WALLBRIDGE & GILBERT
Consulting Engineers

Urban Stormwater Harvesting Options Study

Prepared For

Government of South Australia
Stormwater Management Authority

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DesignFlow

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EXECUTIVE SUMMARY

This investigation has identified that harvesting of approximately 60 gigalitres per annum (GL/a) of urban stormwater could realistically be achieved in the greater metropolitan area of Adelaide.

The study investigated schemes greater than 250 ML/a and has generally not considered opportunities to develop schemes with smaller yields.

There are four main factors that impact the harvestable yield of stormwater:

1) The volume of water generated from a catchment area;
2) The variability of flow in the catchment – i.e. relatively constant flows or reactive flows that vary significantly, with the latter being less conducive to stormwater capture;
3) The land area available for capture and treatment; and
4) The capacity of available storage in either an aquifer or surface storage.

The modelling undertaken revealed that there is a potential to harvest, treat and store approximately 60 GL/a of stormwater (including approximately 18 GL/a from existing and currently planned projects) without purchasing significant land parcels or impacting significantly on existing development. A summary of potential harvest volumes is outlined in Table 1 and Figure 1.

It is estimated that in the order of $600 million to $700 million would be required to expand Adelaide's stormwater harvesting facilities by 42 GL/a to achieve the 60 GL/a identified in this study. This estimate does not include the costs associated with existing schemes or schemes that are currently under construction. Importantly, it does not include allowances for land acquisition, distribution to users, user connections, operation and maintenance, nor establishment or maintenance of the stormwater drainage network.

Further investigations are required for any of the proposed sites before they are developed. In particular, further modelling is required to determine the long term capacity of aquifers to store significant volumes of stormwater, particularly their ability to be pressurised and then drawn down during drought periods.

Overall the investigation provides an overview of opportunities for stormwater to be harvested as part of a multifaceted water security approach for Adelaide.

Table 1 Potential Stormwater Harvest Summary

Catchment	Median Catchment runoff[1] (ML/a)	TOTAL Potential Yield[1] (ML/a)	Required Wetland Area (ha)	Required Bio-filtration Area (ha)	Number of Bores required for injection	Number of Schemes
Gawler River	10,900	6,020	33.7		65	4
Smiths Creek	5,020	3,488	14	2	28	6
Adams Creek	5,020	3,525	28.2		35	7
Greater Edinburgh Parks	3,720	1,990	18		24	1
Little Para River	3,660	2,235	17		19	4
Dry Creek	11,500	8,233	42.2	0.7	63	8
Barker Inlet	3,140	4,082[3]	21.5	1	42	3
Magazine Creek	2,409	1,791[3]	13.5		18	2
Port Road	2,703	1,521[3]	8.9		13	4
Grange area	2,000	1,250[3]		0.7	11	2
River Torrens	19,600	6,691[4]	3.5	6	100	4
Mile End Drain	1,460	850	0	0.5	10	1
Brownhill/Keswick Creek	6,550	4,234[4]	4.2	2.1	52	6
Sturt River	9,670	6,188[5]	9	5.5	89	7
Waterfall	407	0			-	0
Field River	4,780	2,616	4	1.4	Transfer to 5 bores plus surface storage	4
Christie Creek	3,040	1,317	4	1	Surface storage and transfer to 10 bores	3
Onkaparinga River	7,160[7]	2,037	5	1	Surface storage and transfer to 20 bores	3
Pedler Creek	4,860	1,237	2	0.5	Transfer to 5 bores	2
Willunga	1,830	481	2.5		4	1
Misc small and private schemes[6]		400				
TOTAL	**109,429**	**60,186**	**231.2**	**22.4**[2]	**613**	**72**

[1] Estimates include an allowance for future development. The flow estimates exclude water supply reservoir catchments and spills. Estimates using median flows rather than average annual flows have been used as they are considered more relevant for a practical assessment of typical stormwater harvest potential. These flows are based on the catchments assessed only and do not represent the total flow of stormwater to the coast from the Metropolitan area in an average year.
[2] Equivalent area of wetland is estimated to be 10 x biofiltration area, therefore total required area for wetlands if all sites use wetlands is 450 ha.
[3] Flows are transferred into this catchment from the River Torrens.
[4] Flows are diverted from this catchment to other catchments for harvesting.
[5] Flows are diverted into this catchment from Brownhill Creek.
[6] Wetland areas for the small schemes have not been included as the efficiencies of these small wetlands are not known.
[7] Flows in the Onkaparinga River shown in this table are those predicted to be generated from urban catchments they do not include rural flows.

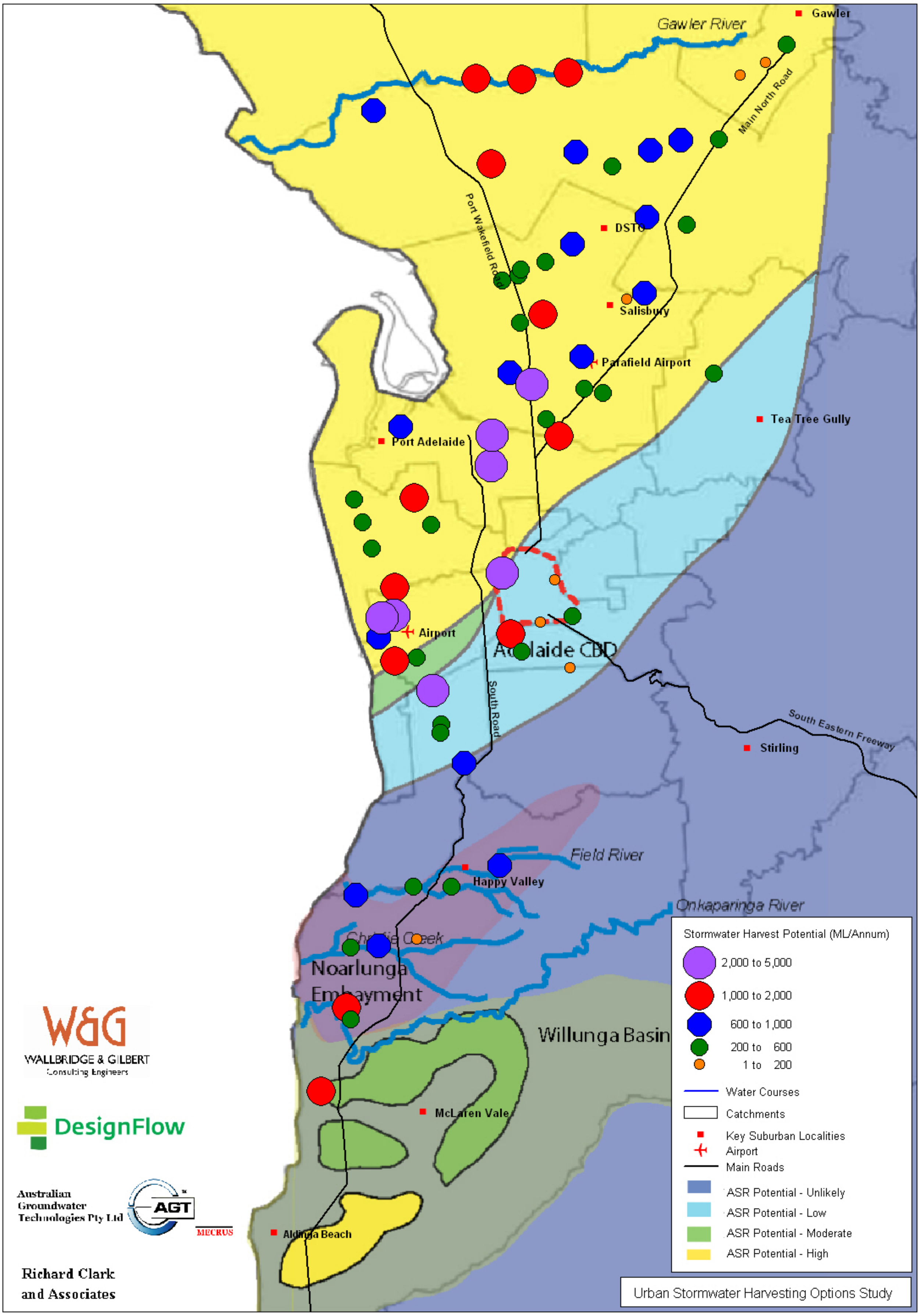


Figure 1 Harvest Scheme Locations and Scale

Existing and Committed Harvesting Schemes

There are a number of stormwater capture and reuse schemes currently in operation. Table 2 lists identified schemes and their potential annual harvesting capability. The list has been compiled based on a previous report prepared by the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB) and through interviews with local councils, Environment Protection Authority (EPA), Department of Water, Land and Biodiversity Conservation (DWLBC), consultants and other State Government agencies.

Table 2 Identified Schemes

CATCHMENT	SITE	COUNCIL	HARVEST VOLUME (ML/a)
(a) OPERATIONAL SCHEMES			
Adams Creek	Springbank Park	Salisbury	600
	Kaurna Park	Salisbury	600
	Edinburgh Parks South	Salisbury	1,360
Dry Creek	Greenfields 1&2	Salisbury	650
	Paddocks	Salisbury	200
	Parafield	Salisbury	1,100
	Pooraka (Unity Park)	Salisbury	80
	Satsuma	Tea Tree Gully	40
	Solandra	Tea Tree Gully	20
	Tea Tree Gully Golf Course	Tea Tree Gully	50
	Kingfisher	Tea Tree Gully	30
River Torrens	Direct Extraction (Torrens Lake)	City of Adelaide	420
Sturt River	Morphettville Racecourse	Marion	600
Field River	The Vines Golf Course	Onkaparinga	80
Various	Private Schemes[1]	Various	400
			6,230
(b) COMMITTED SCHEMES			
Smiths Creek	Munno Para West	Playford	560
	Andrews Farm	Playford	390
	Evanston South	Gawler	350
	Andrews Farm South	Playford	190
Adams Creek	Olive Grove (Adams Creek Wetland)	Playford	80
	Edinburgh Park North	Salisbury	600
	Summer Road/Whites Road	Salisbury	600
Dry Creek	Wynn Vale	Tea Tree Gully	350
	Edinburgh, Modbury	Tea Tree Gully	50
	Greenfields 1&2 Upgrade	Salisbury	1,000
	Parafield Upgrade	Salisbury	1,000
	Pooraka upgrade (Unity Park)	Salisbury	1,100
	Bennet Rd Drain	Salisbury	800
Barker Inlet	Northgate	Port Adelaide & Enfield	30
	Northgate Expansion	Port Adelaide & Enfield	75
	Roy Amer Reserve	Port Adelaide & Enfield	30
Port Adelaide	Grange Golf Course	Charles Sturt	300
	Royal Adelaide Golf Course	Charles Sturt	200
Magazine Creek	Cheltenham Racecourse Redevelopment	Charles Sturt	1,300
	Port Road Redevelopment	Charles Sturt	1,200
River Torrens	Torrens1 (Dernancourt)	Tea Tree Gully	80
	Torrens 2 & 3 (Highbury)	Tea Tree Gully	140
	Lochiel Park	Campbelltown	50
	Felixstow Reserve	Norwood, Payneham & St Peters	*
	Walkerville Recreation Ground	Walkerville	*
Brownhill/Keswick	Orphanage Park	Unley	60
	Glenelg Golf Course	Holdfast Bay	250
Onkaparinga River	Seaford Meadows	Onkaparinga	*
Field River	Flagstaff Hill Golf Course	Onkaparinga	*
	The Vines Golf Course Upgrade	Onkaparinga	40
Christie Creek	Brodie Road Reserve	Onkaparinga	650
	Madeira Drive Reserve	Onkaparinga	180
			11,655

[1]Refers to schemes not large enough to be individually identified as part of the study and private schemes where only limited information was available on expected harvest potential.
* Data not available
Harvest volume – this is the estimated potential annual harvesting capability, actual harvesting volumes will be influenced by climate variability (e.g. year to year rainfall variations) demand rates and other operational factors.

There are seven large scale (>250ML/a) stormwater capture and reuse projects currently in operation and a number of smaller schemes. The existing schemes identified as part of this study are estimated to be capable of harvesting in the order of 6 GL/a of stormwater, excluding allotment scale harvesting (e.g. rainwater tanks). In addition, there are a further 32 schemes that are currently being designed or constructed that are expected to be completed within the next 2-3 years. These schemes could harvest up to an additional 12 GL/a of stormwater.

It should also be noted that it is very likely that over the next 6 months a number of schemes will be planned/developed as part of funding applications for the "Water for the Future, National Urban Water and Desalination Plan: Special call for stormwater harvesting and reuse projects" as announced by the Federal Government in March 2009.

Summary of Ultimate Potential Yield

The study has reviewed the existing and committed schemes outlined in Table 2, along with a number of other potential treatment and harvesting sites across Adelaide. The investigation revealed that there is a potential to harvest, treat and store in the order 60 GL/a of stormwater (inclusive of the 18 GL/a of existing and committed projects). Table 3 provides a summary of the estimated ultimate yield for the greater metropolitan Adelaide area.

It should be noted that some values in Table 3 differ from those values stated for committed schemes in Table 2. The differences can be explained by:

- This investigation has considered whole of catchment harvesting and upstream schemes may impact on yields of committed schemes. The values stated in the committed scheme yields may not have accounted for any upstream schemes being established.
- Stated yields for the committed schemes may have been based on average flows as compared to median flows as used in this study.
- Committed schemes are likely to be based on more detailed modelling and may also have used different buffer storages, extraction rates or injection potential. All of these factors would result in differing estimated yields.

Table 3 Predicted Ultimate Yield

CATCHMENT	SITE	HARVEST VOLUME (ML/a)
Gawler River	Dawson Rd retarding basin	118
	Gawler River (rural linear corridor)	4,740
	Buckland Park	856
	Gawler racecourse	306
Smiths Creek	Evanston South	185
	Blakeview	308
	Munno Para West	1241
	Andrews Farm	400
	Andrews Farm South	500
	NEXY retarding basin	854
Adams Creek	Olive Grove	303
	Edinburgh Parks North	630
	Edinburgh Parks South	760
	Kaurna Park	551
	Springbank Park	398
	Burton West	308
	Summer Rd	575
Greater Edinburgh Parks	Greater Edinburgh Parks	1,990
Little Para	Moss Rd	700
	Pioneer Park	160
	Whites Rd	1,045
	Bolivar	330
Dry Creek	Wynn Vale Dam	346
	Pooraka upgrade	1,360
	Montague Rd	549
	Parafield	862
	Paddocks	584
	Bennet Rd Drain	480
	Greenfields 1&2 (upgraded)	3,269
	Cheetham saltworks	783
Barker Inlet	Hindmarsh Enfield Prospect drain	790
	North Arm East	1,240
	Islington Railyards	2,052
Magazine Creek	Cheltenham racecourse	1,180
	Range wetlands	611
Port Road	Port rd median	571
	Riverside Golf Course	450
	Grange Golf Course	300
	Royal Adelaide Golf Course	200
Grange Area	Pump from Torrens to reserves	900
	Coastal catchments	350
River Torrens	Botanic Gardens	170
	Bonython Park	4,085
	University fields	2,016
	City irrigation	420
Mile End	Adelaide shores	850
Brownhill/Keswick Creek	Urrbrae	140
	Orphanage	210
	Victoria Park	211
	South Parklands	84
	Glenelg Golf Course	460
	Airport	3,130
Sturt River	Science Park	770
	Oaklands Park South	414
	Oaklands Park North	290
	Morphettville Existing	325
	Morphettville new	1,800
	Disused trainline from Brownhill Creek	1,511
	Airport	1,078
Field River	Elizabeth Crescent Reserve	945
	Young Street	430
	Reynella East	351
	Happy Valley Reservoir diversion channel	890
Christie Creek	Madeira Drive	153
	Brodie Road	655
	Morrow Road	509
Onkaparinga River	Hackham South	447
	Garland Park	330
	Rural pumped flows	1,260
Peddler Creek	Peddler Creek Reserve A	756
	Peddler Creek Reserve B	481
Willunga	Willunga	481
Misc	Smaller and private schemes	400
		60,186

NOTE: Yields have been determined on a catchment scale to maximise the available runoff for that catchment. Therefore some committed schemes may show lesser yields in the ultimate outcome shown above, as it was deemed more efficient (in terms of cost/amenity/environment) to capture yields at a different site. The figures presented above show one potential arrangement to maximise the yield volume per catchment. Yield per site may vary slightly at detailed design however the ultimate catchment yields should be of the order given above totalling to approximately 60GL/a across the study area.

Climate Change and Urban Consolidation

To assess the likely impacts of rainfall variation on the harvesting schemes, the systems were modelled under different scenarios including:

1. Wettest and driest years in the 32 year rainfall record (1977- 2009);
2. Predicted seasonal rainfall reduction because of climate change for 2050 (5-10% reduction in annual rainfall);
3. Predicted rainfall reduction from climate change with increased urban density resulting from infill development.

Results of this scenario modelling suggest that in the historical driest and wettest years within the 1977-2009 period, stormwater harvest will vary between 20 GL/a to 90 GL/a. Estimated harvest volumes using lower average rainfall predicted as a result of climate change reduce to 50 GL/a. However, this decrease may be offset by an increase in urban density within the currently developed urban area to the harvest volumes predicted using historical rainfall data (i.e. 60 GL/a). If approximately one quarter of properties were redeveloped by 2050 then the impact of climate change would be completely offset by the increase in impervious area, (Refer to Table 4).

Table 4 Predicted impacts of climate change and urban consolidation

	Current rainfall and current housing density	Impact of climate change with current housing density	Impact of climate change with 5% increase in impervious area[1]	Impact of climate change with 10% increase in impervious area[2]
Potential Harvest	60 GL/a	50 GL/a	55.5 GL/a	60GL/a

Notes:
[1]5% increase in impervious area represents approximately 14% of existing properties being redeveloped.
[2]10% increase in impervious area represents approximately 28% of existing properties being redeveloped.

The Plan for Greater Adelaide outlining likely development, including urban consolidation, is due to be finalised later this year. The outcomes of the finalised plan should be incorporated into the scenario analysis outlined above, however it is expected that urban consolidation is likely to be within the range modelled in this study.

Storage of Harvested Stormwater

Tertiary aquifers (particularly the T2) are considered suitable for storing the majority of the stormwater harvested from the proposed schemes. The most suitable aquifers are in the western and northern regions of Adelaide. The potential for aquifers to accommodate large scale aquifer storage and recovery (ASR) schemes across Adelaide is summarised in Figure 1. Fractured rock aquifers, such as those found in the eastern regions of Adelaide, are not considered reliable enough for large scale ASR but, subject to field testing, may be suitable for smaller scale ASR schemes.

Further modelling is required to better assess the long term capacity of the tertiary aquifers to store the expected volumes of stormwater and their ability to be pressurised and then drawn down during drought periods.

Where the aquifer was not deemed suitable for storage of harvested stormwater or there were existing/potential surface storage structures then surface storage was considered as an alternative method of storing the harvested stormwater.

Schemes in the southern region are limited by the available storage (both aquifer and surface storage). Should significant winter demands arise in this area, or other storage facilities become available, then the potential stormwater harvest could be increased. A pipeline transferring stormwater northward to areas where the aquifer storage potential is greater could also be considered. The cost of such a transfer pipeline has not been considered in this study, but could be considered to maximise the stormwater harvest potential.

Opportunities to link stormwater harvesting schemes with transfer pipelines have been considered and are outlined in this report inclusive of a main running from the Adelaide Airport region to Port Adelaide. Similar linkages have already been developed as part of the Water Proofing Northern Adelaide project in order to increase harvest volumes and provide operating contingency.

Costs

The cost to construct new schemes and undertake upgrades to existing schemes to increase the harvesting and storage potential by 42 GL/a as identified in this study, is estimated to be in the order of $600 million to $700 million. This cost estimate does not include allowances for:

- Land acquisition;
- Distribution networks for delivering harvested stormwater to users;
- Operation and maintenance;
- Establishment or maintenance of the stormwater drainage systems (i.e. the stormwater pipe network).

Refer to Table 5 for a summary of costs on a per catchment basis.

Table 5 Capital costs for new schemes and upgrades

CATCHMENT	COST ($/M)
Gawler River	66.5
Smiths Creek	39.5
Adams Creek	14.5
Greater Edinburgh Parks	31
Little Para River	25
Dry Creek	44
Barker Inlet	49
Magazine Creek	33
Port Road	12.5
Grange area	16.5
Torrens River	75.5
Mile End Drain	7.5
Brownhill/Keswick Creek	36
Sturt River	84
Waterfall Creek	0
Field River	30.5
Christie Creek	16.5
Onkaparinga River	26
Pedler Creek	10.5
Willunga	5
	623

Methodology

The study encompasses the urban (existing and planned by 2030) area within the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB) region, bounded by the Gawler River to the north, the hills face zone to the east and the Willunga Basin to the South. For the purposes of this study it was assumed that all green fields sites within the study area that are zoned for development are developed, as this will be the case into the future.

A steering group was established to administer, provide key stakeholder input and oversee the project. The following organisations/representatives were a part of the Steering Group:

- Stormwater Management Authority - Terry Stewart
- SA Water- Chris Marles / Paul Doherty
- Local Government Association – Colin Pitman / Michael Barry
- Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB) – Steve Gatti
- Office for Water Security – Paul Doherty / Martin Allen

The parameters of the investigation included:

- A focus on large scale schemes with a potential yield over 250 ML/a. This is not to disregard the benefit of smaller schemes. However, for high level planning purposes it is deemed to provide a reasonable estimate of the annual volume of stormwater that can be harvested.
- Distribution and reuse applications of harvested water are not included. The study examines only what can be captured and stored, regardless of whether a user or reuse application is identified.
- Water supply dams or reservoirs are not considered for significant harvested stormwater storage.
- The vast majority of sites investigated are to target urban stormwater.
- Harvesting opportunities are assessed on a catchment wide approach so that the impact of upstream harvesting is accounted for in downstream opportunities.
- A focus on sites that are practical from an engineering and construction perspective and give consideration to the current uses of the open space.
- Site visits for each harvesting location were limited to visual inspections (e.g. no survey was performed).
- Cost estimates for the concepts developed are considered to be in the order of +/- 25%.
- Conservative design assumptions have been adopted, given the purpose of the study is to provide a high level assessment.

For the purposes of determining harvest potential the Adelaide Metropolitan Area was divided into 20 catchments and models developed for each catchment.

Approximately 200 potential harvesting sites were identified and visited to assess whether harvesting is practical, could fit within available space and would not negatively impact on existing land uses. The investigation included consideration of treatment requirements, storage options, discussions with local councils and environmental flows.

Models were calibrated against median stream flow data. Each model assessed a range of capture, treatment and storage configurations to develop an overall optimal harvesting strategy for the metropolitan area.

Wetlands, biofiltration and media filtration were considered as treatment options. Wetlands are considered as preferred treatment systems because of their demonstrated treatment capabilities and aesthetic qualities. Biofiltration (or bioretention) are considered where land availability limits the use of wetlands or where permanent water bodies are not appropriate. Media filtration is considered where land availability limits the other treatment options or groundwater may impact on the function of wetlands or biofilters.

Both aquifer storage and recovery (ASR) and surface storage options were considered to store harvested stormwater. ASR is considered the primary method of storage where it was deemed suitable because of the large scale of possible storage volumes available and minimal land take required.

The impacts of reduced rainfall due to climate change predictions and the increase in runoff due to urban consolidation were then considered.

The models were then run for the wettest and driest years within the rainfall data set (1977-2009) to indicate the predicted range of harvest volumes that would be achieved from year to year.

Results of this scenario modelling suggest that in the historical driest and wettest years within the 1977-2009 period, stormwater harvest will vary between 20 GL/a to 90 GL/a. Climate change is predicted to reduce the harvest in a typical year to 50GL/a by 2050 which may be offset by urban consolidation.

The modelling undertaken revealed there is a potential to harvest, treat and store approximately 60 GL/a of stormwater (including approximately 18 GL/a of existing and currently planned projects) without purchasing significant land parcels or impacting significantly on existing development.

1. INTRODUCTION

1.1. Background

This report has been developed as an initiative of the Stormwater Management Authority, State Government and Local Government to identify the strategic potential for large-scale stormwater harvesting across the Adelaide area. Increased stormwater harvest could assist Adelaide's water security and may also promote other positive stormwater management outcomes including amenity, water quality and flow management.

The aim of this study is to assess the potential for stormwater harvesting, treatment and storage across the Adelaide Metropolitan Area. Adelaide will continue to be challenged with finite water supply as increased development and climate change impact on water availability and demand. Options to capture stormwater prior to its discharge into the Gulf St Vincent are developed and the potential volume of stormwater that could add to Adelaide's water supply quantified in this report.

Greater Adelaide's current water supply comes from a range of sources including the River Murray, the Western Mount Lofty Ranges catchments, groundwater and urban stormwater harvesting. Much of the stormwater generated in metropolitan Adelaide discharges to the Gulf St Vincent.

In 2005 the South Australian Government launched the Water Proofing Adelaide strategy that outlined proposed targets to secure Adelaide's water supply until 2025. Part of this strategy highlights the potential for stormwater treatment, storage and reuse.

Currently reuse of stormwater is undertaken by several Councils with large scale wetland treatment and aquifer injection sites and also on a small-scale by individual allotment owners in the form of private rainwater tanks.

1.2. Objectives

The objective of this study is to identify and develop conceptual schemes for large scale capture and storage of urban stormwater within the Greater Adelaide region and to determine the potential volume of stormwater that could practically be harvested.

The focus of the study is on capture, treatment and storage opportunities on the basis of stormwater quantities, available open space and storage potential (either aquifer or surface storages). It is not intended to identify potential markets for the use of harvested stormwater or investigate possible distribution networks for harvested stormwater.

1.3. Project Scope

The study encompasses the urban (existing and planned by 2030) area within the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB) region, bounded by the Gawler River to the north, the hills face zone to the east and the Willunga Basin to the South.

The extent of urban area to be considered included areas that are yet to be developed, but are planned for urban development by 2030. These are either defined by the urban growth boundary or areas that have current investigations for urban development and are likely to proceed.

The study investigated sites with harvesting opportunities that nominally have the potential to yield over 250ML/a. The main focus on sites with a harvest potential of at least 250 ML/a reflects a practical need to establish a cut-off point for investigation purposes, and that larger schemes may have greater scope for efficiencies. While this general rule applies to most project sites, other opportunities that are identified and have been considered by others have also be included even if the yields are expected to be lower than 250 ML/a.

It is recognised that schemes other than those identified in this study could be developed, however the development of such schemes will impact on any opportunities identified down stream of that site. This study has identified potential harvesting sites that provide a reasonable estimation of the stormwater harvest potential within the region.

Specific elements of this study include:

- Review existing stormwater harvesting schemes and studies
- Compile information on surface water flows generated in the study area
- Identify potential large scale stormwater harvesting and storage schemes (typically greater than 250ML/a)
- Assess groundwater injection and storage potential for the study area
- Develop hydrological models to quantify harvesting potential for each site and assess interactions between different harvesting locations
- Develop preliminary stormwater harvesting concepts that are practical and give consideration to current open space uses
- Assess the impact of predicted climate change and urban consolidation on harvest volumes
- Estimate first order construction costs for the schemes identified.

2. CATCHMENT DESCRIPTION

2.1. Study Area Overview

2.1.1. Major Catchments and Waterways

Major catchments across metropolitan Adelaide have been defined by the Department of Water, Land and Biodiversity Conservation (DWLBC) on the publicly available GIS data library. The major catchments within the study area are:

- Gawler, Smiths & Adams, Little Para, Dry Creek, Port Adelaide, Torrens, Patawalonga, Field River, Christie Creek, Onkaparinga, Pedler Creek and a number of small catchments along the coast (referenced coastal).

For the purpose of this study the area is divided into 20 catchments where potential harvesting opportunities were identified. These catchments are:

Gawler River *	River Torrens
Smiths Creek	Mile End Drain
Adams Creek	Brownhill Creek
Greater Edinburgh Parks	Sturt River
Little Para River	Waterfall Creek
Dry Creek	Field River
Barker Inlet	Christie Creek
Magazine Creek	Onkaparinga River
Port Road	Pedler Creek
Grange area	Willunga

**This catchment included the proposed Buckland Park development*

A map showing the catchment boundaries and waterways is shown in Appendix A.

2.1.2. Land Use

Land use has a significant influence on catchment runoff, particularly the extent of urbanisation. High infiltration rates in predominantly rural areas result in much less runoff compared to urban areas because of the extent of impervious surfaces. Urban areas are therefore the main focus for harvesting sites because of their higher reliability of runoff from even relatively moderate rainfall events. Catchments with long lengths of earth lined channels also have significant losses, which reduce the overall stormwater runoff from the catchment.

Some catchments within the study area, particularly the far northern and southern catchments are expected to have increased urban development. These areas are included as urban in the assessment as modelling represents the potential future harvest volumes. In addition scenario modelling to simulate infill development is presented separately. This accounts for an increase in impervious area when sites redevelop (e.g. one allotment divides into two or more) and therefore produce more runoff from the same area (Refer to details Section 7).

The impact of compulsory allotment rainwater tanks is also considered for new developments sites or infill development. These new sites will have higher proportions of impervious area compared to existing sites with some of the roof areas being directed to tanks for reuse.

3. INVENTORY OF EXISTING STORMWATER HARVESTING SCHEMES

3.1. Introduction

An inventory of existing stormwater harvesting schemes was developed based on a document developed by the AMLRNRMB, consultation with local councils, EPA, DWLBC and consultants associated with the projects.

Local councils are a key source of information and there has necessarily been a significant degree of reliance on information provided by local council officers. However, stormwater harvesting is not an exact science. Projected long term yields from harvesting schemes are dependent on a range of factors including climate, rainfall intensity patterns as well as total rainfall and geotechnical conditions at a site. In addition, assumptions used in stormwater harvesting feasibility investigations (for example in relation to the capacity to inject stormwater into aquifers) may differ from the final outcome, which can only be known following completion of a stormwater harvesting project. Field testing of groundwater systems prior to full-scale development can also differ from pre-held estimates concerning harvest potential for a scheme concept, which may require adjustments to the original scheme concepts and expected yields. In addition, there will be annual variations for all schemes based on climatic, operational and maintenance constraints.

The values quote in this report represent the best currently available knowledge.

Schemes are grouped into three categories:

Operational schemes include completed facilities that are able to effectively harvest stormwater. Harvest volumes presented correspond to current harvest capacity.

Committed schemes include those currently under construction or in the detailed stages of design with committed funding. These schemes are expected to be established within the next two or three years.

Other Schemes include those which are at various stages of planning/design but are yet to have a financial commitment to the construction.

All of the schemes in the above three categories have been included in the catchment wide models created for this study and each has been considered for possible upgrade/modification to increase yields from those currently achieved or planned.

3.2. Existing Scheme Inventory

Tables 6, 7 and 8 summarise existing, committed and other schemes, showing the Council jurisdiction and expected annual harvest volume. The schemes in the "other" category are at various stages of planning and development and some may not be implemented. They have been captured in this table purely to ensure that they were considered in the overall catchment models developed. Brief descriptions of the existing schemes are tabulated in Appendix B.

It should also be noted that it is very likely that over the next 6 months a number of schemes will be planned/developed to various stages as part of funding applications for the "Water for the Future, National Urban Water and Desalination Plan: Special call for stormwater harvesting and reuse projects" as announced by the Federal Government in March 2009.

Table 6 Operational Schemes

OPERATIONAL SCHEMES	CATCHMENT	SITE	COUNCIL	ESTIMATED HARVEST VOLUME ML/yr
	Adams Creek	Springbank Park/Burton	Salisbury	600
		Kaurna Park	Salisbury	600
		Edinburgh Parks South	Salisbury	1,360
	Dry Creek	Greenfields 1&2	Salisbury	650
		Paddocks	Salisbury	200
		Parafield	Salisbury	1,100
		Pooraka (Unity Park)	Salisbury	80
		Satsuma	Tea Tree Gully	40
		Solandra	Tea Tree Gully	20
		Tea Tree Gully Golf Course	Tea Tree Gully	50
		Kingfisher	Tea Tree Gully	30
	River Torrens	Direct Extraction (Torrens Lake)	City of Adelaide	420
	Sturt River	Morphettville Racecourse	Marion	600
	Field River	The Vines Golf Course	Onkaparinga	80
	Various	Private Schemes*	Various	400
				6,230

**Refers to schemes not large enough to be individually identified as part of the study and private schemes where only limited information was available on expected harvest potential.*

Table 7 Committed Schemes

CATCHMENT	SITE	COUNCIL	ESTIMATED HARVEST VOLUME ML/yr
Smiths Creek	Munno Para West	Playford	560
	Andrews Farm	Playford	390
	Evanston South	Gawler	350
	Andrews Farm South	Playford	190
Adams Creek	Olive Grove (Adams Creek Wetland)	Playford	80
	Edinburgh Park North	Salisbury	600
	Summer Road/Whites Road	Salisbury	600
Dry Creek	Wynn Vale	Tea Tree Gully	350
	Edinburgh, Modbury	Tea Tree Gully	50
	Greenfields 1&2 Upgrade	Salisbury	1,000
	Parafield Upgrade	Salisbury	1,000
	Pooraka upgrade (Unity Park)	Salisbury	1,100
	Bennet Rd Drain	Salisbury	800
Barker Inlet	Northgate	Port Adelaide & Enfield	30
	Northgate Expansion	Port Adelaide & Enfield	75
	Roy Amer Reserve	Port Adelaide & Enfield	30
Magazine Creek	Cheltenham Racecourse Redevelopment	Charles Sturt	1,300
	Port Road Redevelopment	Charles Sturt	1,200
Port Adelaide	Grange Golf Course	Charles Sturt	300
	Royal Adelaide Golf Course	Charles Sturt	200
River Torrens	Torrens1 (Dernancourt)	Tea Tree Gully	80
	Torrens 2 & 3 (Highbury)	Tea Tree Gully	140
	Lochiel Park	Campbelltown	50
	Felixstow Reserve	Norwood, Payneham & St Peters	*
	Walkerville Recreation Ground	Walkerville	*
Brownhill/Keswick Creek	Orphanage Park	Unley	60
	Glenelg Golf Course	Holdfast Bay	250
Onkaparinga River	Seaford Meadows	Onkaparinga	*
Field River	Flagstaff Hill Golf Course	Onkaparinga	*
	The Vines Golf Course Upgrade	Onkaparinga	40
Christie Creek	Brodie Road Reserve	Onkaparinga	650
	Madeira Drive Reserve	Onkaparinga	180
			11,655

COMMITTED SCHEMES

** Data unable to be verified*

Table 8. 'Unfunded' Schemes

	CATCHMENT	SITE	COUNCIL	NOMINATED HARVEST VOLUME ML/a
UNFUNDED	Gawler River	Gawler River Flood Mitigation	Gawler	*
	Various	WNA Stage 2	Playford/CTTG/Salisbury	2,000
	Adams Creek	Whites Road	Salisbury	5,000
	Barker Inlet	Barker Inlet Wetland	Port Adelaide & Enfield	300
	Port Adelaide	Grange Lakes	Charles Sturt	1,000
		Riverside Golf Course	Charles Sturt	200
	Torrens River	Botanic Gardens	Adelaide	100
	Sturt River	Oaklands Park	Marion	200
	Aldinga	Sunday Development (Hart Rd)	Onkaparinga	16
				8,816

**Data unable to be verified*

3.3. Current and Future Harvest Volumes

Based on the inventory above, across the Greater Adelaide Metropolitan Area the current annual harvest volume is approximately 6GL. Within the next 2-3 years with the committed schemes coming into operation an additional 12GL should become available. If the “other” schemes are approved and constructed they will contribute 9GL/a, which creates a potential future reuse of 27GL/a, refer to Table 9.

Table 9. Summary of annual potential yield

EXISTING		6	GL/an
COMMITTED	+	12	GL/an
UNFUNDED	+	9	GL/an
TOTAL FUTURE HARVEST		**27**	**GL/an**

This study reviewed existing and committed schemes to determine if expansion or upgrade of the schemes would increase the overall catchment yield. Section 4 of the report outlines the method of selection for new potential harvest sites.

4. INDENTIFICATION & EVALUATION OF POTENTIAL HARVESTING SITES

4.1. Process for Developing and Selecting Harvesting Options

Potential sites for stormwater harvesting were identified by reviewing aerial photography and lands titles records to determine available open spaces near to waterways. Potential harvesting sites require:

1. suitable open space that could be used for stormwater treatment (i.e. high amenity open spaces, were not considered)
2. proximity to watercourses with significant upstream catchments
3. suitable topography for stormwater storage or treatment (e.g. relatively flat grade for wetlands or incised land for storages)

A strong focus of the study was to identify sites that are practical, could fit within existing available space and do not negatively impact on existing uses.

214 sites identified during a desktop study were visited to assess the feasibility of a harvesting and treatment concept. The site visits identified whether:

- treatment could operate by gravity,
- their likely impact on existing land uses,
- the approximate extent of earthworks required, and
- other construction considerations (such as existing infrastructure, significant trees etc.).

No further site investigations such as survey or service location were conducted. From the 214 sites visited 101 were found not to be suitable because of site constraints (the main ones being unsuitable topography or lack of available space) and therefore were not considered further.

Another important component of the site identification process was interviews and discussion with Councils and other agencies. In addition, Councils were consulted to gauge likely acceptance of potential harvesting systems.

Existing, committed and "other" schemes (as described in Section 3) were included in the selection process. Upgrades to existing facilities or an improvement to current design to increase yields were considered and included in the catchment models.

The sites considered feasible after the site inspections were modelled in the context of future development, impacts of other schemes in the catchment and in some cases transfers between catchments. This modelling approach led to a harvest potential for local schemes and on a catchment wide basis. A description of the approach to modelling is outlined in Section 5.

In parallel with the assessment of surface water capture and treatment were investigations into large scare storage options. A focus of the investigation was on ASR (or Managed Aquifer Recharge – MAR) because of the potential to store large volumes of water using a minimal footprint and irrespective of surface topography. Outcomes of this work resulted in Tertiary T1 and T2 limestone aquifers being targeted for storage (refer to Section 4.2). Bedrock aquifers were not considered feasible for large scale storages because of limited storage capacity and variable injection rates because of their heterogeneous nature. Where ASR potential was considered low, surface storages were investigated by assessing available space with suitable topography for storages near to harvesting sites.

Once harvesting models were developed with all potential sites and harvest and treatment volumes quantified, a process of prioritisation was performed to match potential harvest and treatment with available storage capacity. This iterative process generated a list of sites where the hydrology is modelled, there is a suitable available open space for treatment and feasible storage options nearby.

Matching potential harvesting volumes to available storage potential resulted in either untreated or treated stormwater (depending on where available treatment sites are) being transferred to areas with better storage potential. These are described in the individual concept diagrams and the catchment descriptions in Section 6.

4.2. Groundwater Storages

Two storage options have been considered as part of this study, groundwater and surface storage. Groundwater has been considered as the first alternative because large scale storage can be developed with minimal land impact, whereas establishment of large surface water storages in developed areas can be difficult to achieve.

There are variable hydrogeological conditions across the Adelaide Metropolitan Area. Figure 2 presents ASR potential for different areas ranking them from low to high based on the potential for sufficient storage. The potential has been determined based on the availability of T1 and T2 aquifers as the target for large scale storage.

Both the Tertiary Limestone aquifers T1 and T2 are considered the primary targets for aquifer injection, and are the most commonly used aquifers for ASR across Adelaide at present. These aquifers are typically extensive, have significant storage capacity, are capable of good injection rates and enable high recovery efficiencies. Completion details for these aquifers, particularly the lower T1 and T2 aquifers are typically open hole, which is preferred in terms of long term performance. The depths to these aquifers are typically 100m to 200 m. Where available the T2 aquifer is targeted as it generally provides better yields and there are currently less users of this aquifer, hence the potential impact on existing users is reduced.

Where harvesting sites are located in the ‘unlikely’ or ‘low’ areas either surface storages or transfers to areas with better ASR potential were considered. More details of the outcomes of this process are described in Section 6.

