount rate where the discount rate reflects the average cost of capital in real terms. The discount rate may also be considered as an annual rate of investment return.

The following criteria are assumed for the PV analysis:

- A study period of 100 years
- Creek capacity upgrade works (upper Brown Hill Creek) are replaced over years 50 to 52
- All other assets last for the 100 years with no residual value
- A real discount rate of 6% (as recommended by Department of Treasury and Finance, SA Government)
- A 10 year construction program as shown in Table 38
- The DPTI culvert is treated as a Part A Works project
- Current value (2015/16) design and construction estimated costs as shown in Table 34 and Table 38.

16.1.1 Parts A and B

By applying the above criteria, PV costs are:

- $106.8 million for the full works program of Parts A and B
- $90.0 million for the Part A Works
- $15.1 million for the Part B Works

The PV values are dominated by the initial construction cost, as evident from the diminished values due to construction cost spread over a nominal period of 10 years. The PV is relatively insensitive to the annual cost of maintenance.

16.1.2 Part B options

To assist in the determination of Part B Works, PVs were assessed for Options B1, B2 and D as follows (as reported in the Part B Report):

Table 39: PV of Part B options

Option	Assets ($M)	Annual maintenance			
		Assets ($)	Creek ($)	Total ($)	PV ($M)
B1	38	76,000	100,000	176,000	36.5
B2	43	86,000	100,000	186,000	39.0
D	31	62,000	100,000	162,000	31.5

Asset values exclude the cost of acquiring easements and the initial cost of rehabilitating the creek towards achieving good condition because those costs do not attract annual maintenance.

For the PV analysis:

- Option D assumes that the creek capacity upgrade assets have a life of 50 years and are then renewed with no residual value at the end of the study period.
- Options B1 and B2 assume that the assets last until the end of the study period with no residual value.
- The PV of Option D is marginally higher than its initial capital cost due to full renewal after 50 years.
- For a real discount rate of 4%, the respective PV values are $39.4 million (Option B1), $41.9 million (Option B2) and $35.1 million (Option D).

16.2 REDUCTION IN FLOOD DAMAGES

Flood damages are estimated using the GIS techniques outlined in Section 5.3.4. Base case and mitigation case damages over the range of ARIs were compared for assessment of the relative benefit offered by the flood mitigation works.The analysis does not include any estimate of the reduction in intangible flood damages (e.g. long-term social impacts and trauma experienced by flood victims), which may be as high as the tangible damages. Similarly, non-structural floodplain management measures such as flood preparedness and emergency response could be expected to further reduce overall flood damages, but a damage reduction estimate for these factors is not included.

As outlined in Section 5.3.7, damages can be expressed as AAD which is an estimate of the damages that can be expected in any given year on average, considering both the magnitude and the probability of damages occurring, across the entire range of design events. It is a measure that can be used in the assessment of the magnitude of funds that are worthwhile to spend on implementing flood mitigation options. AADs are calculated for base and mitigation cases.

As shown in the following Table 40 and Table 41, the calculation of AADs for the SMP works assumes that there will be no impact on damages for the PMF, which is a conservative approach due to lack of any model results. In reality, there is expected to be some level of protection offered by the mitigation works in the event of the PMF.

16.2.1 Parts A and B

Base case floodplain maps for the 10, 20, 50, 100 and 500 year ARIs are shown at Figure 6, Figure 7, Figure 8, Figure 9, Figure 10 respectively. Mitigation case floodplain maps for the 100 and 500 year ARIs are shown at Figure 18 and Figure 19 respectively.

Base case damages (discussed in Section 5.3) are compared with mitigation case damages to determine the reduction afforded by the mitigation works, as shown in Table 40. The reduction in 100 year ARI damages is in the order of 99%.

Table 40: Reduction in flood damages (catchment-wide works)

Design Flood	Flood Damages ($'million)		
	Base Case	Mitigation Case	Reduction
10 year ARI	4.8	0	4.8
20 year ARI	10.6	0	10.6
50 year ARI	45.0	0.4	44.6
100 year ARI	122.2	0.8	121.4
500 year ARI	434.4	181.7	252.7
PMF	1,000	1,000	0
AAD	5.96	1.92	4.04

Note: Base case PMF damages are an approximate estimate based on original estimates contained in the Floodplain Mapping Study (HTC, 2003).

16.2.2 Part A

If only the Part A Works were implemented (or, until such time as the Part B Works are implemented – on the understanding that it would not be practicable for the Part B Works to precede the Part A Works), the flood mitigation benefit has been outlined in Section 10.10.2.

16.2.3 Part B

For purposes of comparing the main Part B options, the assessment assumes that there is no flooding from the other major watercourses of the BHKC catchment (lower Brown Hill Creek, Keswick Creek, Glen Osmond Creek and Parklands Creek).

The assessment considers the hypothetical scenario of having only stormwater flows feeding into upper Brown Hill Creek. It accounts for breakouts from the creek that would occur down to Anzac Highway and includes the impact of those breakouts as they spread through Mitcham and Unley and into the West Torrens council area. Results of this analysis are provided in Table 41.

Table 41: Flood damages – base case and mitigation case options

Design flood	Flood damages			
	Base Case	**Option D**	**Option B1**	**Option B2**
10 year ARI	-	-	-	
20 year ARI	$1,339,000	-	-	
50 year ARI	$22,273,000	-	-	
100 year ARI	$40,141,000	$137,000	$91,000	$80,000
500 year ARI	$168,316,000	$145,744,000	$123,963,000	$64,655,000
PMF*	$500,000,000	$500,000,000	$500,000,000	$500,000,000

* PMF damages are a rough estimate based on original estimates contained in the Floodplain Mapping Study (Hydro Tasmania, 2003).

Note: Some amounts include corrections made from the Part B Report

As shown above, all mitigation options will result in significant reduction in flood damages for up to and including the 100 year ARI event. The residual damages in the 100 year ARI flood are the result of limited under-floor flooding of properties with frontage to the creek. An assessment of each option in terms of AAD (i.e. the benefit provided) is provided in Table 42.

Table 42: Average annual damages – base case and mitigation case options

	Base Case	**Option D**	**Option B1**	**Option B2**
AAD	$2.2 M	$1.2 M	$0.9 M	$0.8 M
Reduction in AAD	-	$1.0 M	$1.1 M	$1.4 M

Note: Some amounts include corrections made from the Part B Report

16.3 BENEFIT-COST ANALYSIS

Part of the Stage 1 Technical Report of the 2006 Master Plan involved undertaking sensitivity analyses for various parameters in a BCA evaluation, including discount rates and timeframes for implementation of flood mitigation works.

The results showed that implementation of the works (and hence realisation of the flood damages reduction) at the earliest opportunity provides a more favourable BCA outcome. However, this requirement may be constrained by council and government funding limits.

Calculated BCRs are considered to be conservative estimates for factors mentioned previously:

- Intangible damages have not been quantified and therefore the benefit in reducing these damages has not been included. As stated before, it is possible that the intangible damages could at least match the tangible damages amount.
- Multi-purpose benefits, such as improved recreational amenity, biodiversity and stormwater quality improvements and reuse, have not been quantified in dollar terms. Consideration of these benefits would increase the BCR.

16.3.1 Parts A and B

The following BCA is presented in terms of upper and lower bound results to reflect the significant impact of the estimated flood damages for Adelaide Airport. The upper bound analysis uses the airport flood damages estimate (escalated for inflation) carried through from the 2012 SMP. The lower bound analysis adopts a lower nominal estimate (refer Section 5.3.4).

The total costs and benefits over a 30 year period have been brought back to PV estimates with a 6% real discount rate. As a sensitivity measure, a real discount rate of 4% is also applied. Note that the whole of life costs (Section 16.2) are based on a 100 year period and allow for replacement of certain infrastructure after 50 years. The slight differences between the PV estimates for the BCA and the whole of life cost are not material in terms of the order of accuracy of the input data and assumptions.

The capital (design and construction) costs for the proposed works are detailed in Section 15, including the proposed expenditure program at Section 15.5. The BCA includes sunk capital costs of project concept designs, but it does not include sunk administration costs. It is assumed that the flood mitigation works for the full SMP (Parts A and B) will be constructed over a 10 year program.

BCR calculations for the SMP are provided in the spreadsheets at Appendix 35. As shown, costs and benefits increase over the 10 year implementation period. BCR analyses are summarised in the following Table 43 for a 6% discount rate (recommended by Department of Treasury and Finance) and

Table 44 for comparison with a 4% discount rate.

Base case 1 uses the airport flood damages estimate from the 2012 SMP ($56 million / 100 year ARI). Base case 2 uses the lower estimate of airport flood damages ($15 million / 100 year ARI).

Table 43: Summary of BCR for catchment-wide works (6% real discount rate)

	Base case 1	Mitigation case 1	Base case 2	Mitigation case 2
AAD	$8.066 M	$2.130 M	$5.960 M	$1.924 M
PV benefits		$49.296 M		$33.528 M
PV costs		$98.369 M		$98.369 M
BCR		0.50		0.34
Net PV		-$49.073 M		-$64.841 M

Table 44: Summary of BCR for catchment-wide works (4% real discount rate)

	Base case 1	Mitigation case 1	Base case 2	Mitigation case 2
AAD	$8.066 M	$2.130 M	$5.960 M	$1.924 M
PV benefits		$67.594 M		$45.973 M
PV costs		$112.645 M		$112.645 M
BCR		0.60		0.41
Net PV		-$45.052 M		-$66.673 M

If intangible benefits were considered, then it might be expected that the BCR would be at least double the above values.

16.3.2 Part A

A BCA for the Part A Works alone has not been carried out for this SMP. From the 100 year ARI simulation for Part A Works alone (corresponding to Figure 17) residual flood damages across the BHKC catchment are estimated to be $30.5 million, a reduction of $91.7 million from the base case damages of $122.2 million.

This indicates that for the 100 year ARI in isolation of other ARIs the simplistic ratio of benefit to cost is marginally higher (i.e. better) for the whole of catchment 'investment' (benefits of $122 M and costs of $139 M) compared with the Part A Works alone (benefits of $92 million and costs of $111 million). However, this form of analysis which does not consider the full range of ARIs is not a valid BCR methodology.

A simplified BCA was carried out for the 2012 SMP (in Section 14.3 of that document). The analysis determined that the BCR for implementation of the Part A Works alone is about the same as the BCR for implementation of the full flood mitigation scheme (then 0.65). In other words, constructing only the Part A Works provides flood mitigation benefits that, in economic terms, are about the same as constructing the full SMP works (Parts A and B).

16.3.3 Part B

The reduction in AAD for each option was considered against the cost of implementation to determine a BCR for the works. The analysis assumes that the capital cost of each option would be outlaid over the first six to seven years.

The following BCR values are used only as a relative comparison between mitigation options for the Part B Works. It is unrealistic to consider the absolute BCR value in assessing the financial viability of the Part B Works in isolation because it is merely hypothetical to assume that a 100 year ARI event will occur 'neatly' over the Part B area in isolation of the rest of the BHKC catchment.

Table 45: BCR of Part B options

	Option B1	Option B2	Option D
Capital Cost	$40.9m	$44.1m	$35.5m
BCR	0.36	0.43	0.38

The upper Brown Hill Creek flood mitigation works are at optimal effectiveness in conjunction with other flood mitigation works of the BHKC catchment, and therefore a viable BCR assessment would be based on the combination of Part A and Part B Works and undertaken on a whole of catchment basis.

17. IMPLEMENTATION OF THE SMP

17.1 RISK ASSESSMENT

The BHKC project engaged Parsons Brinckerhoff to assist in assessing risks of implementing the SMP in matters such as governance, management, asset maintenance and other associated liabilities over the long-term as well as during the works construction phase.

In terms of governance, it was considered that a special purpose entity is warranted for effective and collaborative delivery between the catchment councils, particularly for mitigating likely risks. Governance is discussed further in Section 17.3.

Major risks have been identified as:

- Funding: Support from state and federal governments is sought for full scheme implementation (or, possibly Part A as a minimum), as distinct from a piecemeal approach (e.g. funding one project at a time) which may not be favoured by some councils particularly where a council is funding works in another council area before there is funding support for all the works across the entire catchment.
- Asset ownership: An individual infrastructure asset may not be of direct benefit to the council in which it is located. Nevertheless, all assets require uniform and coordinated asset management and maintenance for overall scheme effectiveness.
- Land ownership: Infrastructure assets are located on state, federal and privately owned land as well as on councils' land. There may be issues with access and third party responsibilities and liabilities.
- Timing: Construction timing is critical in terms of achieving flood protection in the timeliest manner, as well as efficient works delivery.

Moderate risks have been identified as:

- Program governance: Financial and community impacts of delivery (design and construction) will require a high level of coordination and collaboration between councils, contractors and stakeholders – this would be addressed through the project entity.
- Delivery and contracting strategy: It will be necessary to limit the project's exposure to the risk of delays, design variations and construction cost escalation inherent in what would be a multi-interface project – this will require attention to risk allocation between the project and delivery contractor(s).
- Stakeholder engagement: Ratepayers will hold their own council accountable even though the project may be controlled by the five councils – hence effective links between each council and the project entity will be critical.

Management of the above risks will be dealt with in the charter discussed in Section 17.3.

17.2 INFRASTRUCTURE WORKS PROGRAM

The proposed structural works components have been developed as a package of works that collectively are required to achieve the flood management outcomes of the SMP.

There is a logical progression in which works need to be undertaken. This progression is established according to:

- the relative effectiveness of the individual works, recognising that the Part A Works collectively protect more properties than the Part B Works;
- the requirement to ensure that the staging of the works does not result in the temporary transfer of a flood problem elsewhere; and
- the timing of works has also considered that annual construction expenditure is not excessively 'lumpy' from one year to the next and that there is a relatively smooth flow of expenditure over the nominal 10 year construction period.

Related considerations are as follows:

- Non-structural initiatives, such as planning measures and the flood awareness program, will have immediate benefits and therefore, should be implemented at the earliest opportunity.
- Works involving temporary detention of flood waters can proceed at any time. They provide benefit even if other works are not completed. Hence:
  - The constructed Ridge Park dam already provides stormwater management benefits.
  - South Park Lands / Glenside detention basins are planned to be constructed as a first priority – in addition to stormwater management benefits, coordination of construction with the Glenside Development may result in a financial saving to the BHKC project.
- Channel upgrades should progress from downstream to upstream and ideally should follow the construction of flood detention systems, because channel upgrades are sized for reduced outflows from upstream detention systems.
- The flow diversions from Keswick Creek to Brown Hill Creek must be staged to follow the lower Brown Hill Creek upgrade.

The above considerations can be summarised in the following priorities for implementing the full flood mitigation works program (Parts A and B):

Table 46: Works priorities

1st priority	South Park Lands / Glenside detention basins
2nd priority	Lower Brown Hill Creek upgrade Flow diversions – Keswick to Brown Hill Creeks
3rd priority	Brown Hill Creek upgrade – Area 1 of upper Brown Hill Creek
4th priority	Upper Brown Hill Creek – capacity upgrade works Upper Brown Hill Creek rehabilitation Glen Osmond Creek works

The proposed 10 year implementation program for the structural works is outlined in Table 47.

