Brown Hill Keswick Creek
STORMWATER PROJECT

Brown Hill Keswick Creek Stormwater Management Plan Part B Report

September 2014

ADELAIDE CITY COUNCIL
City of Burnside
CITY OF MITCHAM
THE CITY of Unley
City of West Torrens
Between the City and the Sea

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List of Abbreviations

AMLRNRMB	Adelaide and Mount Lofty Ranges Natural Resources Management Board
ANCOLD	Australian National Committee on Large Dams
AR&R	Australian Rainfall and Runoff
ARI	Average Recurrence Interval
AWE	Australian Water Environments
BCR	Benefit-Cost Ratio
BHKC project	Brown Hill Keswick Creek Stormwater Project
BOM	Bureau of Meteorology
DEWNR	Department of Environment, Water and Natural Resources
DPA	Development Plan Amendment
DPTI	Department of Planning, Transport and Infrastructure
DTM	Digital terrain model
IFD	Intensity-frequency-duration
NRM	Natural Resources Management
OSD	On-site detention
RRR	Rainfall Runoff Routing
RCC	Roller compacted concrete
SOSCAG	Save our Streets Community Action Group
SOCKET	Save Our Creek Environs Trees
SMA	Stormwater Management Authority
SMP	Stormwater Management Plan
USA	University of South Australia
WSUD	Water sensitive urban design
WBCM	Wood Bromley Carruthers & Mitchell

Reference to streets and roads

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

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- Department of Planning, Transport and Infrastructure for hydrologic modelling
- WorleyParsons for hydraulic modelling
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- The Adelaide and Mount Lofty Ranges Natural Resources Management Board for advice regarding creek rehabilitation and maintenance
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- Treevolution for arboreal advice
- Wallbridge and Gilbert on design and construction methodology for culvert crossing of Cross Road
- Civil Surveys and Design for engineering surveying along sections of upper Brown Hill Creek.

Cover photo of Brown Hill Creek flooding in Unley Park in 1934 provided courtesy of the Unley Library.

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 serious flood risks and help safeguard properties across the catchment of Brown Hill and Keswick Creeks.

In 2013, the Stormwater Management Authority (SMA) endorsed the 2012 Stormwater Management Plan (SMP) for the Brown Hill Keswick Creek catchment. The main objective of the 2012 SMP is to mitigate the risk and reduce the impact of major flooding 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.

The 2012 SMP groups works into two Parts:

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

The purpose of this report is to outline the findings of investigations into Part B flood mitigation works and recommend a preferred flood mitigation option.

Part B Process

The 2012 SMP outlines the strategy for determination of Part B Works. The strategy is premised on 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.

The Part B investigation process has benefited from:

- revised hydrology (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 of stormwater inundation beyond the watercourse
- updated project cost estimates based on the revised technical information.

Flood mitigation options

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 5, 6 and 7 of this report respectively, with an overall assessment in Section 8.

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

- A detention dam (at one of two alternative sites)
- High flow bypass culverts
- Creek capacity upgrade works (including bridge upgrade works).

In addition to these components, all of the options include undertaking maintenance works along the full length of upper Brown Hill Creek to rehabilitate the creek to a state of ‘good condition’.

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 it 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 Work

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.

Rehabilitating the creek to 'good condition'

Although maintenance and rehabilitation of the creek is the property owners' responsibility, under all eight flood mitigation options, 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), 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
- 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 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
- On-going routine maintenance which would provide services such as removal of fallen timber within the creek and removal of 'foreign' matter such as building debris which might cause flow blockages and consequent flooding.

Assessment of Flood Mitigation Options

In assessing the respective merits of the eight options, the project has given primary consideration to the level of flood protection, costings and financial implications, community feedback and impact on trees.

Although included in the Part B analysis, options involving bypass culverts (Options A1, A2, C1, C2 and C3) have not been investigated to the same extent as Options B1, B2 and D as initial work undertaken in the Part B process indicated that they would be too costly.

Level of flood protection

All eight options provide approximately the same level of flood protection for the 100 year average recurrent interval (ARI) event. The number of potential flood impacted properties along upper Brown Hill Creek (Mitcham and Unley Council areas) is reduced from over 400 to about 25 properties, with none of those 25 properties likely to experience above floor flooding.

The level of flood protection was verified by floodplain modelling for Options B1, B2 and D. 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 which verifies that these options could all be designed to provide the same level of flood protection as for Options B1, B2 and D.

Comparison of costs

		Estimated costs ($M)							
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**

Comparison of Options B1, B2 and D

From a cost perspective:

- Option D has the lowest capital cost ($35.5m); the lowest annual maintenance cost of $162,000 per annum; and the lowest present value whole of life cost ($31.5m)
- Option B1 has the 2nd lowest capital cost ($40.9m); the 2nd lowest annual maintenance cost of $176,000 per annum; and the 2nd lowest present value whole of life cost ($36.5m)
- Option B2 has the 3rd lowest capital cost ($44.1m); the 3rd lowest annual maintenance cost of $186,000 per annum; and the 3rd lowest present value whole of life cost ($39.0m).

From an economic perspective:

- All three options have an indicative benefit-cost ratio (BCR) in the range of 0.3 to 0.4, based solely on tangible benefits. It is possible that the intangible damages could at least match the tangible damages amount. However, it is unrealistic to consider as absolute a BCR value of the Part B works in isolation. Their real impact is the result of the Part A and Part B Works together having effect across the wider BHKC catchment.

From a works perspective:

Component	**Options**	**B1**	**B2**	**D**
Dam		Site 1	Site 2	Not required
High flow bypass culvert		Not required	Not required	Not required
Estimated number of properties requiring creek capacity upgrade works; requiring an agreement or easement		29	22	66
Number of properties where land acquisition is required		0	2	0
Number of properties requiring an easement for Dam Site 2		0	3	0
Number of public bridge upgrades		4	4	10
Creek rehabilitation works		Full length of creek	Full length of creek	Full length of creek

Preferred option

Option D is the preferred option by the BHKC project as:

- It has the lowest capital cost ($35.5m) by a margin of about $5 million; the lowest annual maintenance cost of $162,000 per annum and the lowest present value whole of life cost ($31.5m)
- It provides the required (100 year ARI) level of flood protection
- For shorter duration storms it provides a higher than 100 year ARI level of flood protection
- It satisfies the project councils' endorsed position to give preference to a feasible 'no dam' solution
- It does not require bypass culverts in suburban streets
- It preserves sites of heritage significance
- It is within the budgeted cost for Part B as estimated in the SMP ($27.3 million compared with $28.5 million).

Community consultation

The project will carry out community consultation on the proposed Part B Works. Feedback collected from the community in this process will be summarised in a report to the five catchment councils who will then review it and, subject to the results, make a final recommendation to the SMA on the Part B Works.

Project implementation

The strategy for the Part B process also requires the five catchment councils (subject to agreement of Part B Works), to consolidate the Part B outcomes, the Part A Works and other flood mitigation measures of the 2012 SMP into a whole of catchment flood mitigation plan (the Final SMP). This work will be progressed during the process for approval of the Part B Works.

Assuming Option D is adopted for Part B, the logical sequence of construction over both Parts A and B of the project is:

1st priority	Lower Brown Hill Creek upgrade/South Park Lands detention basins/Ridge Park detention dam (Part A)
2nd priority	Diversions from Keswick Creek to lower Brown Hill Creek (Part A)
3rd priority	Upgrade of Brown Hill Creek from Anzac Highway to Forestville Reserve (Part A)
4th priority	Upgrade of Brown Hill Creek Part B Works – progressing from downstream to upstream

1 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 serious flood risks and help safeguard properties across the catchment of Brown Hill and Keswick Creeks.

The Brown Hill Keswick Creek catchment comprises four major watercourses – Brown Hill Creek (the most significant, particularly in terms of stormwater flow conveyance); Keswick Creek; and tributaries of Keswick Creek being Glen Osmond Creek and Parklands Creek. The catchment varies considerably from highly urbanised in the middle and downstream sections to predominantly rural in nature in the higher section of Brown Hill Creek.

Brown Hill Creek can be conveniently divided into two sections:

- Lower Brown Hill Creek – which runs downstream from Anzac Highway to its confluence with Keswick Creek at Adelaide Airport (which is also the western end of the catchment study area)
- Upper Brown Hill Creek – being the section upstream of Anzac Highway to its source in the rural land of the Mitcham hills.

In 2010, engineering consultant WorleyParsons was engaged by the BHKC project to prepare an updated SMP for flood mitigation within the Brown Hill Keswick Creek catchment.

The WorleyParsons investigations followed previous flood mitigation studies which were presented in a Flood Management Master Plan for the BHKC catchment produced in 2006 by Hydro Tasmania (now Entura) for the then Patawalonga Catchment Water Management Board.

From all of these investigations, a wide range of infrastructure and non-infrastructure flood mitigation options have been assessed, resulting in several viable and cost-effective options being recommended.

Community consultation was carried out on the draft Stormwater Management Plan (SMP) in November 2011 and after further investigations and reporting in 2012, WorleyParsons produced a consolidated report, 'Brown Hill Keswick Creek Stormwater Project Stormwater Management Plan 2012'. This was subsequently approved by the Stormwater Management Authority (SMA) as the SMP in February 2013 and gazetted on 5 March 2013; and is referred to in this document 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, Keswick Creek, Glen Osmond Creek and Parklands Creek
- Part B Works – designed to provide flood mitigation in the upper Brown Hill Creek catchment.

The purpose of this report is to outline the findings of investigations into Part B flood mitigation works and recommend a preferred flood mitigation option.

2 Background

2.1 Introduction

As outlined in Section 5 of the 2012 SMP, the 2012 SMP was prepared in accordance with the SMA's Stormwater Management Planning Guidelines. The overarching objective of the SMP of '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' is underpinned by six 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.

In relation to 'Protection from flooding', the 2012 SMP aims to provide an acceptable level of protection for the community and private and public assets from major flooding across the BHKC catchment. A 100 year average recurrence interval (ARI) standard of flood protection is the objective generally across the catchment, accepting that in some relatively small areas it may not be economically feasible to achieve that 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.

Presently, upper Brown Hill Creek, based on flood modelling (refer Section 4) is estimated to have about a 20 year ARI level of protection.

The 2012 SMP assessed a wide range of infrastructure and non-infrastructure flood mitigation options. The five catchment councils were able to reach agreement on the preferred flood mitigation works for Part A Works, however they could not finalise a preferred flood mitigation solution for upper Brown Hill Creek Part B Works within the project timeframes.

Section 3.3 of the 2012 SMP therefore outlines a flood mitigation strategy for the BHKC catchment which broadly comprises:

- Agreed Part A Works
- A process to investigate and determine final Part B Works (flood mitigation works for upper Brown Hill Creek)
- Any other flood mitigation measures that may be identified
- Information required to satisfy the SMA Stormwater Management Planning Guidelines.

The strategy also identifies 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. Nevertheless, the SMA, as a condition of its funding assistance, required dam options to be considered.

2.2 Part A Works

Part A Works comprise structural flood mitigation works including:

- Ridge Park flood control dam
- Fisher Street bypass culvert
- Brown Hill Creek upgrade from Anzac Highway to Forestville Reserve
- Diversions from Keswick Creek to lower Brown Hill Creek
- South Park Lands detention basins
- Lower Brown Hill Creek creek capacity upgrade.

Part A Works (which comprise about 80% by value of the total project) have been endorsed by the five catchment councils and now form part of the approved 2012 SMP.

Concept designs are either completed or currently underway for the following Part A Works:

- South Park Lands detention basins (concept design completed)
- Lower Brown Hill Creek upgrade
- Keswick Creek to lower Brown Hill Creek diversions.

Progress on other Part A Works includes:

- Design of Ridge Park detention dam, with construction planned to be carried out in 2014/15
- A section of Brown Hill Creek in Forestville was supplemented in 2013 by a creek diversion culvert and other works as part of the Goodwood Junction rail upgrade project undertaken by the Department of Planning, Transport and Infrastructure (DPTI).

2.3 Part B Works

Although upper Brown Hill Creek is regarded as extending upstream from Anzac Highway to its source in the Mitcham hills, with the completion of the Goodwood Junction rail project, the Part B Works area now essentially extends upstream from the new DPTI culvert entrance near Victoria Street, Goodwood. The DPTI culvert discharges back into the creek in Forestville Reserve (shown in plans at Appendix 1).

Section 7 of the 2012 SMP outlines flood mitigation scenarios for upper Brown Hill Creek. Three options are presented in detail (with reference to the plans at Appendix 1):

- 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 process for determining Part B Works is discussed in Section 3 of this report.

2.4 Other stormwater management measures

The 2012 SMP considers a range of other stormwater management measures including:

2.4.1 Stormwater harvesting

The 2012 SMP outlines 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. During the Part B process the project gave in-principle support for a private proposal being put to the CSIRO which was to research the potential for stormwater harvesting from a detention dam in upper Brown Hill Creek. However, the proposal was not approved for funding.