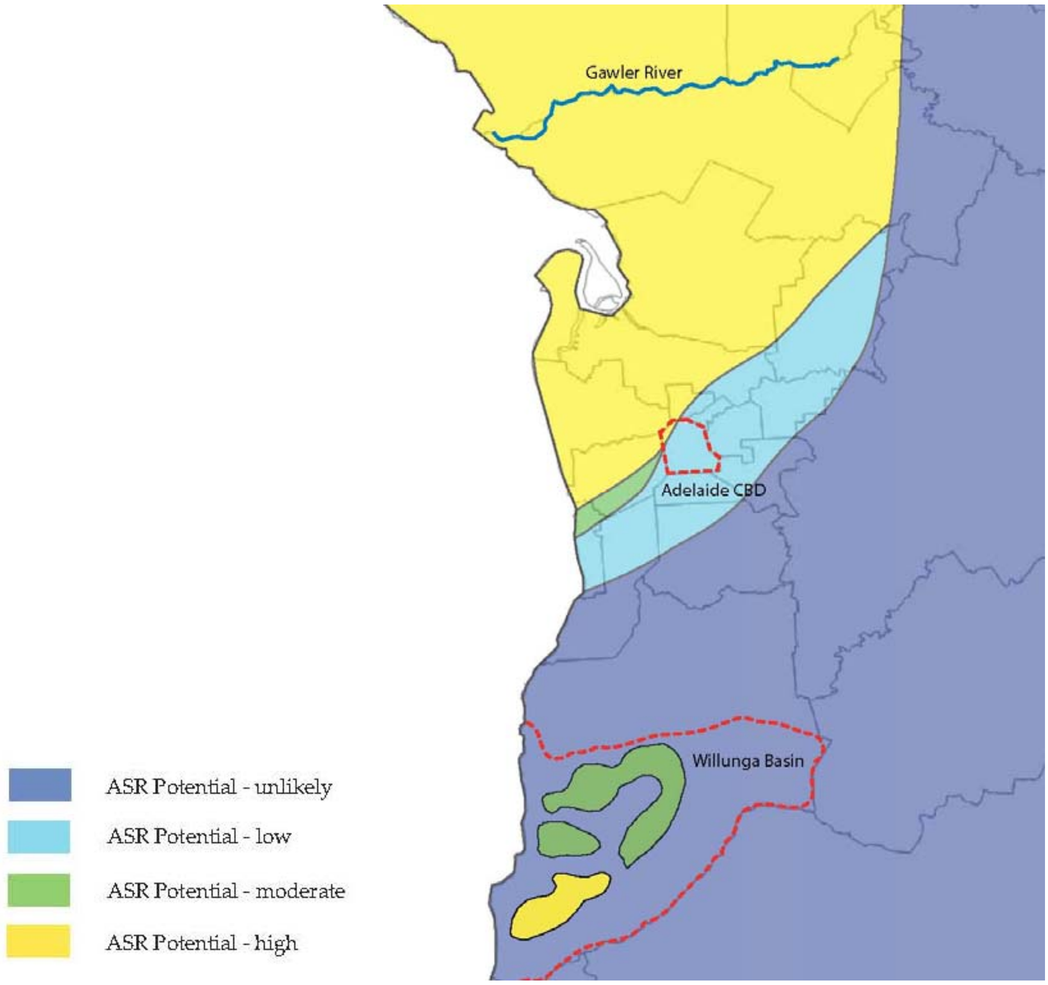


Figure 2 ASR potential across the Adelaide Metropolitan area

While not suited to the large scale schemes considered in this report (i.e. generally greater than 250 ML/a) it is recognised that fractured rock aquifers can be suited to smaller scale systems (generally less than 100 ML/a). This has been demonstrated by numerous small scale schemes in Tea Tree Gully, Campbelltown and Port Adelaide Enfield Councils.

For large scale schemes bedrock (fractured rock) ASR schemes are not considered suitable on the following basis:

- limited storage capacity of fractured rock aquifers, increasing the risk of discharge to the surface
- very variable well yields (2 to 10L/s) at any site due to the heterogenous nature of fractured rock systems
- low recovery efficiencies, due to generally greater groundwater flow velocity (i.e. plume of injected low salinity water moving off site)
- typically compartmentalised fracture systems (resulting in discreet plumes around each well, rather than amalgamation of plumes into a large plume, as would be expected in a porous limestone or sand aquifers).

4.3. Surface Storages

Where ASR was not deemed viable on a large scale, surface storage options were considered. However, possible surface storage opportunities were limited generally because of a lack of available space. Should more surface storage facilities become available, particularly in the south, then it may be possible to increase yields further from what this study identifies.

4.4. Climate Change and Urban Consolidation

The impact of predicted climate change on potential harvest volumes is assessed as part of the harvesting analysis (see Section 7). The approach involved modelling predicted rainfall reductions (by 2050) with the proposed harvesting schemes to estimate the reduction in harvested yield.

In parallel with climate change occurring over time will be infill development (or urban consolidation). The effect of urban development and consolidation will be to increase the proportion of urban area that is impervious and therefore will increase the proportion of rainfall that becomes runoff. This effect may offset the impact of climate change on harvest yields.

To assess the possible interaction of reduced rainfall with increased urban density different possible urban consolidation scenarios were modelled with predicted rainfall reductions. Results, presented in Section 7, show different scenarios as the extent of urban consolidation (and rainfall reduction) by 2050 cannot be accurately predicted.

4.5. Environmental Flow Considerations

There is little information on environmental flow requirements for individual catchments within the study area. For this reason environmental flows are not specifically addressed in this report. As a general rule, however, the opportunities presented in this report entail no more than 70% of the predicted median flow being extracted from any one system. Only urban flows were extracted leaving rural flows in the system. Significant extractions were concentrated at the lower ends of the catchment to avoid impacts on the upstream reaches. Environmental releases from SA Water operated dams were not considered to be available for extraction.

5. ESTIMATING POTENTIAL HARVEST VOLUMES

Two models have been created to simulate the flow conditions across the Greater Adelaide area and then model the potential treatment and harvesting options and yield potential. Watercress, a water resources model, was used to estimate current flows. MUSIC, a water balance and water quality model was used, assess the different treatment and harvesting scenarios to determine potential harvests and assess the impact of predicted climate change and urban consolidation.

5.1 Current Catchment Flow – WaterCress Modelling

Catchment Modelling undertaken using the WaterCress urban hydrology model has indicated that the likely long term average flow of stormwater to the Gulf of St Vincent from within the study area is currently in the order of 115 GL/a.

Modelling was undertaken using the WaterCress model to determine predicted current average annual flows. The WaterCress model has been calibrated over the past 10 years to mean (average) flow values where gauging data are available. The calibrated model has then been run using rainfall data over a period of 30 years to incorporate fluctuating climatic patterns.

A map of predicted average flows form WaterCress models for existing urban development is shown in Appendix C. A detailed discussion of the WaterCress modelling Approach is presented in Appendix D.

Stormwater flows have been gauged at more than 40 locations within the Adelaide Metropolitan Area over periods ranging up to 30 years, but generally between 5 to 10 years. 34 of these having the longer periods of record were used to calibrate the WaterCress rainfall to runoff model. Despite this large number of measurement locations, the spatial distribution is poor and, until very recently, the flows emanating from several large areas (particularly within the western suburbs) have not been measured.

Despite their limitations, the gauges provide the best source of information on the flows within the area. Flow gauges are however, subject to a range of errors, which can affect part or all of their records. Careful screening, analysis and comparisons of the records are therefore necessary to reveal the size and nature of the errors. Since the flow records are the direct result of rainfall, rainfall to runoff modelling, using a model such as WaterCress, can often reveal where flow records are suspected to include some inaccuracies.

Over the past decade, separate WaterCress models have been established covering the majority of the metropolitan area catchments, with most models having been calibrated against one or more of the gauged flow records. The models were established for different purposes, using different standards and over different periods. The present study provided the opportunity to collate these previously established models and to extend, upgrade and standardise them.

The process of calibration is usually employed to enable the various coefficients in a rainfall to runoff model to be adjusted in order that the model reproduces the gauged flows as closely as possible. The model can then be used to predict flows in the gauged catchment over longer periods (say up to 100 years), i.e. over the longer period for which rainfall records may be available. Similarly, the model can also be used to estimate flows in other ungauged catchments deemed to have similar characteristics as those that have calibrated models.

Systematic errors over long periods of record appear to be quite common and are generally introduced during data processing through the adoption of inaccurate and/or poorly estimated relationships between flow depth and volume through the gauge. Such inaccuracies may arise when:

i) gauges are sited on streams with variable geometry arising from seasonal vegetation growth or bed and/or bank erosion and deposition
ii) the water level to flow relations are inaccurate, particularly when they have not been regularly checked by field measurements.

There are many causes for such errors and even at best, most flow records will almost inevitably contain periods of random and systematic errors.

The main aims of the calibration process were therefore to:

1. produce flow estimates for each of the sub-areas identified in Appendix C over a common period of rainfall and development levels. In this case the 33 year period 1970-2002 was used
2. obtain a better understanding of the hydrology of the area. In particular to identify stream reaches which have apparent significant losses to groundwater infiltration.
3. assemble a cohesive model that could be used for future project scenario investigation and planning, based on the best catchment information available.
4. identify which flow gauges may be providing suspect data, in that they display obvious random errors and/or give results which cannot be logically explained.

A finding of this study has been that a number of the gauging stations may be providing suspect data. It may be possible to improve the confidence levels of these sites by changing the station location, more frequent station visits for maintenance and field checking, and installing more gauges along each catchment allowing flow comparison along a water course.

As part of establishing a cohesive model, an additional aim of the calibration process has been to establish 'best' sets of coefficients to be used within the model's rainfall to runoff equations for predicting runoff within defined types of urban catchments. 'Best' is defined as the set of standard surface areas and loss rates that can be quantified from the aerial photographs and which then give the best group calibration to the gauged flow data. This is described in Appendix D.

The grey section of Table 10 shows the average flows as predicted by the model, after calibration, and the average over the same period as recorded by the gauge. The associated correlation coefficient R shows the fit between each month of the record over the months of correlation. In most cases a satisfactory fit could be obtained, but in order to maintain the integrity of the 'standard' runoff generation part of the model (see Appendix D) it was necessary to introduce losses into the model in the form of stream infiltration. In many cases these were required where losses were known to occur (e.g. at locations where the streams cross known fault lines), but in several instances this knowledge or circumstantial evidence was not present. With respect to this, it should be noted that calibration was always started from the upstream gauges and, once calibrated, the same model was adopted for the downstream catchments and gauges. Since, in very few cases was flow required to be added (rather than subtracted) as the calibrations proceeded downstream (e.g. as in the case of the serial gauges in the Patawalonga catchment) it is hypothesised that these losses are a real and significant component of the Adelaide regional hydrology which should be investigated using more refined methods.

Modelled Flows

Table 10 lists the flows predicted by the WaterCress model at the downstream outlet of the catchments modelled. In most cases these are or very near to the sea, but for Smiths Creek the catchment downstream of Andrews Farm was not modelled as no additional flow is likely to be added in the current condition. It also shows the losses that were abstracted as stream infiltration in order to obtain the calibrations and the coefficients of runoff from the total upstream catchment.

Of note is the generally higher runoff coefficients in the central, more densely developed urban areas of Adelaide and the generally lower values of the coefficients to the north and south.

Observations about each catchment are noted in Appendix D.

Table 10 Flow Comparisons

1970 - 2002	Averages						
Catchment	**Av. Catch Rainfall mm**	**Inflow from up stream GL/a**	**Outflow GL/a**	**Est. Losses GL/a**	**Losses as % runoff**	**Runoff Coef. (%)** (excl up stream inflow)	**ACWS Study (CS)**[9]
Gawler	n/a						10.3
Smiths Creek	517	0	1.33 (1)	1.11	45.5	4.5	
Helps Road	470	0	1.21(1)	2.04	62.8	4	5.2 (1)
Little Para	514	0.67	2.47 (1)	1.16	32.0	11	
Dry Creek	544	0	8.84 (2)	0.68	7.1	16.8	10.3 (2)
Enfield/West Lakes	485	0	7.67(2)	n/a		23	
Torrens	659	9.61	32.75 (3)	1.11	3.3	22.5	22.4 (3)
Patawalonga	674	0	22.53 (4)	4.89	17.8	15.8	19.7(4)
Brighton	525	0	2.69 (5)	n/a		19.3	2.7 (5)
South Coast	635	0	8.32 (6)	0.89	9.7	12.5	13.1 (6)
Onkaparinga.	n/a						9.5
Willunga	n/a	0	4.57 (7)	4.44	49.3	3 (est)	2.3 (7)
Total (grey)			82.77 (8)	16.32	16.5		75.7 (8)

Est. total flow to sea (1970-2002) = 82.8 + 19.8 (Gawler+Onkaparinga) + 10.3 (inflows from up stream) + 2.0 (fringe areas) = 115 GL/a

(1) Close agreement if ACWS 'Smith Ck' includes Smiths, Helps and Little Para
(2) ACWS 'Barker Inlet' appears too low if it includes Dry Ck and Enfield/W lakes
(3) 32.75 includes 9.6 spill from Gorge Weir. If removed figures match closely.
(4) Reasonable match.
(5) Good match
(6) ACWS est for Christie Ck at 8.1 appears too high, hence total too high.
(7) ACWS est appears too low
(8) Both exclude inflows from up stream, e.g. Gorge Weir spill
(9) ACWS – Adelaide Coastal Waters Study

Comparison to Coastal Studies estimates**:** The present flow estimates are about 10% higher than the figures published by the Adelaide Coastal Waters Study. However, for both estimates, the total flows are very much affected by the gauged flows for the Torrens and Patawalonga, which together constitute 50% of the estimated discharge. The 25% lower runoff coefficient estimated for the Patawalonga is difficult to explain in view of its higher average catchment rainfall, although it may also have a slightly higher proportion of pervious catchment. These estimates are very dependant on the accuracy of the Holbrooks Road and Anzac Highway gauges. Further analysis can and should be done to calibrate stream gauges and increase data confidence. This will assist in determining and monitoring flows within each catchment. The greater the understanding of a catchments flow characteristics in relation to rainfall the better catchment management can be implemented for both flood control and stormwater harvesting. It is recommended that high flow current metering should be re-instituted to increase the accuracy of the gauge ratings at these key locations.

5.2 Harvesting Assessment In Music

MUSIC (Model for Urban Stormwater Improvement Conceptualisation, see www.toolkit.net.au) was used to assess each of the harvesting and treatment options identified and their interaction on a catchment wide basis. A simple model was developed to simulate catchment hydrology so that the focus of the modelling could be on the harvesting and treatment processes and the interaction between different schemes given the tight timeframes for the study.

Parameters for urban and rural nodes for the models were calibrated against available gauging data (refer to the next section) and then 20 catchment models were developed to cover the entire study region. Calibrated models were then used to simulate each of the potential harvesting sites identified from field visits and Council interviews. The diversion and treatment systems were included within each catchment model and the interaction between each harvest site was a key focus of the optimisation.

Each catchment model was then run to identify the maximum harvest potential for each site using 32 years of historical rainfall data (using the Kent Town rainfall station, 1977-2009 data). Equally important to the harvesting and treatment opportunity is the ability to store treated water economically. Therefore once potential harvests were estimated for each site an extensive iteration process was undertaken to match harvest and treatment potential with the ability to feasibly store treated flows (refer to Section 4.2). The majority of storage potential across Adelaide is in aquifers, therefore groundwater assessment was critical in identifying the preferred harvest and treatment locations presented in Section 6.

The impact of predicted climate change and urban consolidation were also simulated in MUSIC to assess their impact on potential harvests for each location. Results of this are presented in Section 7.

5.3 Calibration Of Harvest Model

5.3.1 Existing Flow Data

Gauging stations along the main watercourses were reviewed to allow calibration of the hydrological model to historical (median) flow data. Flow data were derived from the Department of Water, Land and Biodiversity Conservation website www.e-nrims.dwlbc.sa.gov.au/ refer to Table 11 for details.

Table 11.Gauging data mean and median flows (www.e-nrims.dwlbc.sa.gov.au/)

CATCHMENT	DOWNSTREAM GAUGE REF	DATE RECORD	LOCATION	MEAN (ML/a)	MEDIAN (ML/a)	UPSTREAM GAUGE REF	DATE RECORD	LOCATION	MEAN (ML/a)	MEDIAN (ML/a)
GAWLER RIVER	A5050510	1972-2004	Virginia Park	20,080	17,450	A5050505	1969-2004	Gawler Junction	24,920	17,190
LITTLE PARA	A5040544	1980-1983	Pt Wakefield Rd	1,107	635	A5040541	1980-1983	Halbury	1,309	833
RIVER TORRENS	A5040529	1978-2008	Holbrooks Road	27,550	19,780	-		-	-	-
BROWNHILL/KESWICK	A5040583	1990-2008	D/S Adelaide Airport	6,480	6,027	A5040901	1990-2009	Scotch College	1,861	1,414
STURT RIVER	A5040549	1990-2009	Anzac Highway	9,712	9,389	A5040576	1994-2009	Mitchell Park	6,424	5,531
FIELD RIVER	A5030546	2000-2009	Main South Road	2,159	2,533	-	-	-	-	-
CHRISTIE CREEK	A5030547	2002-2007	D/S Galloway Rd	N/A	N/A	-	-	-	-	-
ONKAPARINGA RIVER	A5030522	1973-1988	Old Noarlunga	22,980	16,670	A5030503	1969-2008	Baker Gully	3,905	3,472
PEDLER CREEK	A5030543	2000-2008	Stump Hill Road	1,188	663	-	-	-	-	-

For the purposes of this study, median flow data were selected for the calibration process rather than average flow data. Median flow data are considered to provide a more representative flow volume for the purpose of assessing potential harvesting quantities. Median flow data also avoid a skewed average flow (mean) in regulated catchments (e.g. River Torrens and Gawler River) where several large rainfall years and where reservoir spills can skew the average annual flows. The harvesting model therefore only considered catchment areas downstream of the reservoirs on the River Torrens and Onkaparinga Rivers catchments. Figure 3 shows the influence of two large flow years in the 30 year record (presumably when the reservoir spills) that results in a mean flow of 30% higher than the median flow in the River Torrens.

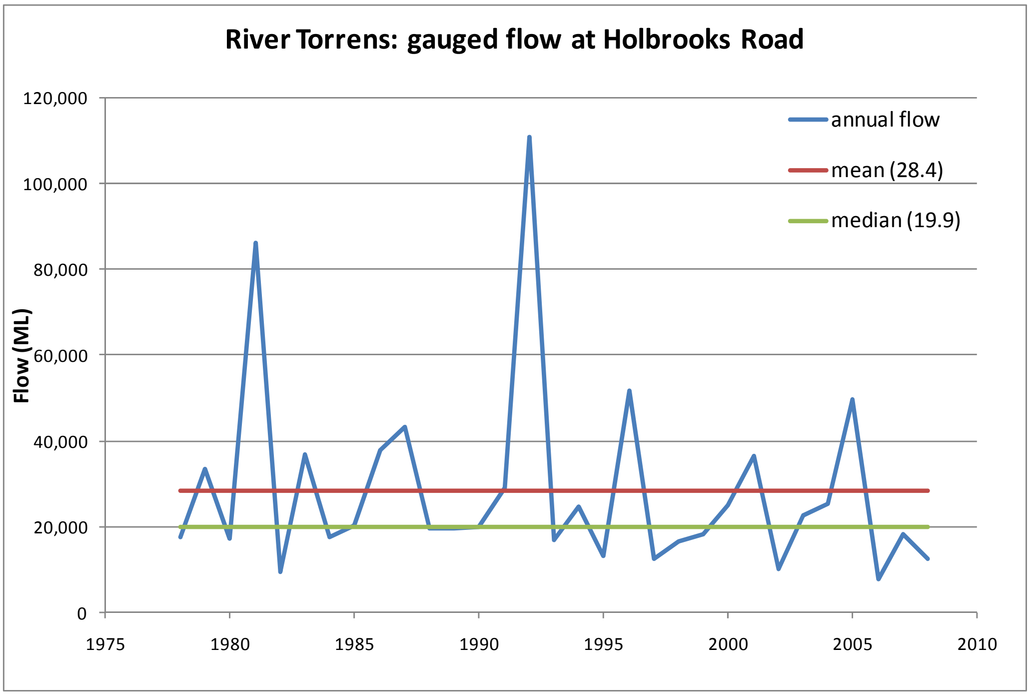


Figure 3. Yearly, mean and median flow data for River Torrens at Holbrooks Road

This approach to calibration is considered conservative when assessing harvesting yields and therefore increases the confidence in being able to deliver the estimated yields for the sites and concepts identified in this report.

To generate flows in the simplified hydrological model one set of rainfall data were selected to simulate runoff in the catchments. Following considerable analysis, the Bureau of Meteorology Kent Town (Station number 023090) was selected as the rainfall file. 32 years (1977 – 2009) of six minute rainfall data were obtained for the modelling process. The average annual rainfall during this period is 544 mm per year. While this is a simplified approach to modelling the catchments across a large distance the calibration process provides sufficient confidence in the model outputs (refer to Figures 4 and 5).

Annual flow data from the model were compared to median flow data from gauging stations for a range of sites and catchment mixes (i.e. percentage of urban development) across Adelaide. Figure 4 and Figure 5 below show a comparison between the gauge data and the model output, expressed as volumetric runoff coefficient (Figure 4) and as the annual flow volumes (Figure 5).

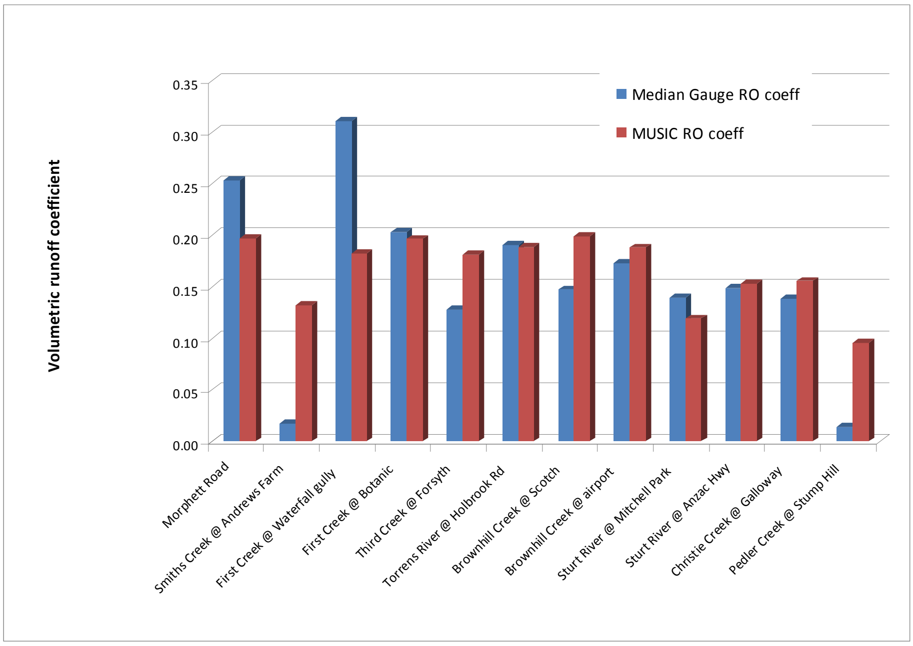


Figure 4. Gauged data versus MUSIC model output expressed as volumetric runoff coefficients

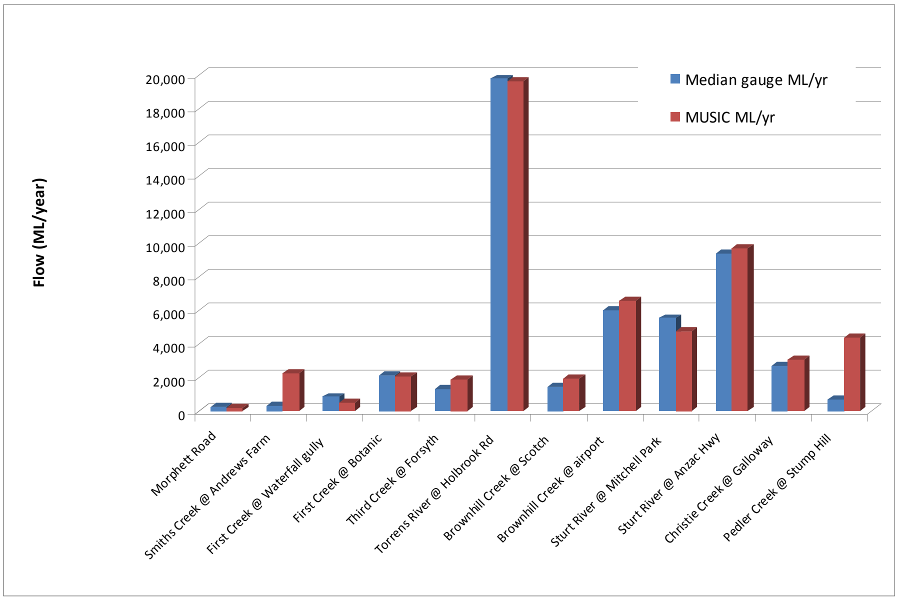


Figure 5. Gauged data versus MUSIC model output expressed as annual runoff volumes

Figure 4 and Figure 5 show a good correlation for annual flows at all sites considered with two exceptions, Smiths Creek and Pedler Creek. Gauged Smiths Creek flows showed very low volumetric runoff coefficients and these are expected to increase substantially with planned urban development in the catchment. In addition, predicted flows were compared to previous studies (Adelaide Coastal Waters Study, Flinders University, 2005) and found the predicted flows to be very close (5.0 and 5.2 GL/a). Pedler Creek calibration could not easily be explained, however given the limited quantity of harvesting available in the catchment, it is not considered to significantly affect the study approach. These calibrations were considered adequate for the main focus of the study – assessing harvesting potential at multiple sites.

5.4 Modelling Stormwater Capture And Treatment

Modelling of the various harvesting options considers both capture and treatment. When modelling stormwater capture, site constraints such as topography and space were considered. Possible capture configurations considered include:

- on-line storage
- direct extraction from streams
- gravity and pumped diversions
- off-line buffer storages.

Arrangements were chosen to best fit within each site considered, and were sized to achieve an optimal configuration in terms of stormwater harvest, where possible.

Treatment options consider a best management practice approach, whereby treated outflows are likely to be of a suitable standard for aquifer injection or surface storage. Depending on the end use of stored water, post treatment may be required. The configurations of treatment systems below are considered to represent best practice in Australian design and will provide sufficient treatment for stormwater to be suitable for aquifer injection.

Wetlands

- Minimum retention time considered as 72 hours to provide sufficient contact time with wetland vegetation for water quality improvement
- An average permanent depth of 0.3 metres (this is assumed to include predominately shallow vegetated areas 100-400mm deep with approximately 10% of the wetland area having deeper open water areas in accordance with best practice design, e.g. Melbourne Water (2005)
- Wetland active storage (or extended detention) of 0.5 metres above the normal operating level
- Maximum wetland treated outflow rate considered at 20 L/s per hectare of wetland area based on the above assumptions.

Bioretention (or biofiltration)

- Filter media hydraulic conductivity of 150 mm/hr
- Loading rate considers one day on followed by one day rest
- A maximum of 300 mm of extended detention on the surface of the filter media
- 500 mm filter media depth with a mean particle size of 0.45 mm
- Maximum bio-retention treated outflow rate considered at 200 L/s per hectare of bio-retention area.

It should be noted that the performance of bioretention facilities for stormwater harvesting applications requires further testing to confirm potential maximum treatment rates. These systems are well documented to provide effective stormwater treatment (e.g. www.monash.edu.au/fawb), however application for stormwater harvesting is limited to small scale systems to date. The City of Salisbury are currently developing a trial at Unity Park to test their effectiveness as a large scale treatment method and to determine the impact of sustained loading without rest periods.

Mechanical / media treatment

Where space limits opportunities for surface treatment systems, mechanical treatment such as sand filters, membranes etc. are considered. Treated outflow rates are selected to provide optimal harvest volumes, where possible. It should be noted that media filters all produce a waste stream that must be accommodated for when designing the system.

6. DETERMINING POTENTIAL HARVEST CAPACITY

Following site visits, discussions with Councils, assessment of existing land uses, topography and storage options in the order of 100 sites were identified for further modelling. These stormwater harvesting sites were considered technically feasible for construction. This list of sites formed the basis for the harvesting models (described in Section 5.2) that assess potential harvest volumes and the interaction between different sites. Some of these sites were then discarded after modelling as either large yield could not be achieved for there were more appropriate schemes developed on the same catchment.

Concept sketches and the tables in the following sections show the locations, operating principles and approximate sizes of the proposed harvesting schemes. In some areas stormwater is transferred between catchments to increase available treatment opportunities (i.e. transferred to where there is available space) or to where groundwater storage is more favourable.

It is important to note that the schemes proposed are considered the most practical large scale schemes identified as part of the study, but are not considered to be the only harvesting opportunities that could be developed within each catchment. Smaller scale schemes could also be developed that are not identified as part of this study. In addition, yields could be increased at some sites, however, this would impact on other downstream schemes in the catchment. While developing these schemes presented in this report an attempt was made to spread the schemes sufficiently to allow for efficient use of the groundwater storage potential. This may also suit future demand locations, however, this was not a major driver for the current study.

The aim of the study was to identify practical and achievable stormwater harvesting potential for the greater Adelaide area but not to limit opportunities for other schemes that may prove to be viable (particularly smaller ones).

Harvest figures stated are based on a typical year and actual volumes will vary on an annual basis depending on rainfall volumes and intensities. Refer to the Section 7 for discussion on analysis performed to assess the impact on yields for climate variability and urban consolidation.

6.1 Summary Of Harvesting Volumes

A summary of modelling outcomes is shown in Table 12.

Table 12 Summary of Modelling Outcomes

Catchment	Number of Schemes	Potential Annual Yield (ML/yr)	% of median catchment runoff
Gawler River	5	6,020	55
Smiths Creek	6	3,488	69
Adams Creek	8	3,525	70
Greater Edinburgh Parks	1	1,990	53
Little Para River	11	2,235	61
Dry Creek	11	8,233	72
Barker Inlet	4	4,082	130*
Range wetlands	2	1,791	74
Port Road	4	1,521	56
Grange area	2	1,250	63
River Torrens	9	6,691	34**
Mile End Drain	1	850	58
Brownhill/Keswick Creek	7	4,234	65
Sturt Creek	8	6,188	64
Field River	5	2,536	55
Christie Creek	3	1,317	43
Onkaparinga River	3	2,037	28
Pedler Creek	2	1,237	25
Willunga area	1	481	26
Misc		400	N/A
TOTAL	**94**	**61,286**	**55**

**Note This percentage is greater than 100% of the catchment flow as water has been transferred into it from the River Torrens catchment.*

*** This catchment appears to have a low percentage of yield, however this percentage does not include the water transferred to other catchments. If the transferred volumes are considered the percentage of harvest is 55%.*

6.2 Guide to Catchment Descriptions

For the purposes of assessing potential harvest the area under investigation was divided into 20 catchments (refer to Section 2.1.1). For each catchment a brief description of the harvesting schemes, the rationale behind the harvesting locations, operating principles and an assessment of storage options is provided.

Information is summarised in tables and concept sketches presented in Section 6. The sketches show how the concepts fit within available land. (Larger scale concept plans are included in Appendix G).

The sketches presented are in a concept form only and the shape and actual area of the wetland would need to be refined during the design phase of the project. The shaded areas in the sketches are approximate only and represent an indicative area required to construct the wetlands inclusive of batters and planted buffer storage etc.

Summary Tables

Summary tables for each catchment present key information that describe each harvest location. The tables are broadly divided into capture & treatment and storage components of the systems, and provide information on:

- **Buffer storage volume** – this is the amount of on-line storage provided that can be used to regulate flows into a treatment system. They can operate either by gravity or be pumped. Where there is no opportunity for on-line storages and flows are directed directly from a waterway the buffer storage is zero.
- **Diversion pump** – this is the rate at which flow is transferred from a buffer storage or waterway to a treatment system.
- **Wetland size** – the area of wetland required for the proposed treatment rate and volume. It has been assessed for each site and deemed suitable for the site conditions and catchment hydrology. The sizes are for wetlands with the configurations described in Section 5.4 (the size may change if the configuration changes during detailed design).
- **Bioretention size** – the area of bioretention (or biofiltration) required for the treatment rate. Based on the configuration described in Section 5.4 Media filtration may also be supplemented for bioretention by matching with treatment rate if deemed more appropriate for a given site.
- **Treatment rate** – the rate at which treated stormwater will be produced from the treatment system (i.e. its maximum outflow). This is the rate that is targeted for groundwater injection to avoid a requirement for significant surface storages prior to injection.
- **Total treated** –the volume of treated water produced by the treatment system for a typical year.
- **Injection rate** – the rate that each potential well could inject to groundwater. This is used to assess the viability of groundwater as a storage option and the number of wells required to match the treatment rate.
- **ASR wells** –the number of wells required to harvest the treated volume of stormwater. This is based on an assessment of the regional capacity of the aquifer and the likely injection rates. (note: injection rates adopted are considered relatively conservative, but this is considered appropriate due to the broad nature of the assessment).
- **Surface storages** – the volume of surface storage required to store the treated volume of stormwater or the volume available given site constraints. Surface storages were only considered where groundwater could not provide sufficient treatment. The feasibility for surface storages were assessed from a desktop assessment and limited site inspections.

Concept Diagrams

To provide an overview of the concepts developed during this investigation, brief concept diagrams have been produced. They provide a quick overview of the operating concepts for each harvest location. Below is a legend to the sketches.

	Indicative number/location of ASR bores required
xha	Area of Wetland required
xha	Area of Bioretention (or Filtration) required
xML	Volume of Storage required
	Stormwater inflow
	Treated water outflow

Cross-Catchment Transfers

Transfers between catchments occur for both treatment and for groundwater injection.

Untreated stormwater is transferred where insufficient space is available within a catchment to maximise the harvesting opportunities. Typically, flows are pumped from one catchment and then are transferred to a treatment site through an existing stormwater pipe network in another catchment to an area that has more available space for treatment and may offer better groundwater injection potential. For example, flow from within the River Torrens is proposed to be pumped to the Hindmarsh Enfield Prospect drainage system that will then convey flow to the Islington Railyards that have available space for treatment and suitable aquifers to store treated water. This approach then reduces the pressure on the lower end of the River Torrens where there is significant treatment and injection proposed from numerous catchments (Sturt River, Brownhill Creek and Keswick Creek in addition to the River Torrens).

The other component of transfer is for treated water to be moved to where there are more suitable groundwater conditions for injection and storage. There are examples of similar systems already in use.

The City of Tea Tree Gully installed such a system as part of Waterproofing Northern Adelaide Project. Approximately 20 km of rising mains enables transfer from various capture and treatment sites to injection sites. The Cities of Salisbury and Playford have significant networks that enables transfer between treatment and injection sites and to customers. This also adds contingency in the event that a particular well or well field cannot be operated.

In addition, several local government areas are planning to connect their networks of treated water (e.g. Salisbury, Tea Tree Gully and Playford). This will allow further transfer of flows for storage and delivery to customers adding flexibility to the network.

This concept is of particular relevance to the west of Adelaide where large volumes of stormwater are proposed to be captured and treated. To use the aquifer as a storage facility it will be necessary to establish some significant transfer mains to service well fields.

The City of Charles Sturt is planning a ring main within its Council area. There may be an opportunity to further expand the system to the north and south to create a transfer main between the Adelaide Airport region and Port Adelaide allowing injection to occur over a significant area. The construction of such a pipeline is considered strategically important if a major ASR scheme is to be developed in Adelaide.

If a line is established to Port Adelaide then this could further be connected to the Salisbury scheme, through the Barker Inlet and Greenfields schemes, and therefore creating a significant regional scheme allowing maximum flexibility between treatment, storage and users for treated stormwater (potentially between the Adelaide Airport region and the City of Playford)

Another important transfer is in the south of Adelaide because of the limited capacity of the aquifer to provide significant storages. This is particularly relevant for Field and Onkaparinga Rivers and Christie and Pedler Creeks. There are significant storage volumes possible in the Willunga basin (up to approximately 4 GL/a, refer to Section 4.2). A transfer main from Christie Creek to the Willunga basin is considered here to transfer treated stormwater. This is based on an understanding that construction of a pipeline is currently underway. The Field River could be connected to such a system in the future to further increase yields but this has not been considered for this study.

A pipeline running parallel to the coast could also be considered to transfer captured stormwater from the southern regions for injection in the more favourable western ASR region. This would result in an increased potential harvest for the Adelaide region, however, on its own the cost to install the pipeline, to achieve an increase in harvest in the order of 10ML/a is currently considered excessive. This could be considered in the future as other infrastructure projects are undertaken that may be able to incorporate this transfer line.

<u>Groundwater Storage Potential Assessment</u>

Preliminary assessments of potential groundwater storage consider storage within the Tertiary Limestone aquifers, in particular the T1 and T2. When reviewing the viability of storing the proposed harvested volumes, typical aquifer properties were considered as well as expected pressure increases due to injection (including well interference effects) across the proposed bore field. Where presented in the following sections, the indicated number of wells required to store the harvested volume are considered viable with respect to injection capacity, aquifer storage and safe operating pressures. Field testing would be required to confirm viability for any schemes that are to be further developed.

Appendix E indicates the likely zone of influence of a large scale (in the order of 5GL/a) ASR scheme in the western region of Adelaide.

Appendix F shows a summary of existing well locations sourced from the Government drill hole database. The status of a significant portion of these wells is not known, and will need to be investigated as part of the detailed design of proposed schemes. In those areas where the T2 aquifer is targeted, the location of T1 wells is not shown. The figure indicating well locations in Appendix F has been included in this report to indicate the number of wells that may be affected by the schemes proposed in this report. It is the first step in undertaking a ground water risk assessment, which is required before any ASR scheme can be developed.

6.3 Gawler River

Flows in this catchment vary significantly from year to year and the construction of dams has altered flows in the downstream sections of the catchment. This altered flow regime and the significant variance in flows from year to year is likely to increase with predicted climate change. A conservative approach to assessing potential harvest volumes from the rural flows was therefore taken. A summary of the proposed harvesting in the Gawler catchment is shown in Table 13.

Table 13. Gawler River

Gawler River	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Dawson Rd retarding basin			0.7		14	118	<5	transfer	
Gawler River (Rural linear)	10	750	25		500	4,740	8-10	50	
Buckland Park	10	140	7		140	856	8-11	15	
Gawler racecourse		20	1		20	306	<5	0	75
					TOTAL	**6,020**		**65**	**75**

Dawson Road

The first harvest site is the Dawson Road retarding basin where an existing retarding basin could be retrofitted with a gravity fed wetland to capture and harvest stormwater. The system is sized to match the upstream catchment and available area in the base of the retarding basin.

The site is located between the Alma Fault (to the east), and the Para Fault. Shallow Carisbrook Sand overlies Tertiary sediments consisting mostly of fine to medium sands. The Tertiary sands inter-bed at the bottom with lignitic layers, most likely of the Clinton Formation. Extraction yield in the Carisbrook Sand generally ranges between 2-4 L/s. The prospects of establishing viable ASR wells are considered to be low to moderate.

It is therefore proposed to transfer treated flows southwards to the Smiths Creek catchment, where ASR opportunities are better and a scheme is possible at Evanston South (refer to Smiths Creek catchment descriptions).

Gawler River (rural linear corridor) downstream of Gawler township

The most significant harvesting scheme in the Gawler catchment is pumping water from the river to treatment areas spread along the banks of the river, west of the Gawler township. The intention is to use wetlands as the main treatment system and distribute the wetlands according to available space and to spread them out with the requirements of ASR well spacings. This is mainly private land and negotiation would need to take place to secure land (primarily rural land). Significant flood mitigation works are being planned for this catchment and this provides an opportunity to co-locate capture and treatment facilities within the mitigation works. A significant opportunity also exists adjacent to the Northern Expressway (currently under construction) where a significant detention basin is proposed. A treatment facility could be co-located within the basin.

The T2 limestone is dense and tighter in this area than further south but provides the best groundwater storage option because the T1 is relatively thin. Injection rates per well will be approximately 8-10L/s/well. For the potential harvest volumes approximately 50 wells are required at 200m centres.

The T1 aquifer along the proposed ASR sites is non existent or thin. ASR will therefore be carried out in the T2 aquifer. However, some 10GL of water is allocated to irrigators using groundwater from the T2 aquifer between Virginia and Gawler, within 4-5km either side of the Gawler River. Apart from the issue of irrigators extracting the low salinity injected water, a large proportion of these existing wells will require modification to the headworks to manage the localised artesian conditions during the injection cycles.

Future Development- No Picture

Buckland Park

Buckland Park is a proposed regionally significant development that is planned on the lower reaches of the Gawler River. As the development is planned a series of wetlands could be incorporated into the development or remotely located with the cooperation of the City of Playford. It should be noted that there is shallow and saline groundwater in the vicinity of development and this may necessitate the need for locating the treatment systems remotely from the development or the installation of media filtration in lieu of wetlands. Specific details of the system layout have not been provided as the development is still in the planning stages and will need to be further developed.

The ASR potential is considered the same as for the banks along the Gawler River (see above) where the T2 is targeted. Concept sketches are not provided as the layout of the site is still being developed and is subject to change.

Gawler Racecourse

The centre of the Gawler Racecourse provides an opportunity for treatment of stormwater. Flow could be pumped from the Gawler River or gravity fed from proposed developments to the east of this area and treated in a wetland for local reuse.

The Gawler racecourse also occurs between the Alma Fault and the Para Fault. There is reportedly an existing well at the northern end of the racecourse, completed in “gravel”- probably the Carisbrook sand overlying Tertiary sands, extraction yield 12L/s, salinity 1,500mg/L. Extraction yield in the deeper Tertiary sands is expected to range between 2-7L/s, but less than 5L/s for injection. These consist of carbonaceous and non-carbonaceous sands, becoming lignitic at depth. The fine sands and lignite are problematic for ASR (low injection rates, high clogging potential) and is therefore not recommended for large scale ASR.