Table 47: Works Program

	1	2	3	4	5	6	7	8	9	10
	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
SMP, RS & funding arrangements	Finalise									
South Park Lands / Glenside detention basins		Design	Construction							
Lower Brown Hill Creek capacity upgrade		Design	Construction							
Flow diversions – Keswick to Brown Hill Creeks					Design	Construction				
BHC upgrade – Area 1 of upper BHC						Design	Construction			
Glen Osmond Creek minor upgrade works									Design	Works
Upper BHC – capacity upgrade works						Preparation		Design & construction		
Upper BHC rehabilitation							Preparation	Design & works		
Ridge Park detention dam	Works completed prior to or during 2015/16									
Brown Hill Creek diversion culvert by DPTI										
Mount Osmond dam modification										

Legend

Part A Works
Part B Works
Part A Works completed

Notes

Most projects can be carried out in stages to suit cash flow if necessary

Some project durations (as shown) are longer than could be achieved under 'fast track' conditions

17.3 GOVERNANCE MODEL

This SMP has been developed, in the main, to address major catchment wide flooding issues as distinct from local drainage issues, and it therefore reflects the following principles:

- All spheres of government have an interest in reducing the flood risk.
- The planning, construction and maintenance of a major regional flood mitigation scheme should be managed and funded cooperatively by all spheres of government.
- The proposed works are of the type covered by the 2006/2013 Stormwater Management Agreement between the State of South Australia and the LGA.
- Cost sharing between the Commonwealth, and state and local governments should reflect their commitment to investing in and maintaining an effective, integrated flood mitigation scheme and should avoid cost shifting.
- Cost sharing between councils should reflect both the extent of their contribution to the problem and the benefits that they each receive from any flood management actions and not be related to the specific location where those actions are implemented.
- The approach should be as simple and transparent as is reasonably possible.

For example, it is contemplated that ongoing maintenance and management of the scheme would involve state and local governments, working in terms of the Natural Resource Management Act and the Local Government Act respectively.

It is assumed that the management of internal council drainage systems that drain the urban areas into the four major watercourses covered by this SMP remains the responsibility of individual councils.

It is noted that the BHKC project will upgrade certain existing stormwater mitigation assets along lower Brown Hill Creek which are maintained by the state. It is expected that general maintenance of such assets will continue to be a state responsibility.

There is commitment by the BHKC project to prepare a charter as the basis of a legal agreement between the councils – in partnership with, or with the support of, state government agencies – for the creation of a regional subsidiary in accordance with provisions of the Local Government Act. The regional subsidiary would have responsibility for implementation and management of the SMP, including construction, operation and maintenance of project assets and ongoing management of other stormwater management strategies of the SMP.

The charter is being prepared through a working group of senior representatives of each of the councils. Key matters being addressed in the charter include:

- board governance;
- management, administration and technical assistance;
- financial contributions by constituent councils for capital and ongoing maintenance and operational costs;
- business, financial and asset management planning;
- ambit for construction, maintenance and operational matters;

- conditions for withdrawal by a constituent council;
- dissolution of the regional subsidiary; and
- use of catchment stormwater.

It is planned that final details and legal due diligence for a charter preparation will be undertaken subject to gazettal of the SMP, and that execution of the charter and formation of a regional subsidiary will be completed before major construction commences.

It is also planned to seek agreements with other stakeholders in respect of funding and other obligations and responsibilities in which there is mutual interest or for which performance by the regional subsidiary may depend.

The regional subsidiary would need to work with the SMA to firstly secure state funding then with the state to secure Commonwealth funding. The regional subsidiary will also need to manage ongoing maintenance and operation of assets which broadly encompass the four major watercourses in addition to the flood mitigation infrastructure components.

This SMP also recommends increased commitment in flood preparedness which may be best implemented at the local level without need for the regional subsidiary to oversee these actions. Local councils should therefore be encouraged to implement these actions for their own areas, in conjunction with assistance from the SES. However, there may be a role for the regional subsidiary to coordinate and ensure a consistent approach between councils.

This SMP also proposes opportunities for councils to improve their approach to managing new development to reduce flood risk and to achieve multi-benefit outcomes. Implementation of these opportunities should be the responsibility of the councils.

The following key financial issues for incorporation in the charter have been agreed in-principle by the Steering Group, but are subject to formal endorsement by each of the councils.

- The regional subsidiary will be assigned ongoing responsibility for the management of BHKC project assets designed for stormwater management purposes as documented in the SMP.
- If a member council of the regional subsidiary wishes to enhance an asset (presumably located within its area) for a benefit or purpose outside the ambit or terms of the SMP, it will be at that council's own cost.
- The cost of ongoing maintenance of assets (including both preventative and reactive) will be apportioned equally between the councils (i.e. one fifth charged to each).
- Other operational costs of the regional subsidiary, including governance, professional advice, administration etc. (but not depreciation) will be also apportioned on a one fifth per council basis.
- The councils will transfer funds to the regional subsidiary each year to cover planned operational costs except depreciation.
- The regional subsidiary will not borrow money for capital works, working capital or other purposes.
- Each council will transfer funds to the regional subsidiary each year to cover its share of planned capital works construction costs in accordance with the cost sharing arrangements between councils specified in Table 52 below and the agreed cost sharing arrangements between spheres of government.

- The councils will each contribute a nominal amount (separate from their share of planned operating costs) which can be drawn upon when there is a short term need for working capital. Each council's share of this pool of working capital will be in accord with its share of the local government share of capital works construction costs.
- Each council's interest in the assets and liabilities of the regional subsidiary will be in accord with its share of the local government share of infrastructure works construction costs. Because the councils will not be contributing funds to offset depreciation expenses but will be doing so for all other operating expenses, each council will effectively share in the regional subsidiary's annual depreciation expenses in accord with its share of infrastructure works construction costs.
- It is recognised that state and Commonwealth contributions will be in the form of grants and not as equity in the project.
- Costs of any of the local government share of asset replacement, renewal or upgrade for the project will be apportioned on the basis of each council's share of infrastructure works construction costs.

Other key principles are still under consideration at this stage, including the following:

- Composition of the board: Regardless of the final decision, the charter will recognise the requirement under the Local Government Act that the regional subsidiary is subject to "joint direction and control of the constituent councils".
- Board membership options range from a single representative from each council (either staff, elected member or independent nominee) to multiple representatives (of same). The board could also include one or more non-voting independent members chosen for their expertise.
- Decision making powers of the board: For example, the power of the board to make key decisions either through a majority of votes (from a quorum or a full board) or by the unanimous agreement of all five councils.
- The definition, physical boundaries and location of assets and associated risk sharing between councils will need to be documented, typically in the regional subsidiary's asset register.
- Issues of access and third party responsibilities with other land owners (private, and state and Commonwealth government entities) will be the subject of legal agreements, yet to be prepared.

17.4 FUNDING ARRANGEMENTS AND COST SHARING

17.4.1 Cost sharing between councils

The proposed cost sharing arrangement for the SMP is based on the following principles:

- The proposed works are the type of works covered by the 2006 agreement between the State of South Australia and the LGA on stormwater management and in particular, both spheres of government each have interest in reducing flood risk.
- Cost sharing between councils should reflect both the extent of their contribution to the problem and the benefits that they each receive from any flood management actions and not be related to the specific location where those actions are implemented.
- The approach should be as simple and transparent as is reasonably possible.

The starting point for proposed local government cost apportionment is based on the benefits that each council will receive from the proposed mitigation works. These benefits are considered in two forms:

1. Benefit from the reduction in flood damages; and
2. Benefits from urban development that has already or may take place in the future that will contribute to the flooding problem downstream.

Consideration of both of these benefits is consistent with the preferred cost sharing approach outlined in the Urban Stormwater Initiative (2005, 2006), which is based on a study by KBR (2004) and Lipp & Kemp (2002). Equal weighting is given to these two types of benefits. The benefit in terms of flood damage reductions has been estimated by reviewing flood damages on a council by council basis for both the base case and SMP mitigation case floodplain mapping.

The following analysis of the proportion of damage reduction in each council area was completed as part of investigations for the 2011 Draft SMP and has not been revisited since then. Therefore, the values in the tables are now different as a result of revised modelling carried out since 2011. Nevertheless, the analysis is considered appropriate in terms of estimating the relative proportion of damage reduction in each council area.

Table 48: Reduction in average annual damages

Council	AAD (up to 500 year ARI)		
	Base case	Mitigation case	Reduction
Adelaide	$53,000	$26,000	$27,000
Burnside	$142,000	$67,000	$75,000
Mitcham	$129,000	$72,000	$57,000
Unley	$2,645,000	$1,082,000	$1,563,000
West Torrens (including airport)	$7,458,000	$1,189,000	$6,269,000

Table 49: Proportion of reduction in damages by council area

Council	Percentage of flood damage reduction
Adelaide	0.3%
Burnside	0.9%
Mitcham	0.7%
Unley	19.6%
West Torrens (including airport)	78.5%

The benefits from past and future urban development and their contribution to increased flows have been apportioned based on the impervious areas within each council area using a projected infill development case. These areas were estimated during development of the 2006 Master Plan and are primary inputs to the hydrologic model on which the testing of the various mitigation scenarios was based.

Table 50: Proportion of impervious area by council areas

Council	Impervious area of catchment within each council (Ha)	Percentage of catchment wide impervious area
Adelaide	138	12.4%
Burnside	190	17.1%
Mitcham	184	16.5%
Unley	238	21.3%
West Torrens (including airport)	364	32.7%

The share of impervious area and flood damages reduction were both considered in determining an average apportionment of cost between the councils (i.e. a 50% weighting is applied to both benefits).

Table 51: Calculated share of local government costs

Council	Percentage share of costs
Adelaide	6.3%
Burnside	9.0%
Mitcham	8.6%
Unley	20.5%
West Torrens (including airport)	55.6%

In reality, such a cost sharing arrangement unfairly penalises West Torrens as some of its impervious area contributes very little to the flood problem due to its location near the base of the catchment.

Negotiation between councils resulted in the cost shares in Table 52. Those figures are not markedly different from the percentages determined above and it has been agreed to retain the Table 52 percentages based on the benchmark cost and any subsequent adjustments approved by the councils. The table also confirms the agreed cost sharing in respect of administration and maintenance costs.

Table 52: Proposed share of local government costs

Council	Percentage share of costs (construction)	Percentage share of costs (Administration and maintenance)
Adelaide	8%	20%
Burnside	12%	20%
Mitcham	10%	20%
Unley	21%	20%
West Torrens	49%	20%

The benchmark cost is the total estimated construction cost of the SMP structural works (Parts A and B).

In respect of any Unley Special Works (refer Section 7.2) that may be included in a future revision of the SMP, the Unley Council cost share will be 100% of the local government component.

17.4.2 Cost sharing between spheres of government

Works approved under a SMP are eligible for state funding assistance channeled through the SMA. Since 1967 major stormwater infrastructure projects have been jointly funded by state and local government. Most of these projects have been on a smaller scale compared with the BHKC project. However, the Gawler River Floodplain Management Authority project (circa 2002) with a works construction cost of about $20 million was funded with the state and Commonwealth governments each contributing 38.75% and local government contributing 22.5%.

The proposed funding model is that the three spheres of government – Commonwealth, the SA State Government and local government (comprising the five catchment councils) each contribute one third of the works construction (capital) cost based on the 10 year construction program.

Even on that basis, the one third share of cost by local government places a significant financial burden on the individual councils, and if the councils' share has to be increased it may result in the program being extended by a number of years, thereby reducing its potential economic and social effectiveness.

Currently, existing Commonwealth funding programs relating to water (specifically under the National Water Initiative) have little to offer in terms of funding of capital works for flood mitigation. In December 2015, a Commonwealth parliamentary committee (Environment and Communications References Committee) tabled its report into 'Stormwater management in Australia'. Recommendations include:

- implementation of a national policy framework for stormwater management (a National Stormwater Initiative); and
- Australian, state and territory governments consider new funding models and financial incentives that would facilitate improved stormwater management outcomes in an economically efficient way.

In the meantime, the councils are continuing to seek any other opportunities for Commonwealth Government financial assistance in time to meet the major budgetary impact commencing in 2016/17.

To date, the SMA through the Stormwater Management Fund (SMF) has supported the BHKC project by contributing 50% of infrastructure related costs (as well as about 40% of SMP development costs), including construction of the Brown Hill Creek diversion culvert at Goodwood and Ridge Park dam (together about $8 million of total cost to the BHKC project).

Even under the 'third / third / third' proposal, it is unlikely that the SMF under its agreed revenue arrangements with the State Government would have sufficient capacity to support the BHKC project over the full SMP works program, without sacrificing support for other stormwater projects. This is a significant risk to timely implementation of the project and the BHKC project Steering Group has considered alternative options, as outlined in the following section.

If at the outset there is no positive response from the Commonwealth Government, the BHKC project would recommend that the catchment councils endorse a strategy along the following lines:

- The five councils allocate funding in their budgets for one third of the cost;
- a funding commitment is sought from the State Government to at least match that commitment; and
- once the State Government has agreed to that commitment, the five councils through the regional subsidiary work jointly work with the State Government to obtain a commitment from the Commonwealth Government for a minimum of one third of the cost to offset against the state and local government contributions.

When arrangements for full or substantial project funding are agreed, incorporating a local government share of cost which is within its capacity to pay, the councils will form a regional subsidiary to enable works to proceed.

17.4.3 Alternative funding models

Without prejudice to the cost sharing proposal of one third of the total cost by the BHKC project councils, there may be alternative funding models if the one third model does not suit all parties. There may be income sources other than the SMF that the state would be willing to utilise to meet its share of the costs and, from the councils' perspective, the other two thirds does not have to be split equally between the state and Commonwealth.

Revenue from the NRM levy has been considered as a possible funding source for part of the state's share of cost – in addition to the SMF and other potential government (federal and state) contributions.

The councils (subject to formal endorsement by elected members) may consider alternatives under which the financing of the project (where the cash comes from to meet the cash flow payments) does not necessarily match the timing of funding (where the income comes from to pay for the project / the project income). The arrangements under which the councils collectively contribute to the construction draw down account may not have to be consistent with the cost sharing arrangements between the spheres of government for the capital works expenditure (i.e. financial) program of Section 15.5.

18. STAKEHOLDER ENGAGEMENT

This section outlines the extent of stakeholder engagement in development of the SMP, commencing from the 2006 Master Plan.

18.1 2006 MASTER PLAN

In the preparation of the 2006 Master Plan there was a three stage process of engagement.

In the first stage, which was mainly a technical assessment, the consultation process focused on engagement between the key stakeholders (the five councils, the PCWMB and relevant state government agencies).

The second stage of consultation focused on councils, residents, interested groups and the general public giving information about the BHKC catchment flood risk and the range of mitigation options being considered.

In the third stage, assessment of preferred options, the consultation process focused again on engagement between the key stakeholders (councils, the Patawalonga Catchment Water Management Board and relevant state government agencies) primarily through the Flood Management Group to reach agreement on the final set of priority works components, resulting in the Master Plan report.

Results from the engagement process were:

- There was support across the catchment for progressing with physical works, in particular temporary storage at the South Park Lands and flood control dams in Brown Hill Creek.
- If the flood control dams in Brown Hill Creek were to proceed there would be a range of ecological issues that would need to be addressed. Support from some community groups was unlikely unless these issues were identified and addressed.
- There would be strong objections to a dam in the Brown Hill Creek Recreation Reserve.
- Many respondents were frustrated that no action had taken place as yet.
- People who were flooded in November 2005 wanted more warning and more help with the clean-up.
- Some respondents thought the flood preparedness component was included in lieu of capital works and there should be more capital works to achieve a higher level of flood protection.
- There was some support for a more coordinated approach between landholders and government on the maintenance of channel capacity.
- Some people thought that Orphanage Park should have been included as a temporary flood storage.

A final set of priority works components was recommended to the Flood Management Group in October 2006.

A detailed report on the consultation process and outcomes is contained in a separate report (QED, 2005).

18.2 INVESTIGATIONS 2008-2010

From 2008 until mid-2010 stakeholder engagement was mainly at the local government level as a result of concerns raised by the City of Mitcham, particularly about the proposed dams in the upper catchment.

A number of reports were prepared during this period concerning the dams in upper Brown Hill Creek, catchment hydrology and the process of developing the SMP. The principal reports were by Gutteridge Haskins and Davey, AWE, VDM Consulting and Ian Nosworthy who conducted a mediation process on behalf of the SMA.

During the same period, community consultation was undertaken as part of development of the concept design for the South Park Lands detention basins, which form a component project of the SMP.