2.4.2 Water sensitive urban design

The 2012 SMP identifies examples of where water sensitive urban design (WSUD) has been implemented by BHKC catchment councils, and recommends further adoption of this measure for lessening wastage of rainfall runoff. 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.

As outlined in the 2012 SMP, WSUD (which may include on-site detention) is not a solution to the existing risk posed by large storm events, particularly in the range of 100 year ARI. WSUD is beneficial in reducing the impact of increased runoff due to urban development and in-fill (refer Section 4.3).

2.4.3 On-site detention

On-site detention (OSD) 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. Reduction in existing flood risk is achieved by the provision of stormwater infrastructure including pipes, detention dams and overland 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 (eg 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.

In South Australia, the OSD experience of Campbelltown Council was reported by the University of South Australia (USA) 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.

The USA (in conjunction with the then Torrens Catchment Water Management Board, now 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 upper Brown Hill Creek catchment, OSD presumably would reduce the impact on local stormwater networks due to runoff from the urban area of the catchment, particularly in shorter duration storms. However, OSD has not been investigated as an alternative flood mitigation measure of the Part B Works for the following reasons:

- OSD could only be a component of an option involving a dam, not a ‘stand-alone’ option because it would not be effective in mitigating rural runoff
- The cost of any option including OSD as a component would be much greater than the viable Options B1, B2 and D

- 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 and is a very unlikely scenario
- The potential construction and maintenance cost per installation – for effectiveness on ARI events much greater than 5 years – would probably impose significant social and economic impacts within the relevant council areas of Unley and Mitcham 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.

2.4.4 Non-structural flood mitigation measures

Non-structural flood mitigation measures of general application across the catchment are addressed in the 2012 SMP at Section 8.3 under the following categories:

- Planning policy and development assessment process
- Flood awareness and preparedness
- Flood warning and emergency response
- Supporting policies and programs
- Channel maintenance and clearing.

Those measures will be retained or enhanced in the Final SMP (refer Section 9.1) resulting from finalisation of the Part B process.

3 Part B Process

3.1 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) centered 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 by-pass culvert from Hampton Street to Malcolm Street (considering two routes – one via Grove Street and the other adjacent to the main 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:

- 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
- 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 outlines an overall approach to finalise the selection of preferred flood mitigation measures for upper Brown Hill Creek. The process includes:

- 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
- 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 requires the project to advance other issues during the Part B process including:

- 'Unley Special Works' at 2012 SMP Section 13.3.3. This addresses the capacity of culverts at Windsor Street, Unley Road and King William Road, which all relate to Glen Osmond Creek and have no relevance to upper Brown Hill Creek
- Quality of stormwater discharge to receiving waters of St Vincent Gulf
- WSUD systems
- Planning controls (Development Application process)
- Private creek maintenance.

With the exception of private creek maintenance, those matters have been partially progressed but are not relevant to this report. They will be addressed more fully in the Final SMP (refer Section 9.1).

3.2 Stormwater Management Authority

As part of the 2012 SMP, the councils committed to a target date to agree a feasible Part B solution within 12 months of the 2012 SMP being gazetted. Throughout the Part B process, the SMA has been kept informed of progress being made towards achieving a successful outcome, including performance against the 12 month timeline.

Although at the time of preparing this report, it is more than 12 months since the 2012 SMP was gazetted (5 March 2013), the SMA has not acted to sanction the project councils as a consequence of the time overrun. Notwithstanding the councils' preference to pursue a 'no dam' solution, the SMA required that dams at both Sites 1 and 2 be considered in the Part B process.

3.3 Upper Brown Hill Creek

Upper Brown Hill Creek is approximately 7 kilometres in length. It can be categorised into sections of private and public ownership. For the purposes of this report:

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

These sections of the creek are described in Section 5.2.

Ownership	Descriptor	Location
Private	Area 1	Anzac Highway to Leah Street
Public		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

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.

3.4 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 5, 6 and 7 of this report respectively, with an overall assessment in Section 8.

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.
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.

3.5 Investigations

The Part B process has been based mainly around the following investigations and deliverables:

- Access to the railway corridor between Cross Road and Vardon Terrace
  - Applies to the extended high flow bypass culvert options (Options C1, C2 and C3)
  - Required to seek in-principle agreement with DPTI for the culvert route
  - Agreement with DPTI included concept design for culvert under Cross Road next to the railway crossing
- Construction cost estimates and constructability factors
  - Estimates required for component works of the main options, including:
    - Detention dams in the rural section of upper Brown Hill Creek
    - Culverts along the high flow bypass culvert routes (Malcolm Street, Route 3 and Route 3A)
    - Creek capacity upgrade works
    - Extraordinary maintenance to restore the creek towards achieving good condition
  - Costs to be compared on equal basis and consistent methodology (eg timing, risks and overheads)
  - Estimates by others to be peer reviewed
- Flow conveyance capacity of upper Brown Hill Creek
  - Based on the 2012 study for AMLRNRMB
  - Critical sections and works required to improve the flow capacity of upper Brown Hill Creek to be identified
  - Additional survey information along the creek particularly relating to constrictions (particularly bridge culverts) and low capacity reaches to be obtained
  - Investigations to include hydraulic modelling and estimated construction costs
- Impact of culvert construction on roadside and nearby vegetation
  - All trees within impact range of culvert construction to be identified and assessed
  - Construction methodology to be considered
- Preliminary concept design of detention dam(s) in Brown Hill Creek
  - Principal focus on dam at Site 1 (Brown Hill Creek Recreation Park)
  - Extended to include basic concept of dam at Site 2 (Ellisons Gully)
  - Estimated construction costs

- Land acquisition and easement costs
  - Carried out as a preliminary desk-top assessment
  - Compensation and associated costs of easements in private properties along Brown Hill Creek (creek capacity upgrade works)
  - Cost of land acquisition at dam Site 2
- Hydrology
  - Use of rainfall data issued by the Bureau of Meteorology (BOM) in 2013
  - Review hydrologic modelling
- Upgrading of floodplain model/Modelling simulations
  - Updated model to incorporate data from the Brown Hill Creek reinstatement investigation (by Australian Water Environments) and physical changes over the BHKC catchment since 2003
  - Updated hydrologic modelling inputs (2013 hydrology)
  - Modelling simulations for base case and post-mitigation options
  - Cross-checking between various hydrologic and hydraulic modelling results
  - Quality assurance checks for modelling parameters over the BHKC catchment (not just for the upper Brown Hill Creek part of the catchment)
- Creek surveys
  - Principally to clarify the creek location in relation to property boundaries
  - Locate the position of principal trees, bridges, retaining walls and other key features along the creek in areas identified for capacity upgrade works
- Field inspections
  - Inspections by the project team including consultants over most of the length of upper Brown Hill Creek.

A number of consultants have been involved in carrying out the above investigations, for which the scope of work and key results are discussed in Section 5 of this report.

4 Flood Modelling

4.1 Overview

Design of the Brown Hill Keswick Creek flood mitigation 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.

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

Hydraulic 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.

More detailed background information on the hydrologic modelling for the BHKC project is provided in the 2012 SMP at Sections 7.1.1 and 7.1.2.

The modelling process follows a number of stages:

- Estimating 100 year ARI rainfall across the catchment (as input into the hydrologic modelling)
- 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)
- Modelling where floodwater both remains in and can spill 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 forecasts of design rainfall events of varying ARIs across Australia.

Rainfall varies significantly. Some storms are short and intense; others have a lower average rainfall intensity but last longer. Both can produce significant floods. So a 100 year ARI storm (for example) 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 (applied to the whole catchment) produces the highest 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.

4.2 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 report, 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 by the BHKC project. Based on advice from the hydrology advisors to the BHKC project (the Stormwater Group of DPTI), the updated data has since been 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 2.

It is understood that other information regarding the use of the new IFD data will be released within the next one or two years and it is possible that new information in the future may result in further adjustments to the BHKC project's 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, including the Part B determination.

4.3 Urban in-fill

The 2012 SMP addresses urban in-fill in the context of:

- Intensification of development at Section 4.3 of the SMP
- Planning policies at Section 13.5.4 of the SMP.

4.3.1 Intensification

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 (ie 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.

Given changes to planning policies, 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 water sensitive urban design (WSUD) including such measures as on-site retention and detention.

4.3.2 Planning policies

The City of Unley Development Plan already incorporates the Natural Resources module from the South Australian Planning Policy Library. Incorporation of this module occurred as a part of recent amendments to the Development Plan.

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:

295 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

(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
- (iv) aquifer recharge.

The Building Code of Australia mandates the installation of a 1,000 litre (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.

The City of Unley is developing the relevant information sheets and incorporation of stormwater management systems will eventually become a requirement of new dwellings and major redevelopments.

The City of Mitcham 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/water course 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 further undertaking a 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 flood plains 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.

4.4 Climate change

Climate change was addressed in the 2012 SMP at Section 2.3. Independent expert hydrological advice then 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.

4.5 Modelling systems

In the Part B process, 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)
- Channel (hydraulic) modelling using MIKE 11 (1D) component of MIKE-Flood.

The RRR model and MIKE-Flood models are discussed in the 2012 SMP at Section 7.1. Both MIKE-Flood and HEC-RAS are proprietary software systems.

Hydrologic modelling underpins the hydraulic modelling (Section 4.1) and floodplain mapping (Section 4.9). More detailed background on the hydraulic modelling for the BHKC project is provided in the 2012 SMP at Section 7.1.3.

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. The inputs include flow hydrographs for which there are four local inflow points along upper Brown Hill Creek.

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 spills into 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, (ie 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 (ie 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 4.9.1.

4.6 Floodplain model upgrade

As described in the 2012 SMP at Section 7.1.3, the original floodplain model (using the MIKE-Flood software) was developed by Hydro Tasmania around 2003. In developing the SMP, WorleyParsons – in accordance with its original brief and terms of engagement subcontracted the floodplain modelling to AWE and Hydro Tasmania.

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 run the model for purposes of floodplain mapping and analysis of base case and flood mitigation options. WorleyParsons upgraded the model, principally in respect of the following enhancements (resulting in the '2014 model'):

- 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's 'n') in the model were updated using data adopted for the 2013 AWE study
- The 'as constructed' Goodwood Junction rail project (DPTI) diversion culvert was included
- 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.

The new DTM was later 'ground truthed' by comparing it with independently surveyed levels at points within the flood extent area of the floodplain.

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

4.7 Creek roughness

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

Roughness factors (Manning's 'n') were critically reviewed following the results of the AWE study for the AMLRNRMB and carried through into the AWE creek assessment study in 2013 (Section 4.8). As noted in Section 4.6, the revised AWE roughness factors were subsequently applied to the upgraded floodplain model.

In 2012 AMLRNRMB commissioned Water Data Services Pty Ltd 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.

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

Due to the relative complexity of the 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 (eg 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, by pruning and removing unsuitable vegetation and generally removing flow constraints and improving flow path, 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.

4.8 Creek capacity

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

- The AMLRNRMB commissioned consultant AWE to assess the hydraulic capacity of the creek channels within the catchment. AWE delivered the resulting 'Channel Capacity Assessment' report in 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 consultant Wood Bromley Carruthers and Mitchell (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 Hydro Tasmania for the 2006 Master Plan and used in subsequent modelling for the SMP incorporates channel capacities that were verified by Hydro Tasmania against the capacities determined by WBCM in 1983. It is therefore assumed that in terms of the channel capacity the Hydro Tasmania 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 Worley Parsons.

AWE was engaged 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.

- Restoration of WBCM flow capacity over the full study length of the creek
- 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 4.7).

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 break-outs and flood extents, particularly in terms of:

- flood extents emanating from the creek which impact on a significant number of houses and buildings
- break-outs 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 break-outs which extend over relatively large areas and consequently impact on a significant number of houses and buildings, as distinct from minor break-outs which cause localised minor flooding and do not produce material damages.

4.9 Floodplain modelling results

Floodplain modelling for the Part B process was carried out by WorleyParsons based on the changes and enhancements made to the MIKE-Flood model outlined in Section 4.6.

4.9.1 Limitations

The resulting floodplain maps have certain limitations:

- The mapping delineates areas over 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 localized 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 (eg 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 metre 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 metres.

4.9.2 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:

- 'Base case' is the existing situation with no flood mitigation works in place over the catchment (sometimes referred to as the pre-mitigation option)
- 'Composite' refers to the use of three storm durations as discussed in Section 4.1
- All modelling simulations were carried out on the (2014) upgraded floodplain model
- For 'Upper Brown Hill Creek' simulations, the other watercourses were not modelled to allow upper Brown Hill creek to be modelled in isolation
- 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.

Summary of simulations:

No.	Simulation on 2013 hydrology (except No. 1)	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 hours
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.

No.	Simulation on 2013 hydrology	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

Floodplain maps for simulations (except Simulation 4) are at Appendix 3.