Treated flows are therefore proposed to be stored in a surface storage because of the limited aquifer capacity of the area. Negotiations with the land owners would be required for this scheme to proceed. Should this scheme not proceed then the capacity of the downstream systems can be increased to accommodate the additional yield potential.

6.4 Smiths Creek

The Smiths Creek catchment has been extensively investigated for stormwater harvesting potential as part of planning the Playford Alive development and through the Waterproofing Northern Adelaide project. Six opportunities are identified in this study as shown in the Table 14.

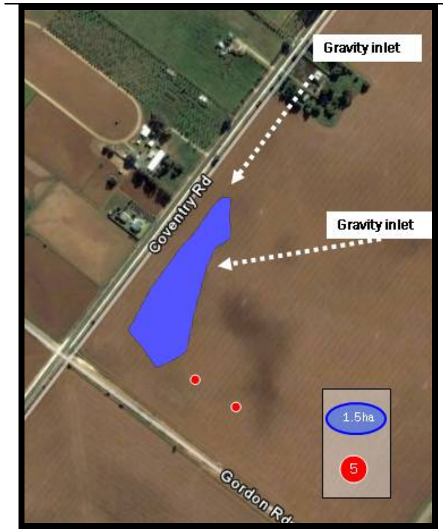
Table 14 Smiths Creek

Smiths Creek	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Evanston South			1.5		44	185	10	5	
Blakeview			2		40	308	20-25	2	
Munno Para West*			7		90	1241	20-25	5	
Andrews Farm			3.2		64	400	20-25	3	
Andrews Farm South			2.8		56	500	20-25	3	
NEXY retarding basin				2	200	854	20-25	10	
					TOTAL	**3,488**		**28**	**0**

** The City of Playford is currently constructing a 4ha wetland at this site which will have an expected yield of 550ML/a*

Five of the sites involve gravity fed wetlands that are accommodated within the existing or planned projects currently being investigated by the City of Playford. Aquifer potential at each site has been assessed as being very good for injection with the possible exception of the Blakeview site where treated flows are proposed to be piped west to more suitable aquifers (e.g. near the Munno Para West site).

The systems are configured so that overflows from upstream systems will reach the downstream wetlands. At the far downstream end of the system a treatment facility is proposed within a planned large flood retarding basin associated with the Northern Expressway. This system will be fed from a small local catchment and any subsequent overflows from upstream schemes. It will be an opportunistic site that because of the size of the basin will be able to harvest even the larger flows within the catchment. As such the annual harvesting volume for this site will vary significantly. It is expected that media filtration will be implemented in this area to enable the system to operate on an as required basis. The site will also be linked to Playford's transfer mains to enable injection at one of Council's other injection sites. This link will enable injection during peak events to be spread amongst Council's other injection sites.



Evanston South

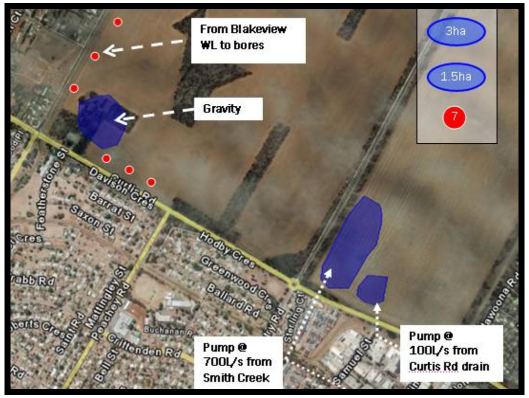
It is proposed to divert water from the Dawson Road wetland to Evanston South and mix with a gravity fed wetland that will treat water from the local catchment. The wetland site occurs just west of the Alma Fault. Close to the fault, the limestone aquifer thins out and/or becomes sandy. West of the Alma Fault, there are changes in facies and there is good potential to intersect the T2 aquifer. It occurs at a depth of 85-95m below ground, and the thickness is anticipated to average 20m. Salinity ranges between 900-1,100mg/L. Injection rate per well is anticipated to be around 10 L/s.

Five wells located 150m-200m apart westerly from the western boundary of the wetland along Angle Vale Rd will be required. This is considered to be well within the storage capacity of the aquifer.

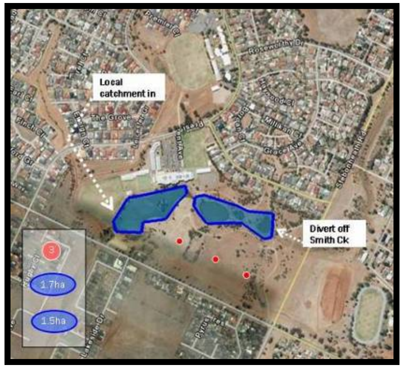
Blakeview

The Blakeview development will provide treatment in a gravity fed wetland system and then transfer treated flows immediately to the west where better injection rates can be achieved (eg. Karri Reserve or Munno Para West, where a recently drilled T2 well has an expected injection capacity of 25L/s)

Munno Para West/Andrews Farm/Andrews Farm South



(a)



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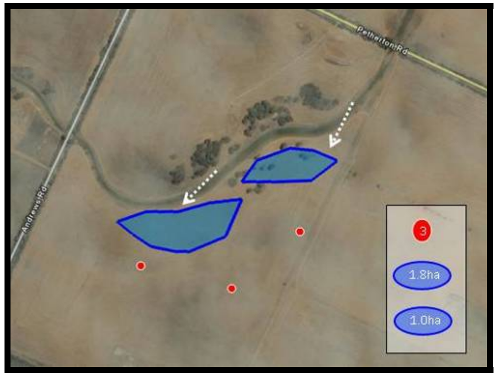


(c)

The Munno Para West (a), Andrews Farm (b) and Andrews Farm South (c) wetland system are all proposed to operate by gravity. The wetland systems are being planned as part of an urban regeneration program and will also add value to the landscape of the area while producing treated stormwater.

To asses ASR potential recent hydrogeological investigations, including drilling, well discharge testing and modelling has demonstrated that:

- the T2 aquifer is homogeneous, with consistent properties
- the injection capacity per well is expected to range between 20-25L/s.
- Well connected aquifers showing high transmissivity.

Analytical modelling, taking into account well interference, continuous injection at 25L/s/well over 70 days (conservative), indicates an impress up to approximately 50m above ground level for the schemes with treatment rate less than 100L/s. This results in the system being well suited for storage of treated stormwater, as has been confirmed by numerical modelling.

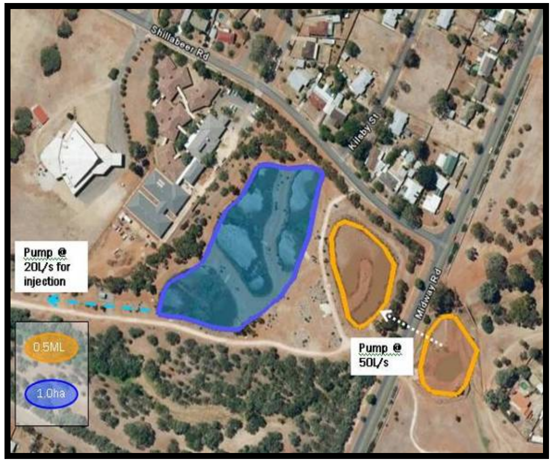
Future Development – No Picture	<u>NEXY RB</u> A significant retarding basin is planned as part of the Northern Expressway. This provides an opportunity to capture local runoff as well as overflows form all of the upstream systems. The intension is to install a media filtration system adjacent the retarding basin. When further planning of the retarding basin progresses a concept can be developed. It is understood that the basin will be well in excess of two hectares in area thus a treatment system of this size will be feasible. An impress of some 90m above ground has been estimated for 10 wells at 200m spacing for storage at 200L/s. This is close to the recommended upper limit, and subject to detailed analysis, may necessitate a wider well spacing.

6.5 Adams Creek

Adams Creek yields are derived from seven treatment systems with all except the Olive Grove system being gravity operated. Table 15 below summarises the harvesting systems. It should be noted that this catchment includes the Helps Road Drain, Edinburgh Parks and RAAF drain catchments.

Table 15 Adams Creek

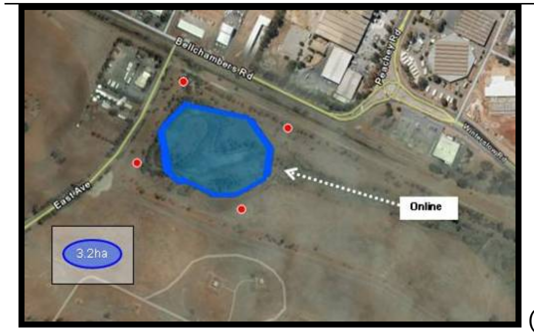
Adams Creek	CAPTURE AND TREATMENT							STORAGE	
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Olive Grove	0.5	50	1		20	303	8	3	
Edinburgh Parks North			3.2		64	630	20-25	3	
Edinburgh Parks South			4		80	760	20-25	4	
Kaurna Park			5		100	551	20-25	5	
Springbank Park			5		100	398	15-20	7	
Burton West			2		40	308	15-20	3	
Summer Rd			8		160	575	15-20	11	
					TOTAL	**3,525**		**36**	**0**



Olive Grove

The Olive Grove system operates with a capture basin on-line from which flow is pumped into a wetland. This system is currently operational. To achieve the yields outlined above the existing site would require to be upgraded. Treated water is conveyed to Ridley Reserve for injection into the T1 aquifer.

Drilling at the Olive Grove Site intersected 16m of T1 aquifer at the site. Subsequent well discharge testing suggested an injection capacity ranging less than 5L/s, against high pumping heads. Furthermore, the T2 aquifer is not prospective at this locality. It is therefore proposed to pipe the water and inject into the T1 aquifer at Ridley Reserve, where two T1 wells have already been established. The City of Playford has already constructed a 150mm rising main between Olive Grove and Ridley Reserve.



(a)

(b)

Edinburgh Parks North and South

The remainder of the systems in Adams Creek are more significant in size, operate under gravity and can inject into aquifers near to where flows are treated. Existing wetlands in the lower end of the catchment (Kaurna Park, Springbank and Burton west) are assumed to be reconfigured to operate more effectively for treatment of flows for a given area to provide the estimates of treated flows in the table above.

Gravity fed wetland systems are proposed to capture and treat flows. To store the treated flows ASR investigations undertaken at Edinburgh Parks North (a) and South (b), and at Kaurna Park showed that the T2 aquifer is well developed and homogeneous, with consistent properties that are well suited to ASR. These are:

- depth to top of aquifer: 117-120m below ground
- thickness: 47-60m
- High transmissivity.

(a)

(b)

<u>Western sites</u>

Systems at Kaurna Park (a), Springbank (a), Burton West (a) and Summer Road (b) are also proposed to be gravity fed wetlands. Most sites are to use existing wetland areas and a new gravity fed wetland is proposed at Summer Road that utilises existing land owned by SA Water. Their treatment areas can all be accommodated within available areas and the treatment rates are well suited to ASR for storages.

6.6 Greater Edinburgh Parks

Greater Edinburgh Parks is a significant industrial development planned for the area. For the purposes of this study it has been assumed that wetlands or other treatment systems will be developed as part of the urban design for the area and harvesting will take advantage of the underlying aquifers to store treated flows. ASR potential is considered to be similar to that for Edinburgh North and South, i.e. well suited. Estimated yields are outlined in Table 16.

Table 16 Greater Edinburgh Parks

Greater Edinburgh Park			CAPTURE AND TREATMENT					STORAGE	
scheme	**buffer storage**	**diversion pump**	**wetland size**	**bio retention size**	**treatment rate**	**TOTAL TREATED**	**Injection rate**	**ASR wells**	**Surface storage**
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Greater Edinburgh Parks			18		360	1,990	15-20	20	
					TOTAL	**1,990**		**20**	**0**

6.7 Little Para River

Aquifers to the eastern end of the urban area were not considered adequate for large scale injection. For example the Cobbler Creek area is underlain by bedrock, and as such is not suitable for large scale ASR and in the Carisbrooke Park area the aquifer potential is not known, but likely to be non favourable because of its location between 2 faults and proximity to the Para Fault.

West of the splinter fault, the T2 aquifer is similar to that occurring at Kaurna Park / Edinburgh Parks - i.e. injection rates of 20-25L/s/well can be expected. The T1 aquifer is also well developed and homogeneous, however, the anticipated injection rates are expected to range between 8-10L/s.

Therefore, while many treatment opportunities exist in these areas the focus is on the western end of the catchment for harvesting.

A summary of the catchment harvesting and storage is shown in Table 17.

Table 17 Little Para River

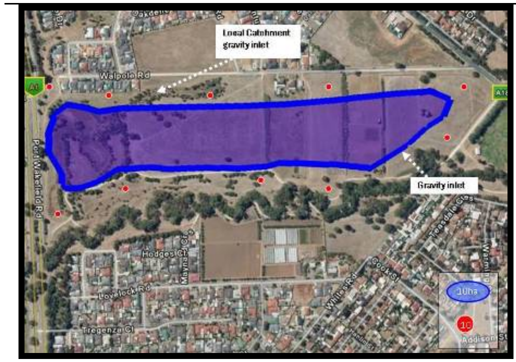
Little Para	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Moss Rd			3		60	700	15	4	
Pioneer Park			1		20	160	15	2	
Whites Rd			10		200	1,045	20	10	
Bolivar			3		60	330	15	4	
					TOTAL	**2,235**		**20**	**0**

Moss Road

The Moss Road site is a potential wetland system that could be gravity fed and takes advantage of a wide power line easement and relatively flat ground. This site would involve reshaping the area under the power lines and injecting treated water locally. The land is currently privately owned but is not considered suitable for development and as such may be available for the development of a scheme. The Stanley Avenue site is further downstream and could be configured to operate under gravity and inject treated water locally. This area could compliment the current park and not impact on current uses adversely. Stanley Avenue could be used if Moss Road land is deemed unsuitable or is not available.

Pioneer Park

Pioneer Park is another gravity fed wetland system that takes advantage of available space in the riparian corridor of the Little Para River. The system will need to fit with the uses of the park spaces, however a one hectare wetland is considered feasible and a local well will store treated water.



Whites Road

The most significant potential harvesting site on the Little Para River is at Whites Road where a significant treatment wetland could be constructed to operate under gravity. For this option to proceed, some land would need to be secured in addition to the existing Council owned land. This wetland would receive flows from the main channel as well as flow from a small development to the north where a current small wetland exists. It would be reconfigured to become one harvesting system. The aquifers in this area are considered adequate to inject the harvest volumes.

<u>Bolivar</u>

To increase the yield from the entire catchment a wetland is also proposed on the west side of Port Wakefield Road. This wetland has been sized to match with the overflows from the upstream catchment and a small local catchment. Shallow potentially saline ground water exists in this area and as a result the bulk of harvesting was preferred further upstream, but this site may be considered if upstream sites are not constructed.

6.8 Dry Creek

Significant harvesting schemes already existing along the Dry Creek Catchment and a number are also being currently developed. Dry Creek contradicts its name and offers significant harvest potential as indicated the Table 18.

Table 18. Dry Creek

Dry Creek			**CAPTURE AND TREATMENT**					**STORAGE**	
scheme	**buffer storage**	**diversion pump**	**wetland size**	**bio retention size**	**treatment rate**	**TOTAL TREATED**	**Injection rate**	**ASR wells**	**Surface storage**
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Wynn Vale Dam	12.5	25			25	346	6-7	4	
Pooraka upgrade			2.4	0.2	200	1,360	12 20	4 8 offsite	
Montague Rd	0.8	140		0.5	140	549	20-25	10	
Parafield		150	4		80	862	20-25	4	
Paddocks			3.8		76	584	12- T1 15-T2	3-T1 3-T2	
Bennet Rd Drain			6		120	480	20-25	6	
Greenfields 1&2			20		400	3,269	12-T1 20-25	6-T1 17-T2	
Cheetham saltworks			6		120	783	20-25	6	
					TOTAL	**8,233**		**63**	**0**

The eastern side of the catchment (East of Bridge Road) is not considered to have very good large scale ASR potential therefore the bulk of the harvesting focuses in the downstream reaches of the catchment.

Wynn Vale Dam

The exception to targeting the lower reaches of Dry Creek is Wynn Vale Dam. It takes advantage of an existing dam, media treatment and a distribution pipe to enable multiple injection wells to be used. The City of Tea Tree Gully is currently developing this scheme as part of their component of *Waterproofing Northern Adelaide*.

Pooraka Upgrade

On-line storage is proposed at Walkerly Heights on the main Dry Creek channel to regulate flows for improved harvesting. This storage is intended to release flows to enable them to be transferred to Unity Park under gravity. There is also an existing pump station located downstream in the main channel which currently transfers runoff to the Unity Park site. Treatment in Unity Park is planned through the upgrade of the existing wetlands as well as the establishment of a biofiltration system. Injection rates around Unity Park are limited therefore it is proposed to transfer flows to the west to wells located along Montague Road. The City of Salisbury is currently upgrading this site as part of *Waterproofing Northern Adelaide*.

Montague Road

A further extraction system will pump flows from a small on line basin (at Linbolm Park) to biofiltration treatment located along Montague Road with injection wells located on Montague Road between Main North Road and Port Wakefield Road.

(a)

(b)

Paddocks and Parafield

Dry Creek also has several significant existing treatment and harvesting schemes that will contribute to generate treated stormwater (the Paddocks (a) and Parafield (b)). These systems have been operating for some time and may consider upgrades in the future.

The T2 aquifer at the Paddocks has not been tested to date. The nominated injection rate of 15L/s is therefore indicative only, subject to drilling and testing

Bennet Road Drain

In addition to the existing schemes, the Bennet Road scheme can capture a significant area under gravity and increase the injection yields at the southern end of the Parafield Airport.

Greenfields

A major wetland system at Greenfields will continue to harvest stormwater and contribute significant quantities of harvested water into aquifers. This system is currently being upgraded by the City of Salisbury to double its capacity while still maintaining its flood mitigation capabilities. This is considered an innovative project that could be adopted at other sites around Adelaide.

Future Development – No Picture

Cheetham salt works

A potential development of the Cheetham salt works site offers an opportunity to incorporate treatment wetlands to capture generated urban flows post development. The wetlands would then be matched with ASR wells in the area that have suitable injection rates and capacity. Salinity in this area is expected to be an issue and as such media filtration may be required in lieu of wetlands. Concepts for the layout of this system can be developed as the urban area is designed.

6.9 Barker Inlet

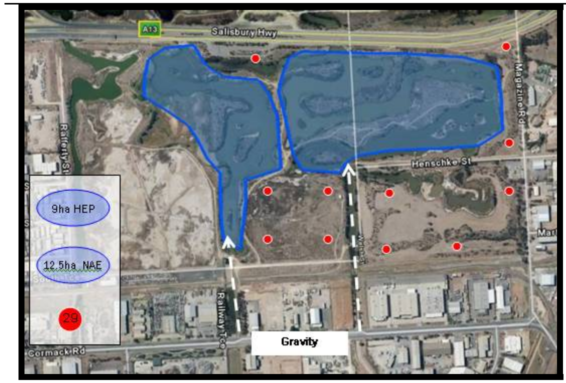
The Barker Inlet can contribute significant quantities of treated stormwater into the underlying aquifers that are well suited to ASR. Existing wetlands will also be supplemented with some biofiltration located in the existing rail yards as shown in Table 19.

Both the T1 and T2 aquifers are extensive and well suited to the expected harvest volumes. Injection rates in the T2 aquifer are expected to range between 13-15L/s in fully penetrating wells. For the T1 aquifer, an injection rate of 8L/s/well can be expected. Injection head for the Railyards is expected to be 80-90m for a 200m spacing. A combination of both T1 and T2 wells may be required to limit injection heads to acceptable limits for the NAE/HEP sites.

There are areas of significant Native Vegetation in the vicinity of the existing wetlands. The detailed design of the wetlands and ASR wellfield will need to consider the existence of this vegetation and how it will be protected.

Table 19. Barker Inlet

Barker Inlet	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Hindmarsh Enfield Prospect drain (HEP)			9		180	790	13-15	14	
North Arm East (NAE)			12.5		250	1,240	13-15	19	
Islington railyards				1	200	2,052	15	13	
					TOTAL	**4,082**		**46**	**0**



Barker Inlet wetlands (HEP and NAE)

The two existing wetlands will continue to capture and treat stormwater under gravity and additional bores will increase the available harvest yield. Construction equipment access may be restricted by the existence of Native Vegetation. Recent drilling at the site was restricted to the road reserve to avoid damaging vegetation at the site.

Islington Railyards

Another significant harvesting opportunity for the catchment is to treat flows that are diverted from the River Torrens catchment. Flows from the River Torrens will be pumped a short distance into the existing drainage system of the Hindmarsh Enfield Prospect drainage system. This system will use the existing pipes to transfer flows to the Islington Railyards (by gravity) where flow will be extracted and treated with biofiltration before injection into suitable aquifers at the site. This is a means to distribute the harvest potential between the catchments to where aquifers are capable of accepting the required volumes of treated stormwater.

6.10 Magazine Creek

The Range Wetland catchment includes the Torrens Road drain and proposed development at Cheltenham Racecourse. Both the T1 and T2 are extensive and well suited for groundwater storages. Table 20 summarises the potential yield in this catchment.

Table 20. Magazine Creek

Magazine Creek	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Cheltenham racecourse		100	6		120	1,180	15	8	
Range wetlands			7.5		150	611	15	10	
					TOTAL	**1,791**		**18**	**0**

Cheltenham Racecourse

To increase yield in this catchment and to distribute potential stormwater harvest through the aquifers, it is proposed to pump flows from the River Torrens into the top of the Torrens Road drainage system. These flows would then be conveyed along the existing stormwater pipe network under gravity to the Cheltenham Racecourse site where a wetland (operating under gravity) will treat the flows. Local injection will store treated water. The City of Charles Sturt is well into the planning phase for this project.

Range wetlands

The remainder of the catchment (and overflows) will be captured in existing wetlands (Range Wetlands) and injected locally. These wetlands have a risk of saline shallow groundwater intrusion which would limit the reuse viability therefore careful consideration to address shallow groundwater is required to pursue this opportunity.

6.11 Port Road

The Port Road area has the potential to harvest flows from its own catchment as well as flows from the River Torrens to better distribute River Torrens water for injection. Grange, Riverside and Royal Adelaide Golf Courses are included in this catchment.

Table 21. Port Road

Port Road	CAPTURE AND TREATMENT						STORAGE		
scheme	**buffer storage**	**diversion pump**	**wetland size**	**bioretention size**	**treatment rate**	**TOTAL TREATED**	**Injection rate**	**ASR wells**	**Surface storage**
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Port rd median			2.4		48	571	15	4	
Riverside Golf Course	20	200	2.5		50	450	15	4	
Grange Golf Course		450	2		45	300	8-T1 15	3 2 -T2	
Royal Adelaide Golf Course		250	2		45	200	8-T1	3	
					TOTAL	**1,521**		**11**	**0**

(a)

(b)

Port Road and Riverside Golf Course

A major upgrade of Port Road will incorporate treatment wetlands and ASR wells along its length. In addition to wetlands along Port Road (a) that will also receive flow pumped from the River Torrens, a further diversion system at the western end of Port Road will deliver flows to available open space in a Riverside Golf Course (b). Flows will be pumped and join local flows in a holding pond that will then pump flows at a suitable treatment rate, into the proposed wetlands. Treated flows will then be injected in an adjacent site where suitable aquifers are expected.

(a)

(b)

Grange and Royal Adelaide Golf Course

The Grange (a) and Royal Adelaide (b) Golf Course schemes have already been developed.

The plants within these wetlands are still establishing. Once they are fully established the schemes should be able to achieve the designed yields.

6.12 Grange Area

Harvesting in the Grange area takes advantage of an existing pipe from the River Torrens to distribute flow to pockets of open space where biofiltration or media filtration is proposed. The treatment sites will then be matched to suitable aquifer injection sites that target both the extensive T1 and T2 aquifers.

In addition water from the River Torrens and existing local pumped drainage outfalls (that direct water directly to the ocean) will be reconfigured to pump to filtration sites and subsequent injection. Table 22 below summarises these opportunities.

Table 22. Grange Area

Grange Area	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Pump from Torrens to reserves		100		0.5	100	900	15	7	
Coastal catchments	1	200		0.3	60	350	15	4	
					TOTAL	**1,250**		**11**	**0**

6.13 River Torrens

The River Torrens is a significant catchment for Adelaide. Aquifers to the east of the city are considered to be risky for large scale ASR systems as they are in fractured rock and therefore only existing schemes are included in this study.

For small scale operation (generally less than 100 ML/a), ASR may be viable, as demonstrated by numerous small scale existing schemes in the Tea Tree Gully, Campbelltown and Port Adelaide Enfield Councils. For large scale operations, there is some doubt on the viability of ASR schemes because of limited storage capacity of fractured rock aquifers, the high risk in establishing a large number of wells with yields in excess of 5 L/s and the generally low recovery efficiencies.

West of the Port Road, both the T1 and T2 aquifers are well developed and homogeneous and well suited to large scale aquifer storages.

With the eastern side of the catchment unavailable for large scale injection and with limited open space and finite aquifers at the lower end of the river an approach to distribute the flows to other catchments was taken to allow an increased yield. These are described in earlier sections and include diversions to the Barker Inlet, Magazine Creek, Port Road and Grange area catchments.

Despite significant flows being transferred to other catchments there is still potential for significant harvesting and storage within the Torrens catchment as indicated in the Table 23. It should be noted that advice from the Adelaide City Council has indicated that even minor level drops in the Torrens Lake (125mm) result in adverse impacts on local business. As such the Torrens Lake was not considered for the use as a capture basin that could be drawn down.

Table 23 River Torrens

Torrens	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection* rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Diversion to Islington railyards	refer to Barker inlet								
Botanic Gardens			0.5		10	170	10-br	1	
Bonython Park	8	500	3	2	460	4,085	10-T1 13-T2	15 T1 24 T2	
University fields		800		4	800	2,016	10-T1 15-T2	20 T1 40 T2	
Diversion to Port Rd and Cheltenham	refer to Magazine Creek and Port Rd								
Diversion to Grange area	refer to Grange area								
City irrigation					0	420			
					TOTAL	**6,691**		**100**	**0**

Note : br indicates injection into a bedrock (fractured rock) aquifer. T1 and T2 also define the target aquifers for injection.

Botanic Gardens

A small system is being planned for the Botanic Gardens. A wetland or biofilter will treat flows from First Creek operating under gravity and an ASR system is planned to store water for irrigation.

Bonython Park

Advice from Adelaide City Council indicated that the main Adelaide Lake was not suitable for use as a significant capture basin as local businesses are very sensitive to changes in the pool level. A drop of 125mm impacts on the ability of local businesses and recreational users to access the lake. However, the lower lakes have been considered to provide buffer storages.

Within Bonython Park the lower lakes are proposed to be reconfigured to provide some temporary in-line storage to then allow flows to be pumped to both a wetland and biofiltration system in less frequented areas of the park. This system could produce significant quantities of treated water and an injection system would need to be devised to accommodate the large treated flows (e.g. target both T1 and T2 aquifers, west of the Para Fault). It should be noted that there are significant groundwater users in this area and consultation will be required prior to the development of a significant ASR in this area.

University Fields

Flow in the River Torrens then continues to the west where a further extraction diverts flow to the Grange area. At this same location it is proposed to pump flows to the University Fields where media filtration can treat significant quantities of water, pumping from this location is proposed to avoid shallow saline groundwater intrusion and any risk of sea water ingress. Wetlands were not considered for this area because of the proximity to the airport runways. The significant quantities of treated flows in this area will be surplus to the capacity of the local aquifers to accept. It is therefore proposed to construct a pipeline to convey treated water to areas that have the capacity to accept treated water to the north along the coast.

City irrigation

After the extraction at Walkerville (i.e. to divert flows to the Islington Railyards) flows continue to the Torrens Lake where direct extraction is currently undertaken for irrigation of the parklands and other facilities. This is included as harvesting for the purpose of this study.

6.14 Mile End Drain

The Mile End drain is a narrow catchment that flows around the northern edge of the Adelaide Airport and through Adelaide Shores. It is proposed to construct an on-line buffer storage to capture flows under gravity and then transfer flows to a biofiltration system for treatment. Treated flows can then be injected locally, potential harvest volumes are shown in Table 24.

Table 24. Mile End

Mile End		CAPTURE AND TREATMENT					STORAGE		
scheme	**buffer storage**	**diversion pump**	**wetland size**	**bioretention size**	**treatment rate**	**TOTAL TREATED**	**Injection rate**	**ASR wells**	**Surface storage**
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Adelaide shores	15	150		0.5	150	850	15	10	
TOTAL						**850**		**10**	**0**

6.15 Brownhill and Keswick Creek

Areas to the east of the city have limited large scale ASR potential (because the target aquifers are in bedrock) and this has directed the harvesting strategy for Brownhill and Keswick Creeks. Several small systems are included in the overall harvesting strategy to take advantage of systems that are either being planned or exist.

Table 25. Brownhill & Keswick

Brownhill	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Urrbrae			1.2		24	140	5-8	4	
Orphanage	0.3	15		0.1	15	210	5-8	2	
Victoria Park			1		20	211	5-8	3	
South Parklands			0.5		10	84	4-5	2	
Divert to disused train line				refer to Sturt River					
Glenelg Golf Course	4	60	1.5		30	460	15	3	
Airport	250	400		2	400	3,130	15	27	
					TOTAL	**4,234**		**41**	**0**

Urrbrae

The Urrbrae wetlands can potentially treat and inject treated stormwater locally, although limited by ASR rates.

The existing ASR facilities will need upgrading to enable the site to be used for stormwater harvesting.

Orphanage

A small system is also planned at the Orphanage where a small in line basin is proposed to allow pumping to a biofiltration system that will minimise the footprint for water treatment on the highly used site. This system will also inject locally.

(a)

(b)

<u>Victoria Park and South Parklands</u>

Two gravity wetlands, one at the Victoria Park Racecourse (a) and one in the South Parklands (b) have been sized with the limits of the aquifer capacity in mind. These systems will be incorporated within flood retarding basins.

At the South Parklands, recent drilling and discharge testing has shown the occurrence of thin shallow T1 overlying undifferentiated Tertiary sediments and bedrock. Well injection yields of 4-5L/s can be expected in that aquifer, however because of the relatively small storage potential (aquifer thickness less than 10m) storage is likely to be restricted to approximately 100ML/yr.

At the Victoria Park Racecourse, the target is the bedrock aquifer. A recently drilled investigation well completed in the bedrock aquifer yielded some 6-8L/s.

Both of these schemes are currently in the planning phase.

<u>Diversion to disused train line</u>

To increase the overall yield from Brownhill and Keswick Creek it is proposed to transfer flows from near the Frewville train station to existing stormwater drains in Anzac Highway. The existing drain will then transfer flow under gravity to a location for treatment and is better suited to injection along a disused train line at the western end of Anzac Highway. The well field for this treatment system will be located to the west of the fault, essentially north west of Anzac Highway where there is good capacity in the T2 aquifer.

Adelaide Airport and Glenelg Golf Course

The major potential harvesting system for Brownhill and Keswick Creeks is at Adelaide Airport where a major on-line storage basin will capture flows under gravity. From the large basin flow can then be distributed to an existing scheme in the Glenelg Golf Course and to a proposed significant biofiltration or media filtration system. A network of wells will then be required to inject treated flow. The location for this infrastructure has been selected with consideration to current uses at the airport, however, further negotiation with Adelaide Airport Limited will be required to pursue these options.

The harvest volume at Adelaide Airport from both Sturt River (refer to the next section) and Brownhill and Keswick Creeks total more than 4 GL/a.

Analytical and numerical modelling has demonstrated that a conceptual wellfield consisting of 30 wells completed in both the T1 and T2 aquifer within the Adelaide Airport site is hydrogeologically viable.

The T1 and T2 wells would be co-located (within 5-10m of each other). Although an initial spacing of 500m for the ASR sites was used in the model, there is scope to reduce the spacing to 200-300m.

Injection rates are expected to range between 8-10L/s for the T1 wells and 16-20L/s for the T2 wells.

The following scenario was modelled:

- T1 aquifer total injection of 2GL into 30 wells at 7.7L/s per well for 100 days.
- T2 aquifer total injection of 3GL into 30 wells at 11.6L/s/well for 100 days.
- After 55 days of rest, 1.6GL and 2.4GL were extracted over 210 days from the T1 and T2 aquifers, respectively.

The modelled head build up at the end of injection after 8 years of operation are shown in Appendix E.

The modelled head build up will have the following estimated impact on existing users during injection:

T1 aquifer: The number of existing T1 wells that will become artesian is of the order of 60 wells, 23 of which are DWLBC observation wells. There are however another approximately 110 wells with status unknown, presumed to be abandoned. *T2 aquifer:* Apart from the existing ASR well completed in the T2 aquifer (Glenelg Golf Club), there is possibly one production well within the area that will likely become artesian. As such the T2 aquifer should be targeting initially until its capacity is reached.

6.16 Sturt River

The Sturt River has harvesting opportunities at many locations in its upper reaches however, the aquifers were not deemed suitable for large scale injection and storage. Therefore the majority of the harvesting systems target aquifers to the west that have better storage potential.

A summary of the possible yields is shown in the Table 26.

Table 26. Sturt River

Sturt			**CAPTURE AND TREATMENT**					**STORAGE**	
scheme	**buffer storage**	**diversion pump**	**wetland size**	**bioretention size**	**treatment rate**	**TOTAL TREATED**	**Injection rate**	**ASR wells**	**Surface storage**
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Science Park			3		60	770	5-8	transfer	
Oaklands Park south	30	30	1.5		30	414	8-10	4	
Oaklands Park North	0.5	200	1.5		30	290	8-10	4	
Morphettville Existing			3		60	325	30	2	
Morphettville new	0.3	400		2	400	1,800	15	25	
Disused trainline from Brown Hill	0	300		1.5	300	1,511	15	20	
Airport	150	750		2	400	1,078	15	25	
					TOTAL	**6,188**		**80**	**0**

Science Park

The existing Science Park wetlands are proposed to be expanded to make use of the existing wetland despite the low potential for large scale ASR. The wetlands will operate under gravity and treated flows are proposed to be piped west along Sturt Road to a train line where better aquifers can accept the treated flow rates and volumes (in the Tertiary limestone in the Marion/Brighton area). This will also reduce the capacity pressure on the aquifers in the lower reaches.

Oaklands Park North and South

The Oaklands Park area represents an area with suitable aquifers for injection and available open space for treatment. The proposal is to construct an on-line basin on the Sturt River and pump out to wetlands located in the southern end of the Oaklands Park reserve for treatment. At the northern end of the reserve it is proposed to install another small on-line basin to also capture a local catchment and pump to another wetland system. It is intended these systems will operate independently but treated water will be injected through a similar well system locally.

Morphetteville

Morphettville racecourse has a wetland/ASR system that captures, treats and stores flows form a local catchment. It is proposed to install an on-line basin on the Sturt River and pump to a biofiltration system also within the race track. A further network of wells will inject water around this location.

A north-east splinter of the Para Fault is inferred to occur at the north-west corner of the Morphettville Racecourse. The majority of the required additional wells will therefore be located north-west of the racecourse,

Disused train line

Flows are to be diverted from Brownhill Creek (as discussed in the previous section) to a disused train line where a bioretention system could be installed. To match the treatment flows with aquifer capacities treated flows would then be pumped into the T2 aquifer.

Adelaide Airport

Another significant harvesting scheme on the Sturt River is proposed at the south western end of the airport. Flow will be collected in a small sump (upstream of any risk of saline water) and pumped to a holding basin in the area north of Brownhill/Keswick Creek. Flow from the basin will then be treated through biofiltration / media filtration in disused areas to the south of the holding basin. Injection will need to be coordinated with the other harvesting systems in the area (see discussion in the previous section on the capacity of the aquifers of the area).

6.17 Waterfall Creek

While harvesting was considered in this catchment, the lack of suitable aquifers for large scale storage, treatment area or surface storage opportunities ruled out harvesting in this relatively small catchment. Opportunistic harvesting using media filtration may be considered, however this should not be a high priority due to the storage limitations within the region.

6.18 Field River

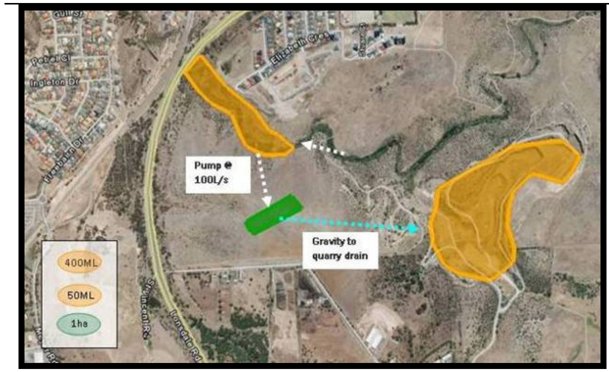
The Field River is a significant catchment with some good opportunities for stormwater treatment. The aquifers in the area however, are not considered suitable for large scale storage being underlain by bedrock with limited large scale storage potential. Therefore further investigation was conducted into surface storage opportunities.

A summary of harvest opportunities is shown in the Table 27.

Table 27. Field River

Field	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Elizabeth Crescent Reserve	50	100			100	945	5-br	2	400
Young Street			2		40	430	5-br	2	100
Reynella East			2		40	351	5-br	1	50
Happy Valley Res diversion channel				1.4	585	890	5-br		Reservoir
					TOTAL	2,616			550

Br- bedrock or fractured rock aquifer



Elizabeth Crescent

A significant on-line storage could be created and flows pumped to a biofiltration system that could drain into the same surface storage as used for the young Street system (i.e. the existing quarry). The potential of these surface storage sites requires further investigation.

Young Street

Just downstream of Young Street on the Field River an area could be converted into a gravity fed wetland system to treat stormwater. There is a large catchment upstream and treated water could then be pumped to a surface storage. A potential surface storage was identified as part of a quarry. Further investigation would need to occur to confirm the viability of the surface storage.

Reynella East

Existing flat ground at the confluence of two tributaries provides a good opportunity to treat stormwater in Reynella East. Treated flow from this area could be stored in a surface dam that may be constructed in the adjacent land that is relatively flat. This system will require further investigation into land ownership, reuse potential will be limited by the size of the storage available.

Happy Valley Reservoir Channel

Significant catchment areas are diverted around the Happy Valley Reservoir by a large diversion channel with mild grade. In the interest of highlighting stormwater harvesting potential, an opportunity to retro fit biofiltration systems into the base of the constructed channel is presented. The most obvious option to store the treated water would be to feed the treated flows into the reservoir allowing all high flows to continue along the bypass channel. While this could be considered outside the scope of the current investigation it is presented as a clear opportunity for stormwater harvesting. It should be noted that if this option was adopted that significant online and automated monitoring and control systems would have to be incorporated to protect the drinking water supply.

6.19 Christie Creek

Flow in Christie Creek can be treated and stored locally in a surface storage as well as being transferred to the Willunga Basin where better ASR potential exists. The catchment is in the Noarlunga Embayment, where undifferentiated Tertiary sediments overlie bedrock. East of the Onkaparinga River, the Port Willunga Formation (aquifer T2) is not present therefore limited large scale storage potential exists. Harvest options assuming surface storages and transfer is shown in Table 28.

Table 28. Christie Creek

Christie	CAPTURE AND TREATMENT						STORAGE		
scheme	**buffer storage**	**diversion pump**	**wetland size**	**bioretention size**	**treatment rate**	**TOTAL TREATED**	**Injection rate**	**ASR wells**	**Surface storage**
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Madeira Drive			1		22	153	<5	0	20
Brodie Road			3		66	655	<5	0	60
Morrow Road	2	200		1	200	509	<5	transfer to Aldinga	
					TOTAL	**1,317**		**0**	**80**

 (a)  (b)	Brodie and Madeira Wetlands at Brodie Road (a) and Madeira Drive (b) can operate under gravity and contribute treated flows to a surface storage in Wilfred Taylor Reserve. Surplus flows can then be transferred downstream to Christies Beach Wastewater Treatment plant and join a pipe that conveys flows to Aldinga for injection.
 	Morrow Road A further system could create a buffer storage above a planned sedimentation pond to allow flow to be pumped to biofiltration for treatment. Treated flows would then also be conveyed to Aldinga for injection.