18.3 2011 DRAFT SMP

In developing the 2011 Draft SMP:

- The study brief was drafted by the Project Technical Group, involving senior staff representatives from each of the five catchment councils, the AMLRNRMB and DPTI (representing the SMA). In that process Mitcham Council included matters of investigation that were of particular local concern. The brief was agreed by the Steering Group.
- In accordance with the study brief and with input from the Study Steering Committee (a subgroup of the Project Technical Group), WorleyParsons reviewed the options identified previously for the 2006 Master Plan for upper Brown Hill Creek together with other options identified in the study brief.
- The review process involved an adaptation of the multi-criteria assessment carried out in preparation of the 2005 Stage 1 Technical Report in order to assess and filter the potential options.

The overall approach for selecting priority works components, which together comprise the recommended stormwater management strategy, follows the methodology in the Stormwater Management Planning Guidelines.

In April 2011 each of the five catchment councils resolved to approve a timing and process plan for completion of a Stormwater Management Plan, including community consultation on the 2011 Draft SMP.

This consultation was carried out between 31 October and 12 December 2011 by an independent consultant team on behalf of the five catchment councils.

18.3.1 Consultation process

The consultation process aimed to:

- provide information to stakeholders and the broader community regarding the 2011 Draft SMP;
- receive feedback on the Draft Plan from stakeholders and the broader community; and

- collate and summarise feedback on the Draft Plan for use by the five councils in finalising the Draft Plan (effectively for the 2012 SMP).

The consultation process comprised three key aspects, namely:

- preparation and distribution of information materials and feedback form;
- conduct of briefings, meetings and open days; and
- receipt, collation and analysis of feedback.

A suite of community information materials was prepared, including:

- a summary report which summarised key aspects of the Draft Plan;
- a summary brochure which provided an overview of the Draft Plan, the consultation process and how people could access more information; and
- fact sheets addressing key components of the Draft Plan.

The information materials and feedback form were made available via a direct mail out to 26,539 property owners and occupiers across the catchment, as well as community, sporting and recreation groups, and Federal and State Members of Parliament, State Government Ministers, government departments, and councils. This information was also available online and from council offices.

Members of the wider community could obtain further information about the Draft Plan by attending any or all of three open days which were held during the consultation period. The open days provided an opportunity to learn more about the Draft Plan and ask questions of members of the project team. In total, approximately 160 people attended the three open days.

It was recognised that there were a number of key stakeholders that had a special interest in the Draft Plan and therefore a number of key groups within the community were invited to meet with members of the consultation team as part of the consultation process.

Consultation on the Draft Plan with representatives of the Kaurna and Ramendjeri peoples was initiated during the consultation period, and is ongoing.

18.3.2 Consultation findings

In total, 2,172 feedback forms were returned by members of the community, of which 2,149 were from respondents with an interest in at least one of the five catchment councils.

Several key trends emerged from the consultation process, taking account of the various avenues for community feedback.

Overall there was general recognition of the importance of undertaking flood mitigation works to reduce the impacts of flooding across the catchment. This was particularly evident from analysis of the feedback forms, with the majority of respondents (74% unweighted data) considering it is important/very important to undertake flood mitigation works compared with only 12% (unweighted data) not considering it not important/not very important.

This support for taking action was qualified however, by the need 'to get it right', and ensure that appropriate infrastructure measures are implemented that adequately reduce the impacts of flooding while at the same time delivering acceptable outcomes in terms of financial, environmental and social impacts.

While views varied in relation to specific infrastructure components of the Draft Plan, the majority of respondents indicated overall support for the Draft Plan.

Analysis of the feedback forms indicated high levels of support for all infrastructure components of the Draft Plan across all five catchment councils, with the exception of the proposed flood control dam at Brown Hill Creek for which there were both lower and more variable levels of support from respondents across the councils.

During the consultation process, the 'No Dam in Brownhill Creek Action Group' emerged. They mobilised a petition which, at the time of being submitted to Mitcham Council and copied to the consultation process, contained 4,010 signatures supporting the statement: *"We, the undersigned, hereby PETITION Council to protect the environment and heritage of Brown Hill Creek by opposing the damming of the Creek"*. It is understood that collection of signatures continued until May 2015, reaching 11,617 signatures.

Based on the feedback forms as well as information received via meetings and written submissions, three key viewpoints emerged with respect to the flood control dam in Brown Hill Creek:

- Strong opposition to any dam on Brown Hill Creek with a view that alternative infrastructure solutions are available;
- Strong opposition to the proposed location of the dam in the Brown Hill Creek Recreation Park based on concerns regarding visual amenity, heritage and the natural environment, but open to the possibility of another location along Brown Hill Creek; and
- Support for the dam together with concerns that opposition to the dam may delay implementation of mitigation works.

The executive summary for the Consultation Report is provided in Appendix 36.

18.4 2012 SMP

The 2012 SMP was finalised taking into consideration consultation findings on the 2011 Draft SMP. It was made public in August 2012 (although not approved by the SMA and gazetted until March 2013). In the period of 2012–2013, targeted consultation was carried out on specific projects of the SMP as outlined below.

18.4.1 Lower Brown Hill Creek upgrade

In December 2012, information was provided by mail-out to residents in close proximity to lower Brown Hill Creek advising of the concept investigation which had recently commenced and the potential scope of creek upgrade works that were being considered. In March 2013, information about the concept investigation was put on public display in local shopping centres and in the public reception area of West Torrens Council.

18.4.2 Brown Hill Creek diversion culvert by DPTI

Unley Council conducted a public meeting in Forestville in December 2012 to outline to the local community the effect of the proposed culvert construction on nearby streets and the Forestville Reserve, and the extent to which Council and the BHKC project were interacting with DPTI on the culvert project. Construction of the culvert was by DPTI and its contractors. The planning approval process and community consultation, including consultation and negotiations concerning private property acquisitions (Victoria Street and Devon Street South) was conducted by DPTI.

18.4.3 Ridge Park flood control dam

Through the Development Assessment process of Unley Council, public notification of the proposed dam construction was first made in April 2012. The Assessment process took longer than expected due to a technical anomaly in the submission, questions of jurisdiction and in consequence of an appeal lodged in December 2013 concerning removal of a tree. Whilst those matters were in train, Unley Council carried out local community consultation in April 2013 concerning the proposed construction, including a fact sheet mail-out and a public meeting. Overall community response was favourable. Information regarding construction activities was provided locally immediately prior to and during construction.

18.4.4 Proposed stormwater drainage system

In response to concerns from residents potentially impacted by the construction of high flow stormwater bypass culverts of the flood mitigation options identified in the 2012 SMP, the BHKC project and Unley Council mailed out a fact sheet (‘Proposed stormwater drainage system’) to over 3,000 addresses in the area of the identified culverts. This further heightened resident awareness and concerns, resulting in the emergence of the Save Our Streets Community Action Group (SOSCAG) special interest group.

18.5 PART B PROCESS

Considerable engagement was undertaken both during the Part B process as well as on release of the Part B Report in September 2014, culminating in formal consultation on the Part B Report for a six week period between May and June 2015. To assist in providing up to date information to the wider community during the latter stages of the Part B process, a BHKC project website was established in May 2015.

18.5.1 Part B investigations

As part of the Part B process, direct contact was made with owners/occupiers of properties through which upper Brown Hill Creek traverses. Area based meetings were held in April 2014 with owners of properties where creek capacity upgrade works were envisaged (under all eight options), with follow up on-site visits on request.

In early September 2014, immediately prior to the release of the Part B Report, letters were sent to all owners/occupiers to advise whether, based on concept level investigations, their property was identified as requiring creek capacity upgrade works under Options B1, B2 or D.

Emerging out of these discussions a new interest group, SOCKET (Save Our Creek Environs Trees), was formed in response to resident concerns about the impacts of undertaking creek widening and rehabilitation works along upper Brown Hill Creek.

In June 2014, a consultation process was held to present and seek feedback on initial options for Orphanage Park. This involved Park users as well as nearby property owners and residents. Outcomes of the consultation were reported to Unley Council in July 2014.

Throughout the Part B process, ongoing interaction was maintained with special interest community groups, in particular the No Dam in Brownhill Creek Community Action Group (now a sub-committee of Brownhill Creek Association), SOSCAG and SOCKET.

18.5.2 Part B Report release

On release of the Part B Report in September 2014, the BHKC project:

- invited representatives of seven special community interest groups to a briefing session to provide an overview of the Part B Report;
- wrote to owners/occupiers of properties through which upper Brown Hill Creek traverses, together with a wide range of key stakeholders groups including federal and state Members of Parliament, advising of the release of the Park B Report; and
- provided copies of the Part B Report and a summary brochure to the public via catchment councils' offices, libraries and websites as well as an updated project website http://bhkcstormwater.com.au/.

All communications advised that a formal community consultation process would be conducted before any decisions were made about the Part B Works. Given the timing of Local Government Elections in late 2014 followed by the summer holiday period, it was advised that consultation was envisaged to commence in March 2015.

18.5.3 Part B Report pre-consultation

Following the release of the Part B Report, the project sought feedback from key community interest groups regarding the draft community engagement strategy and draft feedback forms to be used in the formal consultation process. Communication was also initiated with a wider range of community groups who expressed an interest in the Part B Report.

Continued liaison was maintained with owners and occupiers of properties where creek capacity upgrade and/or creek rehabilitation works were envisaged (under various options) including conducting site visits on request and written advice in March 2015 regarding the timing of the community consultation process on the Part B Report. The project website was maintained to ensure the wider community was aware of the timing of the consultation process.

18.5.4 Part B Report consultation

The formal consultation process on the Part B Report commenced on 13 May 2015 for a six week period. An updated project website went 'live' at this time.

As outlined in the executive summary of the community consultation report 'Consultation findings on the Brown Hill Keswick Creek Stormwater Project: Part B Report' (refer Appendix 37), the purpose of the consultation process was to:

- Inform key stakeholders and the broader community about:
  - the outcomes of investigations on the eight potential options for Part B Works;

  - the identification of, and reasons for, the identification of a preferred option – Option D; and
  - how they could provide feedback on options for Part B Works.
- Seek feedback from key stakeholders and interested members of the public regarding:
  - how important they consider it is to undertake flood mitigation works in the Brown Hill Creek catchment; and
  - their level of support for Option D in comparison with other options.
- Seek additional feedback from owners of properties traversed by upper Brown Hill Creek regarding their specific concerns and opportunities relating to proposed rehabilitation and creek capacity upgrade works (under Options D, B1 or B2).
- Report on the outcomes of the engagement to assist councils in making a final decision regarding Part B Works.

The consultation process comprised three key aspects, namely:

- preparation and distribution of a summary brochure and suite of fact sheets as well as feedback forms with direct mail to owners/occupiers of properties traversed by upper Brown Hill Creek and on request to members of the public;
- conduct of four open days; and
- receipt, collation and analysis of feedback forms and written submissions.

18.5.5 Part B Report consultation findings

The community consultation report details and analyses responses from 818 feedback forms as well as 76 written submissions.

Subsequent to the release of the community consultation report an additional five feedback forms were subsequently included that had been received prior to the cut-off date but had inadvertently been overlooked, Taking into account these additional five forms, a total of 823 feedback forms were returned by members of the community, of which:

- 88 were received from a possible 261 owners of properties traversed by upper Brown Hill Creek;
- two out of a possible 53 from non-owners occupiers of properties traversed by upper Brown Hill Creek; and
- 733 out of 1,074 sent in response to requests from members of the public, the majority of which came from individuals in the City of Mitcham (524 – of which 519 are documented in the community consultation report) followed by the City of Unley (118).

It should be noted that the inclusion of the additional 5 forms did not change the percentages in the level of support for Option D as reported in the community consultation report. An amended Table 3-16 of the community consultation report is included below.

AREA	LEVEL OF SUPPORT FOR OPTION D				
	Yes	No	Unsure	No response	Total
City of Adelaide	3	1	0	0	4
City of Burnside	17	0	0	0	17
City of Mitcham	499	16	4	6	525
City of Unley	70	42	5	2	119
City of West Torrens	3	0	0	0	3
Total catchment councils	592	59	9	8	668
% Total catchment councils	89%	9%	1%	1%	100%
Outside catchment councils	66	1	0	0	67
% Outside catchment councils	99%	1%	0%	0%	100%
Total wider community	658	60	9	8	735
% Total wider community	90%	8%	1%	1%	100%

Of the 76 written submissions received, 60 were from individuals, 13 from community and special interest groups, two from businesses and one from the local Member of Parliament.

The executive summary of the community consultation report (refer Appendix 37) summarises key findings in relation to:

- respondents' perception of the importance of flood mitigation;
- level of support for the preferred Option D;
- level of support for other options;
- affected owners' perceptions of the likely impacts (positive and negative) of creek capacity upgrade and/or creek rehabilitation works; and
- affected owners' preferences regarding legal arrangements.

In summary, respondents' level of support for the preferred Option D varied markedly between creek property owners and members of the wider community with creek property owners equally divided in their support or opposition, compared to overwhelming support (90%) by members of the wider community. Aggregating results, 85% of respondents favoured Option D.

19. SUMMARY OF SMP OUTCOMES

This section summarises how the objectives of the SMP (Section 5) are addressed with reference to the stormwater management and multi-purpose strategies described in Section 13 and Section 14.

Objective 1.1

Provide an acceptable level of protection for the community and both private and public assets from flooding. Subject to economic justification, the objective is to provide a standard of flood protection for development equivalent to the 100 year ARI standard or better.

Strategy: Flood mitigation works

- At the whole of catchment scale (Parts A and B), works are planned to mitigate the 100 year ARI flood conditions over most of the at risk part of the catchment (refer Table 28). Over minor areas at risk, the standard of flood protection will be significantly higher than it currently is. (Section 13.1)
- The Part A Works are effective either as a stand-alone flood mitigation scheme or as integral elements of the overall SMP for the catchment including Part B Works. (Section 10.10)
- The full mitigation scheme (effective for Part A and B works) is estimated to have a BCR in the range of 0.3–0.5 based on tangible flood damage estimates. Economic ratios of this order for flood mitigation infrastructure can be considered favourable in terms of project justification given that intangible social and environmental factors are not included. (Section 16.3.1)

Strategy: Creek maintenance

- Improved management of upper Brown Hill Creek (with its high percentage of private ownership) and other watercourses, including planned ongoing maintenance, will contribute to the overall effectiveness of conveying large stormwater flows. (Section 12.3)

Objective 1.2

Enhance flood mitigation infrastructure with multi-purpose outcomes including visual, aesthetic and amenity improvements for the benefit of the wider community, where it is economically and socially feasible.

Strategy: Flood mitigation works

- The South Park Lands detention basins will incorporate a wetland which will provide enhanced amenity and recreational opportunities in the southern end of Victoria Park. (Section 10.2)
- Similarly, the detention basin in Ridge Park (including MAR storage) incorporates recreational and aesthetic improvements along the creek in the vicinity of the works. (Section 10.6)
- For the upgrade of Brown Hill Creek channel between Forestville Reserve and Anzac Highway, there is potential to enhance the public reserve area which adjoins or contains the creek channel (including Wilberforce Walk). (Section 10.5)

- For the lower Brown Hill Creek channel upgrade there is potential to incorporate amenity features and environmental enhancements along the channel reserve for a significant portion of its length. (Section 10.3)

Objective 1.3

Provide flood forecasting and warnings, and flood preparedness measures to help the community reduce any residual damages to property and risk to life during major flood events, particularly in high hazard areas.