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:

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

No.	Analysis of simulation
5	• Only very minor breakout at Second Ave, resulting in less than 0.5 m^3/s across Anzac Highway
6	• Reduced breakout at Hampton St, but contained within the roadway and down Denning St in the road • About 2 m^3/s is breaking out at Regent Street, with about 1 m^3/s breaking out at Goodwood Rd • 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
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 Rd • 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 St • Some breakouts at Kent Street and Hampton Street • Continuous breakout and flow either side of the creek from Victoria Ave to DPTI culvert • Breakout at Ethel and Charles Streets • Flow across Anzac Hwy 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

No.	Analysis of simulation
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 break-out between Heywood Avenue and Cross Road does not impact above floor level of houses • Proposed creek capacity upgrade works between Cross Road and Hampton Street (not modelled in this simulation) will reduce the localised break-out shown in this area
10B	• Localised break-out does not impact above floor level of houses
10C	• Localised break-out 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
15A	• Localised break-out between Heywood Avenue and Cross Road does not impact above floor level of houses
15B	• Same comment as 10B above
15C	• Same comment as 10C above

4.9.3 Conclusions from the 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 hundred 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 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:

For the whole of the BHKC catchment:

100 year ARI	Number of flood affected properties		
	Over-floor flooding	**Under-floor flooding**	**Total**
SMP (2012)	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.

For upper Brown Hill Creek:

100 year ARI	Number of flood affected properties		
	Over-floor flooding	**Under-floor flooding**	**Total**
SMP (2012)*	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 (ie 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.

4.9.4 Peak flows

The volume of stormwater runoff reaching any point along the creek is a function of the flow rate in the creek assuming 100% containment of flow to the creek. The aim of the creek capacity upgrade option (Option D) is to achieve 100% containment of peak flow to the creek (governed by the 36 hour storm) for the 100 year ARI.

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):

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 Rd	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 Rd	37.1	30.2	28.2	22.4	26.9	20.1
Anzac Hwy	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.

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

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 break-out down to about Avenue Street, no matter how large the dam or at what site
    - 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 break-out 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 $18m^3/s$, based on simulations 3, 12 and 13 which show little or no break-out from the creek through the park. From HEC-RAS analysis, creek capacity through the park was assessed to be about $16m^3/s$.

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 (ie the theoretical break-out 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 Megalitres (ML). To put this volume into perspective an Olympic size swimming pool is about 2 ML in capacity.

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

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:

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

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.

4.9.5 Lower Brown Hill Creek

It is reported in the 2012 SMP 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 has been verified for Option D through RRR modelling and Mike 11 modelling.

The Mike 11 modelling results are included at Appendix 4 which shows peak flows (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.

5 Technical Investigations

5.1 Overview

This section outlines the eight flood mitigation options listed in Section 3.4 with reference to the technical investigations that were undertaken in the Part B process. Flood modelling results (Section 4.9) were used to assist in determining and verifying concept designs outlined in the following sections. Field inspections and surveys were carried out and anecdotal evidence considered in order to validate results of floodplain modelling.

All options provide approximately the same level of flood protection for the 100 year ARI event.

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

- A detention dam (at one of two alternative sites)
- High flow bypass culverts
- 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 3.3.

In addition to these components, all of the options include undertaking maintenance works along the full length of upper Brown Hill Creek to rehabilitate the creek towards achieving a state of good condition. This is discussed in Section 6.1.

5.1.1 Detention dam

A detention dam temporarily stores floodwater generated during a major storm, thereby reducing and controlling the rate of water flowing downstream. In this case a detention dam is designed to 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 (refer Section 3.3)
- Options B1 and B2 – creek capacity upgrade works in Areas 1, 3, 5A and Orphanage Park.

5.1.2 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.

As described above, 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.

5.1.3 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.

It should be noted 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 5.3, 5.4 and 5.5. The designs are based on analysis of MIKE-Flood modelling results (both in terms of the floodplain mapping and Mike 11 flows). Where significant break-outs are evident, the approximate channel dimensions have been adjusted in the model so that break-outs are eliminated (ie flows are therefore contained to the ‘modified’ creek).

In describing creek capacity upgrade works required for Options B1, B2 and D, the estimated properties requiring works are identified. However 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 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 BHKC project aims 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 5 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.

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

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)

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

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

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 was engaged to do 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 above 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.

5.2 Overview of Brown Hill Creek

As outlined in Section 3.3, upper Brown Hill Creek can be categorised into sections as follows (with reference to maps at Appendix 7).

5.2.1 Area 1

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

This section is unique insofar as the property owners generally do not use the creek for any amenity value, as evident from the fence line which separates the creek 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 (ie into Wilberforce Walk)
- A public authority (ie the Project) 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.

5.2.2 Council 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.

5.2.3 Forestville Reserve

Following its upgrading about ten years ago, and with subsequent maturing of its vegetation, Forestville Reserve is an amenity which is highly valued 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.

5.2.4 Diversion culvert

A section of Brown Hill Creek in Forestville was diverted by DPTI in 2012/13 as part of its Goodwood Junction rail upgrade project. The creek was diverted into a new underground culvert constructed along the eastern side of the railway corridor from the creek on the south side of Victoria Street, Goodwood to the northern side of the Glenelg tramway, to discharge into the existing Brown Hill creek within Forestville Reserve.

The new culvert, combined with overflow provisions to convey flows greater than 28 m^3/s over and under the railway lines into the existing 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.

5.2.5 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 runs well inside the boundaries and is integrated with the amenity area at the side and rear of the house. Other properties in this section do not appear to use the creek and generally maintenance appears to be 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, and does not appear to be 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. It is substantially fenced off from the private properties through which it traverses. For a length of 50 metres 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. There is an exception to this, where the creek is landscaped into an owner's property and is readily accessible.

5.2.6 Orphanage Park

Brown Hill Creek bisects Orphanage Park for a length of about 230 metres. Although the alignment is regular, 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.

Orphanage Park was acquired for public ownership in 1999/2000 and the eastern portion, comprising mainly the park area, was annexed by Unley Council for community recreation.

Any solution 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 the Unley Council. This 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."

5.2.7 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 metres high, although lower in places. Ground cover, vegetation and naturalised trees of generally exotic variety 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 built presumably by the private owners from time to time. The walls are built in a range of construction types, including concrete, mortared block work, mortared stone and dry-stacked stone. For a short distance downstream of Malcolm Street, there is a short length of gabion support which may have been installed as part of the road bridge construction.

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.

5.2.8 Area 4

From Malcolm Street to Northgate Street/Heywood 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.

Upstream of Heywood Avenue, the creek is characterised by poor alignment with several acute angle bends. There is a channelized length (concrete base and mortared stone sides) with a series of vertical drops which would act to slow down the flow of water. Generally, between Malcolm Street and Heywood Park, the creek is similar to Area 3 in terms of amenity and usage. Through Unley Park properties, 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 metres 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.

5.2.9 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 metres 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.

Generally, 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 eastern 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.

5.2.10 Soldiers Memorial, JW Morris and Delwood Reserves

In 2011, the City of Mitcham 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 with sufficient capacity for 100 year ARI peak flows.

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 City of Mitcham.

5.2.11 Mitcham shopping centre

For the most part, Brown Hill Creek enters a culvert on the upstream (eastern) side of the shopping centre and, except for about a 60 metre 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 metres) and open channel section can convey the peak flow (ie no dam) without requiring creek capacity upgrade works.

5.2.12 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, grassy banks. A short distance downstream of Fife Avenue (over a short radius180 degree bend) the creek has been significantly landscaped with boulders and the sides engineered with retaining walls of mortared stone or 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 metres upstream of Paisley Avenue.

5.2.13 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, grassy banks.

5.3 Options A1, A2, B1 and 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.

5.3.1 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 megalitres capacity and 12 metres 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 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, the watershed created by any increased height would impact on nearby houses.

The Site 2 dam is located in Ellisons Gully, a tributary of Brown Hill Creek. Due to its location, the Site 2 dam needs to be much larger in size (355 megalitres capacity with wall height of 19.5 metres) 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 flow from a Site 1 dam.

The 2012 SMP outlines at Section 11.2.1 that under the 2012 hydrology, the 90 minute peak flow caused 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 Section 4.9.4.

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 6.

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 ‘desk top’ 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. The SMEC report is listed in the References to this report.

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 7, including the cost of land and easement acquisitions at dam Site 2 as assessed by Maloney Field Services.

5.3.2 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 connect into the creek diversion works installed by DPTI just south of Victoria Street, Goodwood.

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. If a dam at Site 2 had been recommended in the 2012 SMP, it would have been designed on the same principle.

The Malcolm Street to Victoria Street culvert is incorporated in Options A1 and A2, supplemented with creek capacity upgrade works from Anzac Highway to Leah Street (Area 1) and Hampton Street to 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 4.9.4).

As such, the Malcolm Street to Victoria Street culvert can be replaced with creek capacity upgrade works between Mitchell and Malcolm Streets (including Orphanage Park) in Unley. This is the scenario for Options B1 and B2.

5.3.3 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 7.1). 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 5.1.3). It should be noted for both Options B1 and B2, 8 properties are in Area 1 which is within the Part A Works of the BHKC project.

Approximate channel dimensions applied to the hydraulic modelling for Option B1 and B2 (together with Option D) are shown in cross-sections at Appendix 9.

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 7:

- Streamline the transition on both sides of Leah Street culvert – to match the existing bridge width of 4.5 metres
- Streamline the transition on both sides of First Avenue culvert – based on the proposed bridge upgrade width of 6 metres
- Streamline the transition on both sides of Second Avenue culvert – based on the proposed bridge upgrade width of 6 metres
- Streamline the transition on both sides of Third Avenue culvert – to match the existing bridge width of 6 metres
- Between Second and Third Avenues, widen the base to 5 metres (existing width is about 1.5 metres at the concrete base to 2.5 metres at the lower bank)
- Between Second and Third Avenues raise both bank heights by 0.5 metres in places to achieve minimum 2.5 metres channel depth
- Between Third Avenue and Anzac Highway, raise both bank heights by about 0.5 metres to achieve minimum 2.5 metres channel depth.

Orphanage Park

Preliminary concept plan options have been prepared for Orphanage Park for Option D as outlined in Section 5.5.6. 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 eleven 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 7:

- Between Douglas and Regent Streets, achieve 4 metres base width (from the existing width of about 1.5 – 2.5 metres) and 2.5 metres depth of channel (similar to Option D at Section 5.5.7)
- Between Regent and Avenue Streets:
    - Raise the northern/eastern bank as required in places to achieve 2.5 metres depth of channel (generally a raising of about 0.5 metres)
    - Widen the base to about 4 metres for a length of about 70 metres upstream of Regent Street (existing base width is about 1.5 – 2.5 metres)
- Between Avenue and Malcolm Streets:
    - Raise the northern/eastern bank as required in places to achieve 2.5 metres depth of channel (generally a raising of about 0.5 metres)

  - A length of about 35 metres of creek bed (approximately 65 to 100 metres 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 metres
- 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 7:

- 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 metres depth of channel (generally a raising of about 0.5 metres)
  - Between Regent and Avenue Streets, raise the eastern bank as required in places to achieve 2.5 metres depth of channel (generally a raising of about 0.5 metres)
- Streamline the transition on both sides of Regent Street bridge – based on the proposed bridge upgrade width of 4 metres
- 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 7:

- Widen the creek channel (existing base varies from about 1.5 to 2.5 metres) predominately on the eastern side of the creek to about 3.5 metres which is a lesser extent than for Option D (Section 5.5.9).

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 5.5.12).

5.3.4 Public road bridge upgrades

For Options B1 and B2, the following public road bridge upgrades are required:

Bridge	Current form (with dimensions in metres)	Proposed upgrade (with 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 metre 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

5.4 Options C1, C2 and C3

Options C1, C2 and C3 incorporate high flow bypass culverts and creek capacity upgrade works.

5.4.1 High flow bypass culverts

In addition to the Malcolm Street to Victoria Street culvert discussed above in Section 5.3.2, the 2012 SMP investigated two other routes which incorporate but extend on 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 1. 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 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.

5.4.2 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.

5.5 Option D

Option D involves upgrading the capacity of approximately 1.9 kilometres of the creek at critical sections over the full length of upper Brown Hill Creek, as well as upgrading specific creek choke points including public and private bridges.

This option provides about the same flood mitigation protection as other options but does not require a flood detention dam or high flow bypass culverts.

The 2013 hydrologic modelling (refer Section 4.9) 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). This presented the opportunity to re-assess upgrading the creek's capacity as a feasible flood mitigation option for upper Brown Hill Creek.

The creek capacity upgrade concept is designed to mitigate flooding at a catchment scale. The exact scope of creek capacity upgrade works and the extent to which individual properties would be protected, would be determined during the detailed design phase. Approximate channel dimensions applied to the hydraulic modelling for Option D (together with Options B1 and B2) are shown in cross-sections at Appendix 9.