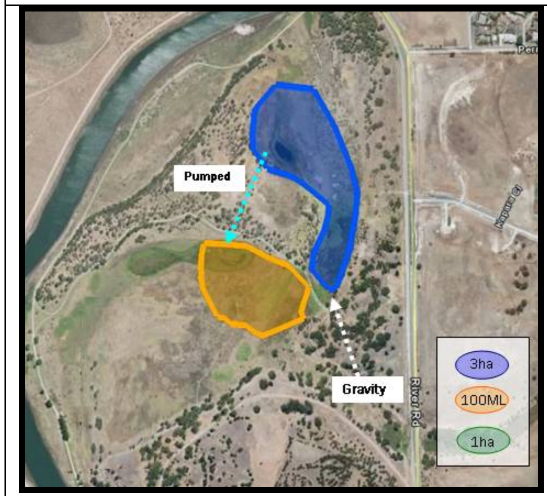
6.20 Onkaparinga River (Noarlunga)

An investigation well drilled in 1978 (PIRSA Rpt Bk 79/08) intersected 36m of undifferentiated sediments (minor limestone, lignitic sands, pebbles and sands in clay matrix) and 30m of clay above the slate bedrock. Therefore the potential for aquifers in this area to store significant quantities of water is considered low. Surface storages as well as transferring flow to the Willunga basin are seen as more promising storage options. If more surface storages can be located it is likely the potential yields for this area could increase.

There are two harvesting systems that target local catchments in the Onkaparinga area for harvesting, Garland Reserve and Hackham Creek while the other opportunity for harvesting is from the Onkaparinga River itself. Harvesting from the river will require an extraction point sufficiently upstream to avoid saline water as well as further investigation into environmental flow requirements. A summary of the opportunities is shown in Table 29.

Table 29. Onkaparinga River

Onkaparinga	**CAPTURE AND TREATMENT**						**STORAGE**		
scheme	**buffer storage**	**diversion pump**	**wetland size**	**bioretention size**	**treatment rate**	**TOTAL TREATED**	**Injection rate**	**ASR wells**	**Surface storage**
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Garland Park	35		2		40	330	<5	0	75
Hackham Creek			3		60	447	<5	0	100
Onkaparinga Rural pumped flows	0	200		1	200	1,260	<5	transfer to Aldinga	0
					TOTAL	**2,037**		**0**	**175**

	<u>Garland Reserve</u> The Garland Reserve site takes advantage of an existing flood retarding basin to retrofit as a holding storage to then release flows into a wetland constructed in a decommissioned wastewater treatment plant. A storage pond could also be constructed as part of the decommissioning and water reused locally. A strong emphasis on using this area will be to ensure there is no contamination from the existing ground conditions that are likely to be contaminated (given it was a wastewater treatment plant). The storage pond would need to be hydraulically isolated.
	<u>Hackham South</u> The Hackham South area will undergo significant development in the coming years and there is an opportunity to create a treatment wetland in the Onkaparinga Recreation Park to treat the generated stormwater. In addition a storage pond could be constructed to provide the opportunity for local reuse.

Onkaparinga Rural Flows

Flows from the Onkaparinga River itself could be pumped to a treatment area within the Onkaparinga Recreational Park. The extraction point would need to be sufficiently upstream to avoid the estuarine environment and a thorough assessment of the ecological requirements performed to confirm this systems viability. It should also be noted that the quantity of flow that is identified here as a harvest opportunity is relatively small compared to the overall flows in the Onkaparinga River (i.e. the modelling has not considered the entire catchment because it was not deemed to be suitable for extraction, as discussed in Section 5).

Treatment would be with biofiltration/media filtration therefore reducing the footprint required in the recreation park. To store the treated flows, they would be pumped to the Aldinga region where better aquifers can accept the treated water (refer discussion in the previous section).

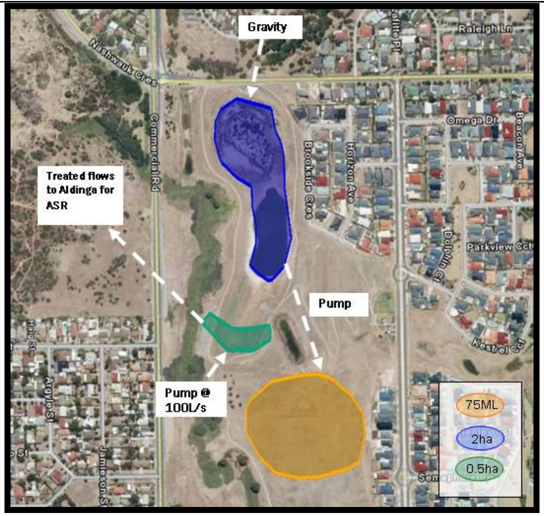
6.21 Pedler Creek

A well drilled at Seaford, approximately 3km north of Pedler Creek Reserve intersected generally clays and fine sands overlying phyllite/slate. Therefore, this area is not considered suitable for large scale storage.

A local harvesting system can use a surface storage system for harvested water. For a larger system (Pedler Reserve A), flows are intended to be directed to Aldinga for ASR injection as indicated in Table 30.

Table 30. Pedler Creek

Peddler			CAPTURE AND TREATMENT					STORAGE	
scheme	**buffer storage**	**diversion pump**	**wetland size**	**bio retention size**	**treatment rate**	**TOTAL TREATED**	**Injection rate**	**ASR wells**	**Surface storage**
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Pedler Creek Reserve A		100		0.5	100	756	<5	transfer to Aldinga	
Pedler Creek Reserve B			2		40	481	<5	0	75
					TOTAL	**1,237**		**5**	**75**



Pedler Creek Reserve B – local urban catchment

Flows from a local catchment into the lower end of Pedler Creek could be harvested by reconfiguring an existing gravity fed wetland system and storing water locally (in a dam) for reuse.

Pedler Creek Reserve A – rural catchment

In addition to the urban runoff harvesting and if the impacts of extraction can be assessed to be acceptable, rural flows from the creek could be harvested. Flows could be pumped into the nearby area (see adjacent figure) to be treated with biofiltration. Treated flows from this system would be transferred to Aldinga where an ASR system is being developed (refer to the next section for discussion).

6.22 Willunga Area

The Willunga area is important to the overall harvesting approach mainly for storage rather than as a source of water (although there is some harvesting from future urban development identified). This area could become a destination for water that is harvested from catchments to the north (e.g. Christie, Onkaparinga and Pedler) as discussed in previous sections.

The Port Willunga Formation aquifer (T2) has been identified as the preferred aquifer for large scale ASR (Onkaparinga CWMB, 2002) and modelling has confirmed its ability to store at least 4 GL/a (Martin R, NHT project 990170).

More detailed modelling carried out in 2002, as part of the Willunga reclaimed water ASR investigations, showed that injection of 2GL/yr in a well field using 11 wells is feasible with acceptable impress of approximately 30m. This work supports the previous assessment that an injection of 4-6 GL/a in the Aldinga-Willunga area would be feasible (refer to the figure in Section 4.2).

In terms of stormwater harvesting, new development in the Willunga area could cater for harvesting. As part of the development, two wetland systems could be incorporated into the proposed development. It is anticipated these systems will be incorporated with the urban design of the development and treated water will be stored in local aquifers. As development is planned, concepts for the harvesting wetlands can be developed. The Table 31 shows potential yields and indicative required infrastructure.

Table 31. Willunga Area

Willunga	CAPTURE AND TREATMENT						STORAGE		
scheme	buffer storage	diversion pump	wetland size	bioretention size	treatment rate	TOTAL TREATED	Injection rate	ASR wells	Surface storage
	ML	L/s	ha	ha	L/s	ML/year	L/s	Wells	ML
Willunga		50	2.5		50	481	12 T2	30*	
					TOTAL	**481**		**30**	**0**

* the number of wells includes injecting flows that are diverted from Christie Creek, Onkaparinga River and Pedler Creek.

7. IMPACT OF CLIMATE CHANGE AND URBAN CONSOLIDATION

7.1 Rainfall reduction

The impact of predicted climate change, particularly reduced rainfall, could have a significant impact on potential harvest volumes.

Historical climate data is not necessarily a valid indicator of future climate, which may contain prolonged periods that are wetter or drier than the historical record used for this analysis. There is significant uncertainty surrounding how climate, and in particular, rainfall, will be impacted by various levels of greenhouse gas accumulation in the atmosphere. Rainfall has a much greater spatial variability than temperature and some areas are likely to become wetter whilst other areas become drier. Further to this there may be changes in the seasonality and intensity of rainfall.

To estimate changes in rainfall due to the impact of climate change, predictions for 2050 by the CSIRO have been adopted (see www.climatechageinaustralia.gov.au/sarain34/php). The CSIRO predicts annual rainfall reduction by 2050 of between 5-10% for the Adelaide region relative to the period of 1980-1999. These estimates assume a level of 'medium' atmospheric emissions. Seasonal reductions are also predicted and the following values for seasonal rainfall reduction are adopted for the purpose of this study (these are all within the ranges quoted by CSIRO):

- Summer = 5%
- Autumn = 2%
- Winter = 10%
- Spring =10%

These values result in an annual decrease in rainfall for the Adelaide region of 8% using the historical rainfall file used in the modelling, which is considered to be representative of CSIRO predictions.

CSIRO also predict changes in potential evapotranspiration for the Adelaide region for 2050 (www.climatechangeinaustralia.gov.au/saevap10.php) of an increase of 2-4%.To assess the impact on potential harvesting volumes a 4% increase is assumed in the modelling.

It is noted that there may also be a change in rainfall intensity as a result of climate change. There are however, no firm predictions on which to base assumptions for the purpose of modelling the impact on harvesting schemes.

Historical rainfall and potential evapotranspiration records were modified with the above changes (to create a *2050 climate file*) and imported into the 20 catchment MUSIC models. Each model set up (e.g. catchment areas, harvesting and treatment devices) were kept identical to the earlier modelling and only the climate files were changed. This allowed the direct impact of predicted climate change to be simulated.

The 2050 climate file scenarios were also used to simulate the impact of urban consolidation on yields. This is discussed in the following section with results presented in Section 7.3.

7.2 Urban Consolidation

Potentially counteracting the impact of reduced future rainfall on stormwater harvest volumes may result from an increase in urban densities. The extent of future urbanisation (i.e. new urban areas) has been included in the modelling presented in Section 5 and 6, however, the impact of infill development (or urban consolidation) was not considered in the results presented in Section 6.

The effect of urban consolidation will increase the proportion of impervious surfaces and therefore increase the proportion of rainfall that becomes runoff. This effect may offset the impact of climate change rainfall reduction on harvest yields.

It is difficult to predict the extent of redevelopment to 2050 and therefore proportion of urban impervious area increase. Information developed for the Greater Adelaide Plan provides some guidance to about 2036, however detailed projections beyond that time are currently not available. Therefore, a range of likely values are modelled in conjunction with the 2050 climate file. MUSIC models for each catchment were adjusted so that they use the 2050 climate file (i.e. rainfall and potential evapotransiration) and urban areas were modified to increase their percentage of impervious surfaces. The harvesting schemes were not adjusted from what is presented in Section 6 (i.e. diversion rates, treatment areas etc. were not adjusted).

To estimate the proportional increase in impervious areas from consolidation the following assumptions were made:

- current directly connected impervious areas are 24% of urban area (directly connected refers to impervious areas that drain directly to the stormwater network and not onto pervious surfaces such as gardens) – this was estimated during the calibration process
- infill development will have directly connected impervious areas that represent 60% of a development.

Using these assumptions, modelling was performed that represent an increase in impervious area by 5% (i.e. from 24 to 29% of urban area) and 10% (i.e. from 24 to 34%). These increases in impervious area are approximately equivalent to 14% and 28% of properties being redeveloping. This is considered to capture the range of possible redevelopment by 2050.

7.3 Results of Climate Change And Urban Consolidation Modelling

Results of modelling the interaction of reduced rainfall, increased potential evapotranspiration with increased urban density are presented in Figures 6 and 7. Each of the 20 catchments were modelled to predict harvest volumes estimated. A summary of the total findings is given in Table 32.

Table 32 Predicted impacts of climate change and urban consolidation

	Current rainfall and current housing density	Impact of climate change with current housing density	Impact of climate change with 5% increase in impervious area[1]	Impact of climate change with 10% increase in impervious area[2]
Potential Harvest	60 GL/a	50 GL/a	55.5 GL/a	60GL/a

Notes:
[1]5% increase in impervious area represents approximately 14% of existing properties being redeveloped.
[2]10% increase in impervious area represents approximately 28% of existing properties being redeveloped.

Figure 6 presents harvesting volumes for the values presented in Section 6 (i.e. current urban densities and historical rainfall) and using the 2050 climate file with 0%, 5% and 10% increase in urban impervious area (as discussed in Section 7.2). Results are shown for each catchment.

It can be seen that generally climate change reduces the yield by approximately between 10-20% from catchment to catchment without any infill development. There is also typically more impact from reduced rainfall on catchments that have higher proportions of rural areas (e.g. River Torrens) compared to more urban catchments (e.g. Dry Creek).

Figure 6 also shows that there is an increase in yields with an increase in urban density. Depending on the catchment land use mix these increases can either be less than the reduction due to climate reduced rainfall (e.g. Torrens River) or exceed the current estimates (e.g. Dry Creek). Totals for all of the catchments combined are presented in Figure 7.

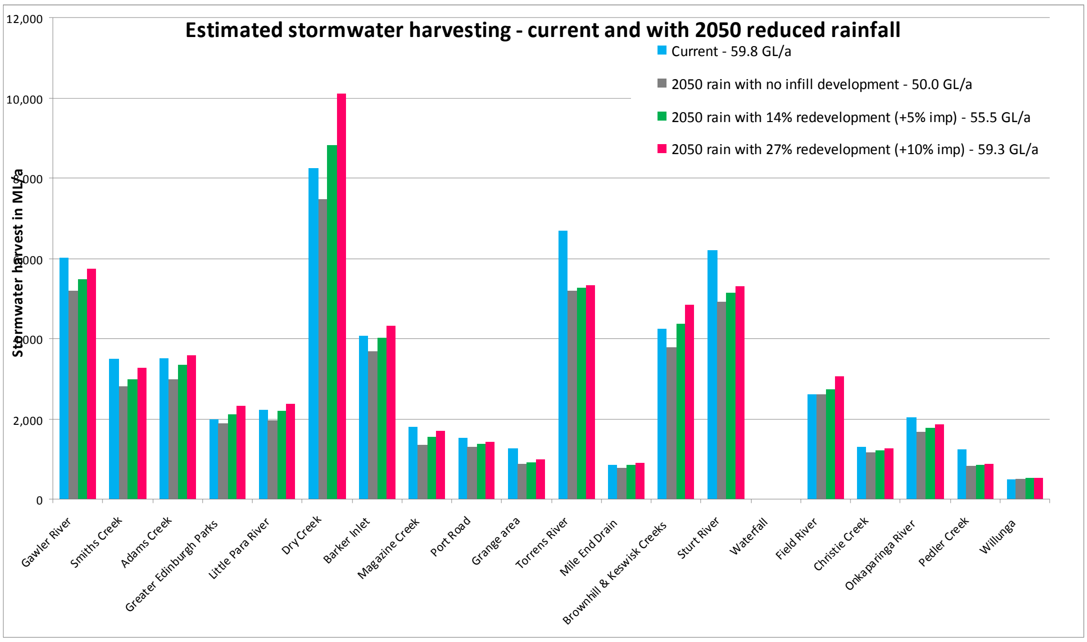


Figure 6 Catchment results for climate change and urban consolidation modelling

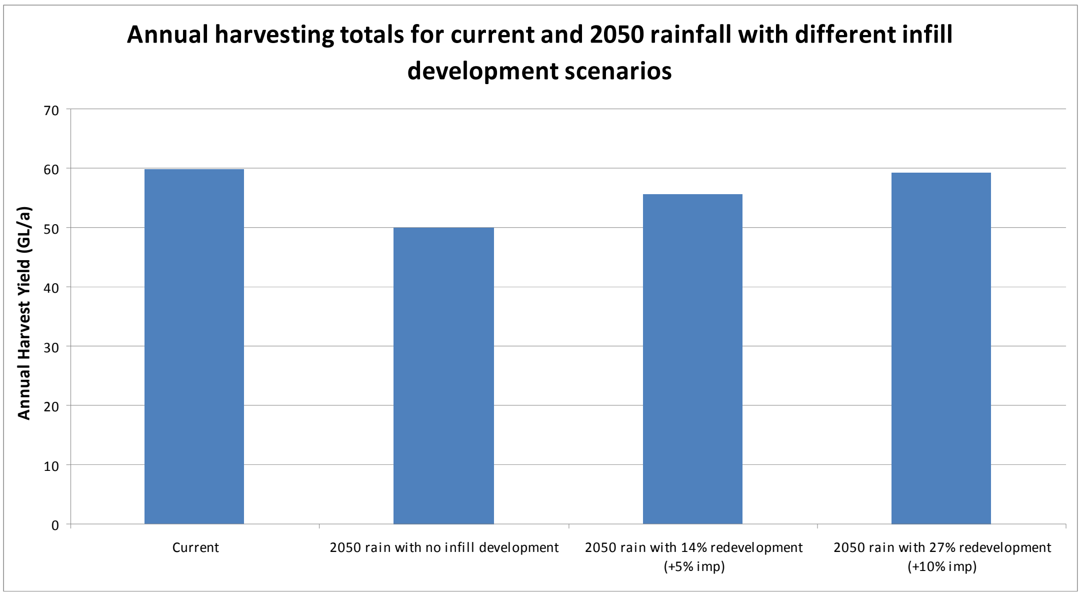


Figure 7 Total yield for Greater Adelaide using climate change and urban consolidation scenario

The combined total harvest for all for the schemes presented (Figure 7) shows that without any infill development predicted climate change will reduce harvests by approximately 17% (approximately from 60 GL/a to 50 GL/a).

The analysis also shows that harvest yields will progressively increase with urban consolidation because redevelopment will increase the impervious proportion of catchment surfaces. An increase of catchment imperviousness by 10% will offset the harvest volume reduction because of predicted rainfall reductions by 2050 (i.e. back to approximately 60 GL/a). This represents approximately 28% of properties redeveloping in this period (as discussed in Section 7.2). It should be noted that rainfall intensity changes have not be accounted for in this modelling. When further quantitative information is available on changes to rainfall intensity patterns then this should be accounted for in the harvesting model for Greater Adelaide.

7.4 Historical Wet and Dry Years

From the 32 years of available six-minute rainfall data, the driest year (1982, 357mm) and the wettest year (1992, 883mm) were simulated through all 20 catchment models. This essentially provides and upper and a lower bound for expected yields based on collected rainfall data.
The analysis showed that yields were 21.7 GL during the direst year (1982) and 93.4 GL during the wettest year of 1992.

Figure 8 below shows the responses for the individual catchments.

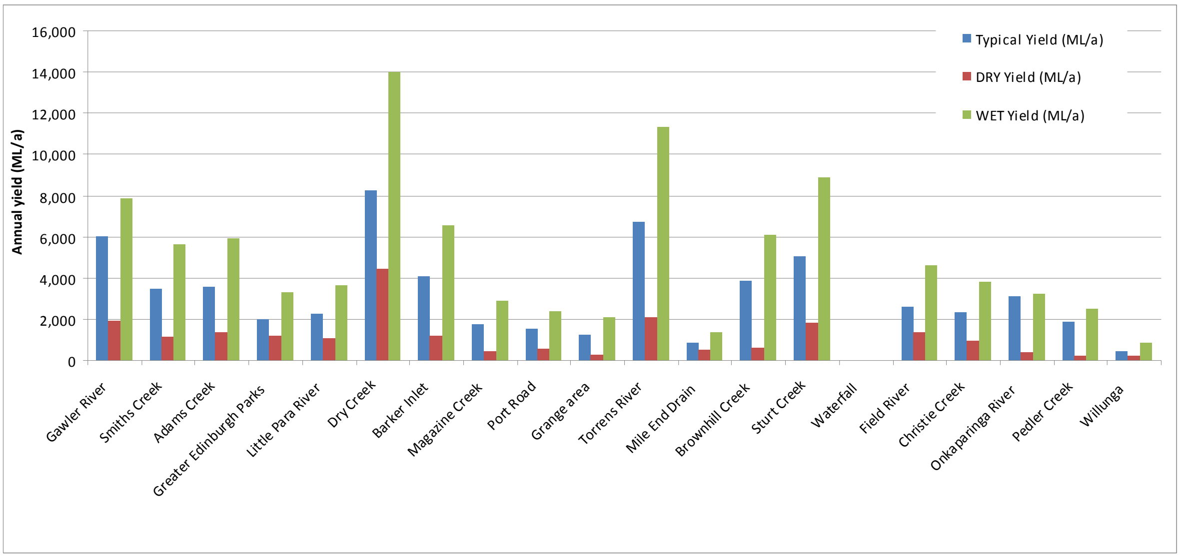


Figure 8. Variable flows wet, dry and typical flows for all modelled catchments

8. COST ESTIMATE

The cost estimates produced for this report are first order costs only.

The costs do not include allowances for the following:

- Treated water distribution
- Land value
- Electrical augmentation
- Excavation in rock
- Variability in well establishment costs due to local conditions or site constraints
- Remediation works to affected nearby bores
- Costs to install stormwater networks within the catchment area.
- Terrestrial landscaping and other aesthetic features often incorporated into wetlands
- Ongoing operation and maintenance
- No allowance has been made for gifted assets i.e. digging of basins for the purposes of completing other projects

The estimated costs included allowances for:

- Transfer pumps
- Transfer pipe work
- Bulk earthworks
- Clay lining
- Transfer structures within the wetlands
- Aquatic planting
- Bore establishment and fit out
- Mechanical and electrical works required for control of injection
- Wellfield pipework

The cost estimates have been based on current rates for bulk earthworks.

ASR establishment has been based on the most recent costs from The Water Proofing Northern Adelaide project.

Wetland costs and biofiltration costs are based on actual construction costs from the Water Proofing Northern Adelaide project.

The per catchment costs presented in Table 33 include costs associated with upgrades of existing schemes and the establishment of new schemes. To increase the typical harvest volume within the study area from current levels to 60 GL/a (i.e. increase of 42 GL/a) it is estimated that approximately $600 million to $700 million of capital works will be required

The costs have not allowed for the fact that the facilities could be co-located with flood mitigation facilities. In this instance a portion of the construction cost may be allocated to the flood mitigation works. This would reduce the theoretical cost of the reuse project. Individual scheme costs may vary due to differing configurations or estimated yields. However, overall the catchment costs are considered reasonable estimates.

All costs are considered in today's dollar terms.

Table 33. Capital costs for new schemes and upgrades of existing schemes

CATCHMENT	COST ($/M)
Gawler River	66.5
Smiths Creek	39.5
Adams Creek	14.5
Greater Edinburgh Parks	31
Little Para River	25
Dry Creek	44
Barker Inlet	49
Magazine Creek	33
Port Road	12.5
Grange area	16.5
River Torrens	75.5
Mile End Drain	7.5
Brownhill/Keswick Creek	36
Sturt River	84
Waterfall Creek	0
Field River	30.5
Christie Creek	16.5
Onkaparinga River	26
Pedler Creek	10.5
Willunga	5
	623

9. FURTHER WORK REQUIRED

The Urban Stormwater Harvesting Options Study has been completed as a coarse model to estimate the potential stormwater capture and storage potential for Adelaide. The following further works are recommended for consideration:

- Demand Profile Analysis
- Distribution network analysis and costing
- Dynamic modelling of the ASR potential to determine long term capacities of the aquifer to deal with drought and multiple wet year occurrences
- Further assessment of surface storage potential
- Consultation with key stakeholders
- Develop a water allocation plan to ensure competing priorities are accounted for. (i.e. a scheme is not developed upstream of an existing scheme that effectively cuts off the downstream scheme)
- Investigation into operation and ownership models
- Detailed design for each site
- A five year review to audit the status of existing and newly constructed schemes and to utilise the latest data on climate change and urban consolidation to update the catchment models.

10 GLOSSARY

AAL	Adelaide Airport Limited
AMLNRMB	Adelaide and Mount Lofty Natural Resources Management Board
ASR	Aquifer Storage and Recovery: a technique whereby water such as treated stormwater can be stored below ground for later extraction and reuse. The method reduces the requirement and extent of surface water storages.
Bedrock Aquifer	typically compartmentalised fractures in bedrock systems (resulting in discreet plumes around each well, rather than amalgamation of plumes into a large plume, as would be expected in a porous limestone or sand aquifers) typically located in the eastern and southern regions of Adelaide.
Bioretention	Is the process of biological removal of contaminants or nutrients as fluid passes through media or a biological system. Typically vegetated systems using vertical filtration for stormwater treatment. (refer to http://wsud.melbournewater.com.au)
Cumec	One cubic metre per second
Detention	Holding water temporarily on-site for slow release into a Council or external stormwater system. Typically, for several hours
Fit for purpose water	Water of a specific quality that is suitable for other uses that may be of a standard not suitable for human consumption
Headloss	The difference between the elevations of surfaces and/or losses associated with friction through pipe networks.
Invert Level	The lowest level of the inside of a pipe, channel or a pit at the point of interest
MAR	Managed Aquifer Recharge
Potable water	Water that is supplied as mains water that is fit for human consumption
Quaternary Aquifer	The shallow unconfined aquifer present over the Adelaide Plain. This aquifer generally holds water of lower quality and is recharged directly by surface water and excess irrigation. The groundwater is subject to salinisation issues due to its shallow location and land current management practices above.
Retention	Retaining stormwater on-site for subsequent reuse over longer term
Tertiary Aquifer	The deeper sedimentary aquifer located over much of the Adelaide Plain. This aquifer generally holds water of good quality, but is increasingly threatened by contamination and overuse by extraction bores. Local Tertiary Aquifers are referred to as the T1 or T2 aquifers. The T2 aquifer is deeper than the T1.
Units of Volume	Kilolitre (kL) 1 kL = 1000 litres
Megalitre (ML)	1 ML = 1000 kL
Gigalitre (GL)	1 GL = 1000 ML

Wetland	An area that is regularly saturated by surface water or groundwater and is characterised by terrestrial and aquatic vegetation types. Constructed wetlands remove pollutants from water by a complex range of processes and mechanisms via physical, chemical and biological means.
Yield	The annual average volume of water that can be made continuously available from a source (watercourse, stormwater drainage system, or catchment area) over a specified period of time (usually 1 year).

11 REFERENCES

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DesignFlow (2008) '*Water Proofing Northern Adelaide: Summary of City of Playford stormwater harvesting'*

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State Government South Australia (2005) *Water Proofing Adelaide- A thirst for change 2005-2025*

Wilkinson J et al (2005) *Adelaide Coastal Waters Study – Technical Report no.3* EPA SA

WEBSITES

CSIRO (2008) Climate Change in Australia: Australia's Future Climate website. www.climatechangeinaustralia.gov.au/sarain20.php

Natural Resources Information Management System http://e-nrims.dwlbc.sa.gov.au/data/data.aspx

City of Salisbury www.salisbury.sa.gov.au

City of Marion www.marion.sa.gov.au

City of Playford www.playford.sa.gov.au

City of Onkaparinga: www.onkaparinga.sa.gov.au

City of Holdfast Bay: www.holdfast.sa.gov.au

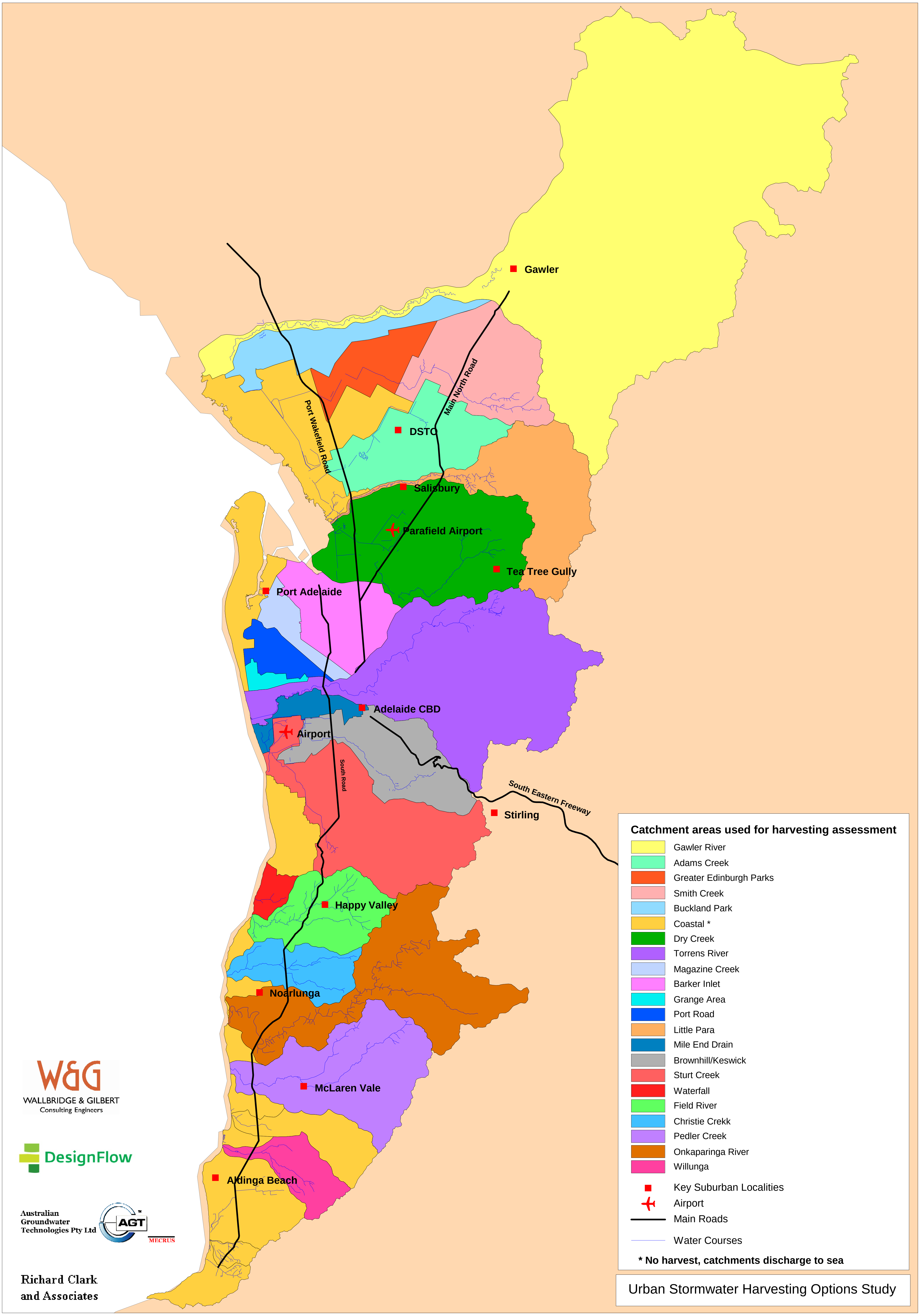
City of West Torrens: www.wtcc.sa.gov.au

City of Charles Sturt: www.charlessturt.sa.gov.au

City of Port Adelaide Enfield: www.portenf.sa.gov.au

APPENDIX A

HARVESTING AREAS CATCHMENT MAP


Gawler
Main North Road
Port Wakefield Road
DSTO
Salisbury
Parafield Airport
Tea Tree Gully
Port Adelaide
Adelaide CBD
Airport
South Road
South Eastern Freeway
Stirling
Happy Valley
Noarlunga
McLaren Vale
Aldinga Beach
Catchment areas used for harvesting assessment
Gawler River
Adams Creek
Greater Edinburgh Parks
Smith Creek
Buckland Park
Coastal *
Dry Creek
Torrens River
Magazine Creek
Barker Inlet
Grange Area
Port Road
Little Para
Mile End Drain
Brownhill/Keswick
Sturt Creek
Waterfall
Field River
Christie Crekk
Pedler Creek
Onkaparinga River
Willunga
Key Suburban Localities
Airport
Main Roads
Water Courses
* No harvest, catchments discharge to sea
Urban Stormwater Harvesting Options Study
W&G
WALLBRIDGE & GILBERT
Consulting Engineers
DesignFlow
Australian Groundwater Technologies Pty Ltd
AGT
Richard Clark and Associates

APPENDIX B

DESCRIPTIONS OF EXISTING SCHEMES

NAME	AQUIFER	COUNCIL	DESCRIPTION
OPERATIONAL SCHEMES			
Springbank Park/ Burton	T2	City of Salisbury	An existing wetland with in-stream integrated wetland, ASR. Distribution of 600ML/a to surrounding community and industrial users.
Kaurna Park	T2	City of Salisbury	An existing wetland with in-stream integrated wetland, ASR. Distribution of 600ML/a to surrounding community and industrial
Edinburgh Parks South	T2	City of Salisbury	An existing off-stream wetland and ASR scheme. Distribution of 1360ML/a for supply to the industry developing in Edinburgh Parks, Holden and to Defence at RAAF and DSTO Edinburgh.
Greenfields 1 & 2	T1A/T1B	City of Salisbury	An existing off-stream wetland taking water from Dry Creek through detention and ASR. Proposed upgrade work will increase the injection from 650ML/a currently, by 1050ML/a (including link to the Greenfields 3 wetland).
Greenfields 3	T1A/T1B	City of Salisbury	An operational wetland for water quality only and currently not injecting, however linked to the Greenfields 1 & 2 sites. Greenfields 1 & 2 currently injecting and will integrate with Greenfields 3 in the proposed upgrade work.
Paddocks	T1	City of Salisbury	In-stream wetland with ASR supplying up to 200ML/a to adjacent recreational facilities and industry.
Parafield	T2	City of Salisbury	Existing wetland and ASR harvesting 1100ML/a. Upgrade to include re-routing of exiting drainage to increase available stormwater supply and increase harvest by an additional 400ML/a to 1500ML/a.
Pooraka (Unity Park)	T2	City of Salisbury	Existing Pooraka wetland with 80ML/an supply. Upgrade to link Pooraka, Montague Road schemes with a detention dam proposed for Wakerley to allow slow release and runoff to Unity Park site to increase harvest by 1100ML/a to a total of 1180ML/a. The upgrade at Unity Park will include wetland and biofiltrations.
Satsuma	Fractured Rock	City of Tea Tree Gully	.Off-stream wetland and ASR taking water from Cobbler Creek. Harvesting 40ML/a, 8L/s pumped into the distribution main.
Solandra	Fractured Rock	City of Tea Tree Gully	Off-stream wetland and ASR harvesting 20ML/a, 8L/s pumped into the distribution main.
Tea Tree Gully Golf Course	Fractured Rock	City of Tea Tree Gully	ASR to approximately 50ML/an used within the Golf Course.
Kingfisher	Fractured Rock	City of Tea Tree Gully	Off-stream wetland harvested from Dry Creek. Supply of 30ML/a, 8L/s pumped into the distribution main.
Grange Golf Course	T1	City of Charles Sturt	Has been constructed but aquatic plants are still establishing. The wetland is within the golf course receiving surrounding residential stormwater, harvest 300ML/a.

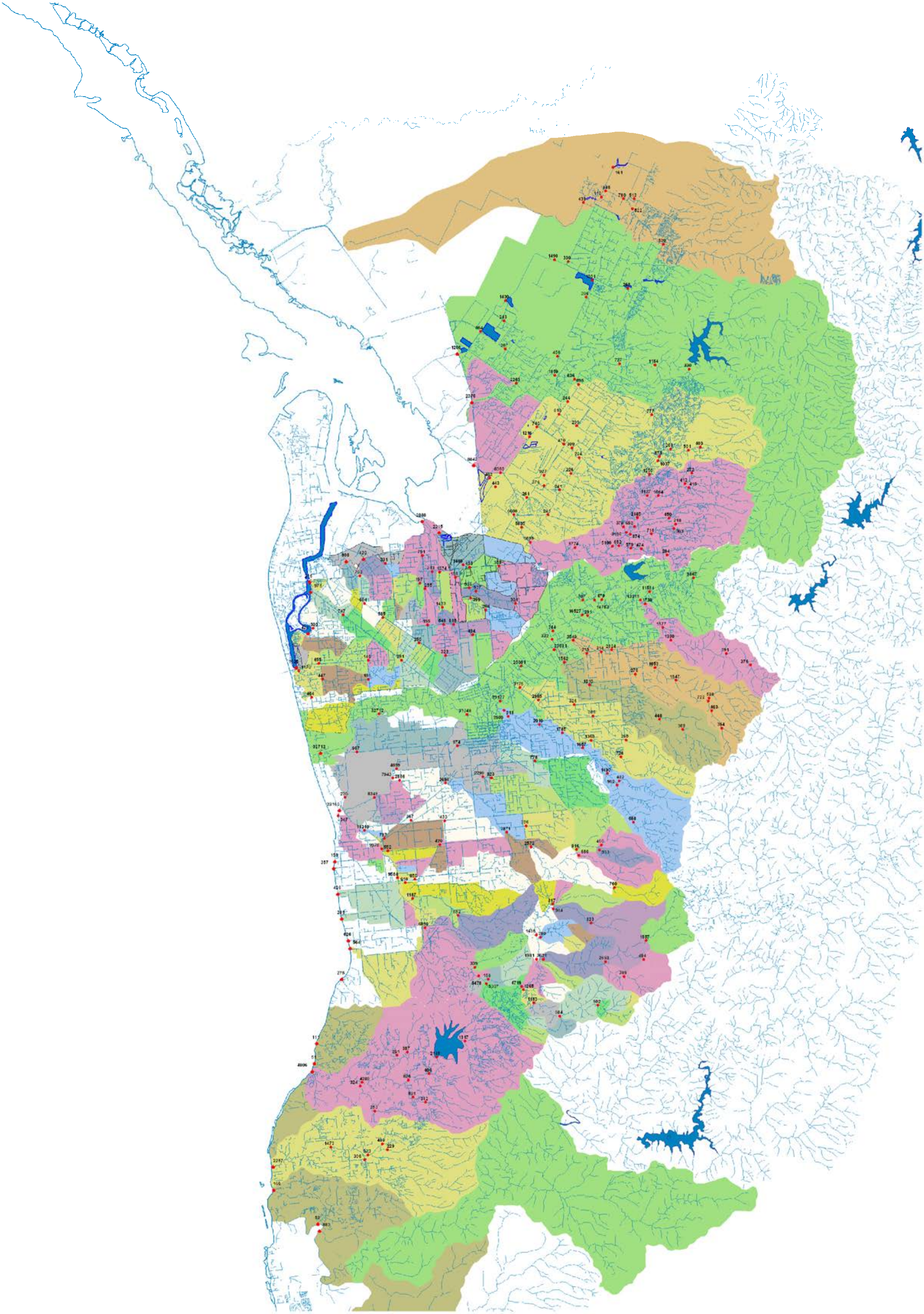
Royal Adelaide Golf Course	T1	City of Charles Sturt	Has been constructed but aquatic plants are still establishing. The wetland within the golf course receiving surrounding residential stormwater, harvest 200ML/a.
Morphettville Racecourse	T1	City of Marion	Catchment includes the upstream residential area, which drains into two parallel drains in Bray Street, adjacent the racecourse. The wetland covers 3.5ha is the middle of the race track. (potential to expand).
Vines Golf Course	Fractured Rock	City of Onkaparinga	The golf course currently diverts from the adjacent stream and stores onsite.

NAME	AQUIFER	COUNCIL	DESCRIPTION
COMMITTED SCHEMES			
Munno Para West	T1 & T2	City of Playford	New Wetland, ASR and distribution network with 560ML/a harvest. Land is currently under construction is due for completion in August 2009. It is located on the corner of Coventry and Curtis Road.
Andrews Farm	T1 & T2	City of Playford	Expand existing wetland, ASR and linked to distribution system. Harvest of 390ML/a. This wetland has replaced the existing first generation wetland with the Stebonhealth flow control park. Due for completion in July 2009.
Andrews Farm South	T2	City of Playford	New wetland within the proposed Parafield Golf Course, ASR, and link to distribution system with 190ML/a harvest
Evanston South		Gawler	Residential development (Evanston Gardens) with new wetlands for harvest of 350ML/a.
Olive Grove (Adams Creek Wetland)	T1	City of Playford	Upgrade to existing wetland to harvest 80ML/a. Consisting of an offline capture basin which pumps water to an offline stream wetland.
Edinburgh Park North	T2	City of Salisbury	Upgrade to existing wetland to harvest 600ML/a
Summer Road/Whites Road	*T2*	City of Salisbury	Part of the Salisbury Stormwater Harvesting (SSH) project which will add a wetland and ASR at Jobson Road Reserve with harvest at Summer Rd/Whites Rd. Due for completion in June 2012 but currently in concept form only. It will only target 600ML/a for ASR and distribution but should add 1200ML/a in potential harvest capacity.
Wynn Vale	*Fractured Rock*	City of Tea Tree Gully	Located in the City of Tea Tree Gully. An existing dam is used as a holding basin with water extracted and treated through a media filter at 25L/s to a 'ring main' to distribute harvests, and draw on surrounding injection sites. Predicted harvest of 350ML/an.
Edinburgh, Modbury	*Fractured Rock*	City of Tea Tree Gully	Upgrade to existing off-stream wetland and ASR to increase storage capacity. 50ML/a harvest predicted.
Greenfields 1 & 2 Upgrade			See summary above in existing schemes.
Parafield Upgrade			See summary above in existing schemes.
Pooraka (Unity Park) Upgrade			See summary above in existing schemes.
Bennet Rd Drain	*T2*	City of Salisbury	Construction of a new wetland on a Southern end of Parafield Airport site. Upgrade of existing wetland and detention basin to composite wetland and harvest facility. Predicted to harvest 800ML/a for supply to community and industrial uses.
Northgate	*Fractured Rock*	City of Port Adelaide & Enfield	Current local ASR with design capacity of 30ML/a. However has not operated since 2003 due to high water turbidity. This issue is being addressed presently to restart operation.