Strategy: Community awareness and emergency response

- It is expected that SES and catchment councils will continue to operate and develop the Floodsafe Program. There is anecdotal evidence that the program is beneficial in raising awareness of the impacts of flooding and mitigation measures that individuals and community groups can take, particularly in respect of protecting private property.
- The BHKC project gave in-principle support to a market survey of property owners along the environs of Brown Hill Creek, carried out in late 2015 by the SES. The survey sought to assess the level of flood risk awareness and response preparedness to flooding by property owners. It is expected that the catchment councils will cooperate with the SES in any relevant recommendations resulting from the survey. (Section 13.2.4)

Objective 1.4

Ensure that new stormwater infrastructure does not increase the risk of flooding in downstream areas.

Strategy: Implementation

- The project has been designed such that all the infrastructure elements including upgraded channels will enable stormwater flow to be conveyed through the system with minimal risk of localised downstream flooding. (Section 17.2)

Objective 2.1

Stormwater discharged to the marine environment should meet targets that are set from time to time including targets in the EPA's ACWQIP.

Strategy: Flood mitigation works

- Flood detention basins in the South Park Lands (Parklands Creek) and in Ridge Park flood control dam (Glen Osmond Creek) have been designed to improve the water quality of normal stream flow through the sites. The South Park Lands project incorporates a wetland in Victoria Park preceded by the Glenside silt trap. (Section 10.2 and Section 10.6)
- The upper Brown Hill Creek capacity upgrade works should help to reduce stream bed and bank erosion and consequent transport of sediments into the lower sections of Brown Hill Creek and, ultimately, the marine receiving waters. (Section 12.3)

Strategy: Stormwater quality and treatment

- Currently there are 10 operational GPTs across the BHKC catchment, and the AMLRNRMB has identified the need for 11 more together with actions to improve existing GPTs.

- The SMP provides an opportunity for catchment councils, through the BHKC project, to take a coordinated and collaborative approach to the management and maintenance of GPTs along the major watercourses of the BHKC catchment, including the installation of new GPTs (with AMLRNRMB funding assistance), in order to further reduce adverse impacts of stormwater quality on the environment. (Section 14.1.3)
- An amount of $1 million is included in the project cost estimate for GPTs and related works (‘water quality works’).
- Targets in respect of management of the quality of runoff and its effect on receiving waters will be pursued with the AMLRNRMB during the phase of full project implementation. (Section 14.1.4)

Strategy: Stormwater harvesting and reuse

- Stormwater harvesting initiatives at Ridge Park and Heywood Park (and the potential offered by South Park Lands) together with other stormwater harvesting schemes already established in the catchment provide a significant reduction in the volume of stormwater discharged into marine receiving waters. The following Objective 3.1 expands on this strategy. (Section 14.2)

Objective 3.1

Maximise the reuse of stormwater for beneficial purposes including watering of community and private open spaces where feasible.

Strategy: Flood mitigation works

- A stormwater harvesting scheme utilising a MAR system has been installed by Unley Council in conjunction with the Ridge Park flood control dam. (Section 10.6)
- The South Park Lands detention basins are being designed to enable retrofitting of a stormwater harvesting facility (such as MAR) should the water demand in the immediate area eventuate and prove to be of value. (Section 10.2)
- A dam in the rural catchment of upper Brown Hill Creek was investigated in terms of stormwater harvesting potential but such a facility could not be justified at this stage due to unsuitable aquifer (geotechnical) conditions, lack of alternative storage and limited demand both in the immediate area and along downstream areas. (Section 14.2.4)

Strategy: Stormwater harvesting and reuse

- Seven schemes, generating from 7 to 300 ML per year of reuse water have been implemented in the BHKC catchment. It is estimated that currently about 12% of flows (or about 16% of urban runoff) in the four major watercourses are or will be harvested for reuse applications. (Section 14.2.6)
- In 2011 the BHKC project applied (unsuccessfully) to the Commonwealth Government for funding assistance under the National Urban Water and Desalination Plan to develop a MAR scheme in the Plympton railway corridor in close proximity to lower Brown Hill Creek (the proposal was supported in-principle by key stakeholders including DPTI as custodians of the land). (Section 14.2.3)
- Preparation of this SMP has not included investigations into specific strategies or targets for increasing the volume of reuse to that already established. Such strategies and targets will be pursued with the AMLRNRMB during the phase of full SMP implementation. (Section 14.2.5)

Objective 3.2

Where possible the drainage network should incorporate WSUD systems that aim to capture road runoff to replenish soil moisture for maintenance of street trees and plantings.

Strategy: Development Plans

- Catchment councils are incorporating WSUD systems into refurbished and new streetscape developments and, in response to council water conservation strategies, such systems will continue to be installed as opportunities arise. (Section 13.2.3)

Objective 3.3

Encourage on-site use of stormwater by installation of rainwater tanks, detention and retention systems in order to minimise the adverse runoff impacts of urban infill.

Strategy: Development Plans

- Council water conservation strategies include requirements for WSUD to be incorporated in neighbourhood level planning.
- Councils are implementing planning policy measures which seek to limit stormwater discharge from new developments to predevelopment volumes and peak rates of discharge.
- The Building Code of Australia mandates for specified applications under the Development Act the installation of rainwater tanks plumbed into non-potable water systems within new dwellings. In addition to the Code, Mitcham Council requires additional stormwater to be stored and managed on site for all newly constructed dwellings. (Section 13.2.3)

Objective 4.1

Watercourses and creeks in public and private ownership should be managed to an acceptable standard.

Strategy: Flood mitigation works

- The Brown Hill Creek capacity upgrade works (both lower and upper sections) present an opportunity to improve the condition of the creek including removal of obstructions and overgrowth of vegetation, particularly exotic and pest species. (Section 10.3 and Section 12.3)

Strategy: Creek maintenance

- Associated with the upper Brown Hill Creek capacity upgrade works, the SMP proposes to rehabilitate the creek and maintain it in suitable condition, including the privately owned sections of creek which comprise most of its length. (Section 12.3.4)
- It is recognised that a recommended practice for maintenance of urban watercourses is being prepared by the AMLRNRMB – the BHKC project will continue to be involved and provide assistance in its preparation. (Section 12.3.3)

Objective 4.2

Where practicable and economically feasible, watercourses should be preserved in as natural condition as possible and should be revegetated and managed to maximise their ecological values and functions and to minimise any potential for stream erosion.

Strategy: Flood mitigation works

- A more natural ephemeral creek system will be created by the South Park Lands detention basins through the reintroduction of a range of aquatic macrophytes and riparian species, and the establishment of conditions for replenishing soil moisture stores for terrestrial plants.
- In the South Park Lands project there will be an improvement in the biodiversity of each site through the inclusion of native vegetation and habitat opportunities. The wetlands will slow down water flow and provide further treatment prior to returning water back into Parklands Creek, thereby improving water quality. (Section 10.2)
- The Ridge Park flood control dam and MAR works incorporate stream rehabilitation and biodiversity improvements. (Section 10.6)

Strategy: Creek maintenance

- Along upper Brown Hill Creek it is proposed that the BHKC project, in collaboration with the creek property owners and the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB), will undertake:
  - a ‘one off’ extraordinary creek maintenance to rehabilitate the creek towards achieving good condition, thereby assisting flow capacity for flood mitigation and improving the creek environment and geomorphology; and
  - planned maintenance periodically through the life of the scheme, aimed at maintaining the creek in good condition after an initial one-off extraordinary creek maintenance is undertaken.

  These works could include erosion controls, bank stabilisation and clearance of major obstructive material and are proposed to incorporate removal of exotic vegetation, thereby providing ecological benefits. (Section 12.3.4)
- As for Objective 4.1

Objective 4.3

Allow sufficient environmental flows to maintain water dependent ecosystems.

Strategy: Flood mitigation works

- Works involving detention of stormwater flows (South Park Lands and Ridge Park) are designed to accommodate environmental flows in accordance with advice from the DEWNR.

Objective 5.1

Open space should be utilised to achieve maximisation of permeable surfaces, OSD and infiltration and stormwater reuse wherever possible.

Strategy: Development Plans

- Councils recognise that WSUD provides an opportunity to assist in the management of flooding risk in the context of new development and urban consolidation. WSUD includes integrating stormwater treatment into the landscape and minimising runoff and peak flow through local retention and detention. (Section 13.2.1)
- Councils will seek to obtain greater understanding of potential impacts of infill development on generation of stormwater runoff and propose improved planning policies and controls for addressing the risks. (13.2.3)
- The above actions in respect of Objective 3.3 are also relevant to this objective.

Objective 5.2

All new development must be built at a level that ensures buildings are not subject to inundation during a 100 year ARI flood.

Strategy: Development Plans

- Councils are required to adopt the SAPPL policies which include a Development Plan overlay showing high and medium flood hazard areas and 100 year ARI flood levels as well as other policies for use of WSUD techniques and measures to minimise impact of stormwater runoff on the local stormwater drainage network.
- Unley Council Development Plan incorporates the Natural Resources module from the SAPPL which addresses the above policies.
- Mitcham Council is proposing to undertake a future Watercourse Development Plan Amendment (DPA) that will introduce policy amendments relating to mitigating the impacts of floodwaters on development adjacent to watercourses (including Brown Hill Creek), together with other flood risk mitigation requirements.
- The catchment councils all generally prohibit new development that would obstruct or interfere with a watercourse or is at high risk of flooding. (Section 13.2.3)

Objective 5.3

New development should be constructed so as to not cause an increase in 5 year ARI flow rates or volumes.

Strategy: Development Plans

- Councils will adopt Development Plans that are in accordance with SAPPL policies which seek to ensure that new development does not reduce the capacity or functionality of the existing stormwater drainage network. (Section 13.2.3)
- The above strategies in respect of Objective 5.1 are also relevant to this objective.

Objective 6.1

Stormwater infrastructure should be managed sustainably by development of asset management and other necessary plans for ongoing management, operation and maintenance.

Strategy: Implementation / governance

- Full implementation of the SMP would be carried out through a regional subsidiary model in terms of the Local Government Act. The Act requires a range of good management practices to be put in place, including asset management planning. (Section 17.3)

Strategy: Creek maintenance

- Where creeks are in private ownership, responsibility for maintenance is not well understood, and creek conditions are generally unsatisfactory, particularly in terms of maintaining flood carrying capacity. The SMP proposes a strategy for maintenance of upper Brown Hill Creek involving creek landowners, catchment councils and the AMLRNRMB. (Section 12.3)

Objective 6.2

A governance framework will be established based on having a single entity (nominally a regional subsidiary in terms of the Local Government Act) responsible for management of project infrastructure.

Strategy: Implementation / governance

- A charter is being prepared which will form the basis of a legal agreement between the councils for the formation and operation of a regional subsidiary in terms of the Local Government Act. The regional subsidiary would be responsible for construction and ongoing maintenance of the flood mitigation infrastructure and management of the SMP (Section 17.3)

Objective 6.3

Financial budgeting and funding arrangements (as between councils and other potential funding contributors) necessary for the timely and effective implementation of the SMP (including construction and maintenance of infrastructure) will be established.

Strategy: Implementation / funding

- The councils have agreed on the cost apportionments between themselves in respect of the local government share of the overall project costs (capital, maintenance and administration).
- Councils' preferred funding model is based on each sphere of government (Commonwealth, state and local) contributing a one third share of the overall project capital cost.
- A 10 year design and construction program for all the works comprising Parts A and B is planned (subject to considerations of the preferred funding model). (Section 17.4)

20. REFERENCES

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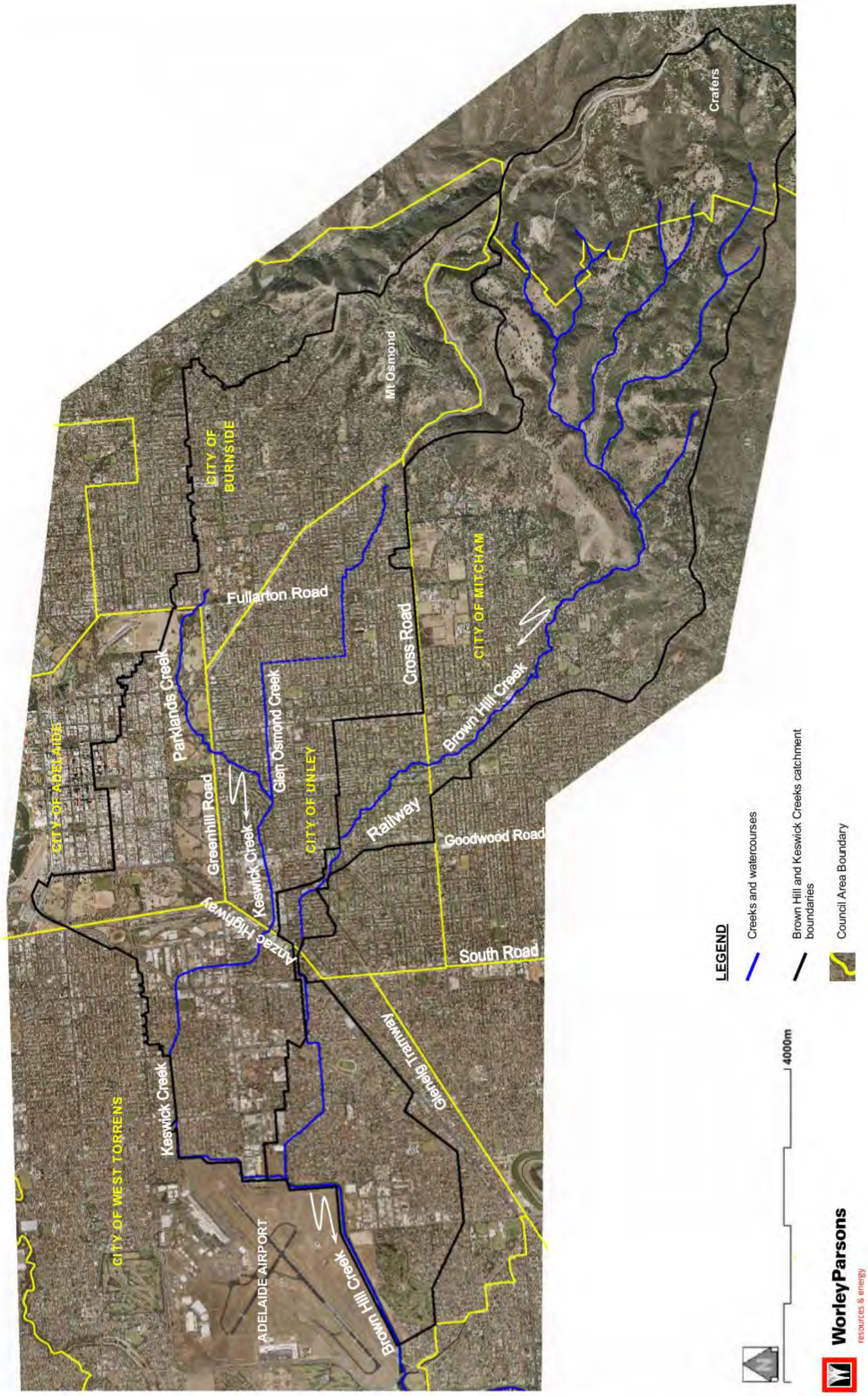