Proposed capacity upgrade works for each section of upper Brown Hill Creek (refer Section 3.3) 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 5.1.3). 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.

5.5.1 Area 1 – Anzac Highway to Leah Street (Part A Works)

Proposed creek capacity upgrade works would affect an estimated ten properties as identified in the plan at Appendix 7:

- 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 metres (at existing invert level) from the existing concrete channel width of about 1.5 metres. 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 metres and therefore the tops of the banks may need to be raised about 0.5 to 0.75 metres 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 metres (from about 1.5 metres) 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 metres 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 metres 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 5.5.2. The same capacity upgrade works to the channel as described in Section 5.5.2 apply to the section of channel through the two properties.

5.5.2 Council owned channel – Leah Street to Ethel Street (Part A Works)

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 metres existing) by up to 0.5 metres.

5.5.3 Forestville Reserve (Part A Works)

Proposed creek capacity upgrade works:

- 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 metres (with removal of the concrete channel with a width of about 1.5 metres) and re-form the banks to achieve a uniform batter.

5.5.4 Diversion culvert – Forestville Reserve to Victoria Street (Part A Works)

No works are required.

5.5.5 Area 2 – Victoria Street (Goodwood) 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 7:

- From the DPTI culvert for a length of about 100 metres upstream, raise the banks by about 0.5 to 1 metre to achieve a channel depth of about 2.5 metres and widen the channel base to about 5 metres from the existing base width of about 2 metres
- 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 (ie vertical, stepped or laid-back – as described at Section 5.1.3)
- 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 7:

- Widen the channel base (1.5 to 2 metres existing width) to about 4.5 metres 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 metre 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.

5.5.6 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 17m^3/s) to convey the required 30m^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 10 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 storm water 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 storm water 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.

5.5.7 Area 3 – Douglas Street to Malcolm Street

Proposed creek capacity upgrade works would affect an estimated fourteen 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 7:

- In general, the creek over the full length of this area requires cross-sectional dimensions having a base width of about 4 metres and a depth of about 2.5 metres. The existing base width is generally about 1.5 – 2.5 metres and depth is generally about 2 – 2.5 metres. Where the bank height is less than 2.5 metres and the creek is roughly trapezoidal in shape (ie 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 metres (approximately 65 to 100 metres 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
  - Two significant River Red Gums in No. 1 Douglas Street
- Raise, replace or remove five private footbridges.

5.5.8 Area 4 – Malcolm Street to Cross Road

No creek capacity upgrade works proposed.

5.5.9 Area 5 – Cross Road to Belair Road

Area 5A: Cross Road to Hampton Street

Proposed creek capacity upgrade works would affect an estimated ten 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 7:

- In general, the channel base needs to be widened to about 4.5 metres (the existing base varies from about 1.5 to 3 metres)
- 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
  - Raise the western bank by about 0.5 metre 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 metres 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 7:

- Replace two driveway bridges at 40A and 42 Kent Street
- Near the southern boundary 42 Kent Street, the creek narrows for about 10 metres, forming a constriction. Subject to detailed design, a feasible design to widen the creek to about 4 metres (whilst retaining existing invert level) is to:
  - Retain the large tree if necessary
  - 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. 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 traversed 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 2.0m 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 metres where possible, construction of some low level retaining, flood walls and levees, creek bed and bank grading improvements and bank stabilisation.

5.5.10 Soldiers Memorial Gardens, JWS Morris Park 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.

5.5.11 Mitcham Shopping Centre

No creek capacity upgrade works are proposed.

5.5.12 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 7:

- Replace two private driveway bridges at 17B and 19 Fife Avenue
- In general, the creek for a length of about 80 metres upstream of 22A Fife Avenue to about 20 metres of Blakissoch Road footbridge needs to have a cross-sectional area equivalent to a base width of about 4 metres and a depth of about 2 metres (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 channelization of irregular shape, to about 4 metres wide base.
- From the Blakissoch Road footbridge to Paisley Avenue, the creek traverses the property of No. 15 Paisley Avenue over a distance of about 35 metres. The house at No. 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 7:

- 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 metres 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 metres
- There is a critical section of creek (flooding break-out) about 180 metres 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 metres.

5.5.13 Area 7 –Muggs Hill Road to Brown Hill Creek Caravan Park

No creek capacity upgrade works are proposed.

5.6 Public road bridge upgrades

For Option D, public road bridge upgrades are required at:

Bridge	Current form (with dimensions in metres)	Proposed upgrade (with 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
Orphanage Park (internal road)	5.25 metre 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	4 x 2

6 Non-Technical Considerations

This section discusses additional aspects considered in the Part B process:

- Proposed creek rehabilitation and maintenance works – which are different to, and separate from, proposed creek capacity upgrade works
- Easements or agreements required to undertake creek capacity upgrade works
- Community feedback to date on Part B flood mitigation options and proposed creek maintenance works.

6.1 Maintaining the creek in good condition

6.1.1 Overview

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 6.1.3, the AMLRNRMB is currently preparing a code of 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 11.

The responsibility for maintenance of watercourses on private land, as between property owners, local government and state public authorities, has been a contentious issue for a long time.

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 Section 6.1.2.

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 costing arrangements are discussed in Section 6.1.4.

6.1.2 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 has been obtained requiring details reported in the 2012 SMP to be clarified and updated. The following discussion therefore 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 Natural Resources Management (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:

- Not to undertake water affecting activities (outlined below) without a permit or contrary to the relevant NRM Plan
- General duty to act reasonably in relation to watercourses (a very broad obligation in relation to the management of natural resources)
- To prevent damage to a watercourse
- Liability to maintain a 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
- 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 lightly 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 the issuing an order under section 16 of the Local Government Act Schedule 1A.

Powers and responsibilities in relation to creeks are summarised at Appendix 12.

6.1.3 Defining 'good condition'

The AMLRNRMB in consultation with the BHKC project, the South Australian Local Government Association and the Department of Environment, Water and Natural Resources (DEWNR) is currently preparing a code of practice for maintenance of urban watercourses.

The code of 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
- Erosion repair and control.

In terms of routine maintenance, particularly for stormwater conveyance, the BHKC project has adopted the following general principles and incorporated these into all of the eight flood mitigation options:

- 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
- 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.

The BHKC project will also incorporate natural resource management principles as follows:

- 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 (eg 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
- 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.

6.1.4 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 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
- 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 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
- On-going routine maintenance such as removal of fallen timber within the creek and removal of 'foreign' matter such as building debris 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 7).

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.

6.2 Requirements for an easement or agreement

During the development of the Part B options, the BHKC project engaged with a number of stakeholder groups as well as undertook direct consultation with creek owners who were potentially affected by creek capacity upgrade works. This initial consultation highlighted that easements are likely to be a major concern for a number of property owners.

As outlined in Section 5, all eight options to Part B, include creek capacity upgrade works of varying extent.

In executing any of the proposed options, the BHKC project must operate in accordance with relevant legislation. 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 a stormwater management plan approved by the SMA and gazetted.

Provided the proposed works do not entail the construction of permanent infrastructure (eg 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 stabilization 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 on-going care, control and management of the works
- Where the property owner wants the AMLRNRMB or council to retain on-going responsibility for care, control and management of the permanent works, then the NRM Board or council must acquire an easement.

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 on-going 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.

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 on-going 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.

The project does not propose to seek easements along the entire length of upper Brown Hill Creek. The project is also not planning to create a drainage 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 6.1. 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.

Other key points are:

- An individual property owner will be able to choose the form of arrangement – either an agreement or easement
- An agreement would not be attached to the title, and would terminate if the property is sold
- An easement will generally transfer a requirement onto the BHKC project/council to be responsible for and/or undertake certain things (eg 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 BHKC project/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 BHKC project
- 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 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 7.2.6.

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 BHKC project 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 BHKC project, subject first to either acquisition of an easement over the works or entering into an agreement
- The BHKC project 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 BHKC project or landowner.

6.3 Environmental impacts

Environmental assessment of the Part B investigations has largely focussed 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 project aims 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 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.

6.3.1 Dams

Based on general site inspections and photographic records, a preliminary desk top 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.

6.3.2 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 (designated 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/Regulated depending on the bypass option chosen. Appendix 13 lists the summary tables from the Treevolution report detailing the number of structural root zone impacted trees.

6.3.3 Creek capacity upgrade and creek rehabilitation works

Based on general site inspections and photographic records, a preliminary desk top estimate has been 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. This assessment has only been undertaken for Options B1, B2 and D for the privately owned sections of the creek.

The location and approximate size of these trees are summarised below, with approximately 179 trees impacted by Options B1 and B2 and 229 trees for Option D. Removal of trees would be compensated by appropriate replanting of native trees on top of the creek banks.

AREA	Girth of tree						Total number of trees	
	Greater than 300mm		150-300 mm		Less than 150 mm			
Option	**B1/B2**	**D**	**B1/B2**	**D**	**B1/B2**	**D**	**B1/B2**	**D**
Area 1	8	10	24	24	13	13	45	47
Area 2	12	36	7	7	10	10	29	53
Area 3	11	11	12	12	5	5	28	28
Area 4	5	12	7	7	5	6	17	25
Area 5	4	9	8	9	3	3	15	21
Area 6	6	8	10	17	29	30	45	55
Total	46	86	68	76	65	67	179	229

In addition to the above numbers, 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 (refer Section 5.5). However it is assumed that the proposed creek capacity upgrade works can be designed to ensure all of these trees are retained.

6.4 Community feedback

In assessing flood mitigation options, consideration has been given by the BHKC project to:

- Community feedback obtained during the consultation process on the draft 2011 SMP, particularly regarding the (then) proposed construction of a detention dam in Brown Hill Creek Recreation Park (Site 1)
- Community feedback obtained following distribution of information in mid-2013 to potentially impacted property owners, regarding progress on investigating flood mitigation options reliant on high flow bypass culverts though the streets of Unley
- Preliminary consultation, conducted between April and August 2014, with creek owners regarding creek capacity upgrades required under Option D (a subset of which are also impacted by Options B1 and B2 as discussed in Section 5.3)
- Preliminary consultation, conducted in June 2014, regarding options for managing stormwater flows through Orphanage Park under a 'creek capacity upgrade' option (refer Section 5.5.6)
- Ongoing discussions with representatives of various special interest groups that have formed in response to specific community concerns including:
  - No Dam in Brown Hill Creek Community Action Group
  - Save our Streets Community Action Group (SOSCAG)
  - Save Our Creek Environs Trees (SOCKET).

Throughout these engagement processes, varying viewpoints have been expressed both for and against key components of flood mitigation options, namely: a dam (at Site 1 or Site 2), high flow bypass culverts, creek capacity upgrade works and creek rehabilitation.

This section summarises the key concerns that have emerged through the above consultation processes regarding each of these key flood mitigation components.

It is noted that, to date, only preliminary consultation has been undertaken regarding creek capacity upgrade works and creek rehabilitation. Proposed consultation on this report (refer Section 9.1) will provide opportunities for a wide cross-section of the community, who are either impacted by flooding and/or proposed mitigation works, to participate in providing their views prior to a final decision being made.

6.4.1 Detention Dam

Detention Dam at Site 1

The draft 2011 SMP proposed the construction of a flood control dam in the Brown Hill Creek Recreation Park (Site 1).

The history of Brown Hill Creek Recreation Park, together with environmental, cultural heritage, recreational and tourism characteristics and qualities of the park and how these should be managed are documented in the *Brown Hill Creek Recreation Park Management Plan* produced in 2003 by the (then) State Government Department of Environment and Heritage.

The management plan notes that the park is one of Adelaide's oldest parks and is classified as a Natural Monument (IUCN Category III); described as "an area containing one, or more, specific natural or natural/cultural features of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance" (*Brown Hill Creek Recreation Park Management Plan,* Section 3).

A comprehensive consultation process was undertaken in late 2011 to seek feedback on specific components of the draft 2011 SMP. Analysis of the feedback forms, received from over 2,000 respondents, showed that although the proposed dam was supported by 60% of respondents it was the least supported component of the draft 2011 SMP. The executive summary of the 2012 *Brown Hill Keswick Creek Draft Stormwater Management Plan Community Consultation Report* states that:

> "Based on the feedback forms as well as information received via meetings and written submissions three key viewpoints (excluding the petition which is dealt with separately below), 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 that 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
> - Support for the dam together with concerns that the 'no dams' position may continue to delay implementation of mitigation works."

The petition referred to above, at that stage signed by over 4,000 people, called for the City of Mitcham to "protect the environment and heritage of Brown Hill Creek by opposing the damming of the Creek". In February 2014, a No Dam in Brown Hill Creek petition with over 10,000 signatories was officially lodged with Mitcham Council. Over 60% of the signatories are from outside the Mitcham Council area which is reflective of the high visitation to the park, estimated in 2003 to be 30,000 to 40,000 people per year (*Brown Hill Creek Recreation Park Management Plan*, 2003). Used by walkers, bike riders and joggers, the park is a popular tourist and recreational resource connecting Mitcham Village at the western end of the valley and trails in the Mitcham Hills.