Northgate Expansion	*Fractured Rock*	City of Port Adelaide & Enfield	Expansion to existing Northgate bore. Expected harvest an additional 50-75ML/an currently at planning stage.
Roy Amer Reserve (Regency Gardens)	*Fractured Rock*	City of Port Adelaide & Enfield	This site has not operated since 1996/97, due to wetland operational issues, which are being addressed. Potential harvest approximately 50ML/yr.
Cheltenham Racecourse	*T1*	City of Charles Sturt	Located at the site of the existing Cheltenham Racecourse, which is planned for residential redevelopment, within the City of Charles Sturt. New wetland treating stormwater from the Torrens Road catchment, (including a diversion from Brompton area). Consideration also for pumped supply from River Torrens. Expected harvest 1300ML/an. Funding application this year.
Port Road Redevelopment		City of Charles Sturt	Upgrade to existing infrastructure to incorporate treatment wetlands with ASR with the median strip along the length of Port Road. Expected harvest 1200ML/ha
Riverside Golf Course		City of Charles Sturt	New wetland and ASR within the golf course which will treat runoff from surrounding residential and commercial areas. Expected harvest 200ML/a.
Torrens 2 & 3 (Highbury)	*Fractured Rock*	City of Tea Tree Gully	Expected harvest 140ML/an.
Lochiel Park		City of Campbelltown	Not yet operational however predicted harvest of 50-75ML/an.
Felixstow Reserve		City of Norwood Payneham & St Peters	Harvest volume unknown.
Walkerville Recreation Ground	*Fractured Rock*	Walkerville Council	Harvest volume unknown
Glenelg Golf Club	*T1*	Holdfast Bay	Currently under construction and near completion. Should soon be operational to predicted harvest rate of 400ML/an.
Orphanage Park		City of Unley	Harvest volume unknown.
Seaford Meadows		City of Onkaparinga	Residential development 3 wetlands proposed within the site for water quality and one south with potential for harvest.
Flagstaff Hill Golf Course	*Fractured Rock*	City of Onkaparinga	The club is currently looking for approval to harvest from the Happy Valley cut-off drain.
Vines Golf Course Upgrade			See summary above in existing schemes.
Broadie Road Reserve WL		City of Onkaparinga	An off-line treatment wetland linked to a pumped distribution network, for storage and reuse. Predicted 650ML/an harvest to storage at Wilfred Taylor Reserve, local irrigation and overflows to Christies Beach WWTP.
Madeira Drive Reserve WL		City of Onkaparinga	Located in Morphett Vale,. An offline treatment wetland linked to a pumped distribution network, for storage and reuse. Predicted 180ML/an harvest to storage at Wilfred Taylor Reserve, local irrigation and overflows to Christies Beach WWTP.

APPENDIX C

WATERCRESS CURRENT FLOW MAPPING



APPENDIX D

WATERCRESS CALIBRATION DATA

APPENDIX D. IDENTIFICATION OF INPUT DATA TO THE WATERCRESS RAINFALL TO RUNOFF MODEL

1. INTRODUCTION

WaterCress models consist of an assembly of nodes which represent specific water related processes occurring within the catchment, plus a series of links between these nodes which represent the passage of water between them. The ‘upstream’ nodes generally represent sub-catchments and the model calculates a continuous time series of runoff from each sub-catchment according to the time series of rainfall over it. These flows are passed via the links to downstream nodes. These either;

- similarly calculate and merge the generation of runoff from further tributary sub-catchments situated downstream, or
- simulate any of the processes associated with the components of a water system, i.e. processes related to different varieties of storage, diversion via weirs, quality improvement in treatment plants, supply to demands and recycling of wastewater, etc.

Once the structure of the model has been established, its operation is governed by the values of the many items of data (ie coefficients, areas, volumes, flow rates, etc) that are needed to describe and limit the many processes occurring within the model nodes.

This Appendix describes the method of estimation of the areas of pervious and impervious surfaces within sub-catchments and the derivation of a set of standard models for different defined degrees of urban density. The implications and performance of the formulae adopted for calculation of runoff on impervious surfaces is then described.

2. AREA ESTIMATION

Accurate estimation of the aggregate of the impervious areas within each catchment is a crucial requirement in order to make an accurate estimation of the catchment runoff. The procedures described in the following sections were developed to provide a best estimate of the impervious and pervious areas based on the time and information resources available.

Step 1 - The total catchment area is firstly subdivided into approximately equal sub-areas, based on elevation contours, isohyets and drainage path mapped information. Boundaries of areas with high relief can be mapped accurately (eg. 49, 51 in Figure 1). Where there is little relief, the delineation becomes less accurate unless detailed drainage plans or survey is available. In all cases boundaries are selected in an attempt to have only one major drainage outlet where flow is passed to the next area.

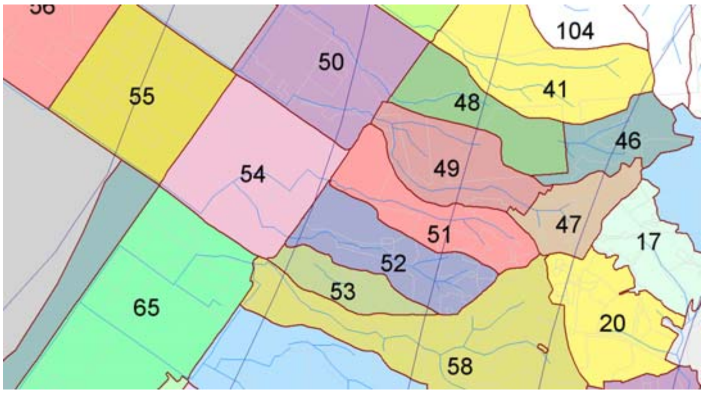


Figure 1. Definition of drainage paths and sub-areas.

Step 2 - Each sub-area has then been separated into 4 basic land use types:

- Areas of relatively homogeneous housing, roads and gardens sub-categorized into one of three different dwelling densities and impervious proportions (shown in Figure 2 shaded red),
- Industrial/Commercial areas with high impervious proportions (shown in Figure 2 shaded yellow),
- Undeveloped hills face/rural catchments (shown in Figure 2 shaded light green), and
- Pervious urban parks and large open areas (shown in Figure 2 shaded darker green)

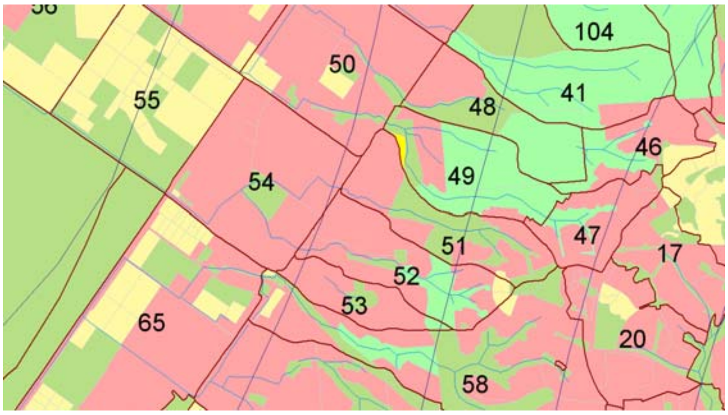


Figure 2. Basic landuse types identified and separated.

These are further described below, with the modelling for the pervious areas within the urban areas and the pervious areas in the last two dot points taken together under the ‘Pervious Areas’ heading in section 2.2.

2.1 Housing (Domestic) Areas

Areas of housing comprise a relatively homogeneous assembly of houses, gardens, roads, verges and small open areas, including a few vacant blocks.

Step 3. Significant pervious areas such as large parks, recreation areas, watercourse reserves, etc. within the housing area are identified and digitized as a separate land use and included separately under the ‘pervious’ classification.

Step 4. All the remaining housing area is assumed to consist of 25% road easement and 75% housing blocks, each with a dwelling. Each housing block is assumed to include;

- 10% of its area taken up by impervious paved paths, driveways, etc.,
- a dwelling with an impervious roof area, and
- a pervious garden area which includes a small share of the aggregated areas of small communal parks.

Step 5. The housing areas are separated and classified into three densities, according to a visual assessment of aerial photos (Google maps) showing the relative proportions of impervious and pervious areas, as below:

2.1.1 Low Density – assumed roof area = 30% of the 90% of the block area remaining after removal of 10% paved areas.

2.1.2 Mid density - assumed roof area = 45% of the 90% of block area. These may be relatively new areas with smaller block areas or older areas with a lot of ancillary shedding or verandahs etc

2.1.3 High Density – assumed roof area = 60% of the 90% of block area. These tend to be the latest developments where block sizes are small and roof areas are large.

Many sample areas were assessed in developing the above classification and assumed proportions. Analysis of the statistics obtained lead to;

- an estimate of 9.8, 12.1 and 13.6 dwellings per hectare for low, medium and high density developments respectively and
- the recognition that as the house roof density increased, the block area per dwelling decreased and the roof area per dwelling increased. House sizes, block areas and roof fractions were adjusted to be mutually statistically compatible.

The process showed that there is a wide variation of the proportions of impervious and pervious areas within the housing areas across different parts of the catchments.

The information on dwellings per hectare (and persons per dwelling, etc) can be used if the model is later used for assessments of water supply and wastewater production. The relations are shown in Table 1.

Table 1. Fraction of impervious area with respect to total residential area

Housing Density	Assumed roof %	Roof fraction	Pavement fraction	Garden fraction	House size	Block area
Low	30	0.23	0.07	0.45	230	766
Medium	45	0.34	0.07	0.34	280	622
High	60	0.45	0.07	0.23	330	550

Step 6. The 25% of assumed road easement area is assumed to be comprised of 15% of impervious paved area and 10% of pervious areas (ie verges and small areas of unpaved land).

Table 2 shows a summary of the assumptions made and used within the GIS to estimate the impervious paved and roofed areas and pervious areas within the sub-areas designated as housing.

Table 2. Impervious area assumed with respect to total residential area.

	Low density	**Mid density**	**High density**
Impervious road	15%	15%	15%
Pervious road (verge)	10%	10%	10%
House roof area	23%	34%	45%
House Pavement	7%	7%	7%
Garden (pervious)	45%	34%	23%
Total Roof	23%	34%	45%
Total Pavement	22%	22%	22%
Total Pervious	55%	44%	23%

In addition to having an increased impervious fraction, the denser developments are also assumed to be connected more directly to the drainage system. For example, while the front part of the roof may be connected by drain to the road (and hence the formal drainage system) the back roof often discharges to the backyard and garden or to rainwater tanks. Larger blocks with lower density clearly have more capacity to discharge water in this way. It is therefore assumed that as block sizes reduce a lesser proportion of impervious runoff will be lost on-site.

It has been assumed in the models provided that the low density development has 50% of its roof connected to the stormwater system. The medium density and high density developments are assumed to have 60% connected.

2.1.4 Industrial/Commercial Areas

The proportions of impervious and pervious areas within each of the sub-areas classified as Industrial/Commercial have been individually assessed using aerial photos (Google maps). Individual blocks were visually inspected and then aggregated to give total roof, paved and pervious areas.

Connection of the Industrial/commercial roof and pavement areas to the drainage system was assumed to be higher than domestic areas. Values of 80% connection for the roof area and 70% for paved area were adopted across all areas.

2.2 Modelling Runoff from Pervious Areas

Pervious areas by definition do not include any significant impervious areas. The following describes the separation of the various separated pervious areas into two types, using different versions of the WaterCress pervious catchment rainfall to runoff model. The parameter values chosen for the versions of the model are adequate to account for different combinations of soils, slopes, degrees of vegetation, etc. and efficiency of inter-connection to the watercourses and drain systems.

Considerable experience has been gained with the prediction of runoff from rural catchments in the Mt Lofty ranges. These include runoff from some hillsface catchments such as First, Third and Sixth creeks, but generally within the higher rainfall areas.

Prediction of runoff from all the rural and hillsface areas within the Dry Creek catchment has been made using a model calibrated to the rainfall-runoff relation of Sixth Creek. This model use has been extended to the watercourse reserves that finger into the perimeter urban areas on the foothills areas.

Very little direct data exists on runoff from aggregated garden areas and other pervious areas within urban areas such as parks, recreation areas and watercourse reserves on lower rainfall and the flatter land. However indirect experience with model calibration of urban area runoff shows that the proportion of runoff from their pervious areas is usually small to negligible in relation to runoff from their impervious areas. For aggregated house garden areas this is not surprising in view of the significant impedance and losses likely to be associated with their cultivation, landscaping and border fencing.

The model used for the urban pervious areas is therefore similar to that for the rural and hillsface areas except that it has been modified by increasing the interception and soil moisture capacities to reduce the amount of runoff predicted (refer calibration later).

The total procedure for separation of sub-catchment, land uses, roof, paved and pervious areas for input to the WaterCress model is shown diagrammatically below.

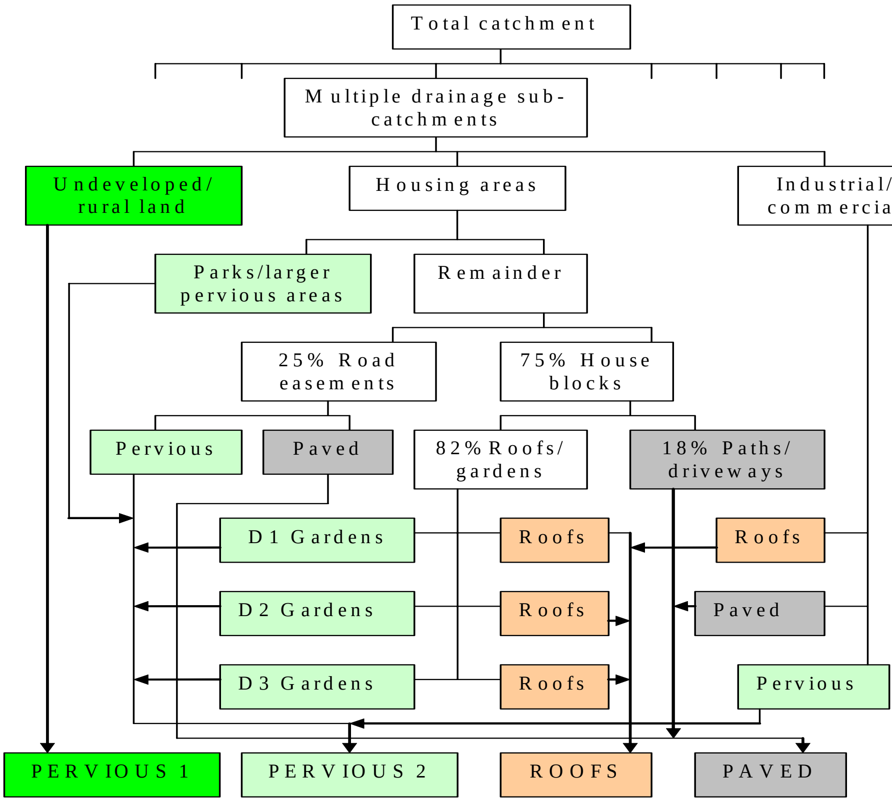


Figure 3. Decision tree for separation of impervious and pervious areas input to the WaterCress model

3. MODELLING RUNOFF GENERATION IN URBAN CATCHMENTS

3.1 Impervious Area Runoff Calculated Continuously at the Daily Time Step

The formulae used in the WaterCress model to make continuous estimates of runoff from impervious areas from continuous records of daily rainfall is essentially the same as that given above for the estimation of event runoff i.e.

Daily runoff = Area * (Daily rainfall – IL) * Conn * OF when rainfall > IL, or

or, Daily runoff = 0 when rainfall <IL, where:

- Area is the total of all the individual (impervious) areas of roofs or paved surfaces within the sub-catchment for which runoff is being calculated,
- IL is the Initial Loss assumed for that surface type,
- Conn is the degree of connectivity for that surface to the main drainage system, and
- OF is the ongoing fraction of rainfall 'lost' after the initial loss had been extracted.

As described in section 2.3, IL can be estimated with some accuracy from plots of event rainfall v event runoff. A similar value will be obtained from plots of daily rainfall v daily runoff, except that the latter will have more scatter.

(Conn*OF) together equal the efficiency of runoff, after the effects of the IL abstractions have been taken into account.

Typical values for "IL, Conn and OF" that have been found to give good calibrations between the predicted runoff and the measured runoff for the majority of gauged urban catchments in Adelaide (which were mainly residential) are:

Table 3.

Parameter	Roofs	Paved Surfaces
IL	1.0 mm/day	2.0 mm/day
Conn	0.5	0.8
OF	0.9	0.85

In calculating total runoff using continuous modelling in a location like Adelaide where there are many days with only a small rainfall, the influence of IL on the proportion of annual rainfall that is converted to annual runoff is quite large, as shown in Figure 4.

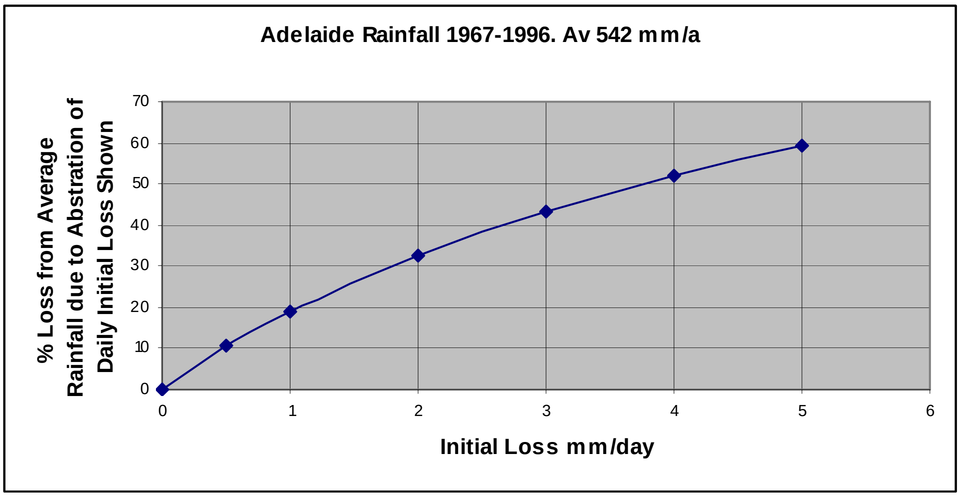


Figure 4. Reduction in Effective Rainfall due to Abstraction of Initial Losses.

This shows the average annual reduction in rainfall due to the abstraction of Initial Losses in the range 0.5 to 5 mm/day from the 30 year Adelaide rainfall (1967-1996). Ie. the abstraction of 1 mm/day from all daily rainfalls in Adelaide over the period 1967 to 1996 would reduce the average effective rainfall from 542 mm/a by 19.5%. A 2 mm/day abstraction reduces the average by 32.5%, etc. Similar reductions would apply to all locations within the Adelaide region with rainfall in the range 450-650 mm. This curve can therefore be used to identify the effect of the (Daily rainfall-IL) part of the above formula on the prediction of annual runoff.

By inserting the values of IL, OF and Conn as given in Table 3 into the WaterCress runoff formula, the average annual runoff depth per unit area of roof and paved areas as a percentage of the annual rainfall would be (1.0-0.195)*0.5*0.9 = 36% and (1.0-0.325)*0.8*0.85 = 46% respectively (where 1-0.195 is the long term reduction in effective rainfall due to the abstraction of an IL of 1 mm/day, etc.). If, as stated, the roofed and paved areas are assumed to occupy equal areas, the average runoff coefficient for the total of the impervious areas would be 41%. If the pervious part of the catchment is assumed to occupy 50% of the total catchment area, but to generate little runoff, then the runoff coefficient for the whole catchment would be 20.5%.

By assuming different values for “IL, Conn, OF” and different proportions of roofed, paved and pervious areas, different average runoff coefficients for the total catchment can be calculated.

Figure 5 shows a theoretical indicative range of runoff coefficients calculated for catchments with different proportions of impervious and pervious areas. Obviously, by including pervious areas into the calculations, which are assumed to have zero runoff, the overall catchment runoff coefficients will be reduced in direct proportion to the proportion of pervious area. Thus while (from Figure 4) an 80% runoff coefficient might apply to a ‘stand-alone’ roof with an initial loss of 0.5 mm/day and when connected directly to the drainage system (ie Conn = 1.0) and having a ongoing loss (OF) of 10%, if the roof was surrounded by an equal area of pervious catchment with zero runoff, the overall runoff coefficient for the total area would drop to 40%.

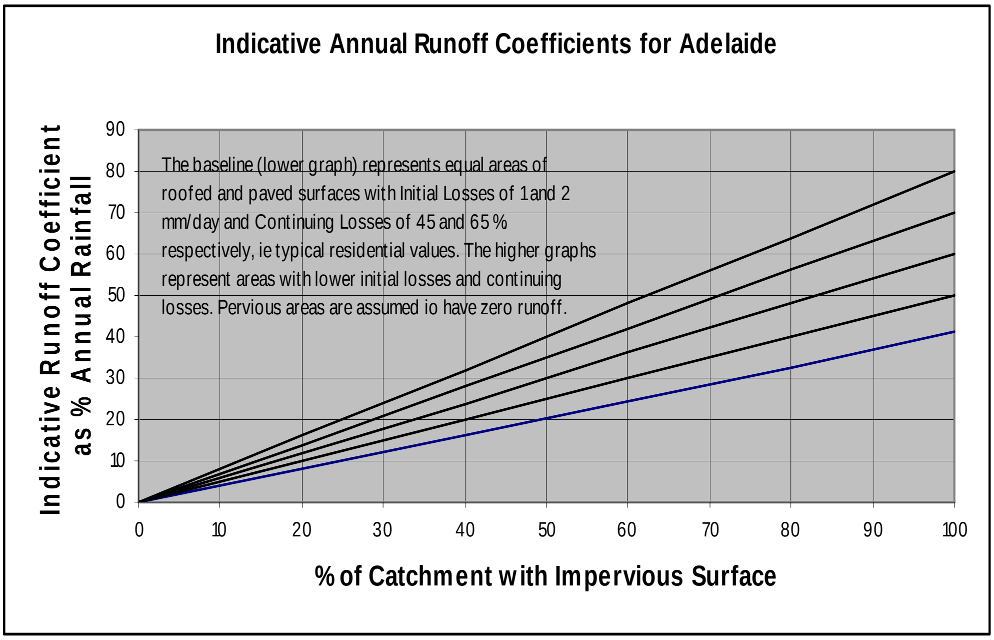


Figure 5. Indicative Runoff Coefficients for Urban catchments with Different proportions of Impervious and Pervious Areas.

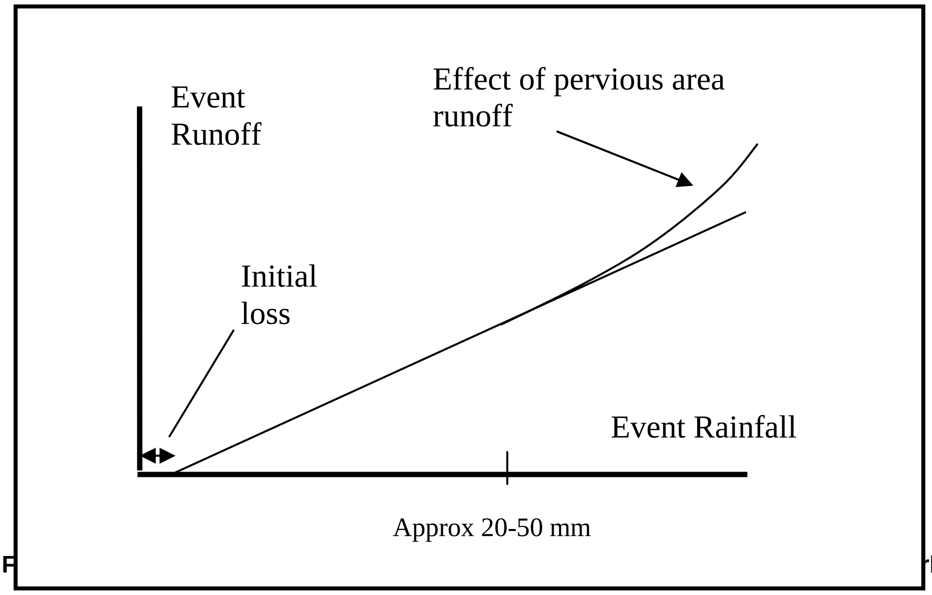
The lower line in Figure 5 is compatible with the runoff coefficients calculated for a range of gauged catchments in Adelaide. For example, the Paddocks residential catchment with about 50% of its area pervious (ie parks and gardens) has a runoff coefficient of 18%. The Parafield catchment which contains some industrial areas, but also a large area of open escarpment area in addition to the normal parks and gardens within its residential areas has a coefficient of 16%. The Adelaide Terrace catchment which contains mainly industrial areas adjacent to South Road with little pervious area has a runoff coefficient of 40%. Since they can all be represented by the lower line relation, by inference they must share compatible values of "IL, Conn and OF". The family of higher lines then represent the relations for situations having lower values of "IL" or higher values of "Conn and OF".

With the exception of Adelaide Terrace, very little data on runoff from industrial areas in South Australia has been recorded to date. General experience shows that runoff efficiency increases as the individual sizes of contiguous impervious areas increase, due to the decreasing ratio of edge length (where infiltration losses may occur) to contributing area. In industrial areas more care is also usually taken in the designed connection of the impervious areas to collector networks and in the sizing of the discharge pipes. However, these effects may be counter-balanced if unlined detention/retention storages are included in future industrial areas.

3.2 Runoff From Urban Catchments Including The Pervious Surfaces.

Runoff from the pervious parts of the catchment is calculated in the WaterCress model via a far more complicated set of equations (Equation 2, not reproduced here – see WaterCress Manual) which simulate the storage and progressive movement of water through three layers of the catchment;

- the surface layer,
- the unsaturated layer of soil beneath the surface and above the groundwater table and,
- the groundwater layer. The runoff from an urban catchment comprising both impervious and pervious areas is then the sum of the runoffs predicted by Equations 1 and 2. The generalized form of the addition of runoff from the impervious and pervious surfaces is shown in Figure 3 below.



F … rban catchment.

Figure 7 shows the results for a relatively homogeneous small residential catchment of 70 ha in Adelaide (the catchment of the Paddocks wetland). Over the period 1992-2002 event rainfall was measured at two locations within the catchment. The catchment is small and has a stable standard weir for flow measurement. The weir has been calibrated by field measurement during low and medium to high flows. The quality of data should therefore be good.

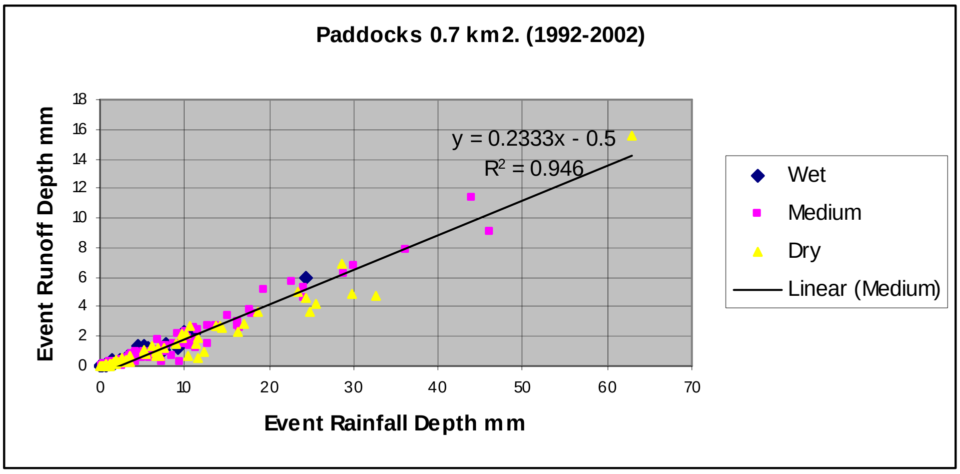


Figure 7. Example of Figure 6 using Paddocks catchment rainfall event data.

The equation runoff/(catchment area) = 0.23 * rainfall -0.5 is shown as the least squares linear fit to the data in which the initial loss IL is 0.5 mm and the coefficient of efficiency of runoff (Conn * OF) is 0.233 (or approx. 23%). The correlation coefficient shows a good fit at R squared = 0.946.

The linear nature and lack of major scatter shown on Figure 7 confirms that a relatively stable linear relation exists between rainfall and runoff in urban catchments in Adelaide. While the data is plotted for events, a similar graph (but with greater scatter) would be obtained using daily data. Calibration between the model and accurately measured flows can be used to determine the size of the initial losses on the impervious surfaces, the efficiency of subsequent runoff on the impervious surfaces, the point of initiation of runoff from the pervious surfaces (not apparent on Figure 7). If the pervious areas appear to contribute, the relative proportions of runoff generated on the impervious and pervious surfaces can be assessed.

The corollary of the above is that any model which has been developed to estimate runoff from rainfall in urban catchments and which uses this simple form of calculation of runoff should be able to predict the runoff with a good degree of accuracy, particularly at lower flows. By extension, any measured flows that do not conform to this general form of relationship (once established by analysis of the bulk of the rainfall and runoff events) should be regarded as being likely inaccurate in respect to either its measured rainfall or runoff.

The line shown on Figure 7 has been fitted to the data falling into the ‘medium’ wet conditions (defined as having an antecedent precipitation, or wetness index of 10-30 mm). It would be expected that

- the wetter condition data (API > 30 mm) would lie above the line (ie. greater runoff would be expected for the same amount of rainfall) and
- the drier conditions data (API < 10 mm) would lie below the line (less runoff would be expected for the same amount of rainfall). This tendency can be seen, particularly if the linear relation was re-drawn curving upwards above about 40 mm of rainfall. Unfortunately there were not many high rainfall events during this time and none under wetter conditions to investigate the runoff from impervious parts of the catchment.

It is probable that the accuracy of estimation of urban runoff would be marginally improved if catchment wetness was included in the prediction equation.

Figure 8 shows the same relation between rainfall and runoff depth, except that the rainfall and runoff have been cumulated to monthly totals. As the monthly total is the addition of several events, the variability is reduced and the R squared value rises to 0.96. As monthly rainfall totals contain several events for which rainfall is insufficient to overcome the initial loss, the % of rainfall that becomes runoff is reduced to about 20%. The upward curvature of the relationship is still indicated weakly, but few data points are available and a greater variability is evident for the higher rainfall months.

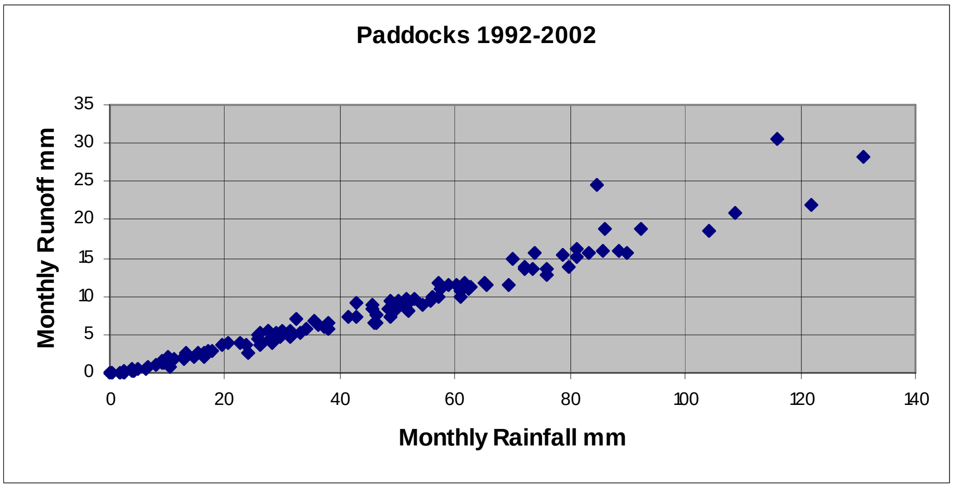


Figure 8. Monthly rainfall v monthly runoff depth for the Paddocks catchment.

Confirmation that models can predict runoff for urban catchments with a good degree of accuracy is shown in Figure 9, which shows the comparison between monthly flows estimated by the WaterCress model using the runoff to rainfall equations as described above to the flows actually measured at the gauging station. Since most rainfall stations measure rainfall at the daily time interval, the model is usually set up to perform its calculations of runoff at the daily time step, using long sequences of daily rainfall records. The model has recently been extended to calculate runoff from rainfall at time-steps down to 6 minutes. Where rainfall data is available at these shorter time intervals greater accuracy in prediction is expected to be achieved.

The model has been calibrated to achieve the best fit by 'trial and error' adjustments to the initial loss and efficiency of runoff coefficients contained in Equation 1 and the 10 different coefficients required for the pervious area Equation 2. The R squared fit between the recorded v modelled monthly estimates is 0.82.

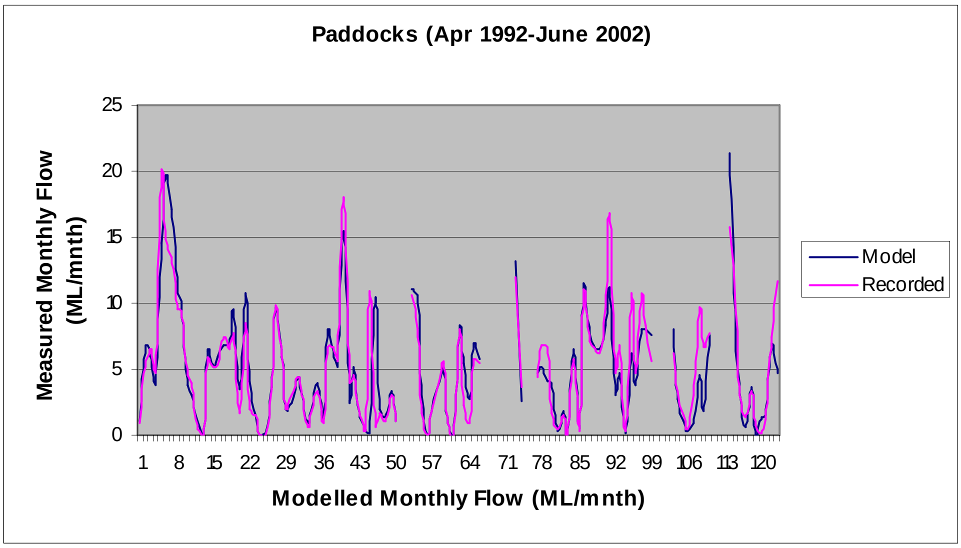


Figure 9. Comparison between monthly flow estimated using the WaterCress rainfall to runoff model and as measured at the gauging station

3.4 Summary

A relatively simple and stable relationship generally exists between rainfall and runoff for the impervious areas of urban catchments. Such a simple relationship does not exist for the pervious areas. Under most situations in low rainfall areas (rainfall < 600 mm/a) the pervious areas only contribute small depths of runoff. Hence, as the proportion of impervious area within any catchment increases and the pervious proportion decreases, the rainfall to runoff relationship generally becomes more linear and precise. A rainfall to runoff model will therefore be able to provide an accurate estimate of the runoff from the catchment provided that:

- the total area of impervious surfaces within a catchment is known and this forms a relatively high percentage of the total area (say > 30%), and
- the rainfall is measured accurately at sufficient locations to give an accurate representation of the rainfall over the whole catchment.

The next Section describes the data errors most likely to influence the accuracy of rainfall to runoff modeling and the manner in which the impervious areas can be best estimated.

4. Accuracy of Key Data used in the Prediction of Flow.

When major discrepancies exist between flows predicted by a rainfall to runoff model and as measured by a gauging station, the source of the discrepancies may be associated with the:

- inaccuracy of the rainfall measurements, and/or
- inaccuracy of the flow measurements, and/or
- inadequacy of the prediction model to take all conditions into account

The adequacy of the prediction models is addressed in Section 2.

4.1 Rainfall data errors

The accuracy of the rainfall records can be checked by comparing one record against the records of its neighbours, either directly, or as cumulated totals over several years. Most errors in recording via pluviometers are associated with power failures, in which case the record is missing all together.

The moving of a gauge into a location having a different exposure, or the construction of a building nearby, which changes the exposure, can give a long term change to the readings. The timing of such events can often be picked up by comparing double mass curves of the cumulated totals of rainfall recorded by the different raingauges within a local region.

The start of a period of systematic errors, or changed exposure, is revealed as a change in the relative slopes of the graphed cumulated rainfall totals. Otherwise errors are usually small and are made even less significant when several rainfall records are used to define the spatial variation of rainfall across the catchment. It would be very unusual for all gauges to be in error together, although high winds may cause a group of gauges to under-or over register together.

4.2 Flow data errors

By contrast, flow is much more difficult to measure and measurements are prone to many sources of error.

Most stream flows are estimated via separate measurements and calculations involving water depth, water velocity and cross section area. Under ideal conditions these measurements bear stable relations to each other, which can be estimated by hydraulic calculation or field measurement. Ideal conditions are rarely met and accurate measurements can usually only be guaranteed if a standard measuring weir is constructed. These are expensive. Where measurements are taken in natural channels away from stable concreted sections, measurement conditions are often far from ideal. Logs, trash accumulations, bank erosion, sediment accumulations and seasonal vegetation growth substantially alter the relations, often from day to day or week to week. Since the calculations of flow are made on the basis of the most recent set of relations available, when any changes occur the calculated flow will be in error until the new set of relations has been established.

As field measurements to check and/or re-establish the relations are

- often hazardous under high flow conditions,
- ii) require skilled operators, and
- are expensive, they are usually infrequent and confined to low flows. Often they are not carried out at all. Under most circumstances high flow measurements are generally recognised as being estimates only.

Thus, unless measurements are carried out in a channel reach where the geometry and surface roughness are fixed (i.e. a concreted channel), the flow measurements should be regarded as a guide only. The measurements are liable to have large random errors due to

- random events, such as blockages by silt or debris, or
- systematic errors due to incorrect assumptions made in developing the hydraulic relations, such as the incorrect estimation of roughness.

4.3 Modelled Flows

Table 4 lists the flow predicted by the WaterCress model at the downstream outlet of the catchments modelled. In most cases these are at or very near to the sea, but for Smith Creek the catchment downstream of Andrews Farm was not modelled as no additional flow is likely to be added. It also shows the losses that were abstracted as stream infiltration in order to obtain the calibrations and the coefficients of runoff from the total upstream catchment.

Of note is the very large increase in runoff coefficient of the higher rainfall, central, more densely developed urban areas of Adelaide and the generally low values of the coefficients overall, particularly to the north and south. The following notes apply to the

information contained in **Tables 4**:

Table 4. Flows predicted by Watercress

Catchment	Av. Catch Rainfall mm	Inflow from u/s GL/a	Outflow GL/a	Est. Losses GL/a	Losses as % runoff	Runoff Coef. (exc u/s inflow)	Coastal Study (CS)
		1970-2002 Averages					
Gawler	n/a						10.3
Smith Ck	517	0	1.33 (1)	1.11	45.5	4.5	
Helps Rd	470	0	1.21(1)	2.04	62.8	4	5.2 (1)
L Para R	514	0.67	2.47 (1)	1.16	32.0	11	
Dry Ck	544	0	8.84 (2)	0.68	7.1	16.8	10.3 (2)
Enfield/WL	485	0	7.67(2)	n/a		23	
Torrens	659	9.61	32.75 (3)	1.11	3.3	22.5	22.4 (3)
Patawalonga	674	0	22.53 (4)	4.89	17.8	15.8	19.7(4)
Brighton	525	0	2.69 (5)	n/a		19.3	2.7 (5)
S Coast	635	0	8.32 (6)	0.89	9.7	12.5	13.1 (6)
Onka.	n/a						9.5
Willunga	n/a	0	4.57 (7)	4.44	49.3	3 (est)	2.3 (7)
Total (grey)			82.77 (8)	16.32	16.5		75.7 (8)
Est. total flow to sea (1970-2002) = 82.8 + 19.8 (Gawler+Onka) + 10.3 (inflows from u/s) + 2.0 (fringe areas) = 115 GL/a							

(1) Close agreement if CS 'Smith Ck' includes Smith, Helps and L Para
(2) CS 'Barker Inlet' appears too low if it includes Dry Ck and Enfield/W lakes
(3) 32.75 includes 9.6 spill from Gorge Weir. If removed figures match closely.
(4) Reasonable match.
(5) Good match
(6) CS est for Christie Ck at 8.1 appears too high, hence total too high.
(7) CS est appears too low
(8) Both exclude inflows from u/s, eg Gorge Weir spill

Outer, low developed catchments: The very low runoff measured in the Willunga basin to the south is similar to that on Smith Creek to the north in areas of similar rainfall. Multiple gauges all indicate this low runoff. The low runoff for Smith Creek is partially caused by the large area of upstream rural catchment with low rainfall which rarely runs off. Another reason for this is likely to be the extensive adoption of earthen drainage paths.