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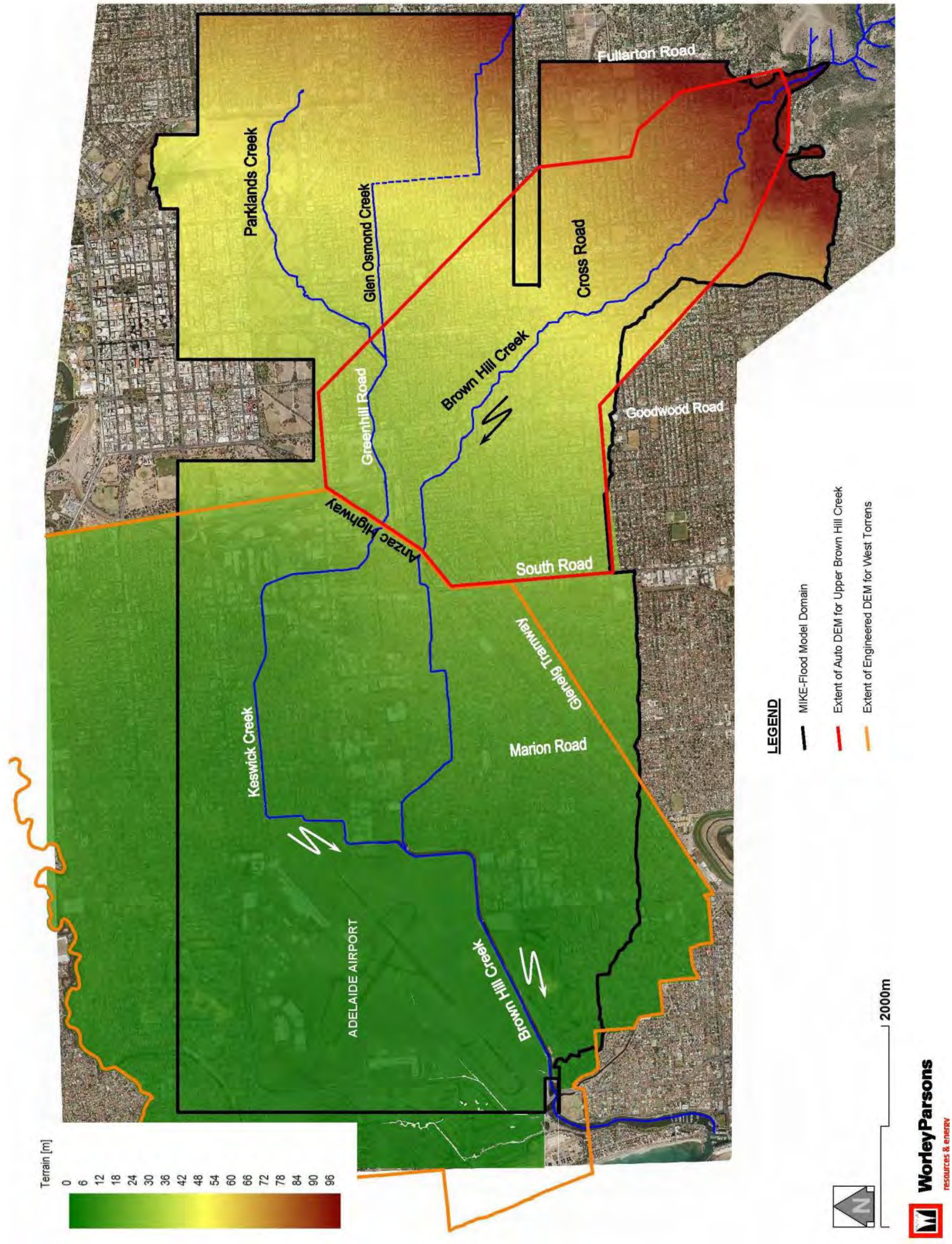

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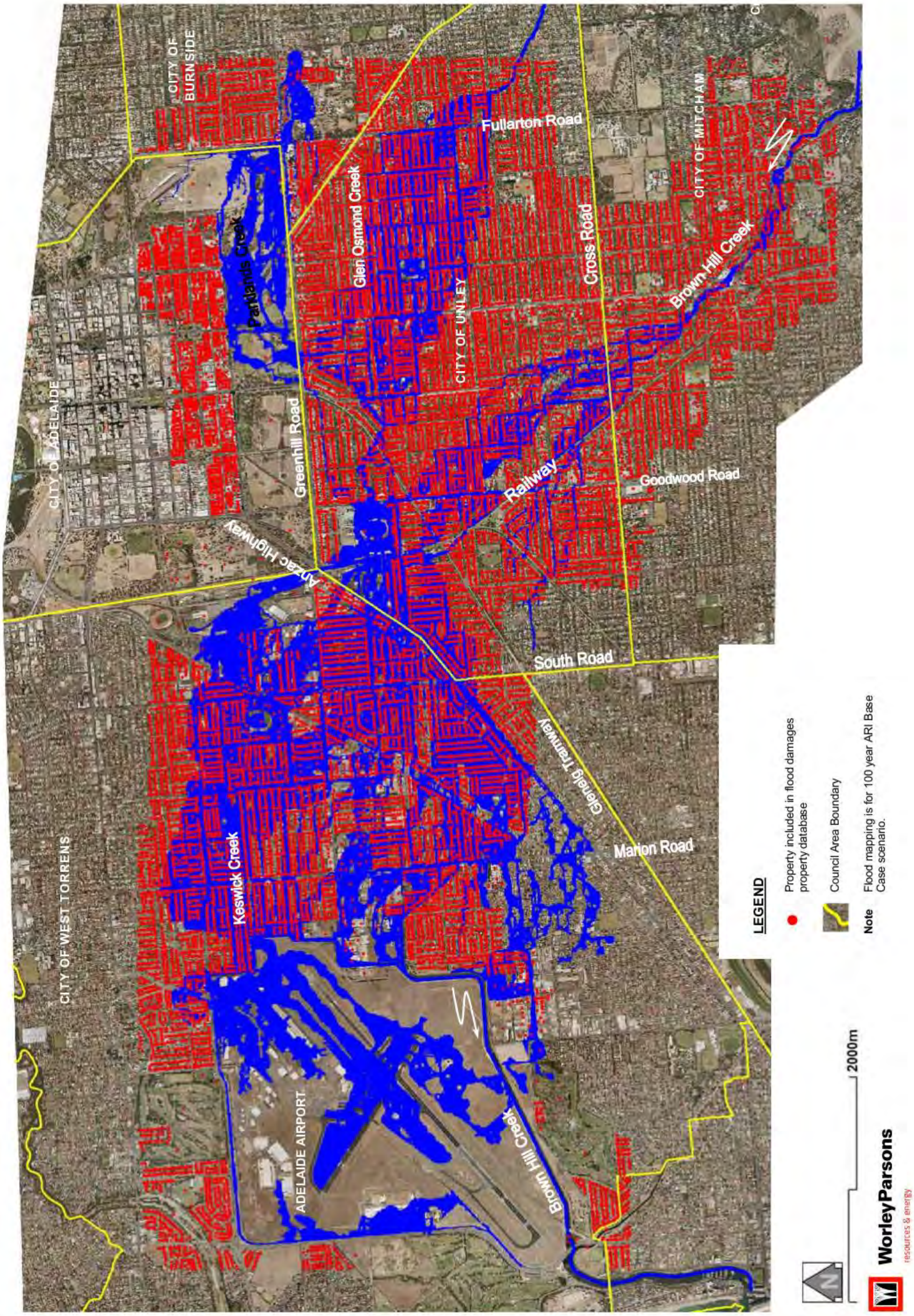

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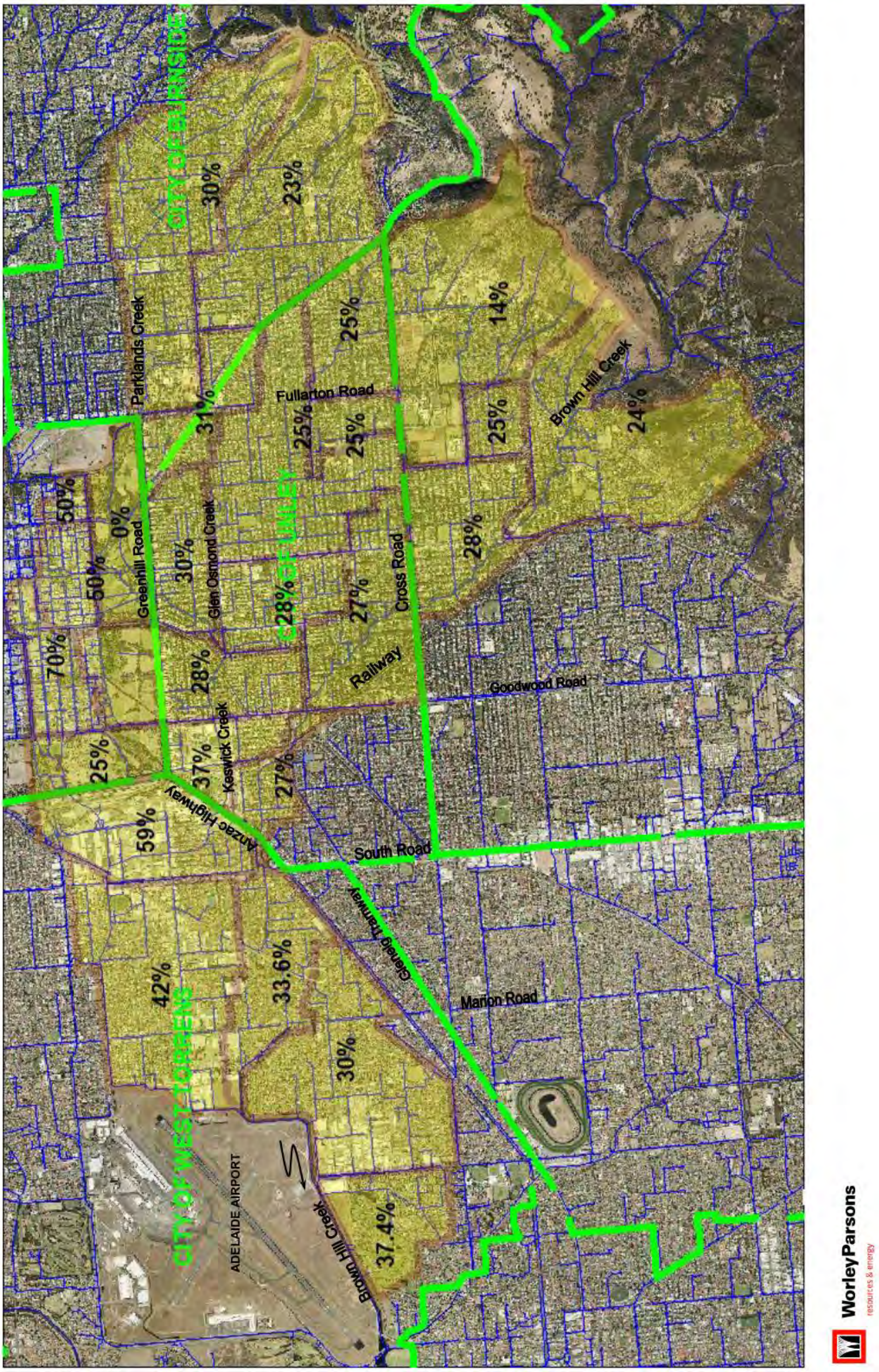

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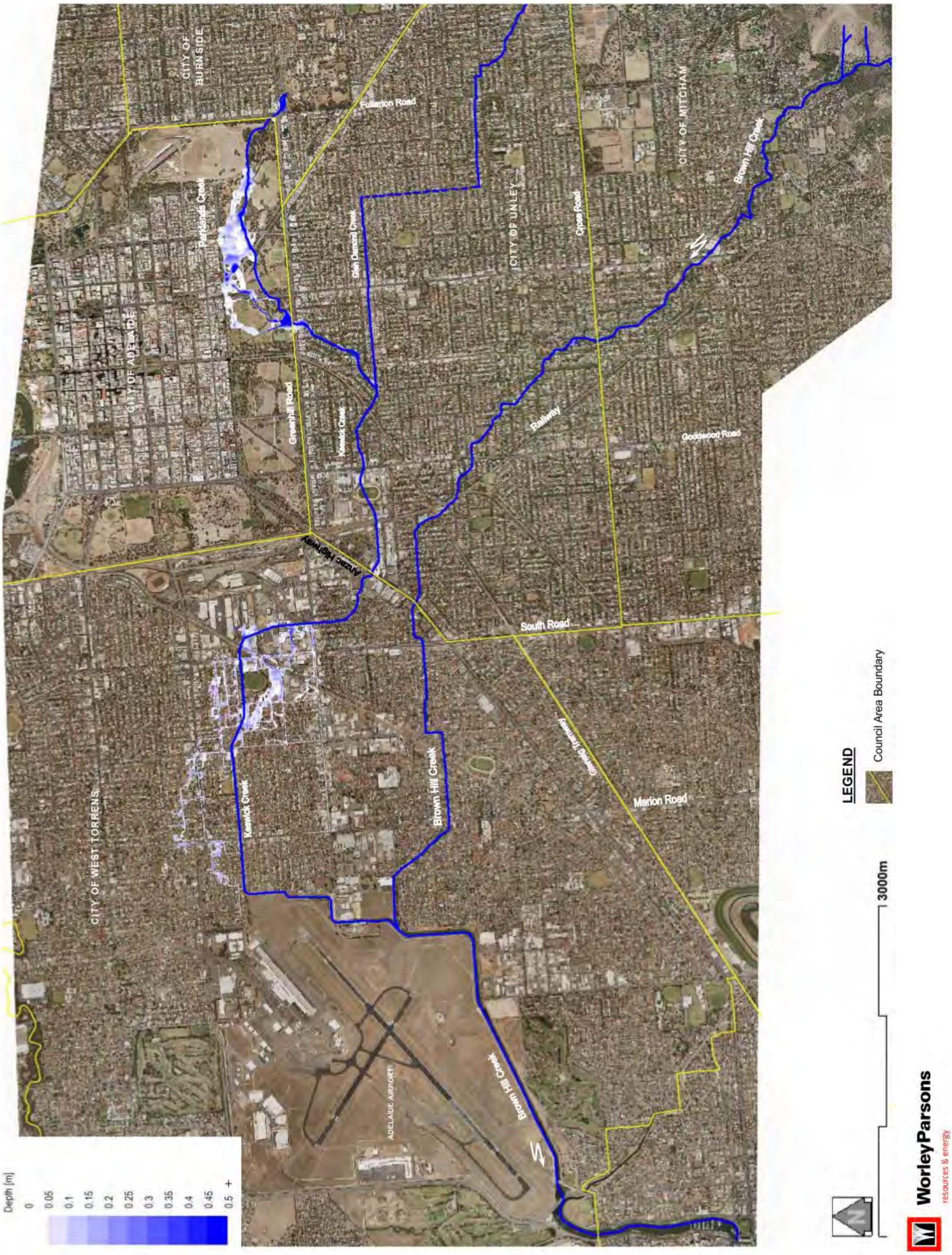