Groups that support a 'no dam' position include: No Dam in Brown Hill Creek Community Action Group, Conservation Council SA, National Trust of South Australia, Nature Foundation SA, the Kaurna Nation Cultural Heritage Association, Mitcham Historical Society and the Friends of Brown Hill Creek.

Community concerns regarding the construction of a dam in Site 1 relate primarily to:

- Detrimental impacts on the environment and heritage values of Brown Hill Creek Recreation Park including risks to:
    - Fauna: particularly threatened species of native mammals, fish, reptiles, amphibians and birds
    - Flora: particularly the four remaining Stone 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

- Ecological restoration works within the park that have been undertaken by volunteers over the last 20 years including local school, service clubs and Friends of Brown Hill Creek
  - Aboriginal heritage: the park is a unique and important part of the living Kaurna culture today, known as 'Wirraparinga': place of scrub and creek
  - European heritage: including Mundy's Quarry wagon loading bay and crushing plant foundations
- Detrimental impacts on the tourist and recreational amenity of the park as a dam would:
  - Dissect the heart of the park resulting in loss of the picnic area developed by the Mitcham Lions Club
  - Disrupt the vista within the Brown Hill Creek valley
  - Act as a barrier to recreational use, particularly to the Warraparinga wilderness walk
  - Place park users at risk if the dam were to fail, with very limited time to issue evacuation warnings
- Detrimental impacts on, and safety risks to, nearby residents resulting from the:
  - Visual impacts and safety risks of the proposed 12m high dam
  - Impeded access with residents living upstream of the dam being unable to exit or enter their properties if the dam were full because the backwater from the dam would flood the only access road
- Construction impacts, as local residents would be adversely affected by:
  - High volumes of truck movements, noise and dust via narrow local roads from Taylors Road
  - The requirement to upgrade existing road infrastructure to cope with the weight and frequency of construction vehicles
  - The need to establish a storage compound in close proximity to the dam site
- The ineffectiveness of a dam in protecting the urban section of the catchment
- The final design and dimensions of a dam, noting that in 2011 this was presented as a concept with minimal detail
- The cost of a dam; with concerns that the costs in the draft 2011 SMP were underestimated.

Detention Dam at Site 2

As an alternative to a dam at Site 1, a second site at Ellisons Gully has been considered. Site 2 is located approximately 200m north of the intersection of Tilleys Hill Road and Brown Hill Creek Road (refer Appendix 16).

Community feedback during preliminary consultations with property owners and residents regarding the creek capacity upgrade works (refer Section 6.4.3) has indicated that those preferring a dam based solution consider that a dam at Site 2 could be a good compromise option as it is located on private property as opposed to a public park.

However, as highlighted by other community members, the No Dam Petition, with over 10,000 signatories, applies equally to Ellisons Gully as Brown Hill Creek Recreation Park as the petition opposes ‘damming of the creek’.

Specific community concerns raised in relation to Ellisons Gully include:

- Detrimental impacts on the environmental and heritage values of the area including:
  - Fauna and flora as per Site 1 given that the Ellisons Gully creek is a contributory of Brown Hill Creek and therefore shares a common riparian zone
  - Aboriginal heritage: with the Kaurna community opposing any damming of the creek
  - European heritage: including impacts on the Mitcham Water Works water supply pipeline
- Detrimental impacts on the tourist and recreational amenity of the area as, although Site 2 is in private ownership, there is a public right of way along the riparian zone and an interpretive public heritage trail is planned to run from the entrance of Brown Hill Creek Recreation Park to the Mitcham Waterworks heritage site at the head of Ellisons Gully. A dam at Site 2 would:
  - Restrict public access into the valley
  - Have a significant impact on the visual amenity of the area which has extensive views across the plains and hills
  - Place recreational users at risk if the dam were to fail, with very limited time to issue evacuation warnings
- Detrimental impacts on, and safety risks to, nearby residents with:
  - Acquisition of land required on two private properties which the dam site straddles. Considerable works have been undertaken on one of the properties to upgrade and recover the agricultural value of the land
  - Easements required on the above two properties and a third property impacted by the 100 year ARI watershed
  - Visual impacts and safety risks of the proposed 19.5 metre high dam on a residential dwelling approximately 200 metres downstream of the dam is likely to result in the property owner selling their house to avoid both construction and post construction impacts
  - A number of parcels of land (currently owned by one landholder) being landlocked, requiring either an alternative new access or separate titles to be combined into a single title
- Construction impacts: The same as for a dam at Site 1.

6.4.2 High flow bypass culverts

A number of bypass or diversion culverts were proposed in the draft 2011 SMP including, in the upper Brown Hill Creek part of the catchment, a high flow bypass system in the form of a box culvert (approximately 1,670 metres long, 1.8 metres wide and 1.5 metres high) from Malcolm Street, Millswood to Forestville Reserve, via Vardon Terrace, Goodwood Road, Arundel Avenue, Chelmsford Avenue, Oakley Avenue, Victoria Street and Foster Street.

During the 2011 consultation process, community feedback was sought on bypass and diversion culverts (collectively rather than by each specific culvert). The 2012 community consultation report notes high levels of support, with 82% of all respondents indicating support for bypass and diversion culverts. However, there was limited understanding of the impact on street trees and disruption to the community at that time.

In light of the high level of opposition to a construction of a dam during the 2011 consultation process, the BHKC project proceeded to investigate alternative 'no dam' options, including extended high flow bypass culverts in the Unley Council area.

In May 2013 a brochure outlining the scope of Part A and Part B works was mailed to over 3,000 addresses in Unley. The brochure focussed mainly on the stormwater high flow bypass culverts being considered in the Part B process. In addition to the Malcolm Street to Victoria Street culvert, the brochure outlined two alternative extended routes (Routes 3 and 3A) that were being considered under 'no dam' scenarios (refer Section 5.4.1).

The brochure raised considerable concern amongst residents and property owners about the likely impacts of high flow bypass culvert options on the ambience and character of streetscapes and suburbs, particularly Unley Park and Millswood. The 'Save our Streets Community Action Group' (SOSCAG) formed in response to these concerns.

Specific community concerns include:

- Detrimental impacts on the streetscape environment with:
  - Risks of damage to, and destruction of, hundreds of street trees
  - Associated loss of natural habitat and bird life
- Overall loss of streetscape character and resultant loss in property values
- Significant disruption to local residents during the construction phase including:
  - Restricted access to properties, and difficulty in finding available car parking in close proximity to houses
  - Safety risks including restricted access for emergency vehicles, dangers of excavation works/machinery particularly to children and pets
  - Noise, dust and vibrations from construction works (noting that vibrations may damage the structural integrity of houses)
  - Possible loss of gas, water, sewerage and telecommunications services due to excavation and relocation
- Broader community based impacts including:
  - Disruption to the major arterial traffic during construction (particularly Cross Road and Goodwood Road)
  - Risk to essential utility services such as telecommunications and rail operations.

The experience of residents and property owners during the construction of the DPTI culvert along Devon Street, Goodwood also raised significant concerns amongst the community that a similar impact could occur along streets of the high flow bypass culverts.

Taking account of community concerns as well as the findings of the Treevolution assessment of potential damage to trees (refer Section 6.3), the City of Unley at their council meeting on 25 November, 2013 formally acknowledged “that many Unley residents will not accept any option that has high flow culverts in Unley streets and seeks to find a viable option that achieves this”.

6.4.3 Creek capacity upgrade works

The draft 2011 SMP included proposals to upgrade the creek channel to create more capacity for stormwater flows, between:

- Hampton Street and Cross Road, Hawthorn
- Leah Street and Anzac Highway, Forestville, plus bridge upgrade at Charles Street
- Anzac Highway, Ashford and the confluence of Brown Hill and Keswick Creeks at Adelaide Airport.

Minor upgrades to some sections of Brown Hill Creek through Mitcham were also identified.

The 2012 community consultation report notes high levels of support, with 88% of all respondents indicating support for channel upgrades (collectively rather than by each specific area). Specific concerns identified in written submissions were noted in Section 6.1 of the community consultation report, including:

- “Concern over private property acquisition associated with channel upgrades
- Do not want existing erosion gabions removed near Wilberforce Walk
- Concern over removal of vegetation and construction of a cement drain between Hampton Street and Cross Road. An engineered solution incorporating levees should be negotiated with each land owner on this section of the creek
- Desire for new infrastructure to not impact on lifestyle amenity or devalue property”.

In relation to the third dot point above, the draft 2011 SMP proposed the construction of a concrete lined channel (250 metres long by 4 metres base width and 2 metres in height) between Hampton Street and Cross Road. A detailed response was received by the property owners located in this section of the creek opposing this proposal. They indicated support for a whole of catchment approach to flood mitigation and presented an alternative proposal of designing an individual levy for each property; for example, increasing the embankment with rammed earth, stepped terracing of the embankment or, in situations where the creek runs close to properties or fixed infrastructure, use of retaining walls or rock gabions.

The above approach has subsequently been adopted by the BHKC project as discussed in Section 5.1.3.

Preliminary consultation has been undertaken with property owners regarding creek capacity upgrade works as proposed in Section 5. Consultation commenced in April 2014, following agreement in February 2014 by the five participating councils to place priority on investigating a 'Creek Capacity Upgrade' option and to engage with directly affected property owners to identify any potential issues associated with this solution.

Area based meetings were initially conducted to provide an overview of potential creek capacity upgrade works. Separate sessions were held for owners of properties located in Areas 1, 2, 3 and 4 and a combined meeting for Areas 5 and 6 (refer Section 3.3 for description of area locations). Following these meetings, a number of individual site meetings with property owners were conducted to discuss specific concerns and opportunities, particularly regarding how any creek capacity upgrade works could be integrated with their existing landscape treatments.

As discussed in Section 5.2.1, property owners in Area 1 identified a number of opportunities for improving the current issues associated with the creek in this area. Following the area meeting and site visits, several property owners have forwarded written support for works to be undertaken.

Responses from property owners in other sections of the creek have been mixed, depending largely on whether the creek is integrated into, or a feature of, their existing landscaping. Where the creek is fenced off and/or not visible from the house or yard, property owners are generally supportive of creek capacity upgrade works being undertaken.

However considerable concerns have been raised by property owners where the creek is an integral component of their property's landscaping. The 'Save Our Creek Environs Trees' (SOCKET) group was formed in response to these concerns, which include:

- Detrimental visual and amenity impacts on private properties including:
  - Loss of trees and vegetation, and associated habitat for birds and wildlife
  - Loss of useable land and/or encroachment on outdoor facilities such as tennis courts and swimming pools
  - Concern regarding the nature of materials to be used – with a strong concern that a 'concrete channel' will be created
  - Frustration with the lack of detail currently available regarding specific works that would be required on their property
  - Concern that further widening of the creek channel may be required in the future
  - Concern regarding the adequacy of project funds to undertake works and make good any damage to existing landscapes
- Concerns regarding access and safety arising if modifications to the creek reduce:
  - Safe access into and out of the creek
  - Safe access to sections of their property bisected by the creek
- Detrimental environmental impacts including scouring of the creek bed and banks and associated loss of trees and vegetation due to higher velocity of flows resulting from increasing the creek capacity

- Significant disruption during the construction phase to:
  - Individual property owners where works are required, including noise, dust, inconvenience, restricted access to property etc
  - Nearby residents with movement of vehicles and materials
- Requirement for an easement, with strong concerns that an easement will:
  - Result in loss of property value
  - Relinquish property owners' of control over future works. In particular, there is a concern that if the required creek capacity upgrades have been underestimated, or increase in the future, that further works could be undertaken without the consent of the owner

  A number of property owners have indicated their support for the project taking responsibility for on-going maintenance of infrastructure assets, however this requires an easement (refer Section 6.2)
- Reduction of property values due to impact of works and requirements for an easement/agreement
- The efficacy of Option D, (creek capacity upgrade works) to provide effective flood protection flooding as this is conditional on the obtainment of an easement/agreement from all property owners.

Community feedback regarding proposed creek capacity upgrade works at Orphanage Park is discussed in Section 5.5.6.

6.4.4 Creek maintenance works

Previous community consultation materials (2011 draft SMP community engagement brochures and the May 2013 brochure regarding culverts) identify the need for creek maintenance works to clear impediments, including vegetation, that block flows along the creek.

The 2012 community consultation report notes that 'Support for improvements to creek maintenance programs' received 93% support overall, which was the highest level of support for a specific component of the draft 2011 SMP.

However, based on preliminary consultation with property owners regarding creek capacity upgrade works, it is evident that:

- Many property owners are unaware of their responsibilities to maintain their section of the creek in 'good condition' (as outlined in Section 6.1)
- Many property owners and adjoining owners are likely to have concerns about the proposed 'one off' extraordinary creek maintenance outlined in Section 6.1.4
- There is a perception that creek maintenance works are only required under Option D, not for all options as indicated in Section 6.1.4.