Helps Road drain: The runoff measured at Bellchambers Road is as might be expected in view of the low rainfall hillsface rural catchment area upstream of the Elizabeth area. Very little additional runoff is generated from the undeveloped parts of the catchment down to the Railway Crossing gauge, so that the runoff coefficient falls significantly. Large losses are assumed to take place in the Kaurna Park wetland downstream of the Railway Crossing, but has not been quantified to date, so that the runoff coefficient for the Burton/Paralowie area is unclear, but must also be relatively low. The whole catchment is in the process of major industrial development and the runoff is expected to increase significantly in the near future.

Little Para R: Large infiltration losses along the Little Para River have been investigated and documented and have been incorporated into the model. The catchment is now almost totally developed so that the proportion of low runoff rural catchment is low and therefore, despite the known infiltration losses, the runoff coefficient is higher than for the catchments above.

Parafield drain and Dry Creek: The calibration of the model undertaken at Valley View was good. This site has a purpose built gauging weir. The adoption of this calibration in conjunction with the 'standard' runoff models indicated that the Bridge Road gauge is over-estimating. This site has a very complex geometry and the rating is uncertain (verbal BoM) and hence a close calibration at this site was not pursued. The runoff coefficients appear as might be expected in relation to the rainfall and level of development.

Enfield River, Torrens and Patawalonga: The River Torrens has a higher proportion of its urban area in the higher rainfall zone than the Patawalonga. The runoff from the rural areas of the Patawalonga (as calibrated) were large and large losses had to be made on both the upper and middle reaches of Brownhill Creek and the Sturt River to accommodate the calibration of the gauges in the lower plains reaches. The lower end of the Sturt River is a concreted channel and losses in this section would be expected to be low. The large difference between the runoff coefficients for the RiverTorrens and Patawalonga is difficult to explain. A possibility is that the Holbrooks Rd gauge on the Torrens over-estimates while the Anzac Highway gauge on the Sturt River under-estimates and the checking of the gauges should be given high priority.

The high runoff coefficients for the Enfield/West lakes catchments may be due to the fact that no losses were extracted as no gauges were available to enable a calibration of the model used.

South Coast: The gauges both calibrated well with almost no need to abstract infiltration losses.

Comparison to Coastal Studies estimates: The present flow estimates are about 10% higher than the figures published by the Adelaide Coastal Waters Study. For both estimates, the total flows are very much affected by the gauged flows for the Torrens and Patawalonga, which together constitute 50% of the discharge. The 25% lower runoff coefficient estimated for the Patawalonga is difficult to explain in view of its higher average catchment rainfall, although it may also have a slightly higher proportion of pervious catchment. These estimates are very dependant on the accuracy of the Holbrooks Road and Anzac Highway gauges. In general the gauged flows have been shown to be error-prone and much further analysis can and should be done to improve the confidence level of the data if more accurate estimates are to be made. High flow current metering should be re-instituted to increase the accuracy of the gauge ratings at these key locations.

The present estimates show a total of 82.8 GL/a discharging at or near the sea from the modelled catchments. If the Coastal Study estimates are added for the Gawler River and Onkaparinga, plus the inflows from upstream are included and an allowance of say 2 GL/a is made for the small fringe areas where flow estimates have been omitted, the total flow to the sea for the 33 year period 1970-2002 is estimated at 115 GL/a.

4.4 Inferred Hydrology – Where are losses taking place?

Figure 10 shows the runoff coefficients modelled for a sample of individual impervious and pervious areas and for their combinations when assembled together into their sub-areas within the various WaterCress models. It can be seen that the sub-area runoff coefficients range between those of the impervious and pervious areas depending on their proportions within the sub-areas.

Figure 10 indicates that about 50% of the rain falling on the impervious areas runs off. The impervious area coefficients are only slightly related to rainfall. The scatter is due to the different proportions of paved and roofed areas and assumptions associated with the connectivity of the impervious area to the drainage network. Since the impervious areas form above 20% of the total catchment area, the high coefficients result in the impervious area runoff forming the majority of the total runoff volume.

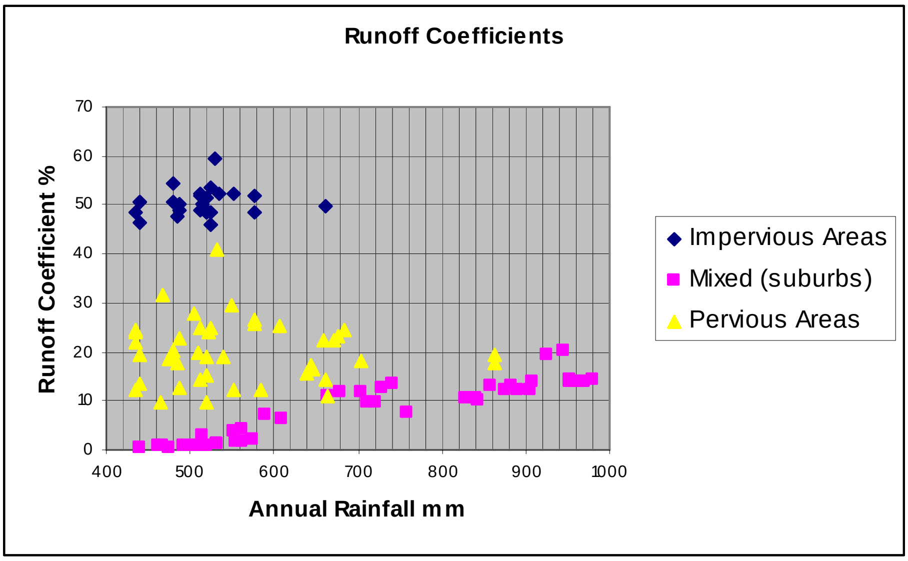


Figure 10. Typical Runoff Coefficients calculated by the WaterCress Model.

It can be seen that the coefficients of runoff for the pervious areas are strongly related to rainfall. With the average rainfalls over most of the developed plains area being less than 550 mm, it can be seen that the contribution of flow from the pervious areas within the urban areas (or the hillsface catchments with rainfall less than 600 mm) is small. The larger rural areas with higher rainfall provide larger volumes, but only run off after the impervious areas in the lower catchments have already contributed their larger flows to any downstream harvesting capture storages.

The runoff coefficients from the suburbs are highly variable and range between the pervious and impervious values, depending on their proportions within the suburban catchments

In the calculation of runoff from impervious surfaces, an initial loss is abstracted from the rainfall which can be conceptualised as the amount of rainfall that is needed to wet the surface and initiate runoff. It is estimated that about 20% for a roof and 30% for a paved surface, thus leaving 80 and 70% to immediately runoff.

Once initiation has commenced further amounts of loss are abstracted, identified as continuing and connection losses. These conceptually account for the losses that occur when the runoff starts to fill puddles and flow onto and soak into adjacent pervious areas. These losses are an additional 20-25% of the rainfall and together with the initial losses account for the 50% of the losses taking place from the impervious surfaces. These losses are assumed to occur close to the location where the rain falls.

Table 4 shows the instream losses that are required to take place if the runoff models are retained in their 'standard' forms while the modelled flows are also arranged to equal the gauged flows. Thus while the modelling undertaken assumes that most of the losses occur at or close to the location where the rain falls, it also indicates that a significant amount of the loss (presently estimated at about 16%) also occurs while the runoff is passing downstream to the sea. It can be seen from **Table 4** that the proportions that the losses form of the total runoff initially generated (i.e. the outflow + losses) are highly variable, ranging from 63% on Helps Road to only 3% on the River Torrens.

A corollary of this is that the maximum volume of harvesting could be obtained by capturing the runoff close to its location of generation, rather than capturing it at downstream locations. A case in point is that a raintank that can capture up to 80% of rainfall from a roof is therefore probably the most efficient means for capturing stormwater (although it may not be the most economic).

It is recognised that the method of derivation of these loss values is somewhat arbitrary, depending on the assumption that a 'standard' set of models for estimating runoff from impervious areas should be adopted. However, losses taking place from low flows in stream channels via infiltration into the bed can be visually observed at many locations. The losses from the Little Para in Carisbrook Park have been well documented and the recharge of the aquifers beneath the Adelaide Plains from surface flows crossing the escarpment fault lines is a recognised phenomena. Moreover, where a downstream gauge shows flows significantly less than predicted by the use of models with the 'standard' reductions already in place, it may be hypothesised that unaccounted losses are either actually taking place or the gauge is in error, which is quite possible. Examples are:

- In the case of the upper and middle Sturt River, the models calibrated to the three gauges recording flow from the rural catchments show far higher flows when the results are carried through to the three gauges recording flow along the Lower Sturt River channel. It is unlikely that errors in all the 6 gauges involved would support this same finding.
- In the case of Smith Creek, flows have been measured by two gauges at different (but close) locations and over different periods. The only way the model could be made to reproduce these flows, using 'standard' assumptions about the generation of runoff from the upstream urban catchment was by assuming losses in the reaches downstream of the escarpment which forms the upstream boundary of the urban area and in the urban reaches as well.
- In addition to the above, significantly lower than expected flows have been identified during the calibration process at the downstream gauged locations on Helps Road Drain, Little Para River and Willunga Basin. These indicate that losses may also be taking place over reaches away from the fault lines.

APPENDIX 1 **WC2000\drycreek DATA FOR TOWN NODES**

Page 1

filename	node no.	**Roof1** with tank not connected **All nodes use Adel.evap** rain_name	rain factor	no. hses	**Roof2** m2	Roof2 ILmm	Roof2 Conn	Roof2 OF	Roof2 ALI
twn_A3.txt	2	Goldgrve30mins9406.rai	1.08	358	235	0.5	0.6	0.95	0.95
twn_c2.txt	5	Goldgrve30mins9406.rai	1.00	481	306	0.5	0.6	0.95	0.95
twn_d2.txt	8	Goldgrve30mins9406.rai	0.99	793	325	0.5	0.6	0.95	0.95
twn_f2.txt	11	banksiapk30mins9406.rai	0.94	1181	274	0.5	0.6	0.95	0.95
twn_g2.txt	14	Ridgehvn30mins9406.rai	0.98	586	297	0.5	0.6	0.95	0.95
twn_h2.txt	17	banksiapk30mins9406.rai	0.98	557	235	0.5	0.6	0.95	0.95
twn_i3.txt	21	banksiapk30mins9406.rai	1.06	362	265	0.5	0.6	0.95	0.95
twn_j3.txt	25	banksiapk30mins9406.rai	0.99	589	234	0.5	0.6	0.95	0.95
twn_k3.txt	29	banksiapk30mins9406.rai	0.99	1612	234	0.5	0.6	0.95	0.95
twn_l2.txt	32	banksiapk30mins9406.rai	0.96	929	236	0.5	0.6	0.95	0.95
twn_m2.txt	35	Ridgehvn30mins9406.rai	1.01	1645	281	0.5	0.6	0.95	0.95
twn_n2.txt	38	Ridgehvn30mins9406.rai	1.00	1074	281	0.5	0.6	0.95	0.95
twn_p2.txt	41	Ridgehvn30mins9406.rai	0.99	858	284	0.5	0.6	0.95	0.95
twn_q2.txt	44	Ridgehvn30mins9406.rai	0.99	1127	285	0.5	0.6	0.95	0.95
twn_r2.txt	47	Valleyvw30mins9406.rai	1.02	2297	268	0.5	0.6	0.95	0.95
twn_s2.txt	50	Ridgehvn30mins9406.rai	1.00	1056	281	0.5	0.6	0.95	0.95
twn_t2.txt	53	Ridgehvn30mins9406.rai	1.00	1395	281	0.5	0.6	0.95	0.95
twn_u2.txt	56	ttgdpt30mins9406.rai	1.02	1956	295	0.5	0.6	0.95	0.95
twn_x2.txt	61	ttgdpt30mins9406.rai	1.03	664	245	0.5	0.6	0.95	0.95
twn_y2.txt	64	ttgdpt30mins9406.rai	1.03	975	262	0.5	0.6	0.95	0.95
twn_z2.txt	67	ttgdpt30mins9406.rai	0.98	544	274	0.5	0.6	0.95	0.95
twn_ac2.txt	72	ttgdpt30mins9406.rai	1.01	843	275	0.5	0.6	0.95	0.95
twn_ad2.txt	75	ttgdpt30mins9406.rai	1.02	683	255	0.5	0.6	0.95	0.95
twn_ae2.txt	78	valleyvw30mins9406.rai	1.05	981	287	0.5	0.6	0.95	0.95
twn_af2.txt	81	valleyvw30mins9406.rai	1.04	1455	287	0.5	0.6	0.95	0.95
twn_ah2.txt	84	valleyvw30mins9406.rai	1.02	789	241	0.5	0.6	0.95	0.95
twn_ai2.txt	87	valleyvw30mins9406.rai	1.02	692	321	0.5	0.6	0.95	0.95
twn_aj2.txt	90	valleyvw30mins9406.rai	1.01	476	263	0.5	0.6	0.95	0.95
twn_al2.txt	93	valleyvw30mins9406.rai	0.99	3980	281	0.5	0.6	0.95	0.95
twn_am2.txt	96	bridgerd30mins9406.rai	1.00	2444	317	0.5	0.6	0.95	0.95
twn_z69.txt	194	bridgerd30mins9406.rai	1.00	2011	283	0.5	0.6	0.95	0.95
twn_z72.txt	197	bridgerd30mins9406.rai	1.00	799	299	0.5	0.6	0.95	0.95
twn_z71.txt	200	bridgerd30mins9406.rai	1.00	723	270	0.5	0.6	0.95	0.95
twn_z70.txt	203	bridgerd30mins9406.rai	1.00	862	277	0.5	0.6	0.95	0.95
twn_par1.txt	2	ridgehaven30mins9406.rai	0.98	83	337	0.5	0.6	0.95	0.95
twn_par2.txt	119	parafieldAP30mins9507.rai	1.08	823	293	0.5	0.6	0.95	0.95
twn_par4.txt	6	parafieldAP30mins9507.rai	1.03	852	243	0.5	0.6	0.95	0.95
twn_par5.txt	9	parafieldAP30mins9507.rai	1.02	919	240	0.5	0.6	0.95	0.95
twn_par6.txt	12	ridgehaven30mins9406.rai	1.01	366	331	0.5	0.6	0.95	0.95
twn_par7.txt	15	ridgehaven30mins9406.rai	1.01	514	331	0.5	0.6	0.95	0.95
twn_par8.txt	18	ridgehaven30mins9406.rai	0.97	200	235	0.5	0.6	0.95	0.95
twn_par9.txt	21	ridgehaven30mins9406.rai	0.96	170	235	0.5	0.6	0.95	0.95
twn_par10.txt	24	parafieldAP30mins9507.rai	1.07	1286	249	0.5	0.6	0.95	0.95
twn_par11.txt	27	ridgehaven30mins9406.rai	0.97	457	236	0.5	0.6	0.95	0.95
twn_par12.txt	30	parafieldAP30mins9507.rai	1.07	1246	234	0.5	0.6	0.95	0.95
twn_par13.txt	33	leichardt30mins9406.rai	1.02	1057	271	0.5	0.6	0.95	0.95
twn_par14.txt	36	parafieldAP30mins9507.rai	1.02	0	120	0.5	0.6	0.95	0.95
twn_par15.txt	39	parafieldAP30mins9507.rai	0.99	576	234	0.5	0.6	0.95	0.95
twn_par17.txt	44	parafieldAP30mins9507.rai	0.99	703	267	0.5	0.6	0.95	0.95
twn_bea1.txt	48	leichardt30mins9406.rai	1.05	1662	271	0.5	0.6	0.95	0.95
twn_kes1.txt	51	leichardt30mins9406.rai	1.02	1877	271	0.5	0.6	0.95	0.95
twn_Pad1.txt	54	leichardt30mins9406.rai	1.00	821	235	0.5	0.6	0.95	0.95
twn_Pad2.txt	57	leichardt30mins9406.rai	1.02	1821	242	0.5	0.6	0.95	0.95
twn_Pad3.txt	60	leichardt30mins9406.rai	0.99	550	235	0.5	0.6	0.95	0.95
twn_Bea2.txt	63	parafieldAP30mins9507.rai	1.04	1160	264	0.5	0.6	0.95	0.95
twn_Pad4.txt	66	leichardt30mins9406.rai	1.01	1822	273	0.5	0.6	0.95	0.95
twn_prak1.txt	71	leichardt30mins9406.rai	0.95	0	120	0.5	0.6	0.95	0.95
twn_prak2.txt	74	leichardt30mins9406.rai	0.95	882	274	0.5	0.6	0.95	0.95
twn_maws1.txt	77	parafieldAP30mins9507.rai	1.01	1262	320	0.5	0.6	0.95	0.95
twn_maws2.txt	80	parafieldAP30mins9507.rai	1.02	0	120	0.5	0.6	0.95	0.95
twn_cavan.txt	83	parafieldAP30mins9507.rai	1.01	169	331	0.5	0.6	0.95	0.95
twn_maws3.txt	86	parafieldAP30mins9507.rai	0.98	257	331	0.5	0.6	0.95	0.95

APPENDIX 1

Page 2		Pave1					Pave2				
	node	**Paths**	Pave1	Pave1	Pave1	Pave1	**Roads**	Pave2	Pave2	Pave2	Pave2
filename	no.	m2	ILmm	Conn	OF	ALI	m2	ILmm	Conn	OF	ALI
twn_A3.txt	2	73	1.0	0.5	0.85	0.95	154	1.0	1.0	0.85	0.95
twn_c2.txt	5	54	1.0	0.5	0.85	0.95	119	1.0	1.0	0.85	0.95
twn_d2.txt	8	52	1.0	0.5	0.85	0.95	112	1.0	1.0	0.85	0.95
twn_f2.txt	11	64	1.0	0.5	0.85	0.95	138	1.0	1.0	0.85	0.95
twn_g2.txt	14	73	1.0	0.5	0.85	0.95	118	1.0	1.0	0.85	0.95
twn_h2.txt	17	72	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_i3.txt	21	64	1.0	0.5	0.85	0.95	135	1.0	1.0	0.85	0.95
twn_j3.txt	25	71	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_k3.txt	29	71	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_l2.txt	32	71	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_m2.txt	35	58	1.0	0.5	0.85	0.95	124	1.0	1.0	0.85	0.95
twn_n2.txt	38	59	1.0	0.5	0.85	0.95	125	1.0	1.0	0.85	0.95
twn_p2.txt	41	57	1.0	0.5	0.85	0.95	122	1.0	1.0	0.85	0.95
twn_q2.txt	44	58	1.0	0.5	0.85	0.95	123	1.0	1.0	0.85	0.95
twn_r2.txt	47	55	1.0	0.5	0.85	0.95	118	1.0	1.0	0.85	0.95
twn_s2.txt	50	58	1.0	0.5	0.85	0.95	124	1.0	1.0	0.85	0.95
twn_t2.txt	53	58	1.0	0.5	0.85	0.95	124	1.0	1.0	0.85	0.95
twn_u2.txt	56	56	1.0	0.5	0.85	0.95	120	1.0	1.0	0.85	0.95
twn_x2.txt	61	69	1.0	0.5	0.85	0.95	148	1.0	1.0	0.85	0.95
twn_y2.txt	64	64	1.0	0.5	0.85	0.95	136	1.0	1.0	0.85	0.95
twn_z2.txt	67	61	1.0	0.5	0.85	0.95	129	1.0	1.0	0.85	0.95
twn_ac2.txt	72	53	1.0	0.5	0.85	0.95	115	1.0	1.0	0.85	0.95
twn_ad2.txt	75	66	1.0	0.5	0.85	0.95	141	1.0	1.0	0.85	0.95
twn_ae2.txt	78	57	1.0	0.5	0.85	0.95	122	1.0	1.0	0.85	0.95
twn_af2.txt	81	55	1.0	0.5	0.85	0.95	57	1.0	1.0	0.85	0.95
twn_ah2.txt	84	47	1.0	0.5	0.85	0.95	101	1.0	1.0	0.85	0.95
twn_ai2.txt	87	55	1.0	0.5	0.85	0.95	118	1.0	1.0	0.85	0.95
twn_aj2.txt	90	63	1.0	0.5	0.85	0.95	137	1.0	1.0	0.85	0.95
twn_al2.txt	93	58	1.0	0.5	0.85	0.95	124	1.0	1.0	0.85	0.95
twn_am2.txt	96	52	1.0	0.5	0.85	0.95	112	1.0	1.0	0.85	0.95
twn_z69.txt	194	56	1.0	0.5	0.85	0.95	120	1.0	1.0	0.85	0.95
twn_z72.txt	197	61	1.0	0.5	0.85	0.95	131	1.0	1.0	0.85	0.95
twn_z71.txt	200	54	1.0	0.5	0.85	0.95	115	1.0	1.0	0.85	0.95
twn_z70.txt	203	57	1.0	0.5	0.85	0.95	122	1.0	1.0	0.85	0.95
twn_par1.txt	2	48	1.0	0.5	0.85	0.95	108	1.0	1.0	0.85	0.95
twn_par2.txt	119	56	1.0	0.5	0.85	0.95	120	1.0	1.0	0.85	0.95
twn_par4.txt	6	69	1.0	0.5	0.85	0.95	148	1.0	1.0	0.85	0.95
twn_par5.txt	9	73	1.0	0.5	0.85	0.95	157	1.0	1.0	0.85	0.95
twn_par6.txt	12	52	1.0	0.5	0.85	0.95	112	1.0	1.0	0.85	0.95
twn_par7.txt	15	53	1.0	0.5	0.85	0.95	111	1.0	1.0	0.85	0.95
twn_par8.txt	18	70	1.0	0.5	0.85	0.95	155	1.0	1.0	0.85	0.95
twn_par9.txt	21	71	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_par10.txt	24	68	1.0	0.5	0.85	0.95	145	1.0	1.0	0.85	0.95
twn_par11.txt	27	72	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_par12.txt	30	71	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_par13.txt	33	59	1.0	0.5	0.85	0.95	128	1.0	1.0	0.85	0.95
twn_par14.txt	36	50	1.0	0.5	0.85	0.95	63	1.0	1.0	0.85	0.95
twn_par15.txt	39	71	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_par17.txt	44	61	1.0	0.5	0.85	0.95	132	1.0	1.0	0.85	0.95
twn_bea1.txt	48	60	1.0	0.5	0.85	0.95	129	1.0	1.0	0.85	0.95
twn_kes1.txt	51	61	1.0	0.5	0.85	0.95	131	1.0	1.0	0.85	0.95
twn_Pad1.txt	54	72	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_Pad2.txt	57	70	1.0	0.5	0.85	0.95	149	1.0	1.0	0.85	0.95
twn_Pad3.txt	60	71	1.0	0.5	0.85	0.95	153	1.0	1.0	0.85	0.95
twn_Bea2.txt	63	64	1.0	0.5	0.85	0.95	136	1.0	1.0	0.85	0.95
twn_Pad4.txt	66	58	1.0	0.5	0.85	0.95	125	1.0	1.0	0.85	0.95
twn_prak1.txt	71	50	1.0	0.5	0.85	0.95	63	1.0	1.0	0.85	0.95
twn_prak2.txt	74	61	1.0	0.5	0.85	0.95	130	1.0	1.0	0.85	0.95
twn_maws1.txt	77	49	1.0	0.5	0.85	0.95	107	1.0	1.0	0.85	0.95
twn_maws2.txt	80	50	1.0	0.5	0.85	0.95	63	1.0	1.0	0.85	0.95
twn_cavan.txt	83	53	1.0	0.5	0.85	0.95	112	1.0	1.0	0.85	0.95
twn_maws3.txt	86	51	1.0	0.5	0.85	0.95	109	1.0	1.0	0.85	0.95

Appendix 2 WC2000\drycreek DATA FOR URBAN (INDUSTRIAL) NODES

filename	node no.	rain_name	rain fact.	no. hses.	roof m2	roof conn	roof il	roof of	roof ali	pave m2	pave conn	pave il	pave of	pave ali
urb_A4.txt	3	goldgrve30mins9406.rai	1.08	1	3000	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_c1.txt	4	goldgrve30mins9406.rai	1	1	88000	0.8	0.5	0.95	0.95	46000	0.7	1.0	0.85	0.95
urb_d1.txt	7	goldgrve30mins9406.rai	0.99	1	81000	0.8	0.5	0.95	0.95	110000	0.7	1.0	0.85	0.95
urb_f1.txt	10	banksiapk30mins9406.rai	0.94	1	3000	0.8	0.5	0.95	0.95	10000	0.7	1.0	0.85	0.95
urb_g1.txt	13	ridgehvn30mins9406.rai	0.98	1	3000	0.8	0.5	0.95	0.95	17000	0.7	1.0	0.85	0.95
urb_h1.txt	16	banksiapk30mins9406.rai	0.98	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_i2.txt	20	banksiapk30mins9406.rai	1.06	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_j2.txt	24	banksiapk30mins9406.rai	0.99	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_k2.txt	28	banksiapk30mins9406.rai	0.99	1	33000	0.8	0.5	0.95	0.95	35000	0.7	1.0	0.85	0.95
urb_l1.txt	31	banksiapk30mins9406.rai	0.96	1	5000	0.8	0.5	0.95	0.95	9000	0.7	1.0	0.85	0.95
urb_m1.txt	34	ridgehvn30mins9406.rai	1.01	1	13000	0.8	0.5	0.95	0.95	13000	0.7	1.0	0.85	0.95
urb_n1.txt	37	ridgehvn30mins9406.rai	1	1	22000	0.8	0.5	0.95	0.95	24000	0.7	1.0	0.85	0.95
urb_p1.txt	40	ridgehvn30mins9406.rai	0.99	1	19000	0.8	0.5	0.95	0.95	22000	0.7	1.0	0.85	0.95
urb_q1.txt	43	ridgehvn30mins9406.rai	0.99	1	4000	0.8	0.5	0.95	0.95	5000	0.7	1.0	0.85	0.95
urb_r1.txt	46	valleyvw30mins9406.rai	1.02	1	47000	0.8	0.5	0.95	0.95	131000	0.7	1.0	0.85	0.95
urb_s1.txt	49	ridgehvn30mins9406.rai	1	1	27000	0.8	0.5	0.95	0.95	35000	0.7	1.0	0.85	0.95
urb_t1.txt	52	ridgehvn30mins9406.rai	1	1	10000	0.8	0.5	0.95	0.95	14000	0.7	1.0	0.85	0.95
urb_u1.txt	55	ttgdpt30mins9406.rai	1.02	1	20000	0.8	0.5	0.95	0.95	68000	0.7	1.0	0.85	0.95
urb_x1.txt	60	ttgdpt30mins9406.rai	1.03	1	25000	0.8	0.5	0.95	0.95	20000	0.7	1.0	0.85	0.95
urb_y1.txt	63	ttgdpt30mins9406.rai	1.03	1	41000	0.8	0.5	0.95	0.95	50000	0.7	1.0	0.85	0.95
urb_z1.txt	66	ttgdpt30mins9406.rai	0.98	1	208000	0.8	0.5	0.95	0.95	180000	0.7	1.0	0.85	0.95
urb_ac1.txt	71	ttgdpt30mins9406.rai	1.01	1	35000	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_ad1.txt	74	ttgdpt30mins9406.rai	1.02	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_ae1.txt	77	valleyvw30mins9406.rai	1.05	1	7000	0.8	0.5	0.95	0.95	11000	0.7	1.0	0.85	0.95
urb_af1.txt	80	valleyvw30mins9406.rai	1.04	1	19000	0.8	0.5	0.95	0.95	12000	0.7	1.0	0.85	0.95
urb_ah1.txt	83	valleyvw30mins9406.rai	1.02	1	66000	0.8	0.5	0.95	0.95	129000	0.7	1.0	0.85	0.95
urb_ai1.txt	86	valleyvw30mins9406.rai	1.02	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_aj1.txt	89	valleyvw30mins9406.rai	1.01	1	0	0.8	0.5	0.95	0.95	1000	0.7	1.0	0.85	0.95
urb_al1.txt	92	valleyvw30mins9406.rai	0.99	1	183000	0.8	0.5	0.95	0.95	168000	0.7	1.0	0.85	0.95
urb_am1.txt	95	bridgerd30mins9406.rai	1	1	132000	0.8	0.5	0.95	0.95	53000	0.7	1.0	0.85	0.95
urb_z69.txt	196	bridgerd30mins9406.rai	1	1	50000	0.8	0.5	0.95	0.95	69000	0.7	1.0	0.85	0.95
urb_z72.txt	199	bridgerd30mins9406.rai	1	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_z71.txt	202	bridgerd30mins9406.rai	1	1	34000	0.8	0.5	0.95	0.95	50000	0.7	1.0	0.85	0.95
urb_z70.txt	205	bridgerd30mins9406.rai	1	1	35000	0.8	0.5	0.95	0.95	69000	0.7	1.0	0.85	0.95
urb_par2.txt	121	parafieldAP30mins9507.rai	1.08	1	87000	0.8	0.5	0.95	0.95	131000	0.7	1.0	0.85	0.95
urb_par4.txt	8	parafieldAP30mins9507.rai	1.03	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_par5.txt	11	parafieldAP30mins9507.rai	1.02	1	31000	0.8	0.5	0.95	0.95	39000	0.7	1.0	0.85	0.95
urb_par6.txt	14	ridgehaven30mins9406.rai	1.01	1	24000	0.8	0.5	0.95	0.95	21000	0.7	1.0	0.85	0.95
urb_par7.txt	17	ridgehaven30mins9406.rai	1.01	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_par8.txt	20	ridgehaven30mins9406.rai	0.97	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_par9.txt	23	ridgehaven30mins9406.rai	0.96	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_par10.txt	26	parafieldAP30mins9507.rai	1.07	1	25000	0.8	0.5	0.95	0.95	45000	0.7	1.0	0.85	0.95
urb_par11.txt	29	ridgehaven30mins9406.rai	0.97	1	4000	0.8	0.5	0.95	0.95	3000	0.7	1.0	0.85	0.95
urb_par12.txt	32	parafieldAP30mins9507.rai	1.07	1	346000	0.8	0.5	0.95	0.95	258000	0.7	1.0	0.85	0.95
urb_par13.txt	35	leichardt30mins9406.rai	1.02	1	12000	0.8	0.5	0.95	0.95	4000	0.7	1.0	0.85	0.95
urb_par14.txt	38	parafieldAP30mins9507.rai	1.02	1	5000	0.8	0.5	0.95	0.95	2000	0.7	1.0	0.85	0.95
urb_par15.txt	41	parafieldAP30mins9507.rai	0.99	1	146000	0.8	0.5	0.95	0.95	105000	0.7	1.0	0.85	0.95
urb_par16.txt	43	parafieldAP30mins9507.rai	1	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_par17.txt	46	parafieldAP30mins9507.rai	0.99	1	0	0.8	0.5	0.95	0.95	0	0.7	1.0	0.85	0.95
urb_bea1.txt	50	leichardt30mins9406.rai	1.05	1	12000	0.8	0.5	0.95	0.95	35000	0.7	1.0	0.85	0.95
urb_kes1.txt	53	leichardt30mins9406.rai	1.02	1	1000	0.8	0.5	0.95	0.95	29000	0.7	1.0	0.85	0.95
urb_Pad1.txt	56	leichardt30mins9406.rai	1	1	21000	0.8	0.5	0.95	0.95	19000	0.7	1.0	0.85	0.95
urb_Pad2.txt	59	leichardt30mins9406.rai	1.02	1	21000	0.8	0.5	0.95	0.95	19000	0.7	1.0	0.85	0.95
urb_Pad3.txt	62	leichardt30mins9406.rai	0.99	1	12000	0.8	0.5	0.95	0.95	9000	0.7	1.0	0.85	0.95
urb_pad.txt	64	leichardt30mins9406.rai	0.96	1	4000	0.8	0.5	0.95	0.95	5000	0.7	1.0	0.85	0.95
urb_Bea2.txt	65	parafieldAP30mins9507.rai	1.04	1	150000	0.8	0.5	0.95	0.95	293000	0.7	1.0	0.85	0.95
urb_Pad4.txt	70	leichardt30mins9406.rai	1.01	1	70000	0.8	0.5	0.95	0.95	80000	0.7	1.0	0.85	0.95
urb_prak1.txt	73	leichardt30mins9406.rai	0.95	1	218000	0.8	0.5	0.95	0.95	307000	0.7	1.0	0.85	0.95
urb_prak2.txt	76	leichardt30mins9406.rai	0.95	1	13000	0.8	0.5	0.95	0.95	53000	0.7	1.0	0.85	0.95
urb_maws1.txt	79	parafieldAP30mins9507.rai	1.01	1	128000	0.8	0.5	0.95	0.95	171000	0.7	1.0	0.85	0.95
urb_maws2.txt	82	parafieldAP30mins9507.rai	1.02	1	0	0.8	0.5	0.95	0.95	48000	0.7	1.0	0.85	0.95
urb_cavan.txt	85	parafieldAP30mins9507.rai	1.01	1	391000	0.8	0.5	0.95	0.95	514000	0.7	1.0	0.85	0.95
urb_maws3.txt	88	parafieldAP30mins9507.rai	0.98	1	0	0.8	0.5	0.95	0.95	46000	0.7	1.0	0.85	0.95

APPENDIX E

ASR ZONES OF INFLUENCE

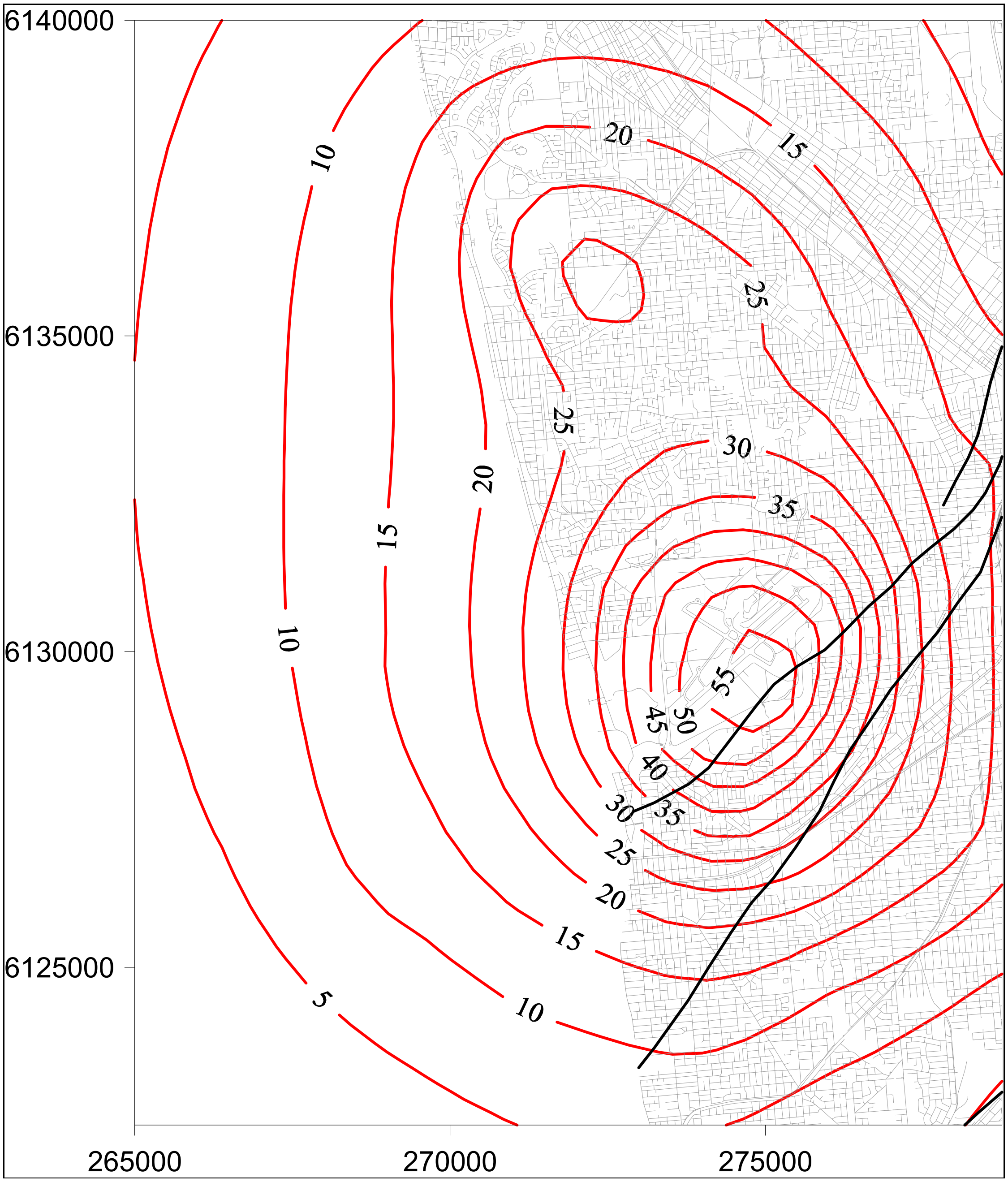


Figure E1: T1 Aquifer water level changes at end of year 8 injection (2GL/yr).