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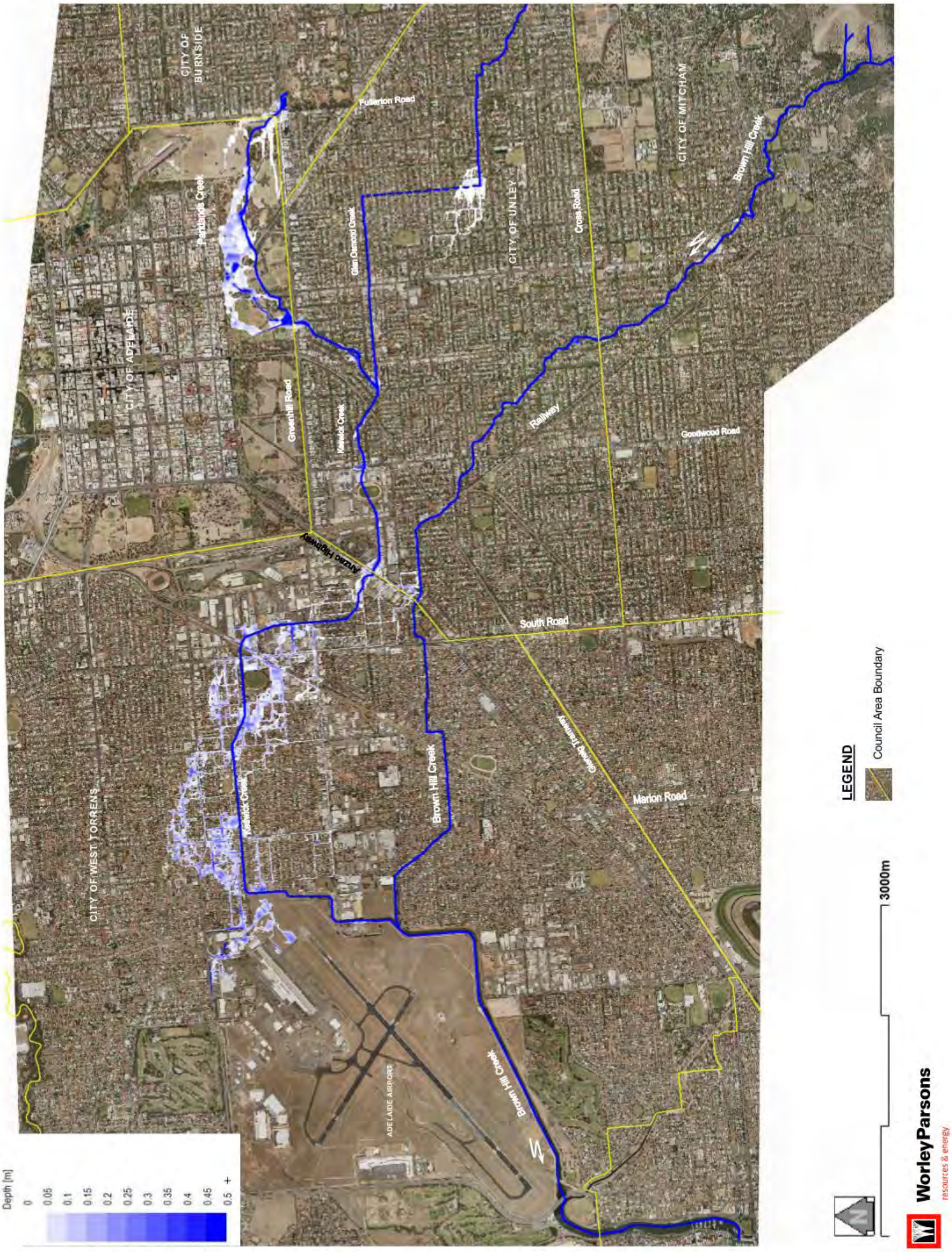

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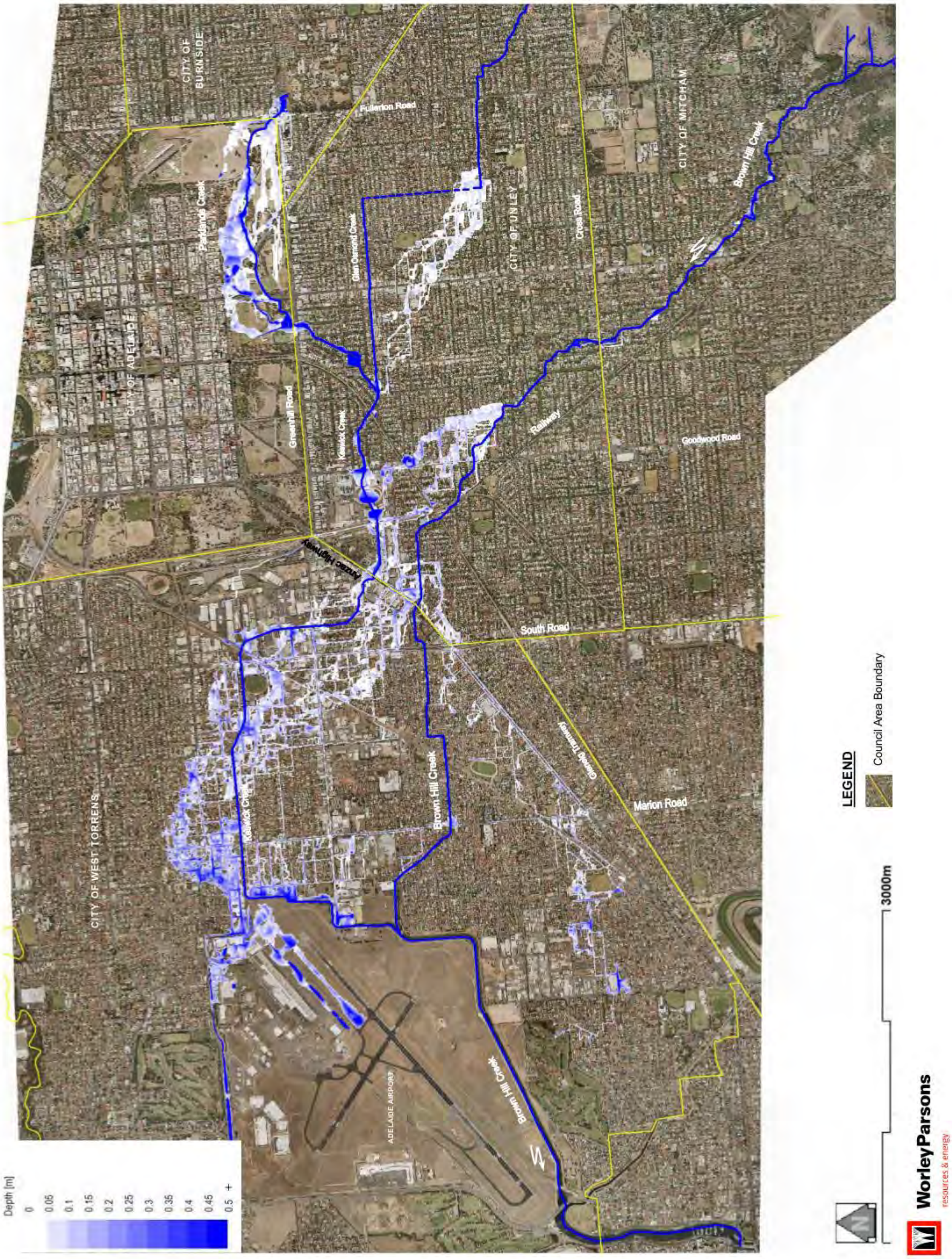
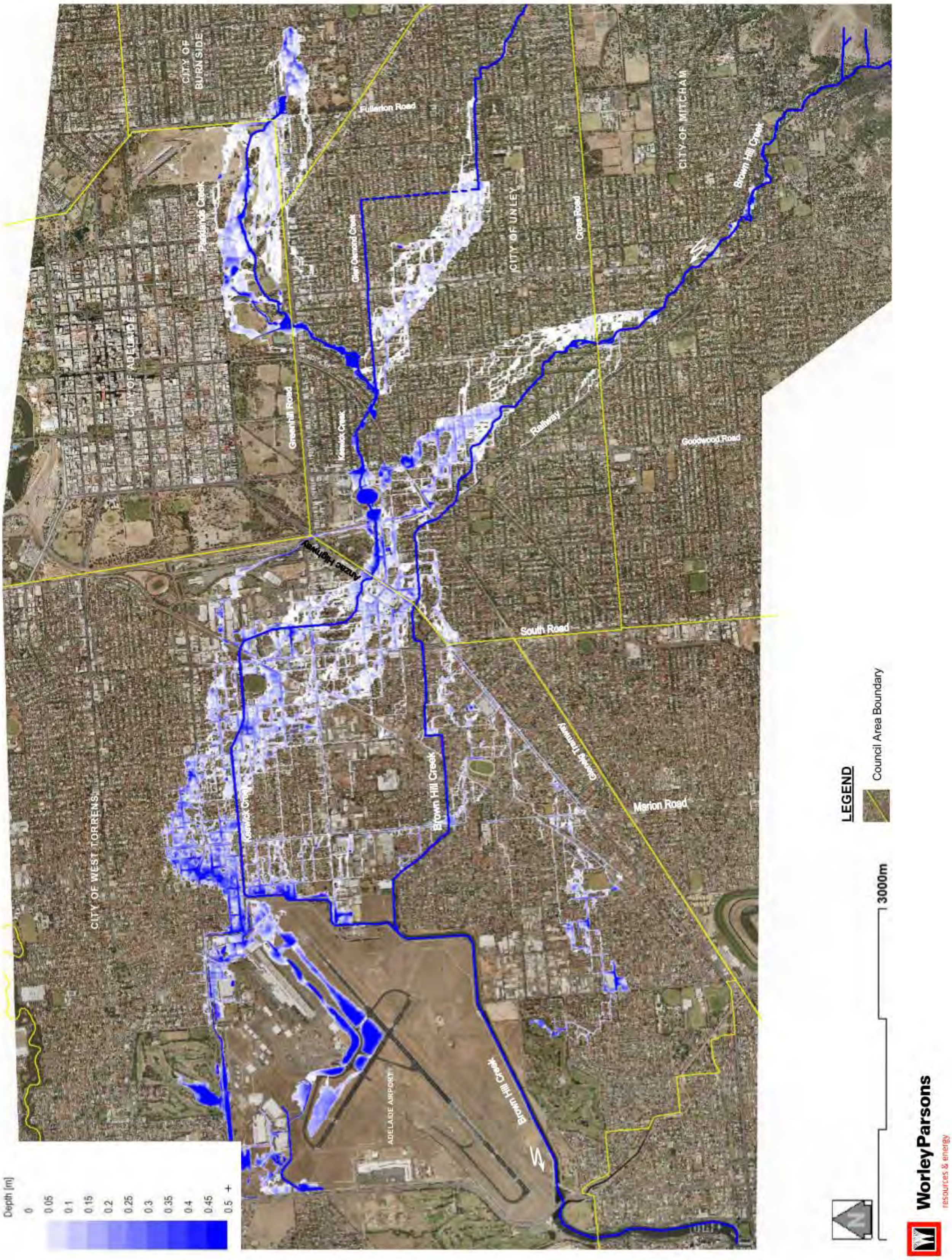


Figure 9:
Base case 100 year ARI



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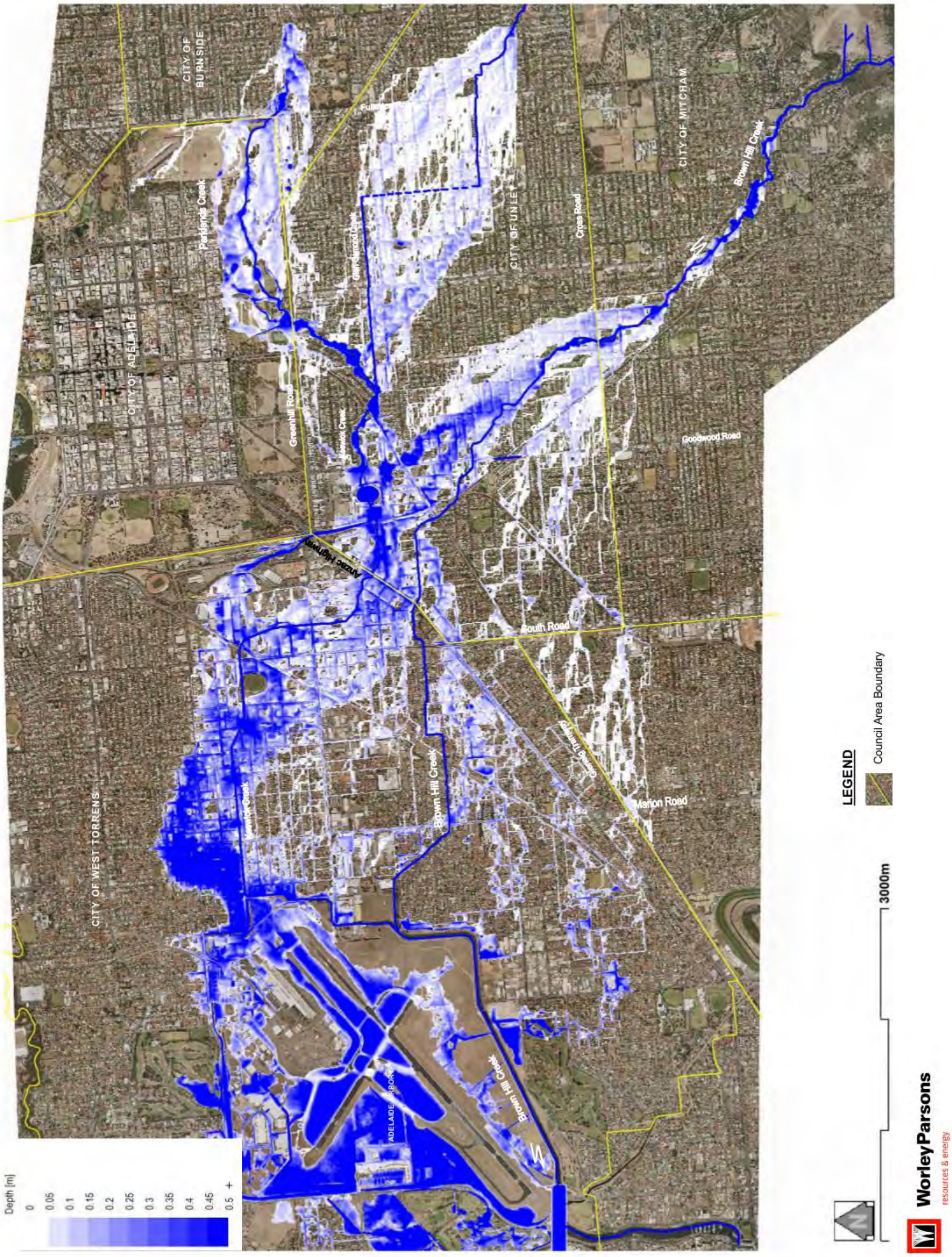

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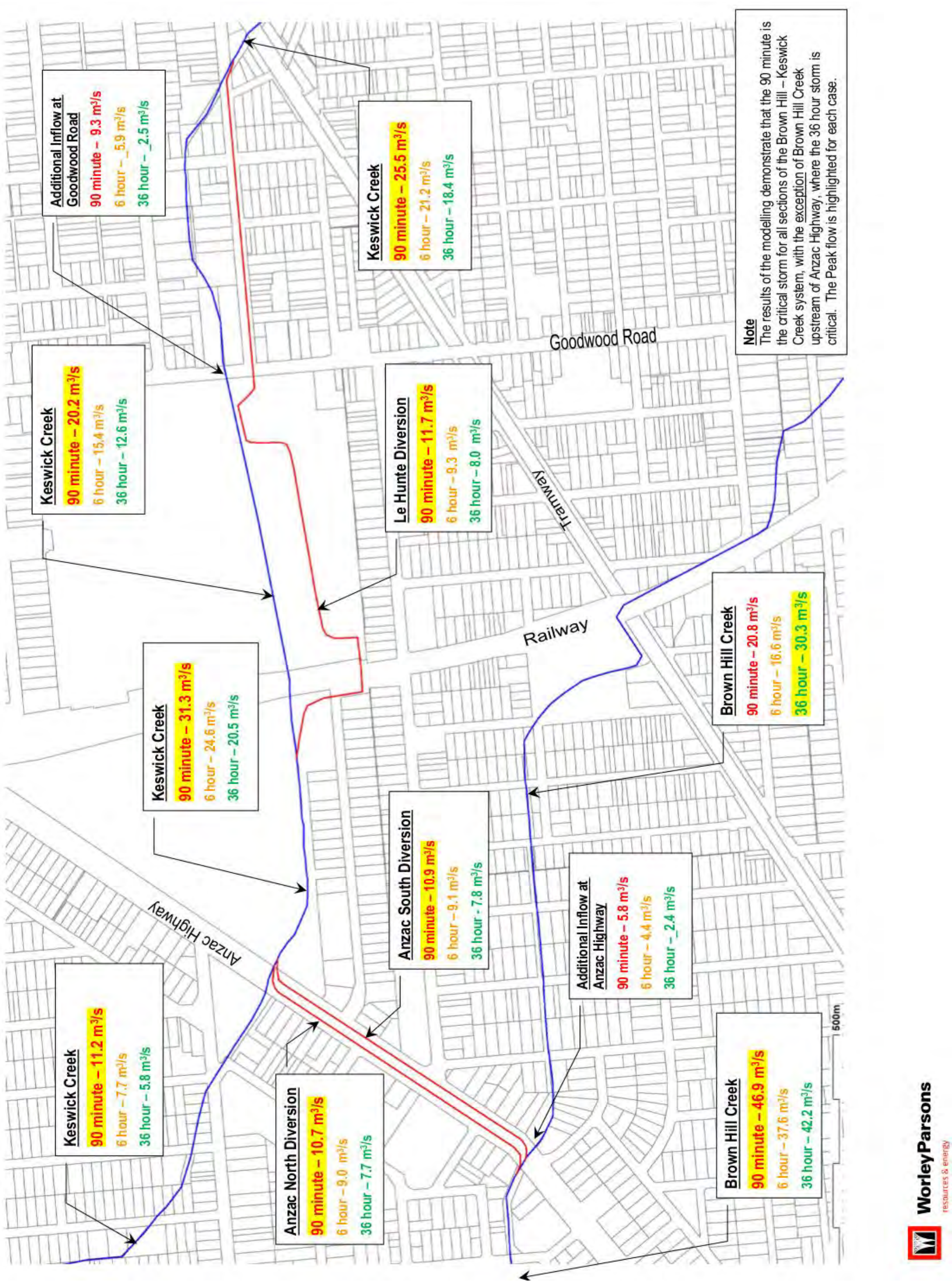