Initial concerns have been expressed that removal of vegetation and trees will impact on the visual and environmental amenity of the creek. Although it is proposed that the 'one off' extraordinary creek maintenance will entail progressive removal of invasive vegetation, concern is likely to be expressed regarding the lag time in re-establishing native plants on top of the banks.

7 Financial Considerations

7.1 Total cost estimates

Costplan was engaged to review and if necessary update cost estimates in the 2012 SMP. Costplan provides a civil engineering based cost planning, estimating, project management and planning service to government agencies, consultants and construction contractors. The objectives sought for all cost estimates include consistency of risk and overheads, greater rigour and transparency, local knowledge, and common dollar values (nominally 2013/14).

Capital costs of all options are summarised as follows:

		Estimated costs ($M)							
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 above costs do not include an amortised amount for depreciation and maintenance over the asset lives. Present value whole of life costs are discussed at Section 7.3.

Each of the component costs are described in more detail in Section 7.2 as well as Appendix 14.

7.2 Component cost estimates

7.2.1 Detention dam

The estimated cost of a dam at Site 1 (Brown Hill Creek Recreation Park) reported in the 2012 SMP is $10.8 million (2012 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 5.3.1, the BHKC project engaged SMEC 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 has 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):

	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 15.

For the BHKC project costings, the estimated costs of Options A1 and BI 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. The amount takes into account an arrangement to enable legal road frontage to be maintained to affected properties and an area of easement for periodic flooding purposes (due to 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 16.

7.2.2 High flow bypass culverts

The estimated costs of culvert options of the 2012 SMP (Section 2.3 and with reference to Appendix 1) were re-estimated.

	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 17.

7.2.3 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 18.

7.2.4 Public bridge upgrades

Public bridges need to be replaced under Options B1 and B2 (refer Section 5.3.4) and Option D (refer Section 5.5). 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 18.

7.2.5 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 in 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 18.

7.2.6 Easements

Maloney Field Services (MFS) provided advice in relation to the process and cost of procuring 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 procured).

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
- Contingency at 10%.

Assumptions by MFS include:

- Acquisitions are for easements rather than 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 metres 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 project capital costs (Section 7.1 and in Appendix 14) allow for easements on all the properties identified for creek capacity upgrade works. In reality 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 upper bound costs.

Estimated easement costs are detailed at Appendix 19.

7.2.7 Brown Hill Creek diversion by DPTI

All options include a cost of $5 million by the BHKC project for the DPTI culvert (refer Section 5.2.4).

7.3 Economic assessment

7.3.1 Whole of life cost

In terms of capital costs (construction, land and easement costs) benefit-cost ratios have been assessed for Options B1, B2 and D by applying the methodology outlined in the 2012 SMP at Sections 7.4 and 9.2.

Maintenance costs of civil engineering assets, including culverts, dams, retaining walls and earthworks are assumed to be about 0.2% of asset construction cost on an annual basis. Maintenance costs of creek rehabilitation are assumed to be about $100,000 per annum.

		Annual maintenance			
Option	**Assets ($M)**	**Assets ($)**	**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 procuring easements and the initial cost of rehabilitating the creek towards achieving good condition because those costs do not attract annual maintenance.

For the present value (PV) analysis:

- A study period of 100 years is assumed
- A real discount rate of 6% is applied (as recommended by Department of Treasury and Finance, SA Government)
- For a real discount rate of 4%, the respective PV values are $39.4 M (Option B1), $41.9 M (Option B2) and $35.1 M (Option D)
- Option D assumes that the 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 values are dominated by the initial capital cost, as evident from the diminished values for Options B1 and B2 due to capital cost spread over a nominal period of three years. The values are relatively insensitive to the annual cost of maintenance. The PV of Option D is marginally higher than its initial capital cost due to full renewal after 50 years.

7.3.2 Reduction in Flood Damages

Flood damages for the Part B Works process have been estimated using the same geographic information system (GIS) techniques used in the development of the 2012 SMP.

Existing damages for upper Brown Hill Creek flows were calculated to provide a base case for assessment of the relative benefit offered by the Part B Works. These base case damages were assessed using the flood mapping for base case conditions and the GIS property database for the catchment, which includes a total of some 25,000+ properties.

The assessment has only considered the impact of upper Brown Hill Creek flows (ie those feeding into the creek down to Anzac Highway). It accounts for breakouts from the creek that would occur down to Anzac Highway and includes the impact of these breakouts as they travel through Mitcham and Unley and into the West Torrens council area. The assessment assumes that the Part A Works have been completed and are effective in reducing/eliminating flooding from other reaches of other creeks (eg Glen Osmond Creek and lower Brown Hill Creek). This is considered to be an appropriate approach for assessing the relative benefit of the Part B Works.

Using the same approach, an assessment of the residual damages in each mitigation scenario was also undertaken using the post-mitigation flood mapping. The results of this analysis are provided in the following table.

Design flood map	Total damages (2012 $)		
	Base Case	Option D	Options B1 & B2^
10 year ARI	-	-	-
20 year ARI	$1,339,000	-	-
50 year ARI	$22,273,000	-	-
100 year ARI	$28,687,000	$137,000	$91,000
500 year ARI	$150,547,000	$119,409,000	$80,436,000
Probable Maximum Flood (PMF)	$500,000,000*	$500,000,000*	$500,000,000*

^ Options B1 and B2 result in similar level of damages

* Note – PMF damages are a rough estimate based on original estimates contained in the Floodplain Mapping Study (Hydro Tasmania, 2003).

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.

The average annual damage (AAD) 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.

The AAD was calculated for base case conditions and each mitigation option. The table below also shows the reduction in AAD for each option (ie the benefit provided).

	Base case	Option D	Options B1 & B2^
Average Annual Damage	$2.1m	$1.1m	$0.9m
Reduction in AAD	-	$1.0m	$1.2m

^ Options B1 and B2 result in similar AAD.

7.3.3 Benefit Cost Analysis of Mitigation Options

The reduction in AAD for each option was considered against the cost of implementation to determine a benefit-cost ratio (BCR) for the works.

The analysis assumes the following:

- Capital cost of each option to be outlaid over the first 6 to 7 years
- An overall design life of 100 years, including an allowance for the future cost to reinstate creek upgrades after 50 years
- A real discount rate of 6%
- On-going maintenance costs of 0.2% of the CAPEX to the previous 2 years
- Separate on-going creek channel maintenance costs of $100,000 per year.

	Option B1	Option B2	Option D
Capital Cost	$40.9m	$44.1m	$35.5m
BCR	0.33	0.40	0.34

The above 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. The upper BHC 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.

The BCR is considered to be a lower bound estimate in light of the following (based on commentary in the 2012 SMP at Section 14.2):

- Intangible damages, such as long-term social impacts and trauma experienced by flood victims, have not been quantified and therefore, the benefit of the stormwater management strategy in reducing these damages has not been assessed. 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 reuse, have not been quantified in dollar terms.

8 Selection of Preferred Option

8.1 Preliminary Assessment

8.1.1 Introduction

Investigations under the Part B process initially commenced on the original five options brought forward from the 2012 SMP – being dam based options A1 and A2, and bypass culvert options C1, C2 and C3. All five options required bypass culverts to meet the100 year ARI flood mitigation target.

Based on the results of updated creek capacity assessments and introduction of the 2013 hydrology, three new options were developed which met the flood mitigation target for the BHKC project at substantially lower cost:

- Option B1 – dam at Site 1 with creek capacity upgrades in lower reaches of upper Brown Hill Creek
- Option B2 – dam at Site 2 with creek capacity upgrades in lower reaches of upper Brown Hill Creek
- Option D – creek capacity upgrade along upper Brown Hill Creek without a dam.

All eight options require creek rehabilitation along the full length of upper Brown Hill Creek to ensure that the creek's condition is improved.

Early investigation work under the Part B process enabled the respective merits of the eight options to be assessed. This preliminary assessment was based on level of flood protection, environmental impacts, community feedback and estimated costs.

8.1.2 Flood protection

Flood modelling results (Section 4.9) indicate that all eight options investigated provide approximately the same level of flood protection for a 100 year ARI event, with the number of potential flood impacted properties along upper Brown Hill Creek (Mitcham and Unley Council areas) being reduced from over 400 to approximately 25 properties, with none of those 25 properties likely to experience above floor flooding.

Option D had the added advantage of providing a higher level of flood protection for short duration urban storms (higher than 100 year ARI storms) as, by upgrading the capacity of Brown Hill Creek to accommodate the 100 year ARI peak flow generated from the rural part of the catchment by the 36 hour storm, the urban creek will have more capacity to convey peak stormwater flows off the urban part of the catchment resulting from shorter duration storms. This provides some additional reserve capacity if urban peak flows increase in the future due to redevelopment, climate change or increases in land use density.

8.1.3 Environmental Impacts

Environmental assessments for the early stages of the Part B investigation have largely focussed on the assessment of impacts on trees.

As discussed in Section 6.3:

- An assessment was made by Treevolution evaluating the potential impacts of culvert construction on local street trees, with the findings being that large high flow bypass culverts would potentially have a significant impact on approximately 200 street trees, 20 to 40 of which are Significant/Regulated depending on the bypass option chosen
- A preliminary desk top study indicates that the number of trees that would need to be removed in privately owned sections of the creek resulting from a combination of creek capacity upgrade and creek rehabilitation works is 179 for Options B1 and B2 and 229 for Option D – removal of trees would be compensated by appropriate replanting of native trees on top of the creek banks
- The construction of a flood detention dam at Site 1, may potentially 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. A further estimated 30 trees would need to be removed; excluding any trees that might need to be removed to create a work area/compound
- 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.

8.1.4 Community feedback

There was a diversity of opinion across the various communities on the merits and concerns of each of the options with a number of community interest groups being active in expressing strong views against particular components of the flood mitigation options. While there was no general consensus across the groups the principal concerns expressed by one or more of the groups related to:

- Construction of dams in upper Brown Hill Creek, particularly the dam at Site 1 in the Brown Hill Creek Recreation Park
- Construction of high flow bypass culverts through Unley streets
- Creek capacity upgrades in private property with specific concerns about the impact on amenity, existing landscaping, easements and potential adverse impacts on property values
- Impacts on Brown Hill Creek Recreation Park, Ellisons Gully, Orphanage Park and Forestville Reserve.

Community concerns are outlined in Section 6.4 and have been taken into account by the project in assessing options. As discussed in Section 9.1, the project will undertake a community consultation process prior to making a final decision about the Part B Works.

8.1.5 Estimated Costs

Initial work undertaken in the Part B process indicated that options involving high flow bypass culverts (Options A1, A2, C1, C2 and C3) would be more expensive than Options B1, B2 and D.

8.1.6 Initial Selection of Options

Following introduction of the 2013 hydrology and upgraded flood modelling, the original five options (option A1, A2, C1, C2 and C3) needed substantial technical development to redesign these options to reflect the lower flood flows and changes in creek capacity.

The project therefore determined that further detailed investigation would only be undertaken on Options B1, B2 and D as these options were considered to meet the project's flood mitigation, environmental and other objectives, and also had the lowest capital costs.

The following sections therefore provide an assessment of Options B1, B2 and D.

8.2 Comparison of Options B1, B2 and D

8.2.1 Assessment Criteria

The BHKC project involves a complex trade off of technical, environmental, social and community needs together with a comparison of costs and benefits.

Central to this comparative assessment are the criteria considered by the project to determine a preferred option. A similar process to that used in the previous SMP's has been adopted. Each option was assessed in general terms against assessment criteria adopted by the project for the Part B assessment, being:

- Flood protection
- Technical feasibility
- Likely community acceptance
- Environmental impacts
- Impacts of recreational amenity
- Heritage impacts
- Construction impacts
- Maintenance arrangements.

The relative cost of implementation and ongoing maintenance of each option was also considered including whole-of-life cost.

These criteria are discussed in the following sections.

8.2.2 Works Summary

The following table provides a brief overview of key project parameters for Options B1, B2 and D.

Component	Options	B1	B2	D
Dam		Site 1	Site 2	Not required
High flow bypass culvert		Not required	Not required	Not required
Estimated number of properties requiring creek capacity upgrade works; requiring an agreement or easement		29	22	66
Number of properties where land acquisition is required		0	2	0
Number of properties requiring an easement for dam Site 2		0	3	0
Number of public bridge upgrades		4	4	10
Creek rehabilitation works		Full length of creek	Full length of creek	Full length of creek

8.2.3 Flood Protection

Flood modelling results (Section 4.9) indicate that Options B1, B2 and D all provide flood protection for the critical 100 year ARI events (36hr and 90 min storms) and reduce the properties at risk of flooding from around 400 properties down to 25 properties. The 25 properties are at risk of under-floor flooding, not over-floor flooding.

Each of the three options (B1, B2 and D) proposed in this report meet the BHKC project's 100 year ARI flood protection design standard.