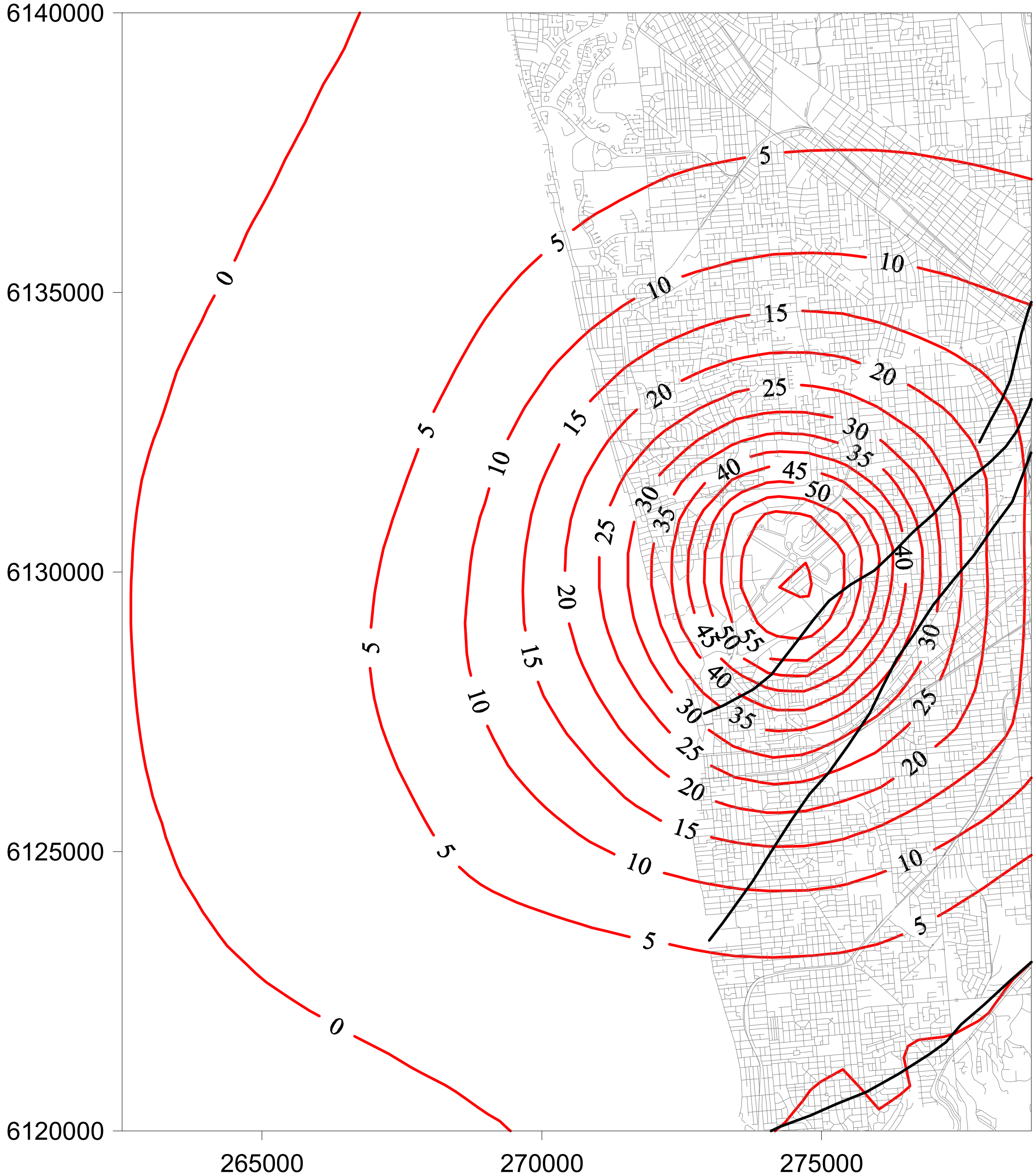
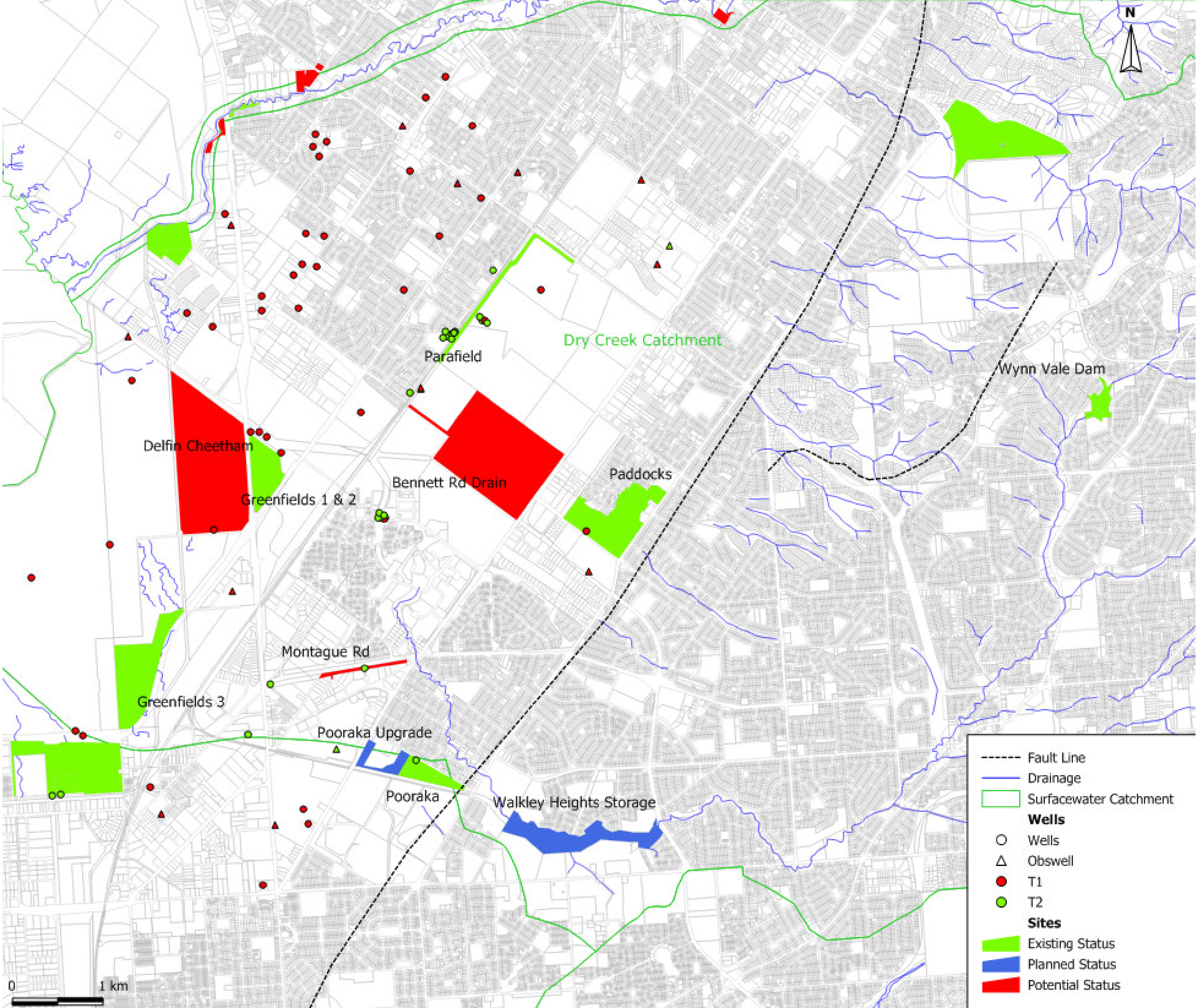


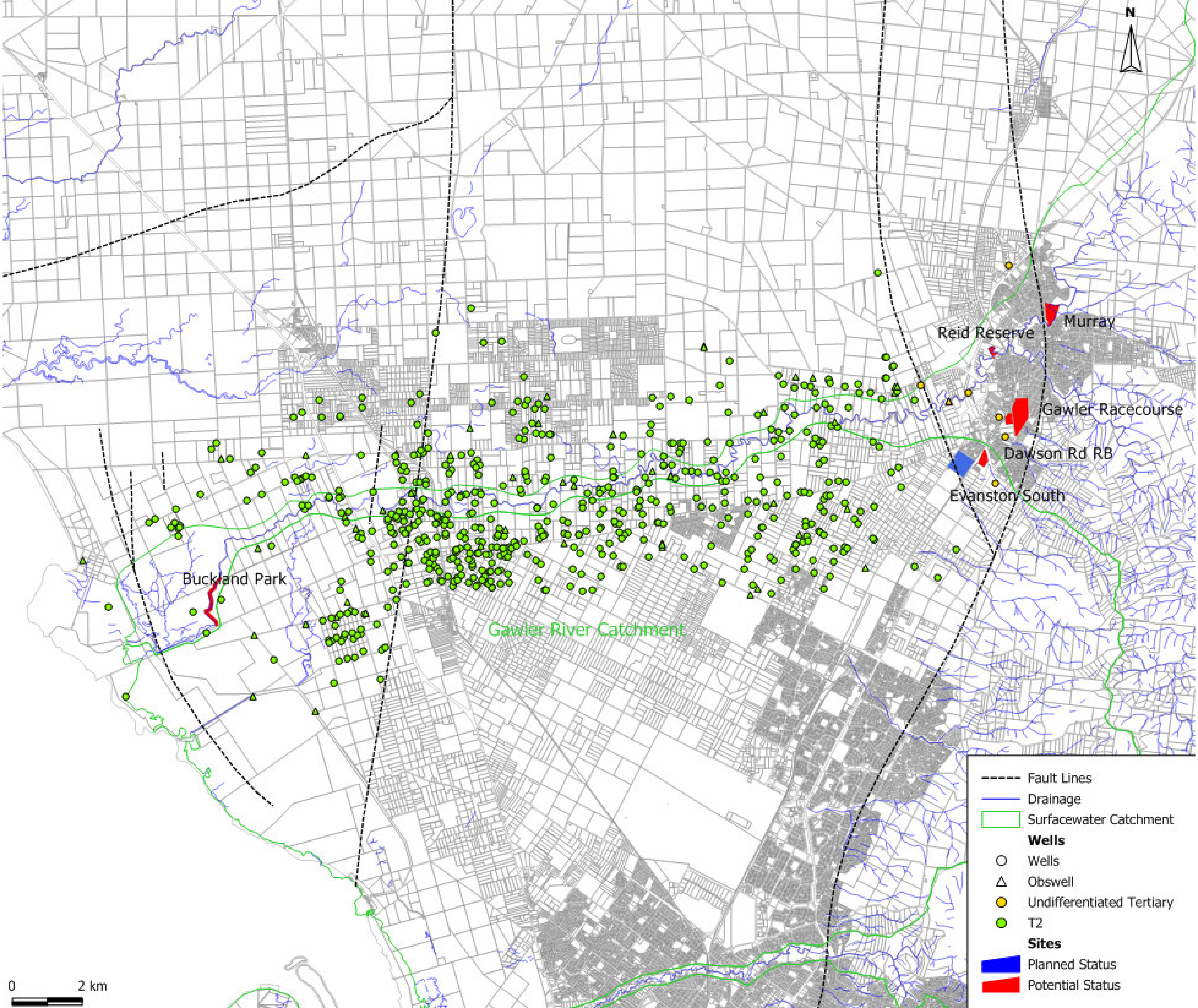
Figure E2: T2 Aquifer water level changes at end of year 8 injection (3GL/yr).

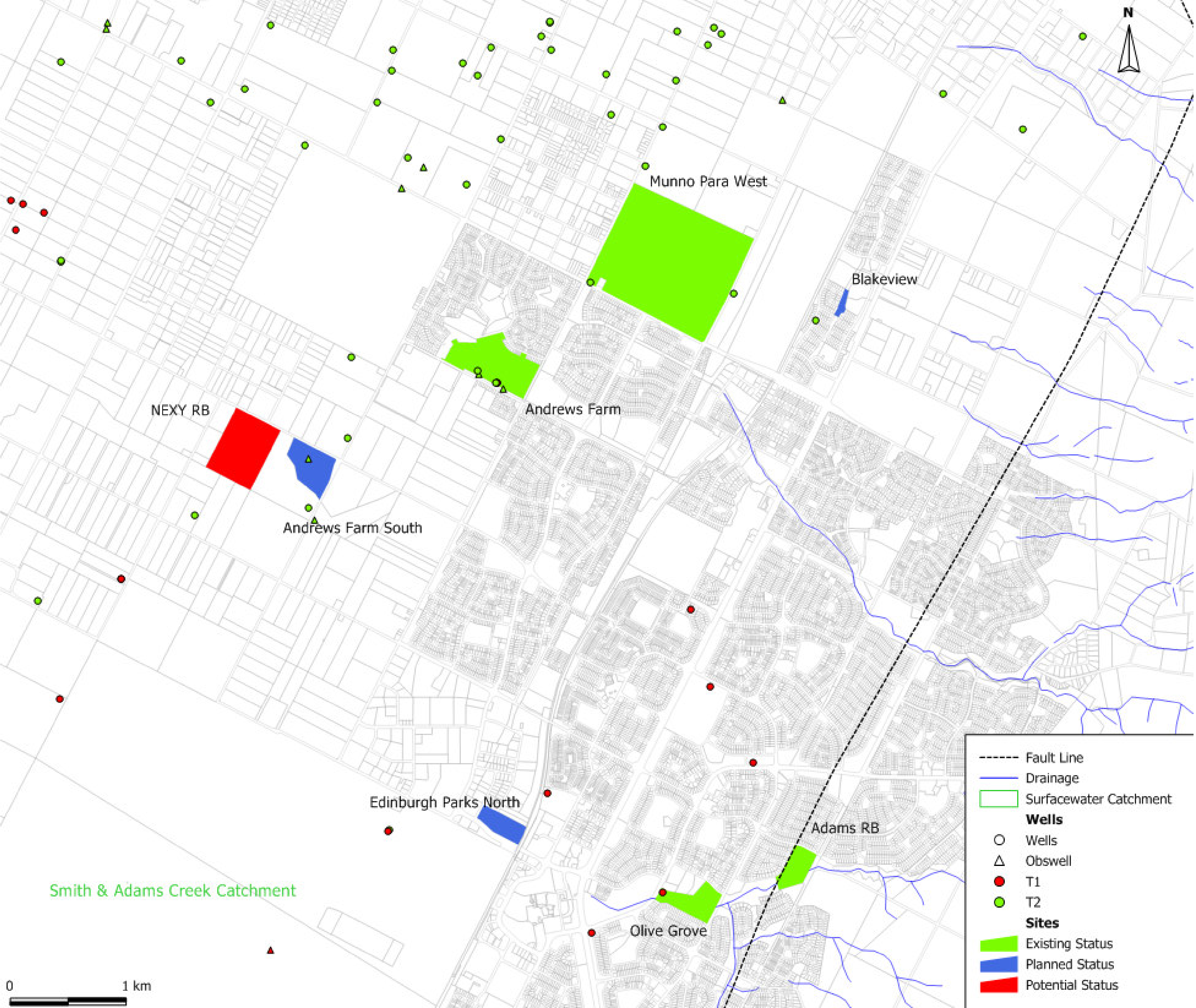
APPENDIX F

KNOWN WELL LOCATION PLAN

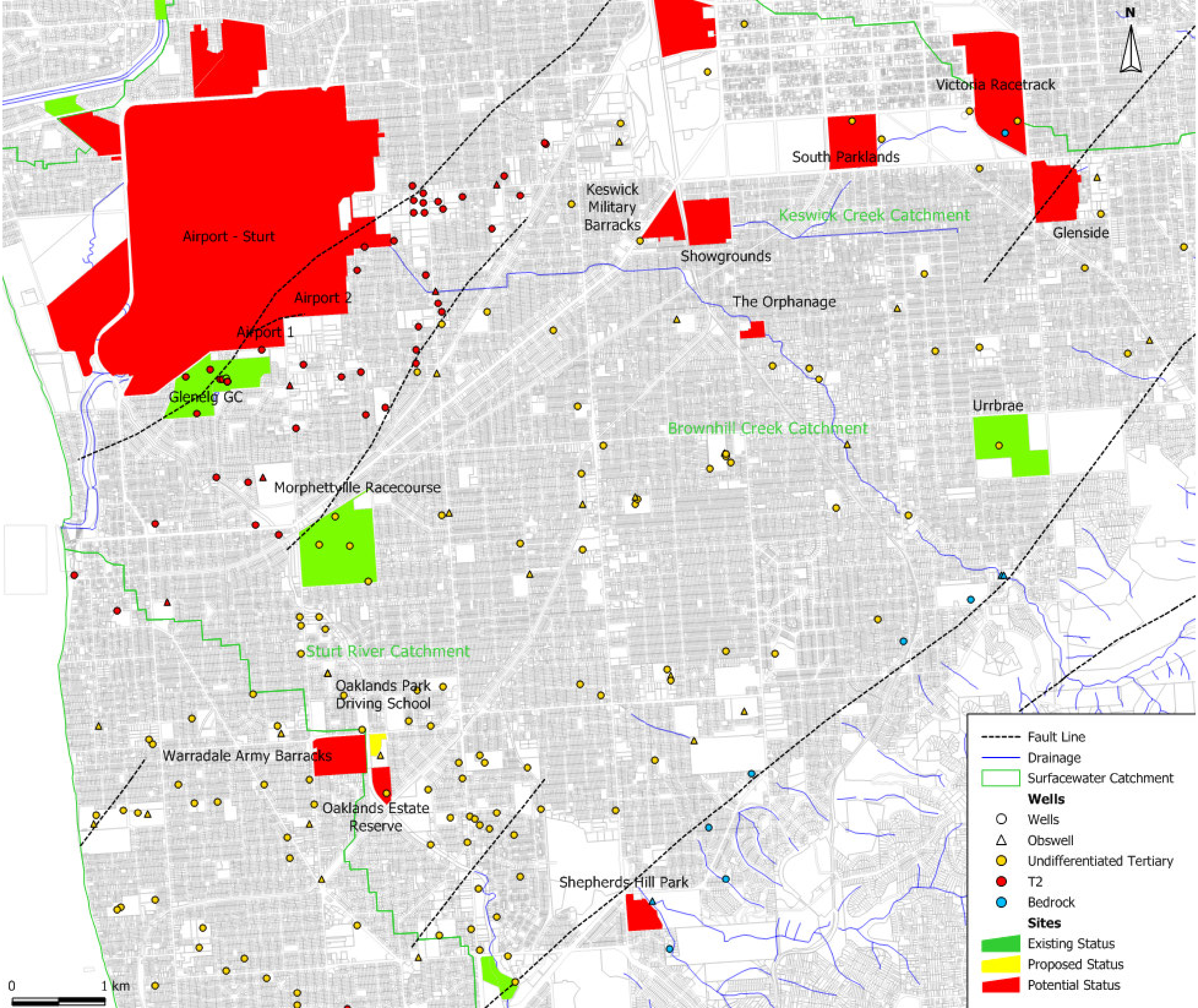


N
Dry Creek Catchment
Parafield
Wynn Vale Dam
Delfin Cheetham
Bennett Rd Drain
Paddocks
Greenfields 1 & 2
Montague Rd
Greenfields 3
Pooraka Upgrade
Pooraka
Walkley Heights Storage
Fault Line
Drainage
Surfacewater Catchment
Wells
Wells
Obswell
T1
T2
Sites
Existing Status
Planned Status
Potential Status
0
1 km


N
Murray
Reid Reserve
Gawler Racecourse
Dawson Rd RB
Evanston South
Buckland Park
Gawler River Catchment
Fault Lines
Drainage
Surfacewater Catchment
Wells
Wells
Obswell
Undifferentiated Tertiary
T2
Sites
Planned Status
Potential Status
0
2 km



N
Munno Para West
Blakeview
Andrews Farm
NEXY RB
Andrews Farm South
Edinburgh Parks North
Adams RB
Olive Grove
Smith & Adams Creek Catchment
0
1 km
Fault Line
Drainage
Surfacewater Catchment
Wells
Wells
Obswell
T1
T2
Sites
Existing Status
Planned Status
Potential Status

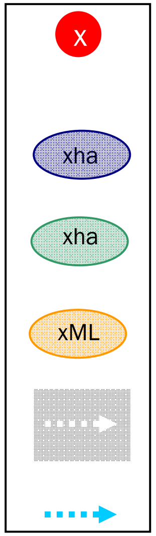

N
Victoria Racetrack
South Parklands
Keswick
Military
Barracks
Keswick Creek Catchment
Glenside
Airport - Sturt
Showgrounds
Airport 2
The Orphanage
Airport 1
Glenelg GC
Urrbrae
Brownhill Creek Catchment
Morphettville Racecourse
Sturt River Catchment
Oaklands Park
Driving School
Warradale Army Barracks
Oaklands Estate
Reserve
Shepherds Hill Park
0
1 km
Fault Line
Drainage
Surfacewater Catchment
Wells
Wells
Obswell
Undifferentiated Tertiary
T2
Bedrock
Sites
Existing Status
Proposed Status
Potential Status

APPENDIX G

PROPOSED SCHEME CONCEPT PLANS

TYPICAL SCHEME CONCEPT LAYOUTS

Legend



Indicative number/location of ASR bores required (T1/T2 can be located directly adjacent ie.shown by one point)

Area of Wetland required

Area of Bioretention (or Filtration) required

Volume of Storage required

Stormwater inflow

Treated water outflow

Concept plans are not given for the sites below due to the preliminary nature of the site development.

- Buckland Park
- NEXY RB
- Greater Edinburgh Park
- Cheetham's Redevelopment
- Willunga

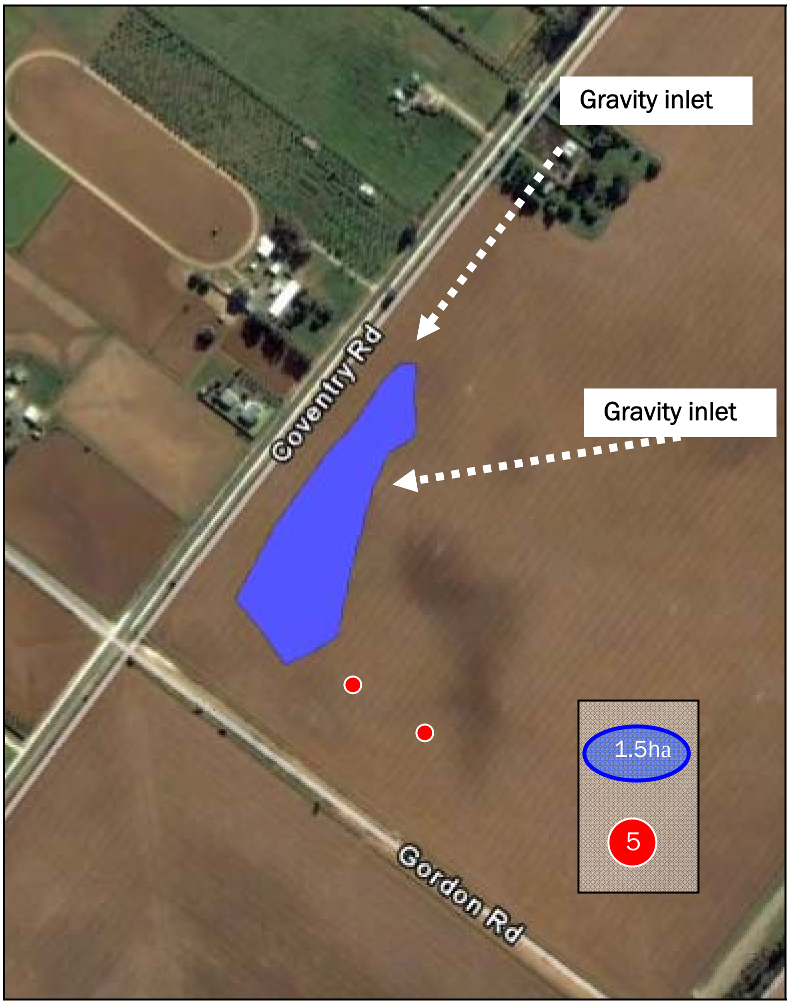
Refer to modelling summary for details of required treatment/storage requirements which will be integrated into the planning and development of these sites.

A number of existing sites have been included, the concept plans show the elements to be maintained or upgraded to provide efficient harvest potential.

GAWLER RIVER

DAWSONS ROAD RETENTION BASIN

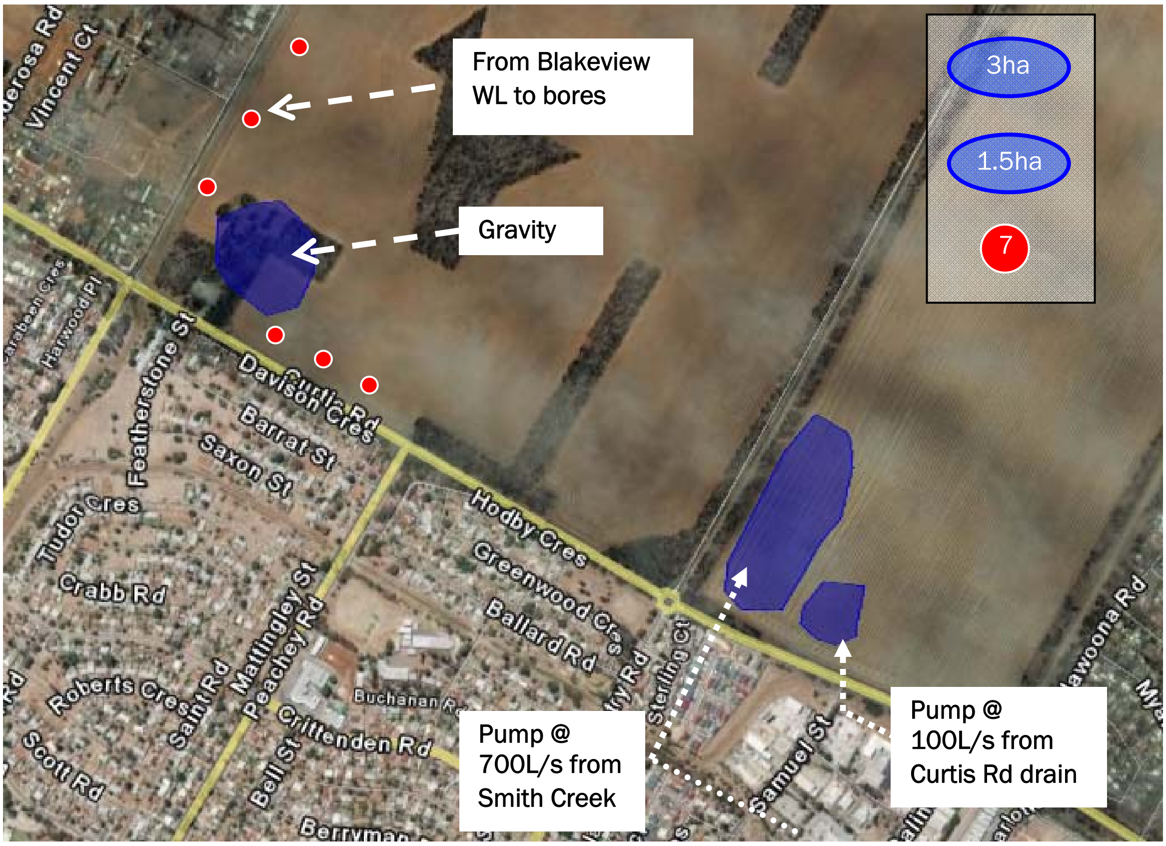
GAWLER RACECOURSE



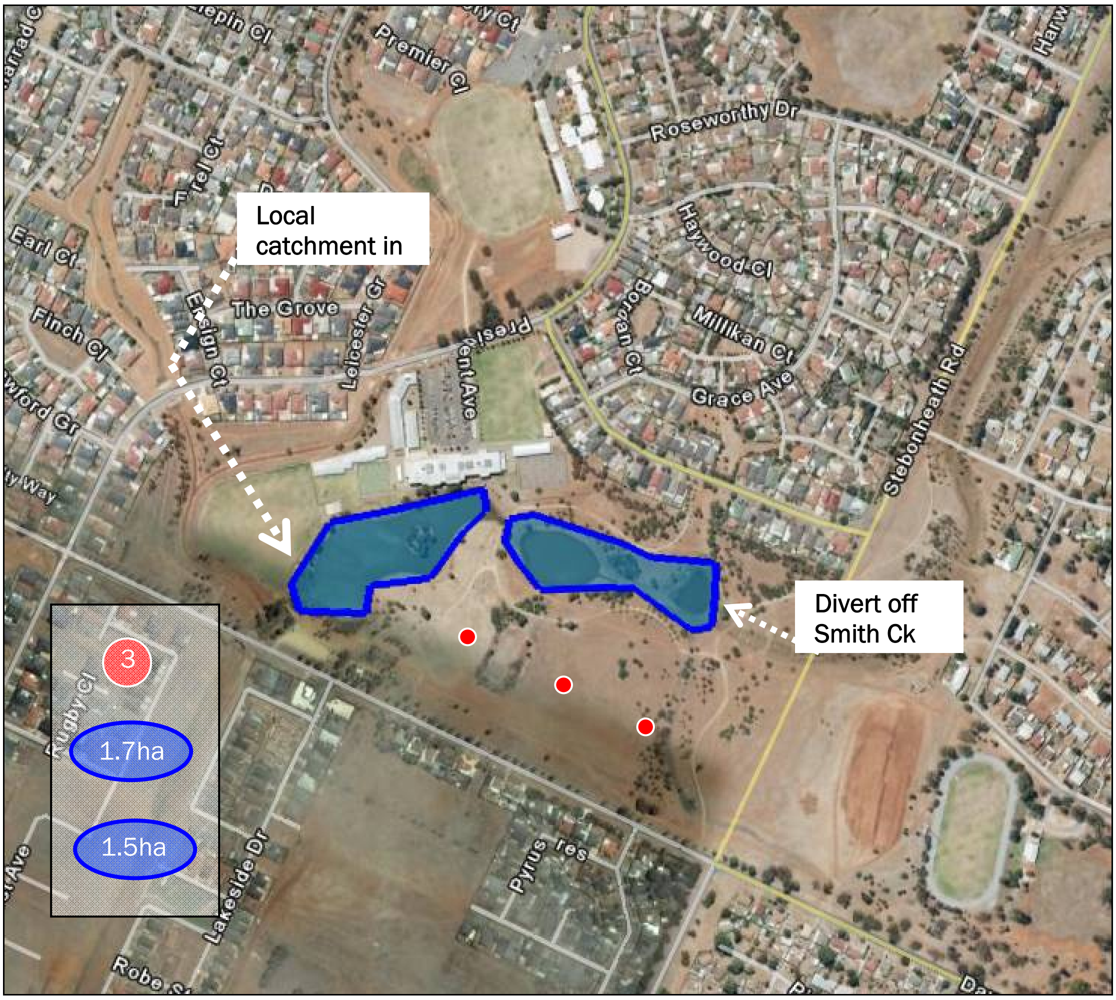
EVANSTON SOUTH


Pump @ 40L/s to bores
Blakeview residential development boundary
7ha
2ha
Medlow Rd
Scoular Rd
Lawder Rd
Purdie Rd
Bentley Rd
Craigmore Rd
Camelot Dr
Woodcroft Dr
Maltarra Rd
Park Lake Bvd
Balmoral Cct
Elmwood Cct
Cherrytree Cres
A20

BLAKEVIEW

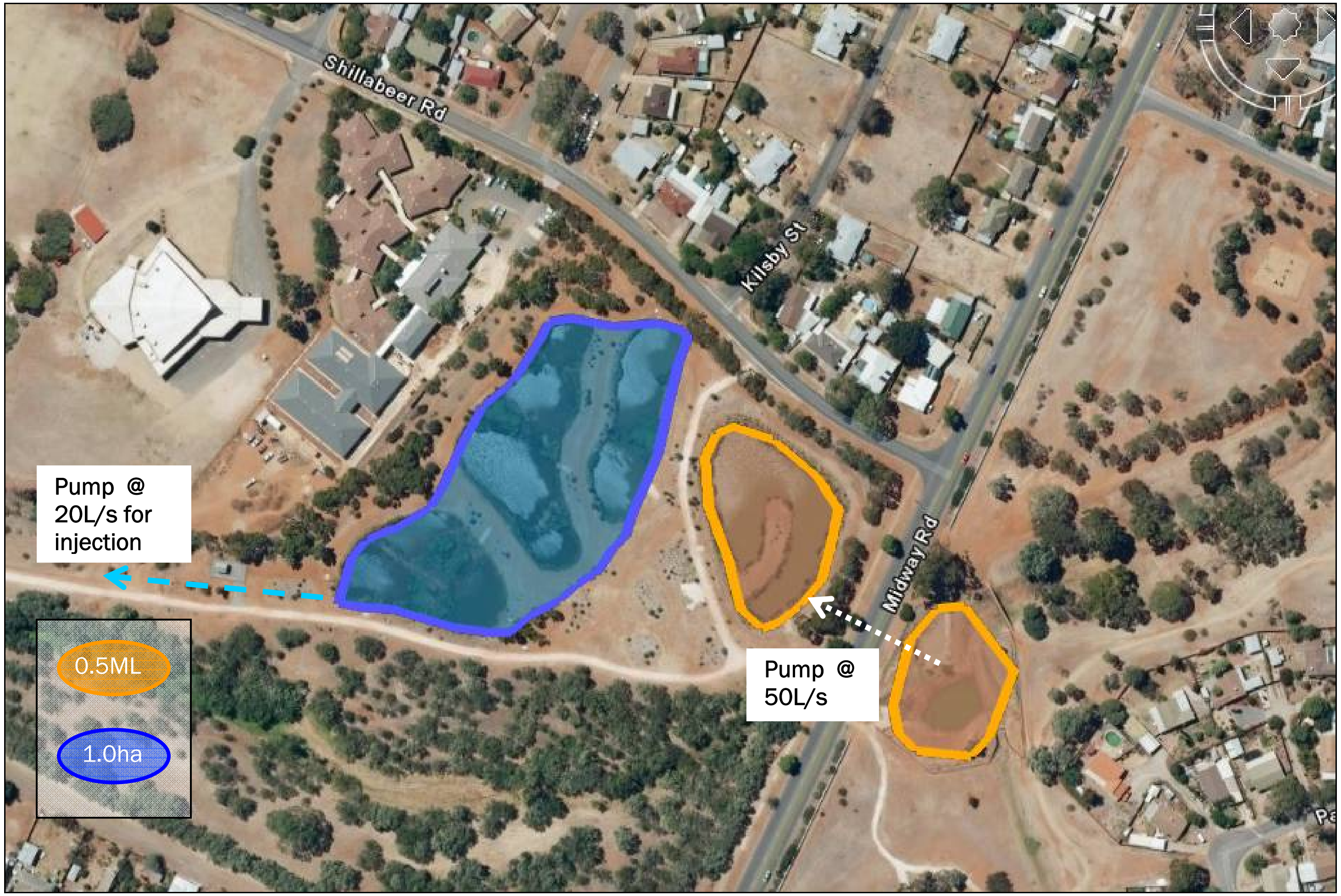


MUNNO PARA WEST



ANDREWS FARM

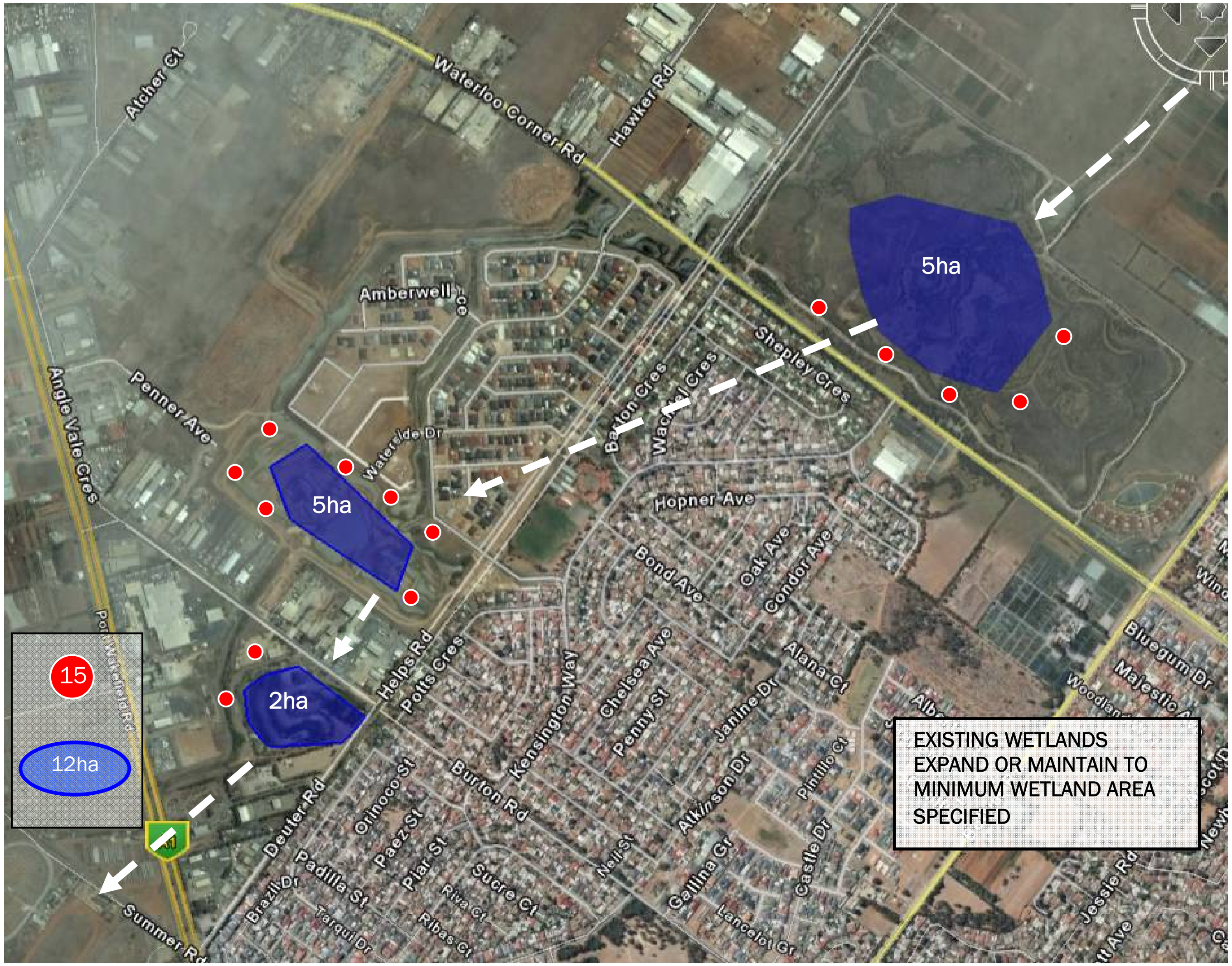
ANDREWS FARM SOUTH



ADAMS CREEK (OLIVE GROVE)

EDINBURGH PARKS NORTH

EDINBURGH PARKS SOUTH



KAURNA PARK, SPRINGBANK PARK, BURTON WEST

SUMMER ROAD

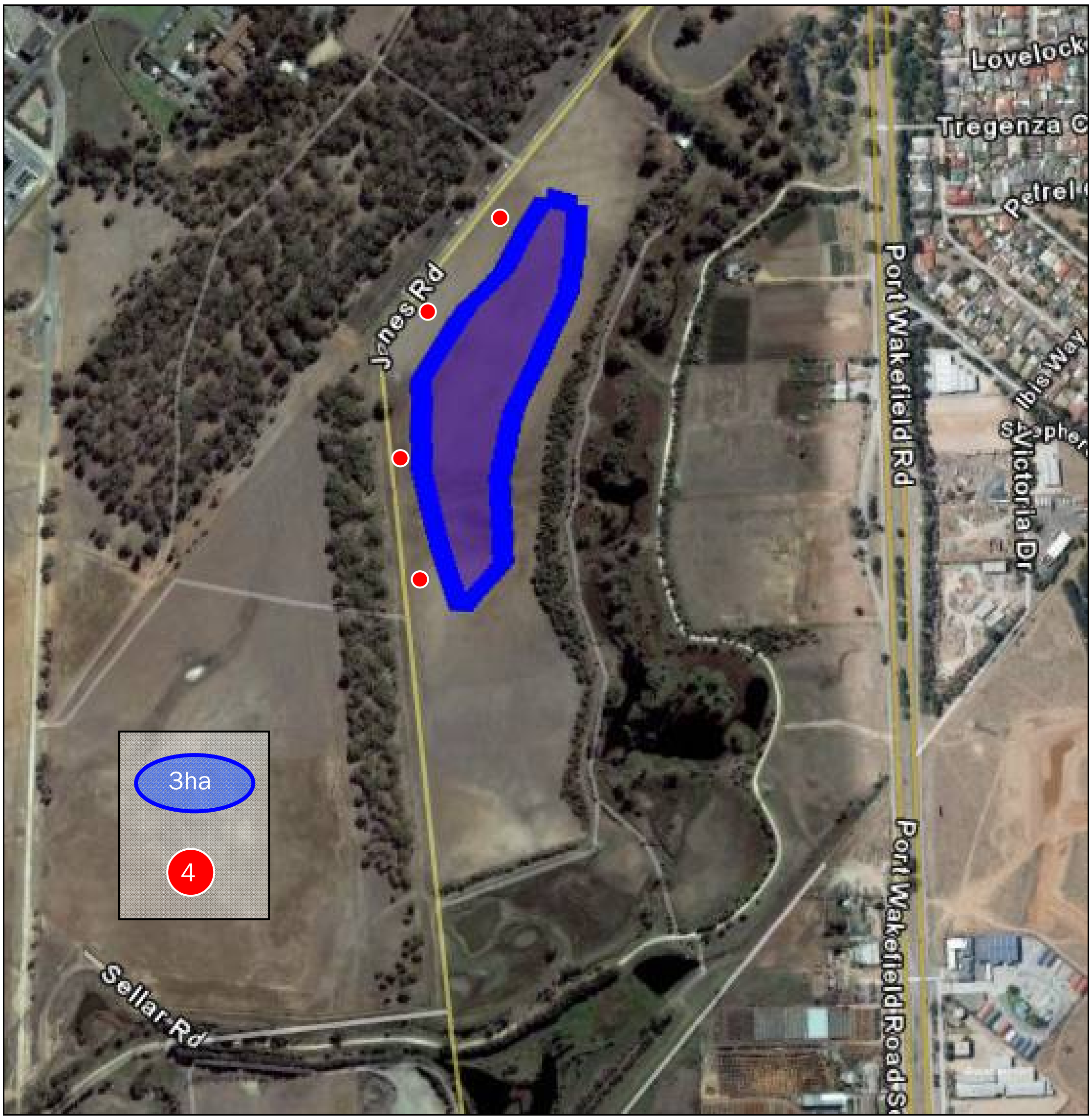

Gravity
Inlet
4
3
Hibiscus St
Corton St
Prunus Ave
Moss Rd
Martin Irvine
Jenkins Dr
Surrey

MOSS ROAD

PIONEER PARK

Local Catchment gravity inlet
Gravity inlet
Walpole Rd
Hodgson Rd
Oakdene Ct
Port Wakefield Rd
Lennox Dr
A1
A18
Hodges Ct
Maynard Cr
Lovelock Rd
Tregenza Ct
Whites Rd
Cook St
Teasdale Cres
Hanlin Ct
Addison St
10ha
10

WHITES ROAD


Lovelock
Tregenza C
Petrel
Jones Rd
Port Wakefield Rd
Ibis Way
Victoria Dr
3ha
4
Sellar Rd
Port Wakefield Road

BOLIVAR

WYNN VALE DAM

WALKLEY HEIGHTS STORAGE & POORAKA UPGRADE (UNITY PARK)

MONTAGUE ROAD

Walker St
Stilves Dr
Lamorna Pde
Derwent St
Newlyn Tce
Ryder Ave
McCartney Rd
Grimmett Ave
Armstrong Ave
Kittyhawk Ln
Pump @ 150L/s
100ML
4ha
4