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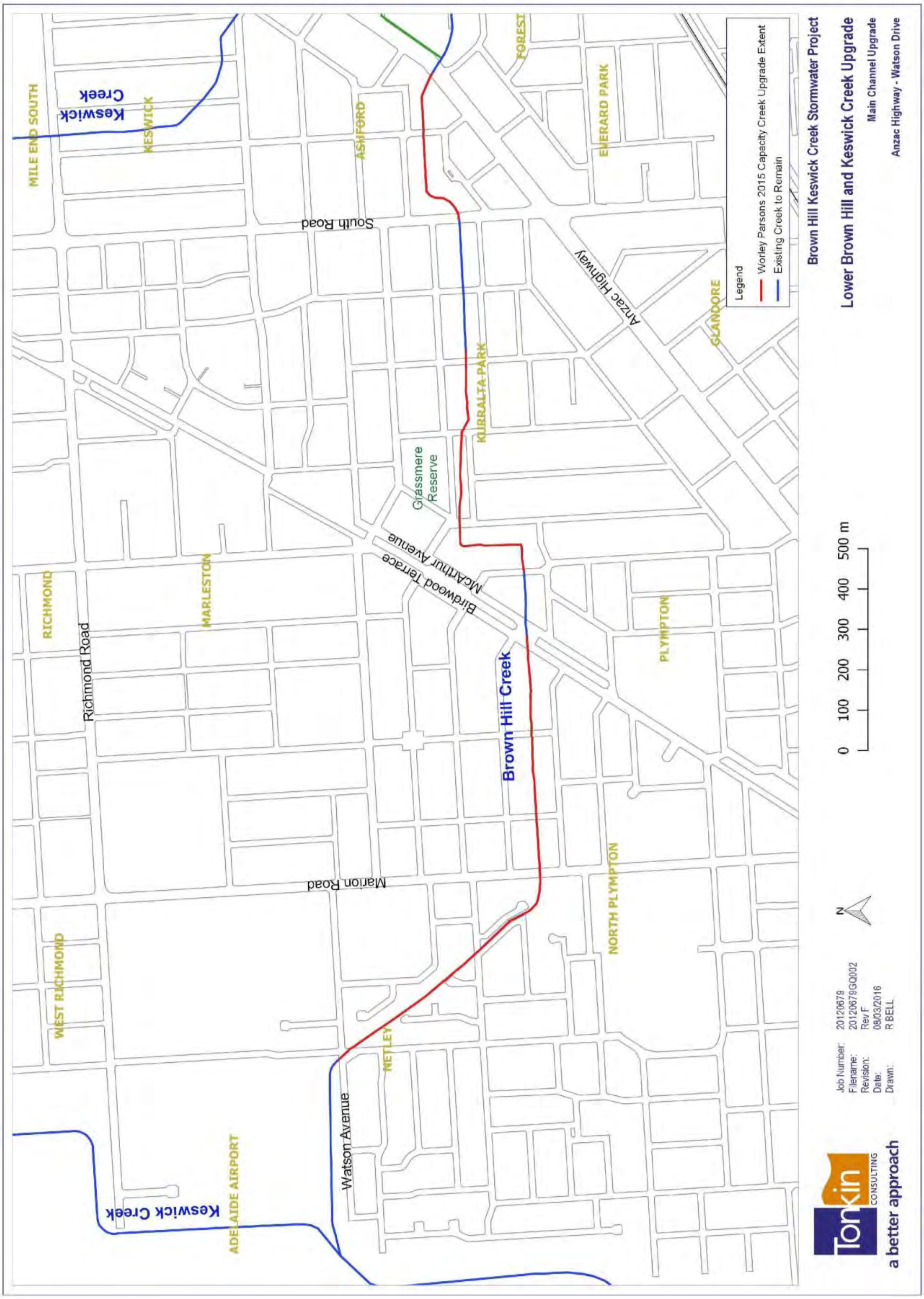

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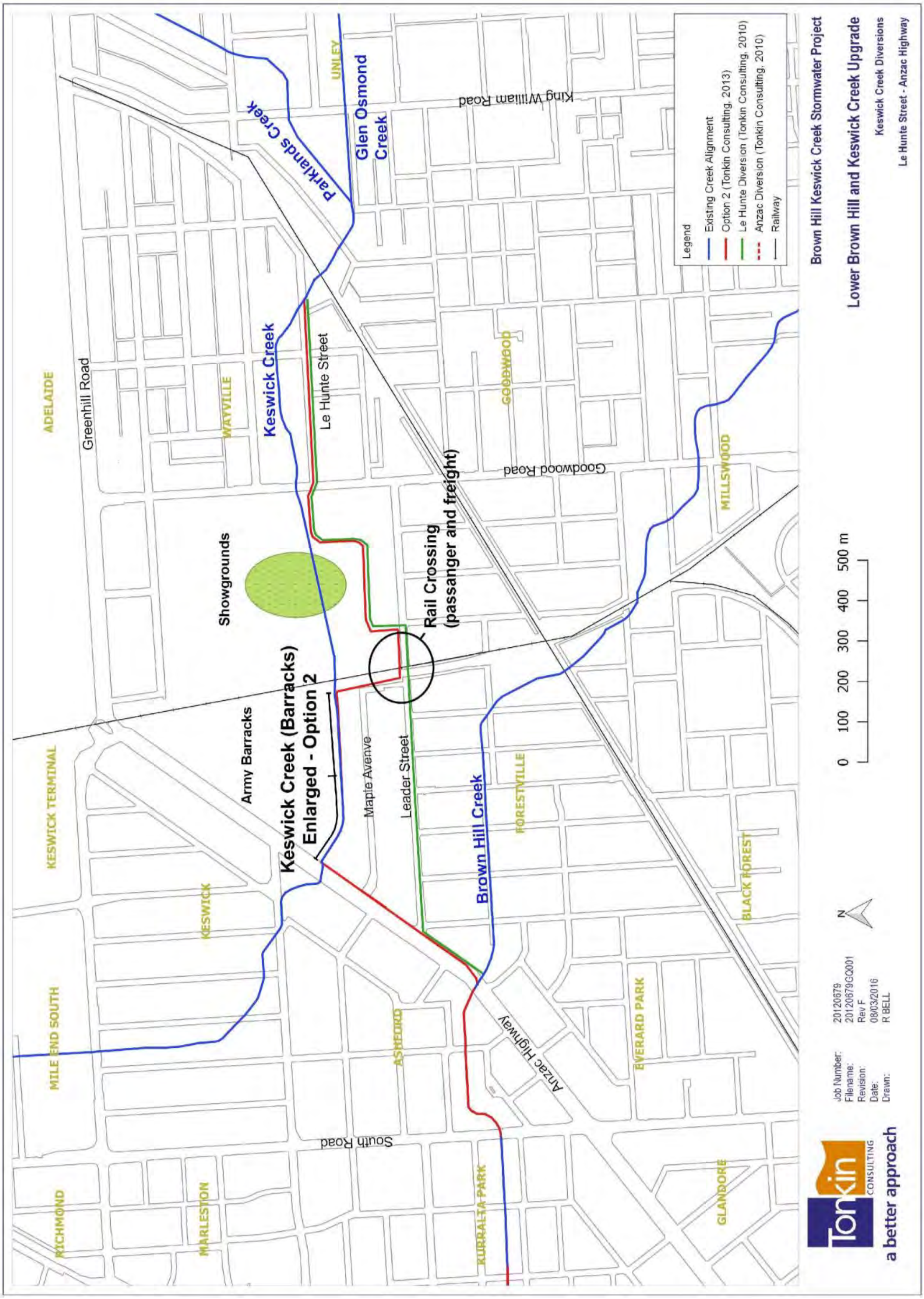

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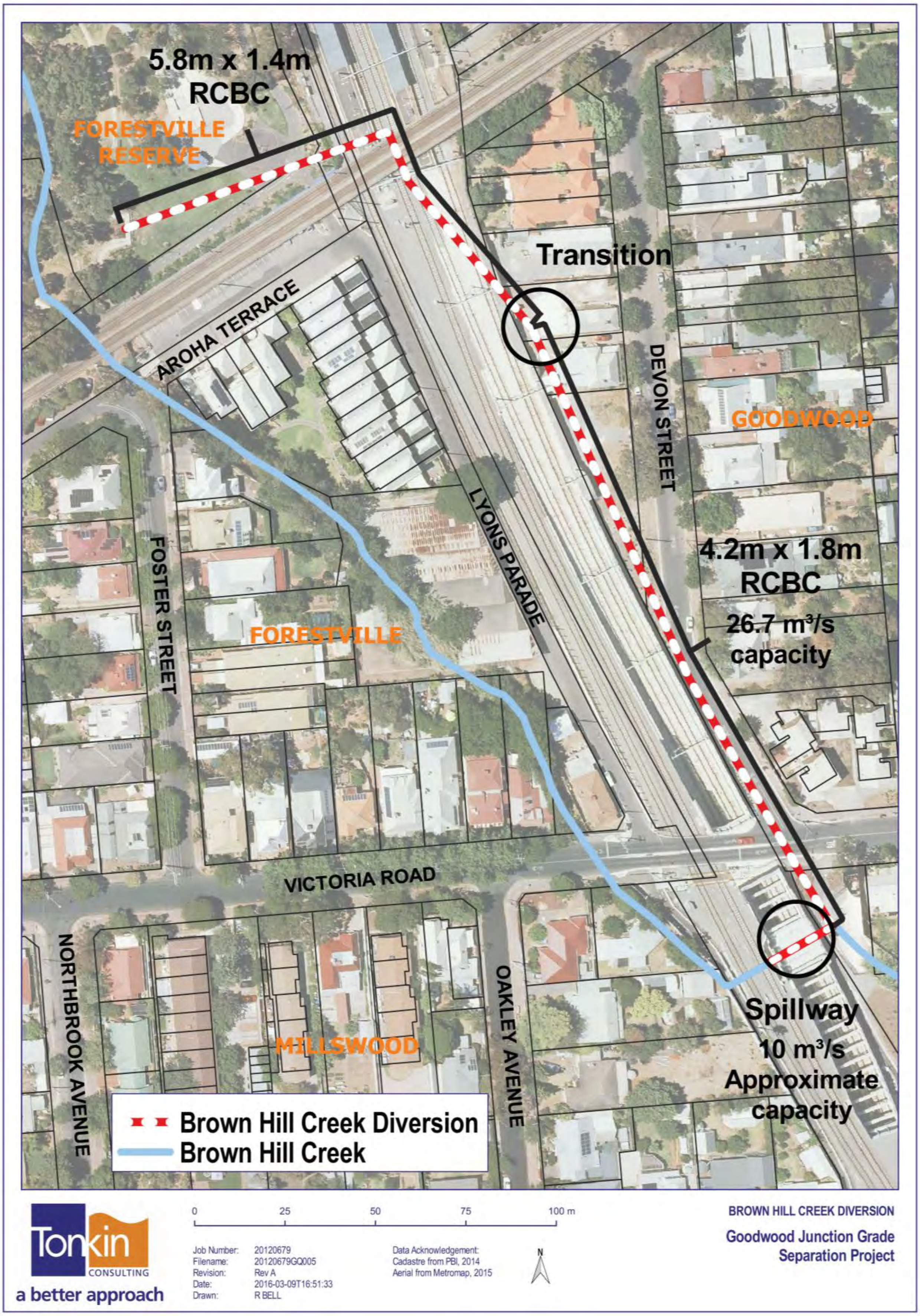

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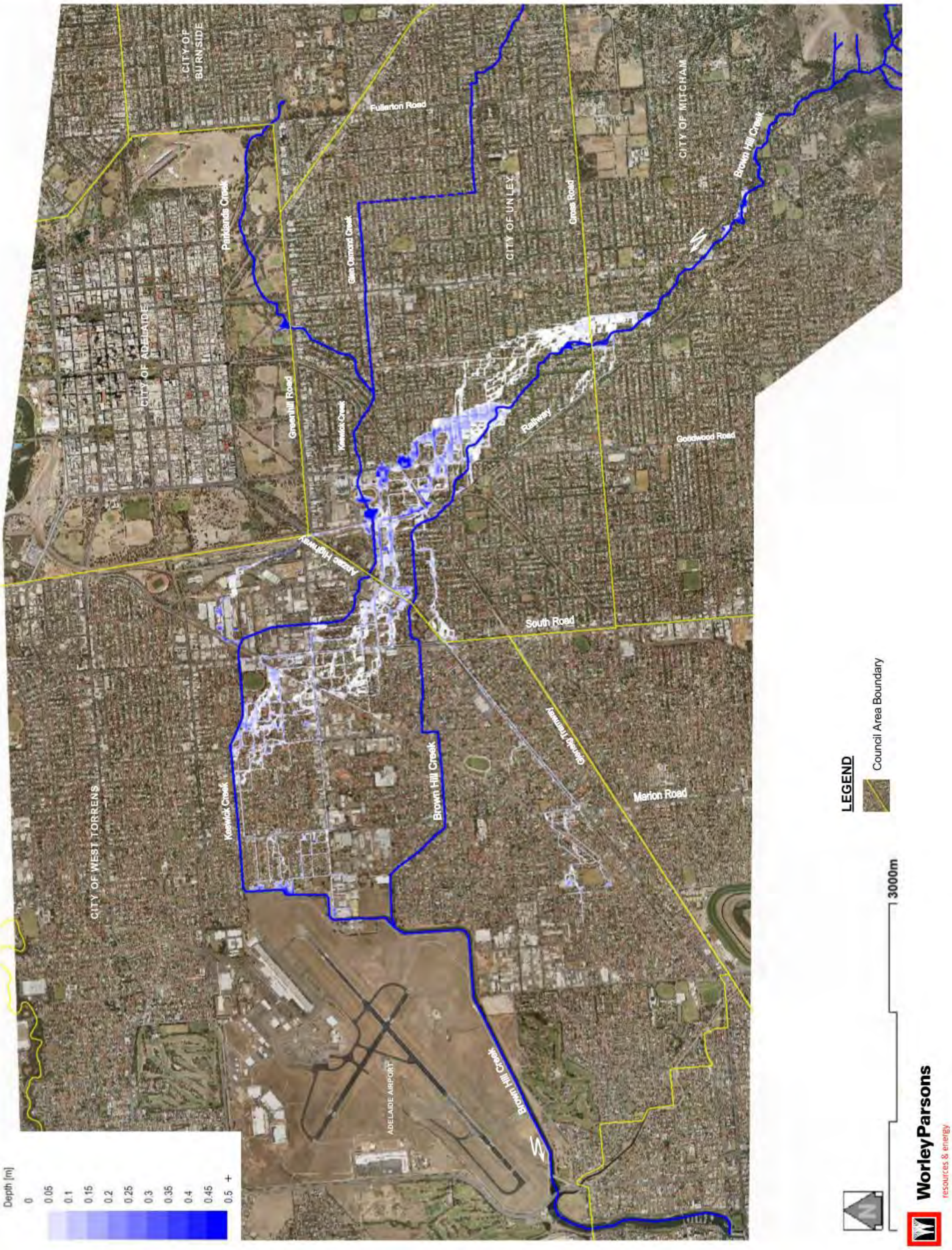