Other factors include:

- Option B2 (dam at Site 2 in Ellisons Gully) – under ARI events greater than 100 years, a dam at Ellisons Gully provides additional flood mitigation capacity which is reflected in the slightly higher BCR generated by this option
- Option D – provides slightly higher flood protection than Options B1 and B2 for short duration storms generating peak flows from the urban area of upper Brown Hill Creek. This is because the creek capacity upgrade works in Brown Hill Creek are designed to accommodate larger flood flows generated from the rural part of the catchment. As a result, shorter duration storms with higher than a 100 year ARI flood flow can be passed through the upgraded channel without breakout. This provides some additional flood mitigation capacity for urban peak flows should these increase in the future due to redevelopment, climate change or increased land use density.

8.2.4 Technical Feasibility

In the Part B investigations, the existing capacity of Brown Hill Creek was reassessed based on detailed cross-sectional survey, site inspections and updated modelling. However, each option presents its own issues which are summarised below:

Issues common to Options D, B1 and B2

- No high flow bypass culverts are required (subject to final design for Orphanage Park)
- Creek rehabilitation is planned for all sections of the creek which are not subject to creek capacity upgrade works in order to improve the overall creek hydraulics and environment
- Integration of creek capacity upgrade works with existing landscaping (eg retention of critical trees) would be addressed with property owners on an individual basis during the detail design stage
- Proposed collaboration between the BHKC project, AMLRNRMB and private creek owners to ensure that the creek capacity upgrade works and associated improvement in creek environment are planned and implemented to meet, as far as possible, the requirements of both the project and creek owner.

Option D

- Requires creek capacity upgrade works at 66 properties (36 in Unley and 30 in Mitcham) along upper Brown Hill Creek (compared with 29 and 22 properties for Options B1 and B2 respectively)
- Peak flow rates for Option D are higher than Option B1 and B2 and arise from the longer duration 36 hour storm generating flow from the rural catchment (details in Section 4.9.4)
- Results in the highest hydraulic capacity for the creek
- Requires 10 public bridges and 4 private bridges to be widened and upgraded as part of the creek upgrade works
- No flood detention dam is proposed under Option D.
- Requires removal of around 229 trees in privately owned sections of the creek and appropriate replanting with native trees
- Generates slightly higher peak flow velocities throughout upper Brown Hill Creek than Options B1 and B2, however design of the creek capacity upgrade and rehabilitation works can be developed to cater for these flow rates.

Option B1

- Requires a 12 metre high flood mitigation dam (likely to be roller compacted concrete construction) with an extended spillway apron/stilling basin to be built in the Brown Hill Creek Recreation Park
- Peak flow rates arising from Option B1 at locations within the catchment are shown in Section 4.9.4
- Requires creek capacity upgrade works at 29 properties along upper Brown Hill Creek principally in Areas 1, 3, 5A and in Orphanage Park

- Extent of upgrade works is less than in Option D as the peak flow rate for the attenuated flow is lower
- Requires 4 public road bridges to be upgraded and widened
- Requires removal of around 179 trees in privately owned sections of the creek as well as approximately 30 in the dam site (and possibly more for a work area/compound) and appropriate replanting with native trees.

Option B2

- Requires a 19.5 metre high flood mitigation dam (likely to be roller compacted concrete construction) with extended spillway would be built on private land in Ellisons Gully
- Design approach is similar to Option B1; however, the dam at Site 2 only captures flows from the rural portion of one tributary of upper Brown Hill Creek and therefore needs to be larger than the dam at Site 1 for the impact to be evident downstream
- Peak flow rates arising from Option B2 at locations within the catchment are shown in Section 4.9.4
- Requires creek capacity upgrade works at 22 properties along upper Brown Hill Creek principally in Areas 1, 3, 5A and in Orphanage Park
- Extent of upgrade works is less than in Option D as the peak flow rate for the attenuated flow is lower
- Requires 4 public road bridges to be upgraded and widened
- Requires removal of around 179 trees in privately owned sections of the creek as well as approximately 30 in the dam site (including a work area/compound) and appropriate replanting with native trees.

8.2.5 Community Acceptance

Community acceptance of Options B1, B2 and D varies significantly. All options have supporters and opponents; however there appears to be little support for Option B1 due to the proposed dam in the Brown Hill Creek Recreation Park.

<u>Issues raised by the community in support of each option include</u>:

Option D

- Achieves 100 year ARI flood mitigation
- Lowest capital cost
- Supported by ‘no dam’, heritage, environmental and Aboriginal groups
- Petition of over 10,000 signatures recommending that a ‘no dam’ solution is implemented submitted in February 2014 to Mitcham Council
- Does not require large flood detention dams in Brown Hill Creek Recreation Park or Ellisons Gully, so aligns to the BHKC project councils’ stated preference of pursuing a feasible no-dam option
- Achieves environmental benefits due to creek capacity upgrade works and rehabilitation works

- Avoids damage to environment due to dam construction
- Protects European and Aboriginal heritage
- Protects recreational use and visual amenity in Brown Hill Creek Recreation Park and Ellisons Gully.

Option B1

- Achieves 100 year ARI flood mitigation
- Second highest capital cost and least expensive flood detention dam option
- Little support for constructing dam in the Recreation Park.

Option B2

- Achieves 100 year ARI flood mitigation target
- Third highest capital cost
- Impact on private property is reduced along creek due to reduced scope of creek capacity upgrading
- Supported by ‘no culvert’ and ‘no creek upgrade’ groups and some creek owners who do not support creek capacity upgrade works option
- Achieves some environmental benefit due to creek upgrading and rehabilitation.

Issues raised opposing each option include:

Option D

- Creek upgrading has greatest impact on creek properties both in number (66 properties versus 29 and 22 for Options B1 and B2 respectively) and extent of work (creek upgrade works are approx. 1 metre – 1.5 metre wider under Option D)
- Requires up to 44 more agreements or easements to be established with creek property owners
- Mixed views in relation to creek capacity upgrade works in relation to visual and amenity impacts, local flood protection, access and safety, and design of new infrastructure
- Likely property owner opposition to easement or agreement
- Requires removal of around 229 trees in privately owned sections of the creek
- May impact adversely on some existing landscaping
- Construction in private property (often backyards) creates significant adverse impacts on creek properties
- Replacement of bridges creates local traffic disruption and creates adverse impacts on adjoining local residents
- Mixed views in relation to creek capacity upgrade works in relation to visual and amenity impacts, local flood protection, access and safety, and design of new infrastructure
- Concern that increased velocity of flows will result in more scouring of the creek bed and banks and associated loss of trees and vegetation

- Greater extent of creek capacity upgrade or culvert works required at Orphanage Park compared with Options B1 and B2
- Creek rehabilitation required along full length of upper Brown Hill Creek likely to meet with community concerns about loss of visual amenity resulting from removal of invasive vegetation and lag time for re-establishment of replacement native vegetation.

Option B1

- Community concerns over dam at Site 1 within the Brown Hill Creek Recreation Park include adverse impacts on local environment, visual amenity, ambience, recreational use, local heritage features and safety
- Threat to one of the Stone Pines, which are listed on the National Trust of SA's *Register of Significant Trees*
- Requires removal of around 179 trees in privately owned sections of the creek
- Requires removal of around 30 in the dam site and possibly more for a work area/compound
- Flood water inundates Recreation Park when dam fills depositing silt and creating risks to survival of local trees and plants
- Construction would impact on residents of Brown Hill Creek Road and Mitcham due to traffic, noise and congestion
- Brown Hill Creek Recreation Park damaged due to construction of the dam
- Requires creek capacity upgrade works in 29 properties and creek rehabilitation over the remainder of the creek.

Option B2

- Dam at Site 2 on private property within Ellisons Gully impacts adversely on local heritage items (Mitcham Water Works, route of the original bullock track from Adelaide to Melbourne), visual amenity, recreational use and commercial activity (one of the property owners uses this section of his property for primary production)
- Requires removal of around 179 trees in privately owned sections of the creek
- Requires removal of around 30 in the dam site including a work area/compound
- Flood water inundates Ellisons Gully when dam fills depositing silt and creating risks to survival of local trees and plants
- Construction would impact on residents of Brown Hill Creek Road and Mitcham due to traffic, noise and congestion
- Likely to require compulsory acquisition of land from existing owners who are unwilling to sell for the purpose of building a dam
- Recreational use of the walking trails in Ellisons Gully (private trails but open to the public) lost as a result of dam construction
- Requires creek capacity upgrade works in 22 properties and creek rehabilitation over the remainder of the creek.

It is not possible at this point of the investigation to identify a clear community preference. The BHKC project therefore proposes to refer this report to community consultation for feedback and further comments.

8.2.6 Environmental Impacts

A detailed environmental assessment has not been undertaken as part of the concept investigations for Part B Works. However a review of environmental factors has identified the following potential impacts:

Option D

- Creek capacity upgrade works combined with creek maintenance works achieve environmental benefits by removal of invasive vegetation, replanting with native trees, bank stabilisation and improved creek hydraulics
- Requires removal of approximately 229 trees through the privately owned sections of the creek
- Provides an opportunity to partner with creek property owners, AMLRNRMB and the BHKC project to provide ongoing support and oversight of the creek and its natural environment
- Construction adversely impacts on 66 properties where creek capacity upgrade works are required with lessor impact on properties where creek rehabilitation required.

Option B1

- Dam at Site 1 could impact on one of the 'Stone Pine' trees listed on the National Trust of SA Register of Significant Trees – it is closely situated to the foot of dam Site 1 and could be damaged during construction of a dam
- Requires removal of approximately 179 trees through the privately owned sections of the creek, as well as approximately 30 in the dam site (and possibly more for a work area/compound)
- Flood water inundates Recreation Park when dam fills depositing silt and creating risks to survival of local trees and plants
- Construction would impact on residents of Brown Hill Creek Road and Mitcham due traffic, noise and congestion
- Requires creek capacity upgrade works in 29 properties and creek rehabilitation over the remainder of the creek.

Option B2

- Dam at Site 2 in part occupies land used for primary production
- Requires removal of approximately 179 trees through the privately owned sections of the creek, as well as approximately 30 in the dam site (including for a work area/compound)
- Flood water inundates larger section of Ellisons Gully when dam fills depositing silt and creating risks to survival of local trees and plants
- Construction would impact on residents of Brown Hill Creek Road and Mitcham due to traffic, noise and congestion
- Requires creek capacity upgrade works in 22 properties and creek rehabilitation over the remainder of the creek.

8.2.7 Impact on Recreational Amenity

The Brown Hill Creek Recreation Park and its extended walking trails into Ellisons Gully are an important regional recreational resource which provides walking, bike riding and limited horse riding opportunities in a relatively natural environment immediately adjacent to the Adelaide suburban areas. The value of this recreational resource is similar to Waterfall Gully and Belair National Park, but not yet as well known and busy as these two significant recreation areas.

One of the current landholders in Ellisons Gully provides public access to his private land on defined trails so that the public can enjoy the scenic beauty and solitude available in Ellisons Gully. The construction of a dam at Site 2 would disrupt the opportunity to access this land for recreational purposes.

Similarly, constructing a dam in Brown Hill Creek Recreation Park at Site 1 would also impact recreational activities, being in close proximity to a popular picnic area, redirection of walking trails and road and obstructing the valley views available throughout the valley.

Creek capacity upgrade works under Options B1, B2 and D on private properties do not contribute or diminish the recreational use by the general public as there is typically only private access, but may impact on the recreational usage enjoyed by a property owner.

The creek also runs through a number of parks in both Unley and Mitcham, most notably Orphanage, Forestville, JWS Morris, Delwood and Soldiers Memorial Gardens. All of these parks are used extensively by their communities and design options to ameliorate any deleterious impact on the recreational amenity have been included in each option where appropriate.

Creek capacity upgrade works on public land will potentially increase public recreational opportunities depending on the particular design.

8.2.8 Impact on Property Owners

Options B1, B2 and D impact on creek property owners through creek capacity upgrade and rehabilitation works required under these options. Options B1 and B2 also impact on property owners due to construction of flood mitigation dams at Site 1 (Brown Hill Creek Recreation Park) and Site 2 (Ellisons Gully) respectively. The impacts of the dams are discussed later in this section.

The general location of properties requiring creek capacity upgrade works under Options B1, B2 and D is identified in plans at Appendix 7. Lists of properties requiring creek capacity upgrade works are presented in Section 5.1.3.

In relation to Options D, B1 and B2 the potential impacts on property owners are as follows:

Impacts common to Options D, B1 and B2

- Potential failure of creek upgrade works to integrate with existing land use, landscaping or site structures
- Imposition of an agreement or easement on owners of properties affected by creek capacity upgrade works
- Concern that property values will be adversely affected if there is an easement over creek capacity upgrade works.

Option D

- Creek capacity upgrade works on 66 properties
- Potential loss of approximately 229 trees through the privately owned sections of the creek
- Potential damage to existing property, noise, dust, disruption and safety issues associated with construction in private property.