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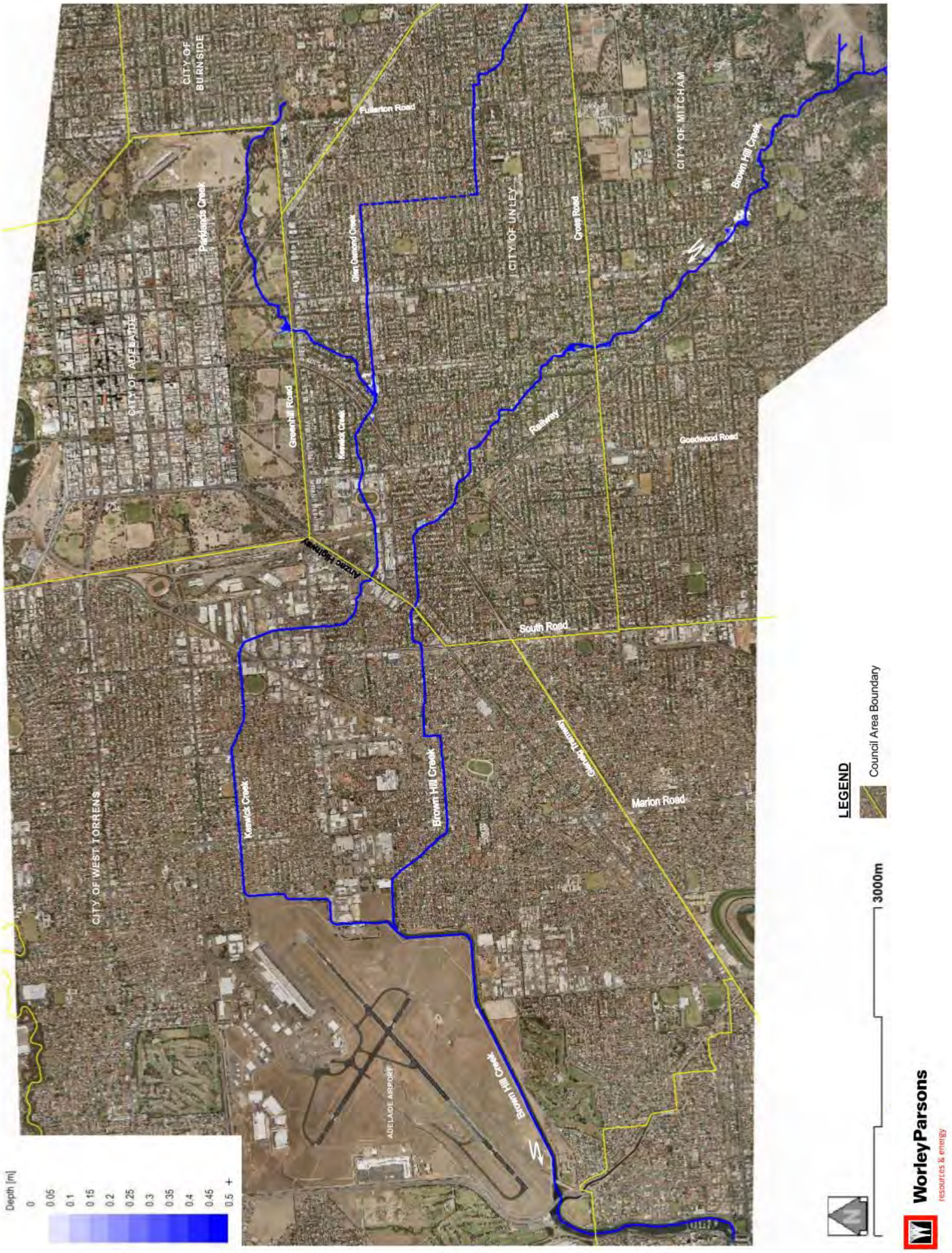

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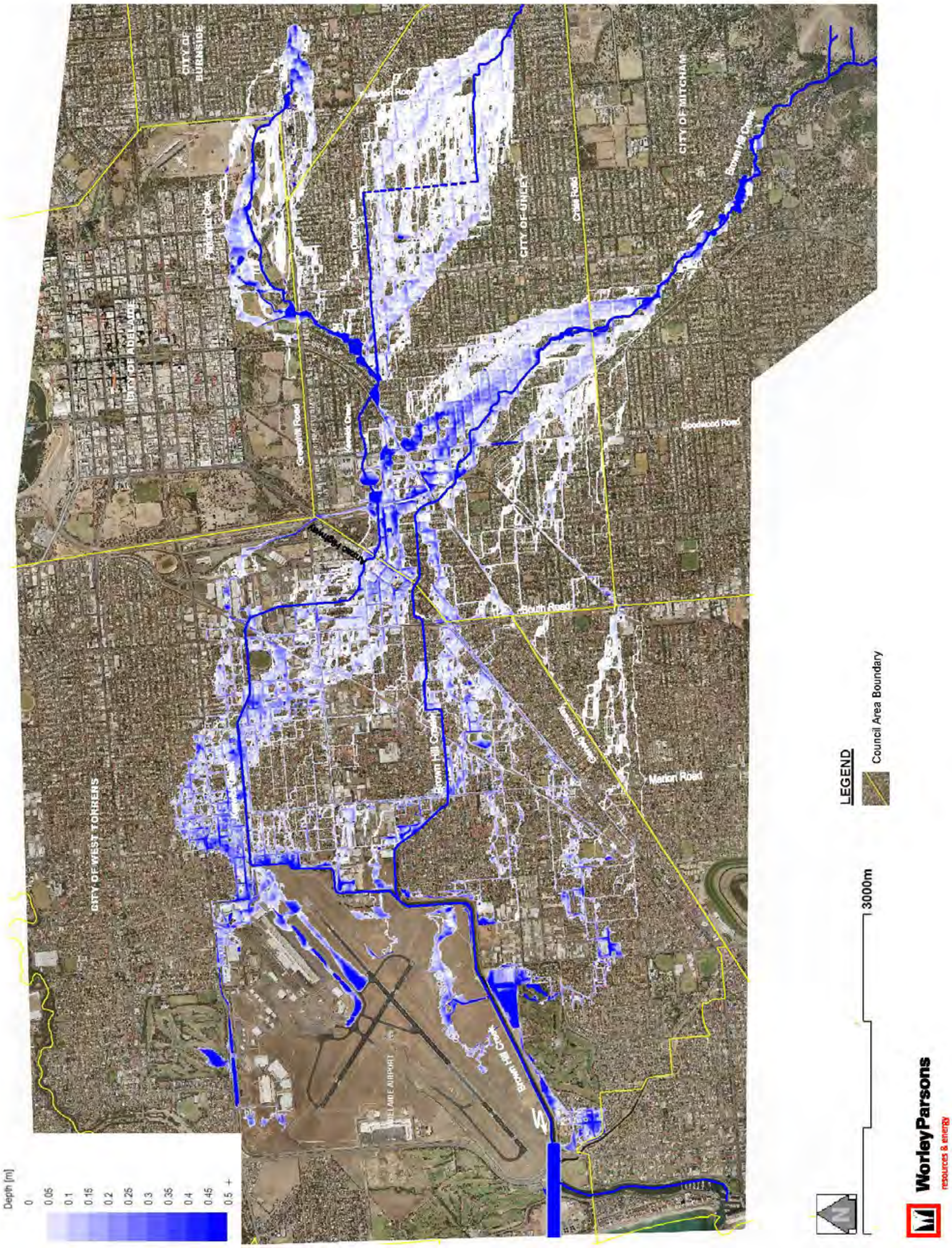

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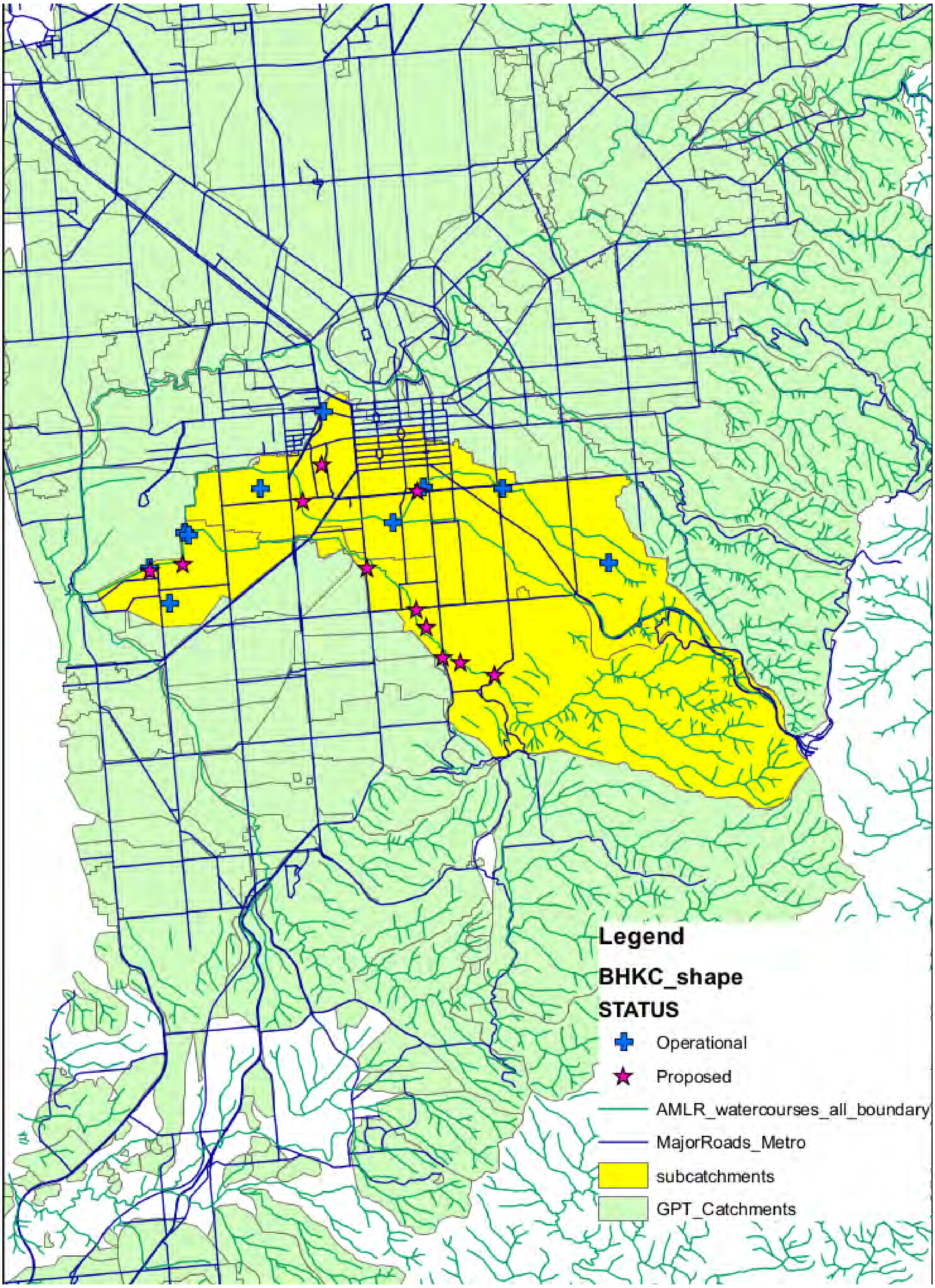

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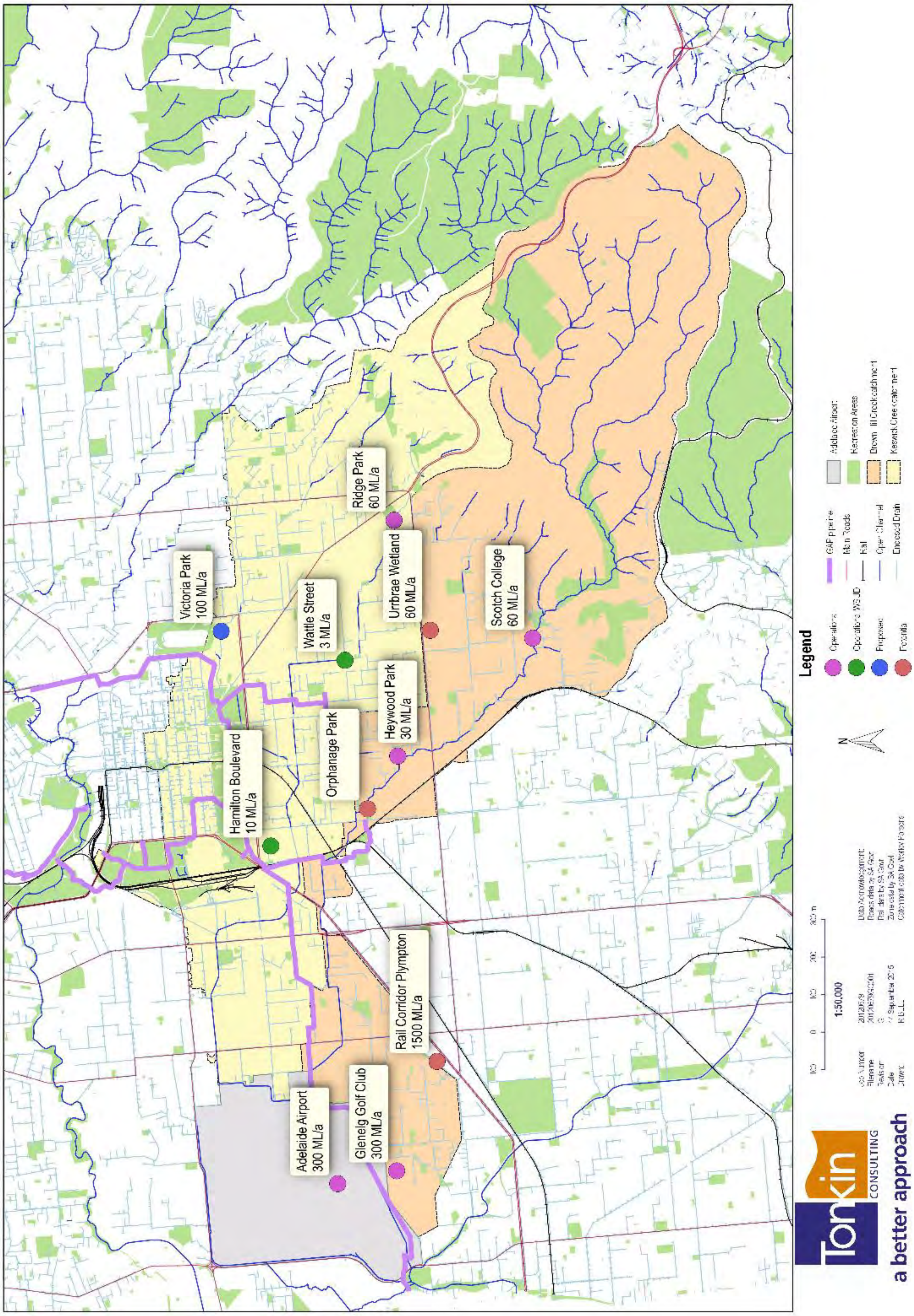

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