Option B1

- Creek capacity upgrade works on 29 private properties
- Potential loss of approximately 179 trees through the privately owned sections of the creek
- Potential loss of approximately 30 in the dam site and possibly more for a work area/compound
- Potential damage to existing property, noise, dust, disruption and safety issues associated with construction in private property (creek capacity upgrade works)
- Construction impacts such as noise, dust and disruption on the residential properties near the Site 1 dam
- Possible loss of business for the Brown Hill Creek caravan park during the construction period.

Option B2

- Creek capacity upgrade works on 29 private properties
- Potential loss of approximately 179 trees through the privately owned sections of the creek
- Potential loss of approximately 30 in the dam site including requirements for a work area/compound
- Potential damage to existing property, noise, dust, disruption and safety issues associated with construction in private property (creek capacity upgrade works)
- Possible loss of business for the Brown Hill Creek caravan park during the construction period
- Land acquisition and easements affect two private property owners who are likely to oppose such requirements
- Construction of a dam creates land locked allotments upstream of the dam, necessitating either alternative access route to be constructed or separate titles to be combined into a single title
- Owner of residential property immediately downstream of the proposed dam at Site 2 is likely to have concerns over safety, visual amenity and construction disruption.

It is probable that the potential impacts of Options B1, B2 and D can be minimised during the detail design stage of the project based on a strong partnership between the BHKC project, AMLRNRMB and property owners.

8.2.9 Cost Considerations

The cost of the project is an important consideration. Costs arise in two ways, being the original capital cost of the scheme (generally within the first 5-7 years for the overall project) and ongoing maintenance costs. These are combined into a whole of life cost as well as used in determining a BCR for each option. In summary:

Option D

- Lowest capital cost ($35.5 million)
- Equal lowest BCR of 0.34
- Is within the budgeted cost for Part B as estimated in the 2012 SMP
- Lowest annual maintenance cost of $162,000 per annum.

Option B1

- Second lowest capital cost ($40.9 million)
- Equal lowest BCR of 0.33
- Is more than the budgeted cost for Part B as estimated in the 2012 SMP
- Second highest annual maintenance cost of $176,000 per annum.

Option B2

- Third lowest capital cost ($44.1 million)
- Highest BCR of 0.40
- Is more than the budgeted cost for Part B as estimated in the 2012 SMP
- Highest annual maintenance cost of $186,000 per annum.

The current BCR of Options B1, B2 and D is 0.34, 0.40 and 0.33 respectively, although the BCRs currently do not have any estimate of the intangible costs of flooding (eg emotional distress, loss of income and disruption of lives). It is possible that intangible damages would be at least as much as tangible damages.

The project places a higher priority on options with low capital and maintenance costs to ensure that the funding being sought is as low as possible, and because the BCR assessed for upper Brown Hill Creek only (ie separate from the whole catchment) is not a clear determinant.

8.2.10 Option Selection

All three options – ie B1, B2 and D are technically feasible.

Option B1 has raised significant community concern due to the impact a dam would have on the Brown Hill Recreation Park. In particular, concern has been expressed about the adverse environmental, recreational and heritage impacts of this option.

Option B2 and Option D both have some level of community support, notwithstanding community concerns outlined in Section 6.3. Both options are technically feasible, and both create positive and negative impacts across a range of criteria.

Option D leads to more impacts on local creek owners (66 in total) due to creek capacity upgrade works. A number of these property owners have expressed significant concerns regarding the requirement for an easement/agreement, impact on their properties, amenity and loss of property value as possible consequences of implementing this option (Option D).

In a similar vein, Option B2 reduces the impact of creek capacity upgrade works on creek property owners (reduced from 66 down to 22 properties) but creates environmental, heritage and amenity impacts in Ellisons Gully. The resulting loss of visual amenity and recreational access affects a growing number of users who enjoy walks and recreational activities in Ellisons Gully.

Several landholders are also impacted by Option B2 due to loss of their primary production land in one case, and land locking of a number of allotments in another. A local residential property in close proximity to the dam is also likely to be impacted by construction.

Option D, at a capital cost of $35.5m, is the lowest of the three options and has the lowest ongoing maintenance costs.

Having regard to the data available to the project, Option D is preferred for the following reasons:

- It has the lowest capital cost ($35.5m) by a margin of about $5 million; the lowest annual maintenance cost of $162,000 per annum and the lowest present value whole of life cost ($31.5m)
- It provides the required (100 year ARI) level of flood protection
- For shorter duration storms it provides a higher than 100 year ARI level of flood protection
- It satisfies the project councils' endorsed position to give preference to a feasible 'no dam' solution
- It does not require bypass culverts in suburban streets
- It preserves sites of heritage significance
- It is within the budgeted cost for Part B as estimated in the SMP ($27.3 million compared with $28.5 million).

The project proposes that further community consultation occur to enable the community to provide further feedback and comment on the Part B investigations and the preferred Option D.

Following completion of the consultation process and analysis of the feedback, the project will review the consultation results and make any final changes to the report.

9 Project Implementation

9.1 Consultation and decision making

The 2012 SMP strategy for the Part B Works process states that the project will carry out community consultation on the proposed works.

As noted in Section 6.3.3, in February 2014, the five participating Councils agreed to place priority on investigating the 'Creek Capacity Upgrade' option and to engage with directly affected property owners to identify any potential issues associated with this solution.

Since then, the BHKC project has:

- Conducted initial meetings and follow-up onsite visits with owners of properties where capacity upgrade works are likely to be required
- Conducted a drop in session to present and seek feedback on initial options for Orphanage Park. Park users as well as nearby property owners and residents were invited to attend the drop in session and/or complete an online feedback form
- Written to owners/occupiers of properties through which upper Brown Hill Creek traverses to provide an update on the BHKC project and to advise whether, based on concept level investigations, their property is identified as requiring creek capacity upgrade works under Options B1, B2 or D
- Continued to meet with special interest groups:
  - Save our Streets Community Action Group (SOSCAG)
  - SOCKET (Save Our Creek Environs Trees)
  - No Dam in Brown Hill Creek Community Action Group.

Following endorsement of the technical report for consultation, it is proposed that the BHKC project:

- Finalise a brochure outlining the options and a feedback form for comment
- Advise of consultation process by writing to owners/occupiers of:
  - the 66 properties identified as requiring capacity upgrade works under Option D
  - the remaining properties through which upper Brown Hill Creek traverses where creek maintenance works are proposed (under all options)
  - properties identified by Mitcham and Unley Councils
- Write to other key stakeholders including:
  - Federal and State Members of Parliament in the five catchment council areas
  - Indigenous communities, the Kaurna and Ramindjeri peoples, with an attachment to the land

  - The AMLRNRMB
  - DPTI
  - Department for Health
  - State Emergency Service
  - Environment Protection Authority (EPA)
  - Adelaide Airport
- Promote the consultation process to the wider community though:
  - Advertisements in council newsletters and relevant Messenger newspapers directing them to the Project website
  - Dedicated webpage linked to Council websites
  - Signs on public open space potentially impacted by any of the eight options for Part B Works
  - Use of Councils' social media (eg Facebook, twitter)
  - Notices at Council offices and libraries
- Conduct Open Days in the Mitcham and Unley Council areas
- Continue to meet with special interest groups: SOSCAG, SOCKET and No Dam in Brown Hill Creek Community Action Group
- Conduct meetings with other relevant groups.

Feedback collected from the community during this period will be summarised in a report to the five catchment councils who, after reviewing it, will make a final recommendation to the SMA on the Part B Works.

The strategy also requires the five catchment councils (subject to agreement of Part B Works), to prepare an updated SMP which consolidates all the changes into a whole of catchment flood mitigation plan (the Final SMP). This work will be progressed during the process for approval of the Part B Works.

9.2 Delivery strategy

The delivery strategy for Part B Works, and how this dovetails with Part A Works, is dependent on which option is endorsed.

In terms of a strategy for implementing the works of Parts A and B:

- Detention works can be carried out at any time – they are effective in terms of flood mitigation immediately from when they are completed
- Construction of Ridge Park flood control dam is planned for 2014/15
- Detention basins in the South Park Lands are at detailed design stage and construction could be implemented, subject to approvals, as soon as funding issues are resolved
- Creek capacity upgrade works should start from the downstream end of the catchment and work upstream

- Under a 'no dam' option for Part B, the works (comprising either high flow bypass culverts and/or creek capacity upgrade works) would not be commenced until Part A Works for lower Brown Hill Creek and the Keswick Creek diversion are completed.

The logical sequence of work over both Parts A and B of the project (assuming Option D is adopted for Part B) is:

1st priority	Lower Brown Hill Creek upgrade/South Park Lands detention basins/Ridge Park dam (Part A)
2nd priority	Diversions from Keswick Creek to lower Brown Hill Creek (Part A)
3rd priority	Upgrade of Brown Hill Creek from Anzac Highway to Forestville Reserve (Part A)
4th priority	Upgrade of Brown Hill Creek Part B Works – progressing from downstream to upstream

Therefore, commencement of Part B Works based on Option D would be at least several years later than commencement of full BHKC project implementation and, ideally, would follow completion of the creek upgrade from Anzac Highway to Forestville Reserve.

If Part B were based on either of Options B1 or B2, the dam works could be carried out at any time.

Creek maintenance and rehabilitation works could be carried out at any time.

9.3 Governance

In respect of project governance and delivery, the BHKC project has considered the option of creating a regional subsidiary as provided for in the Local Government Act. Attention has also been given to the need to ensure that responsibilities are appropriately allocated between the spheres of government. As part of the assessment, an internal risk assessment was carried out.

Under the Local Government Act two or more councils may, with Ministerial approval, establish a regional subsidiary and assign it with responsibility to carry out specified activities on their behalf. A regional subsidiary is a body corporate that can make its own decisions within the constraints specified in its charter. This charter is determined by the member councils and can only be varied with their full agreement. The councils remain ultimately responsible for a regional subsidiary's activities, assets, liabilities and performance. A regional subsidiary thus provides a legal framework for councils to work together to achieve outcomes that involve collaborative activity.

The councils have not yet formally finalised what roles associated with the management of the flood mitigation and stormwater management works will be carried out independently by individual local governments and be their own direct ongoing responsibility and what functions may be the responsibility of a regional subsidiary. It is likely that at least some operational responsibilities of a proposed regional subsidiary would be undertaken on its behalf by a specific local government (for example in maintaining works that become assets of the regional subsidiary but are located in that local government's area).

The BHKC project is currently giving active consideration to the above matters. The optimal and preferred allocation of responsibilities between the parties, once determined, will inform consideration of various other factors relevant to the establishment and ongoing operation of a regional subsidiary. These include governance structures and decision-making processes and cost-sharing arrangements for the regional subsidiary's activities.

9.4 Funding

The position of the BHKC project in respect of funding is outlined in the 2012 SMP (Section 15.4). Essentially:

- Construction cost sharing arrangements between the five councils have been agreed
- The catchment councils propose a three way equal share of funding between local, state and federal spheres of government.

Critical to the overall successful implementation of the project is funding. During the Part B process, BHKC project councils, the Local Government Association and the SMA have made representations to the state and federal spheres of government regarding potential funding assistance.

Approval and gazettal of a Final SMP (in satisfaction of the SMA's requirements) can be used to demonstrate the catchment councils' readiness to fully implement the Plan subject to agreement of a funding model. The Final SMP is expected to include governance arrangements, as outlined in Section 9.3 above, for implementation also following agreement of a funding model.

9.5 Program

Key milestones:

Commenced engagement with special interest groups	April 2014
Councils' endorsement or noting of Part B outcomes	September 2014
Update Part A of the 2012 SMP	September 2014 – March 2015
Councils' approval to undertake community consultation	February 2015
Community consultation on Part B outcomes	March/April 2015
Councils' approval of Final SMP (including endorsement of Part B outcomes)	April/May 2015
Approval of Final SMP sought from SMA	May 2015

References

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WorleyParsons (2012) *Brown Hill Keswick Creek Stormwater Project Stormwater Management Plan 2012*

Appendices

1 Maps of high flow bypass culvert options
2 Letter of advice concerning hydrology
3 Floodplain maps
4 Peak flow interaction between creeks
5 Potential creek capacity upgrade treatments
6 Concept sketches of dams
7 Areas of creek capacity upgrades
8 Cross-sectional impressions of culverts in streets
9 Typical channel dimensions
10 Orphanage Park options
11 Property Owners Guide to Managing Healthy Urban Creeks
12 Powers and responsibilities in relation to creeks
13 Potentially impacted trees along culvert routes
14 Consolidation of estimated costs
15 Estimated costs of dams
16 Extent of land potentially affected by the Site 2 dam and watershed
17 Estimated costs of high flow bypass culverts
18 Estimated costs of creek capacity upgrades, public bridge upgrades and creek rehabilitation
19 Estimated costs of easements