PARAFIELD

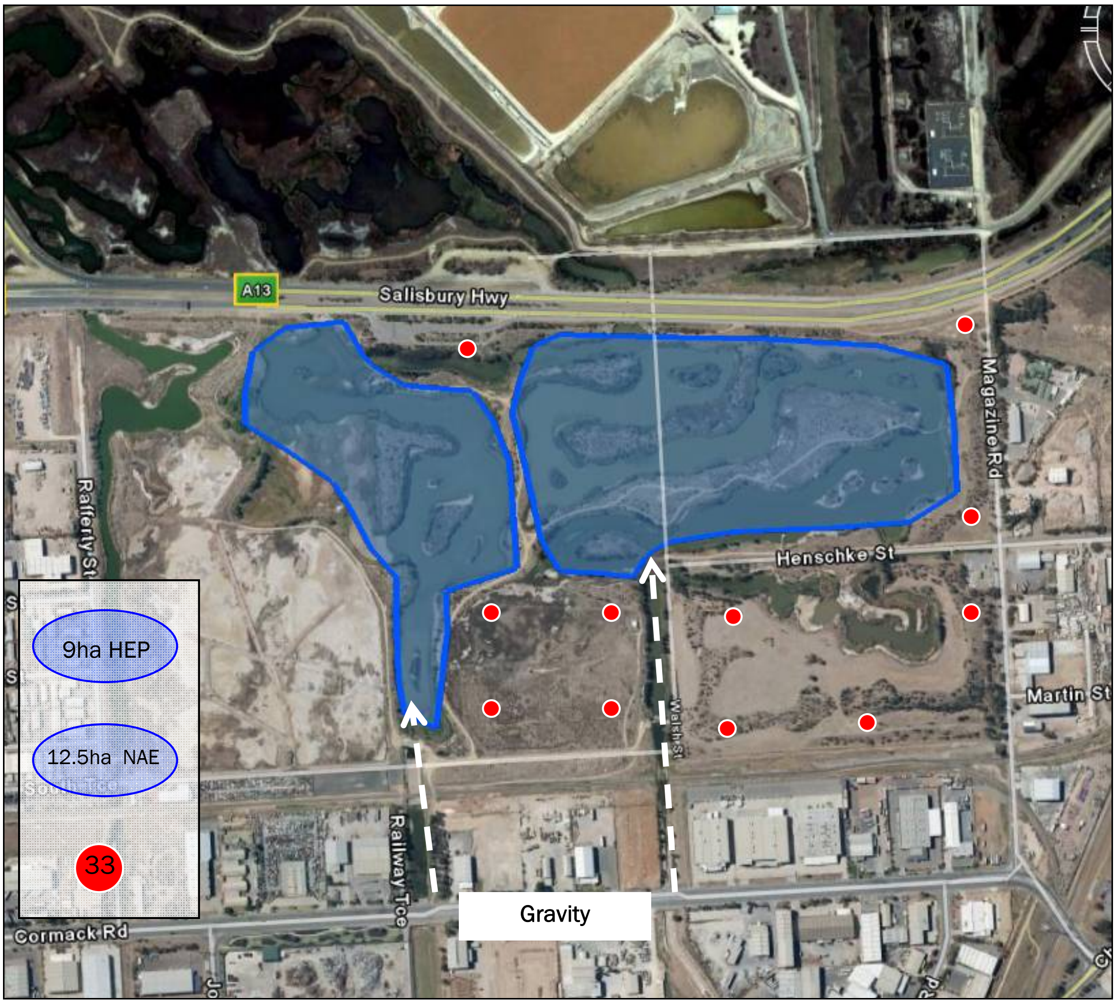

Gravity Inlet
3.8ha
6
Maxwell Rd
Bridge Rd
Kindale Ct
Mores Ct
Weston Ct
Nutter Ct
Farr Ct
294 m
© 2009 MapData Sciences Pty Ltd, PSMA
Google

PADDOCKS

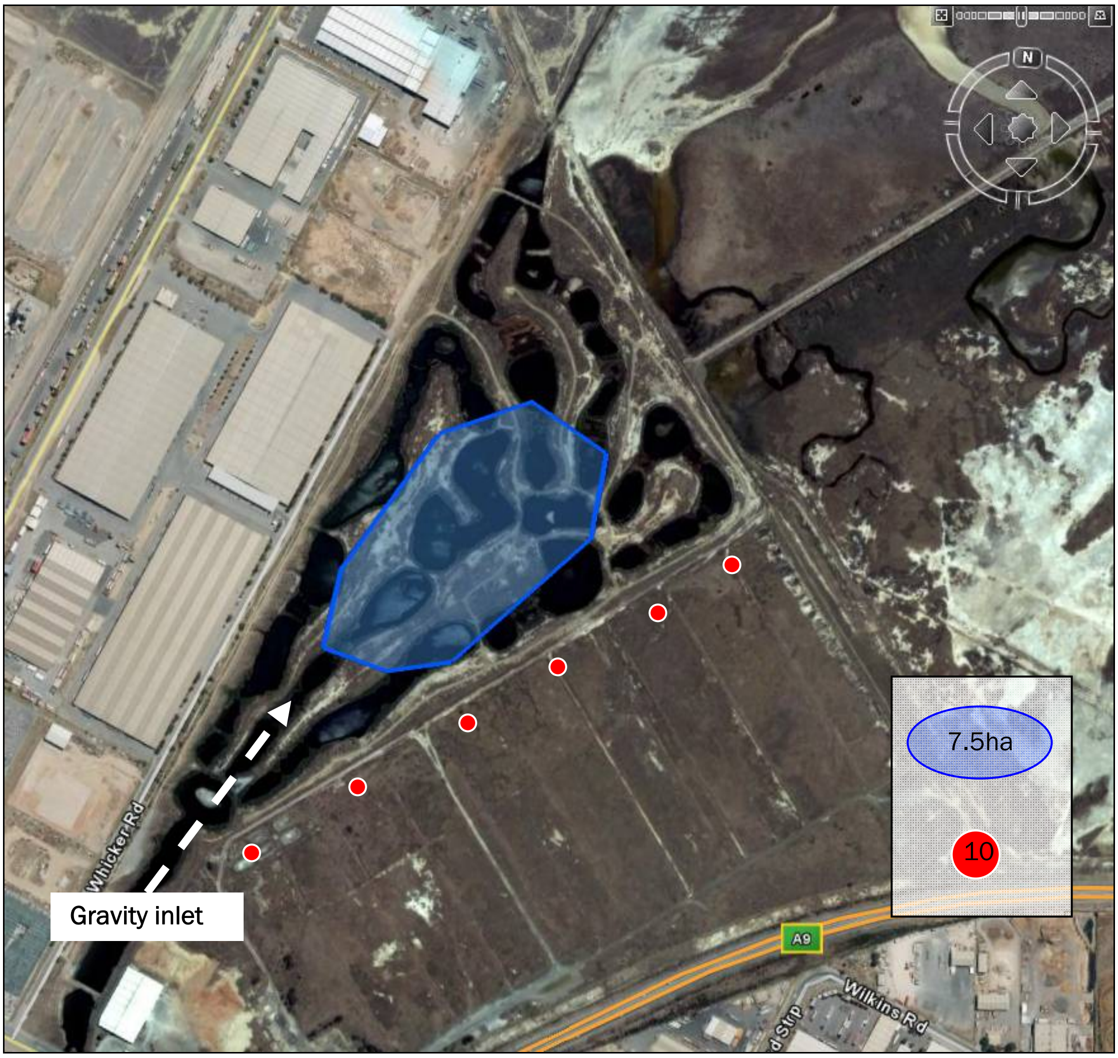
BENNET ROAD DRAIN

GREENFIELDS 1 & 2

ISLINGTON RAILYARD



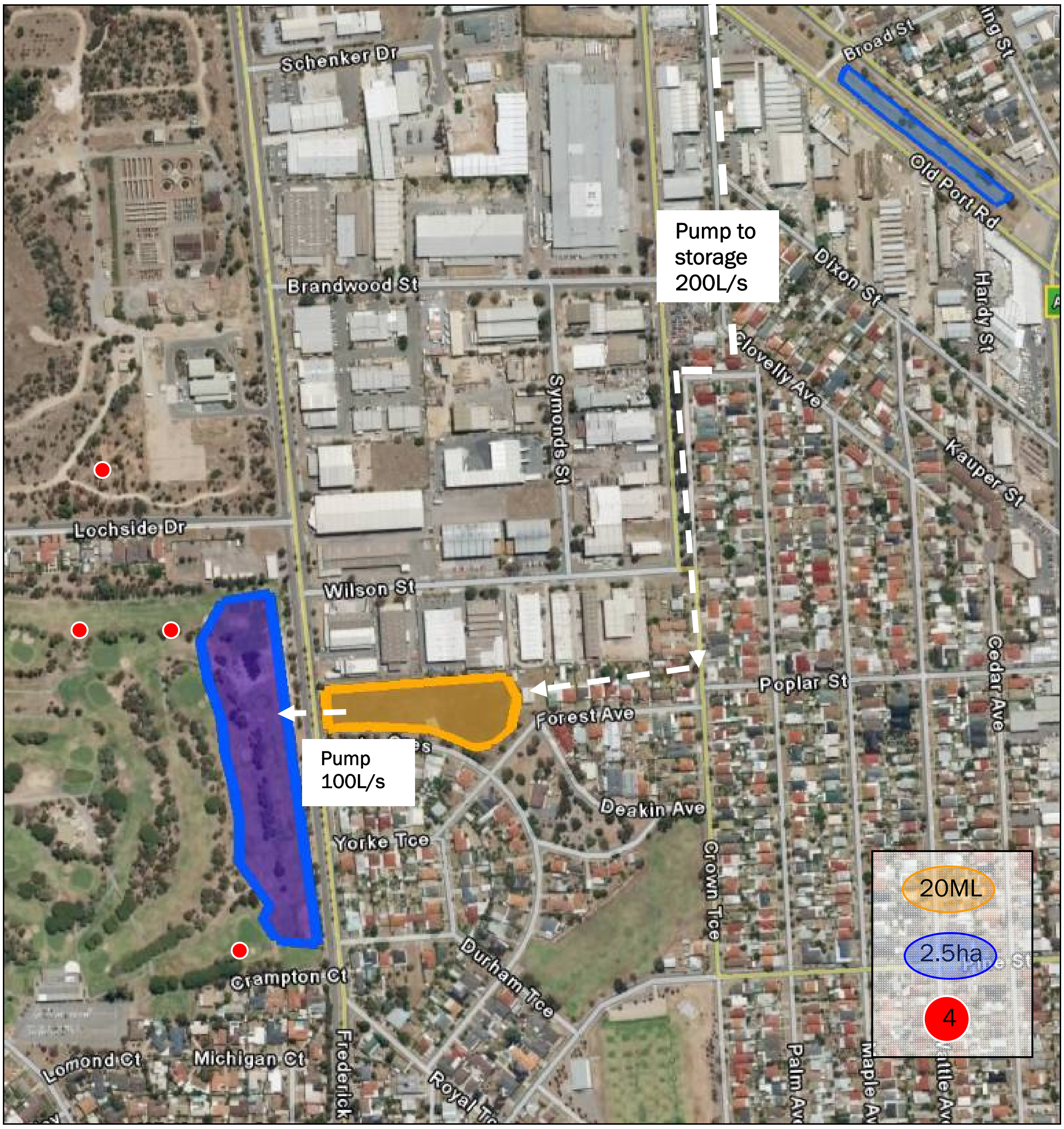
NAE & HEP at Barker Inlet



RANGE WETLAND

CHELTENHAM RACECOURSE RE-DEVELOPMENT

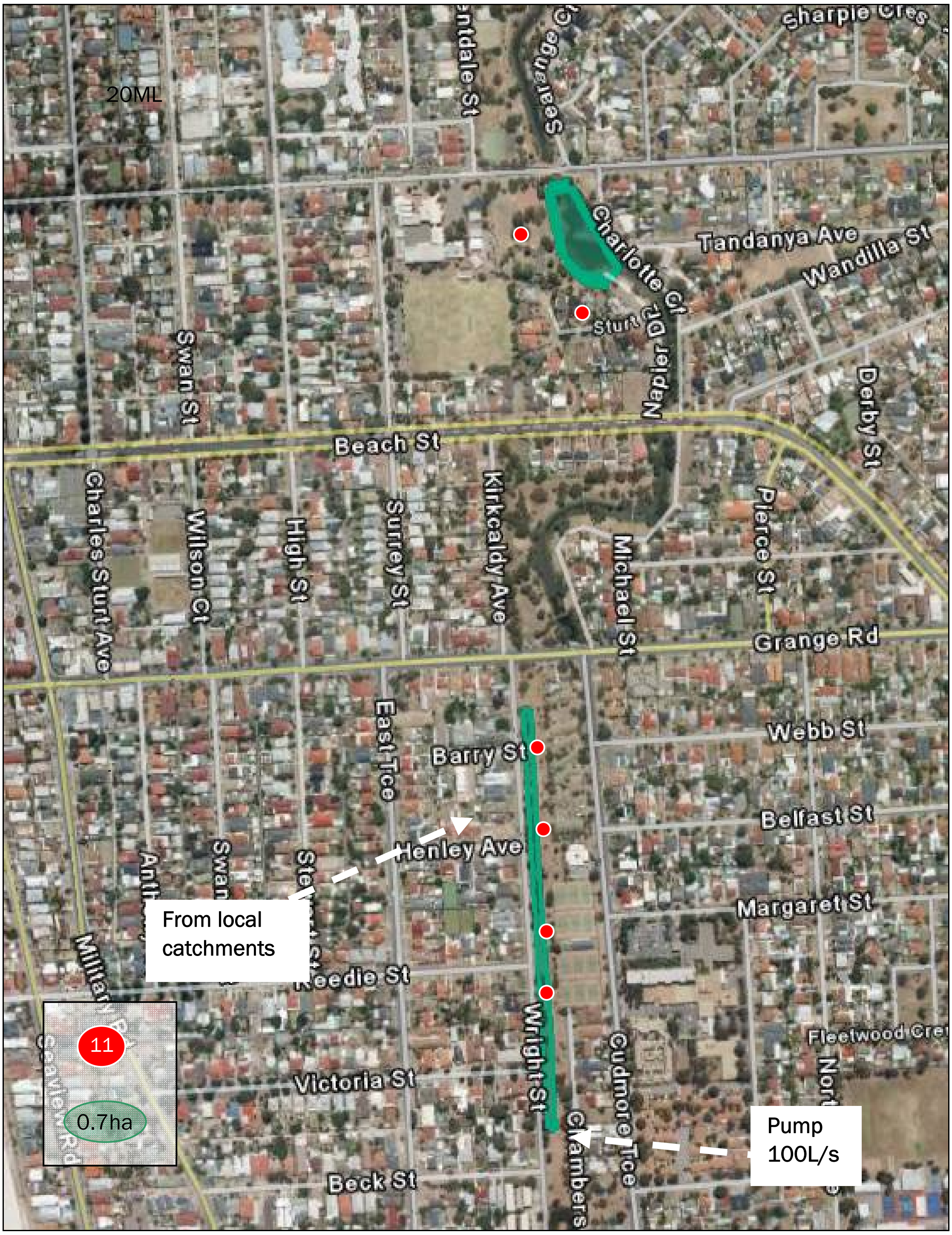
PORT ROAD MEDIAN



RIVERSIDE GOLF COURSE

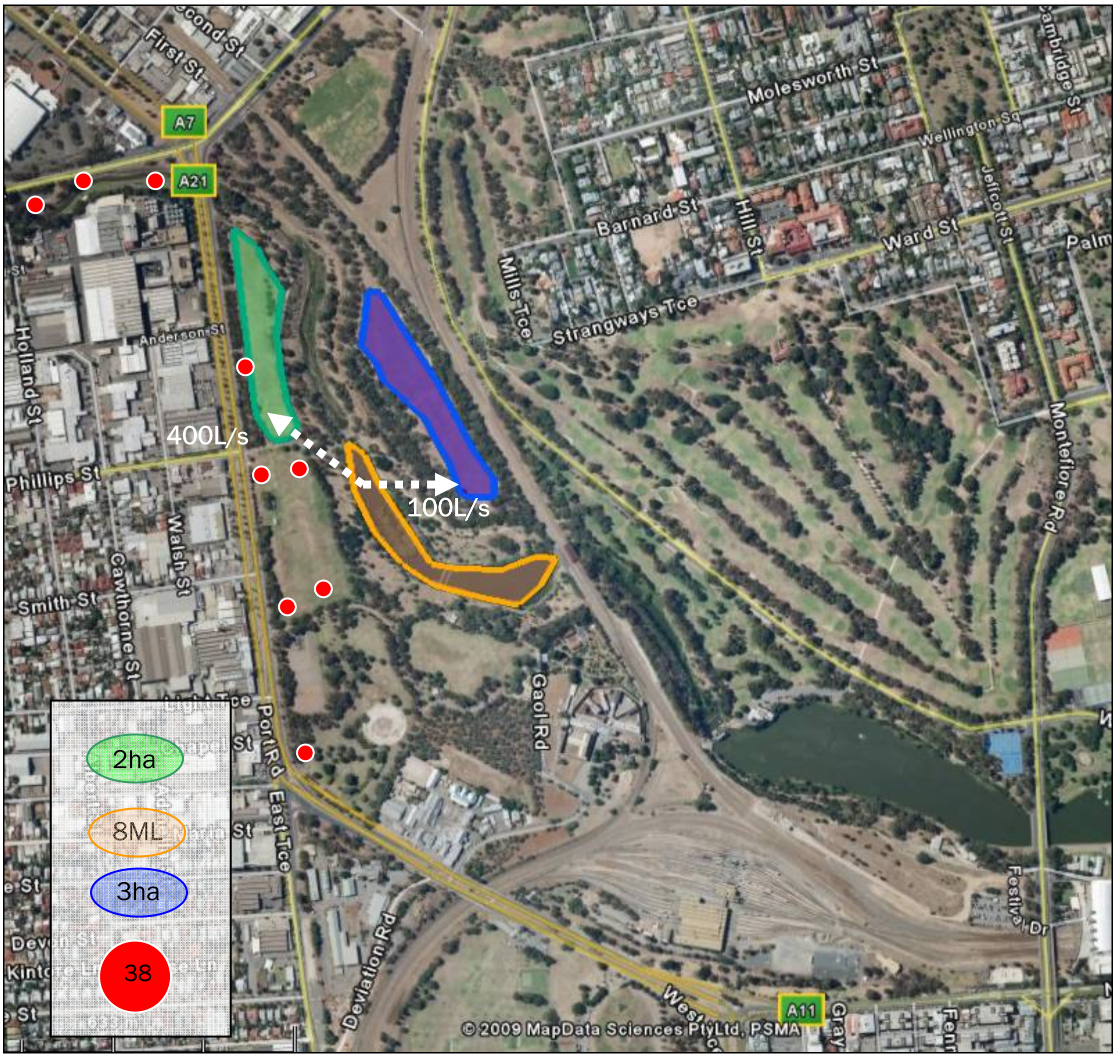
GRANGE GOLF COURSE

ROYAL ADELAIDE GC



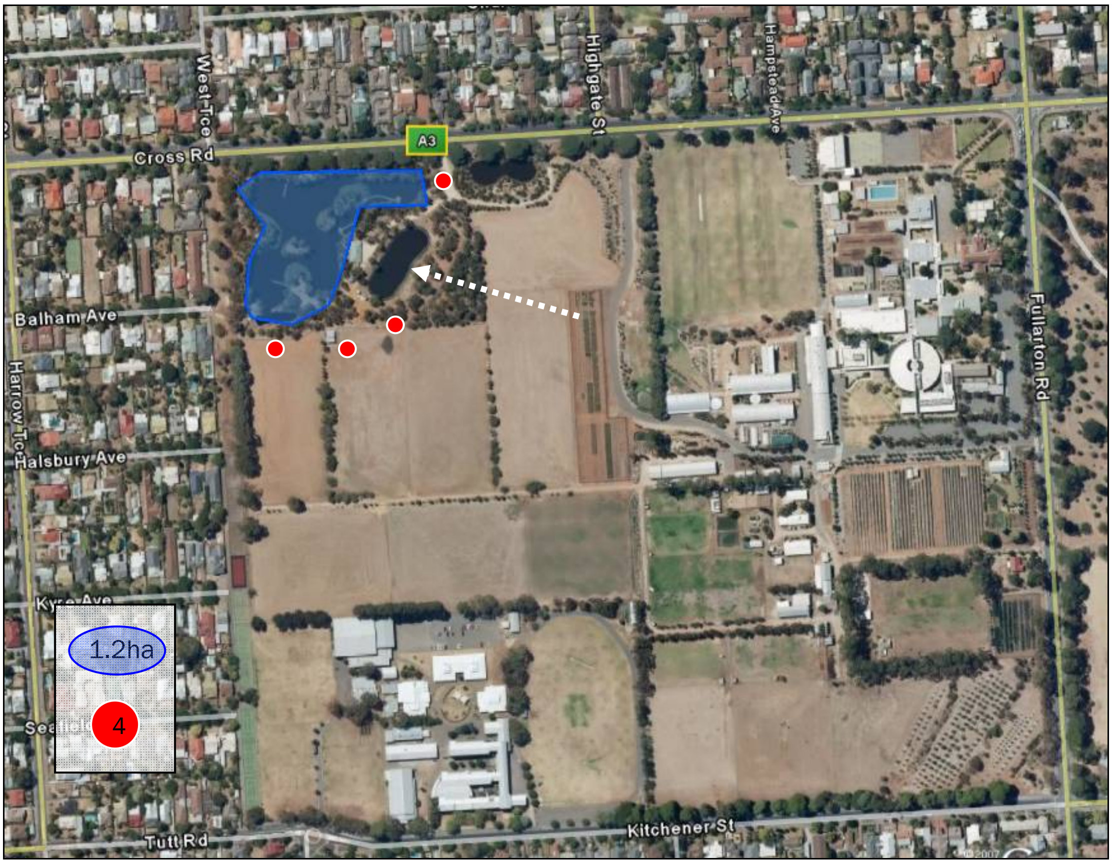
GRANGE LAKES

BOTANIC GARDENS



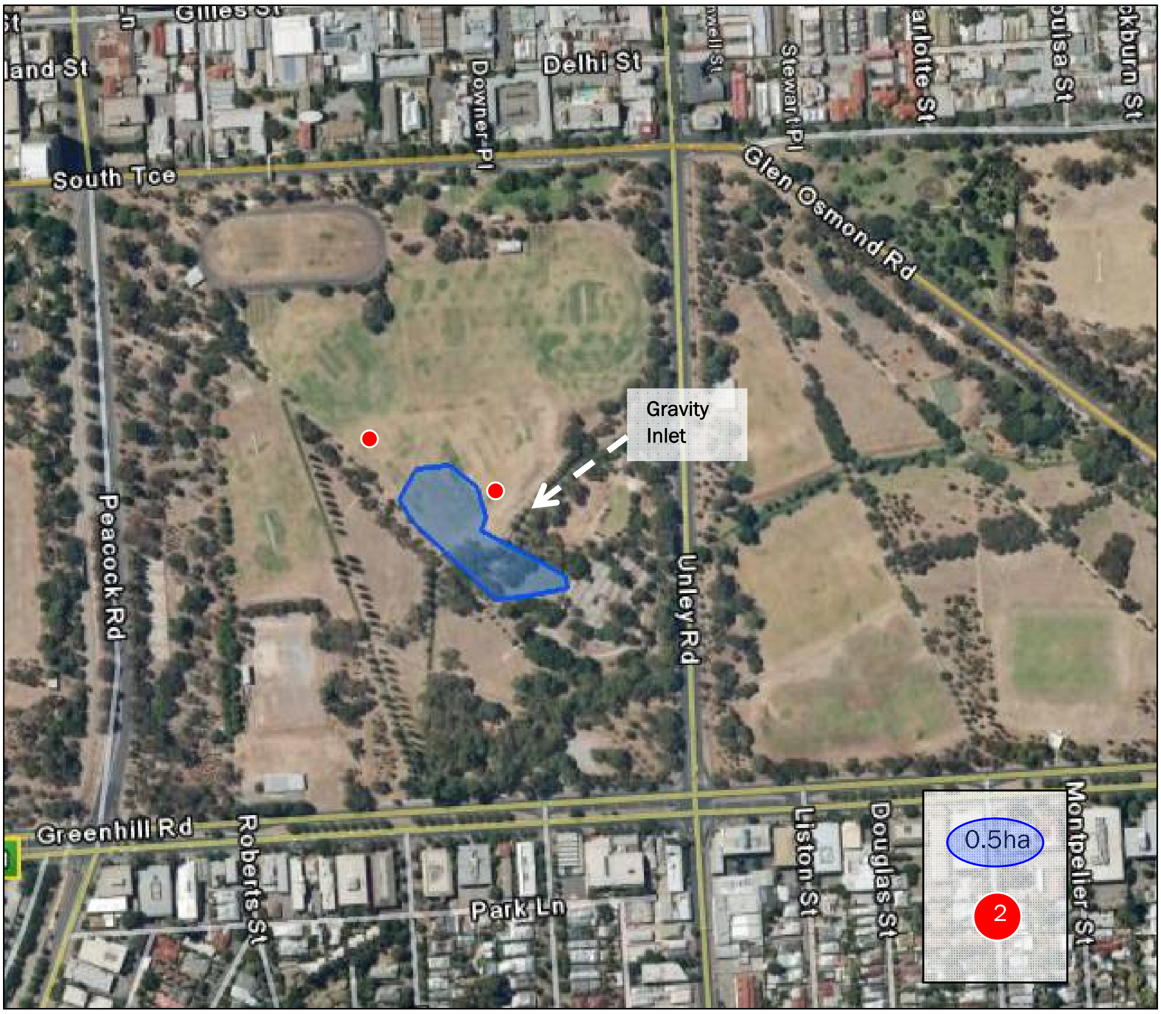
BONYTHON PARK

UNIVERSITY FIELDS



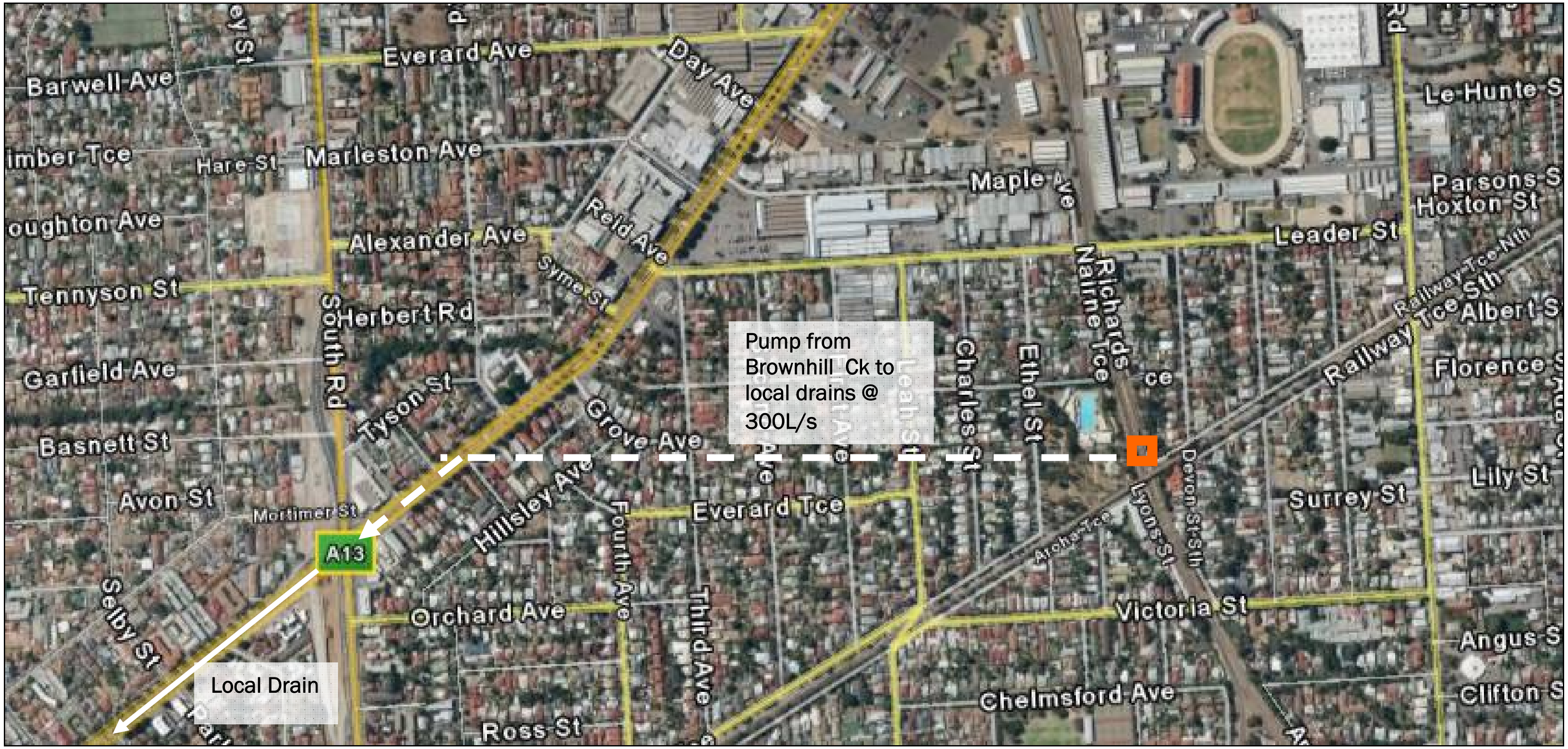
Cross Rd
West Tce
Highgate St
Hampstead Ave
A3
Balham Ave
Harrow Tce
Halsbury Ave
Kyre Ave
Seafield
1.2ha
4
Fullarton Rd
Kitchener St
Tutt Rd

URRBRAE



SOUTH PARKLANDS (PEACOCK)

VICTORIA PARK



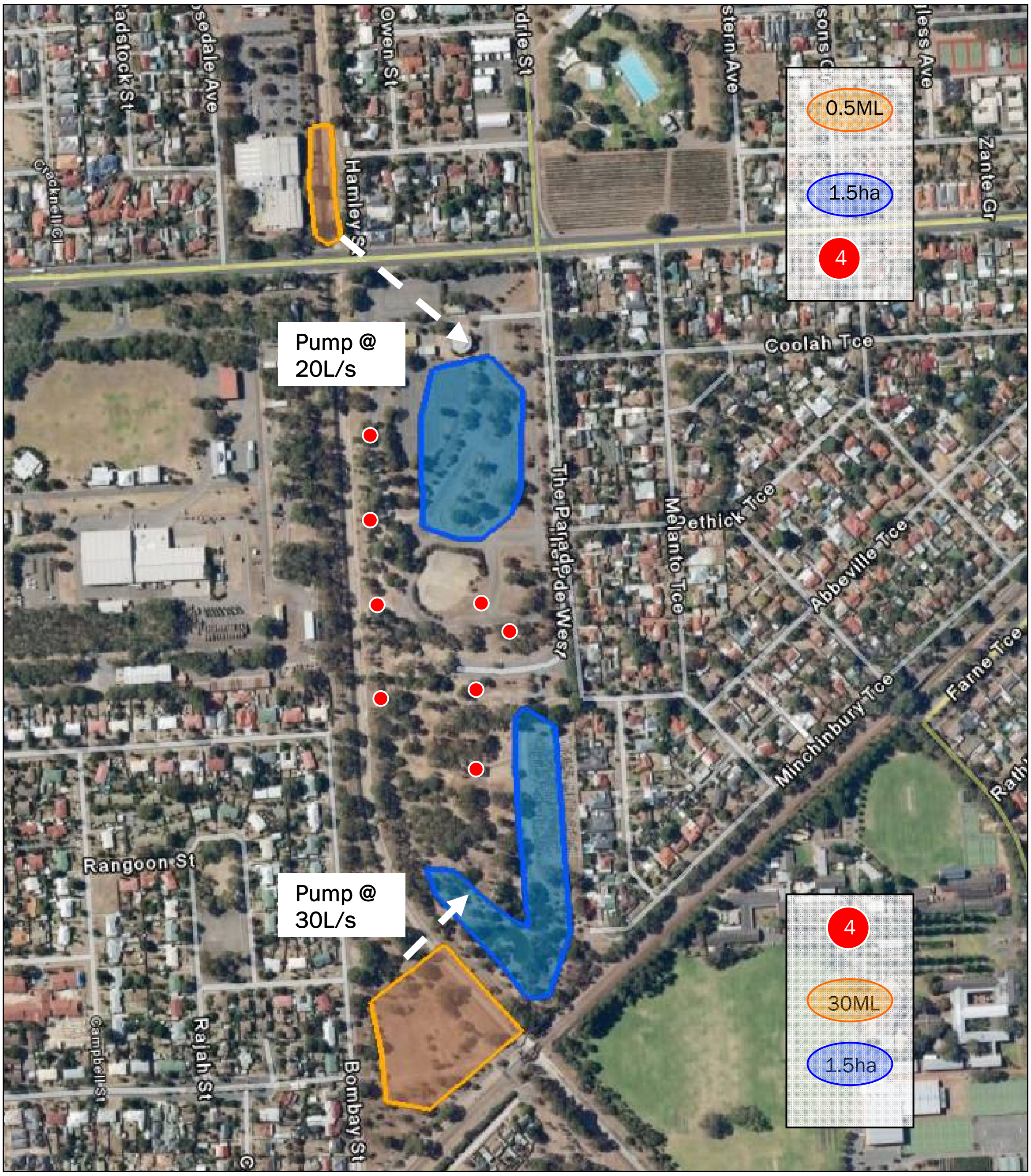
PUMP FROM TRAMLINE BROWNHILL CREEK

THE ORPHANGE

GLENLG GOLF CLUB & BROWNHILL CREEK AIRPORT

ADELAIDE SHORES

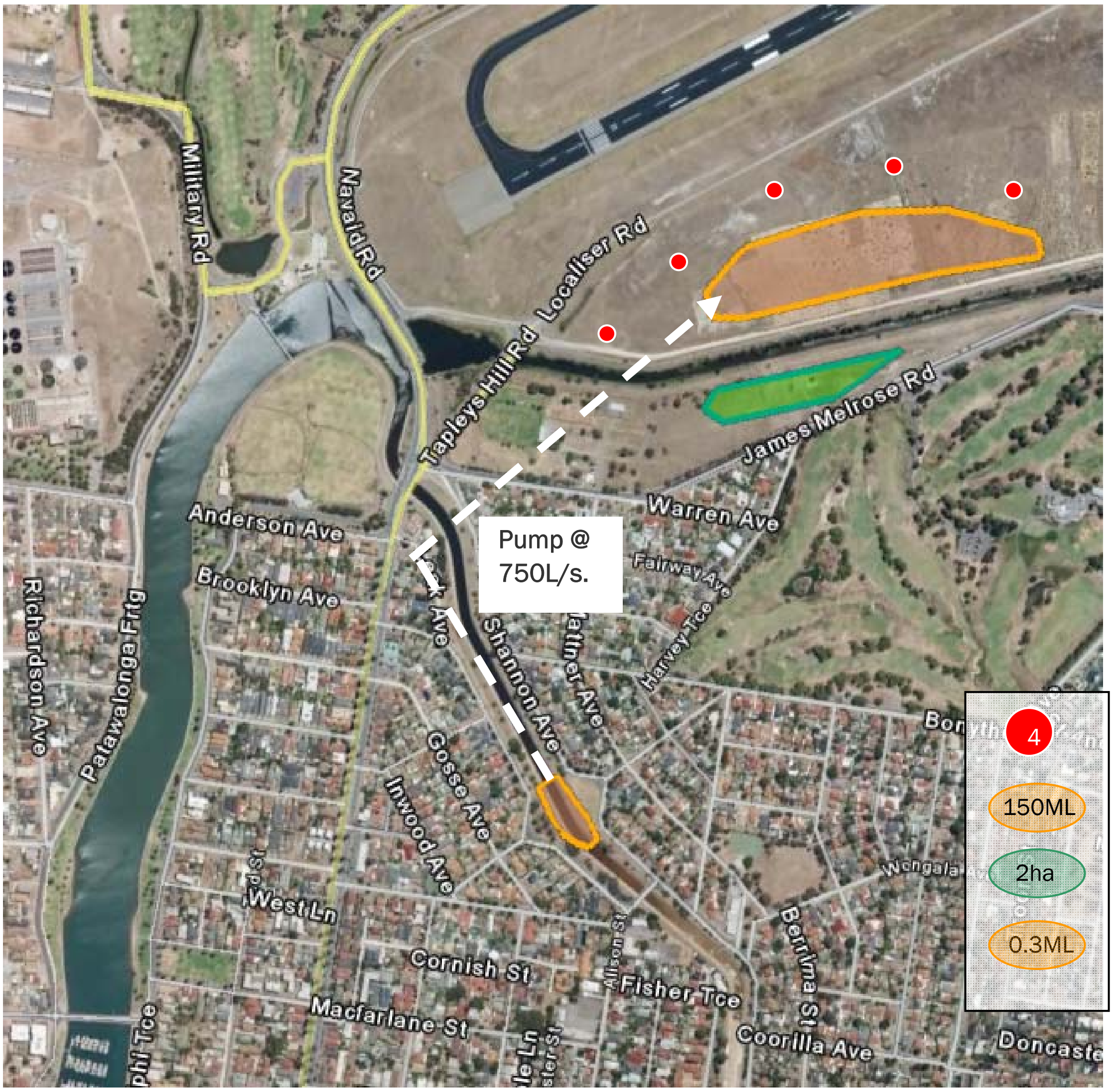
SCIENCE PARK



OAKLANDS PARK

MORPHETTVILE RACECOURSE

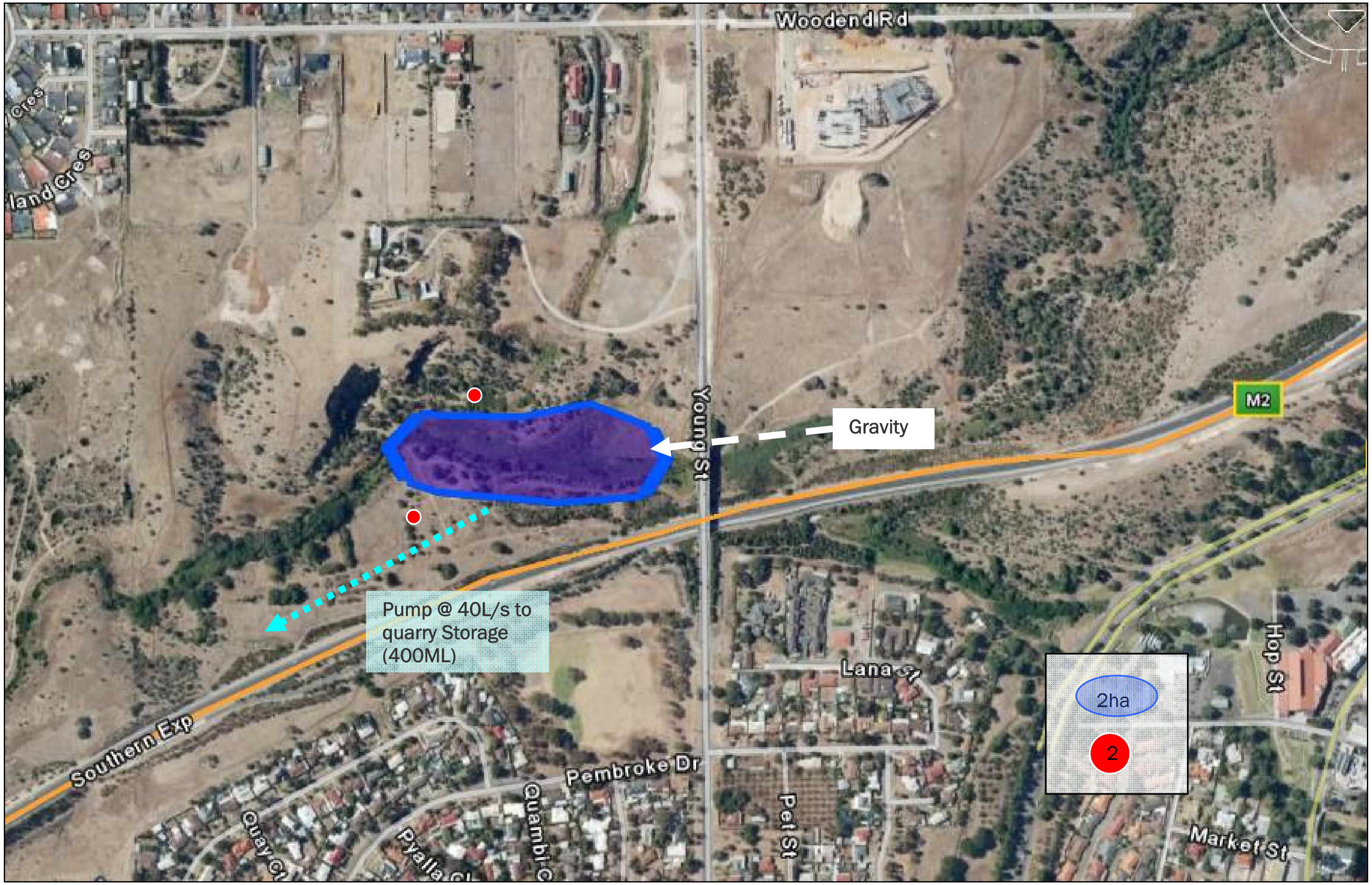
ANZAC HWY BIORETENTION



ADELAIDE AIRPORT - STURT RIVER

HAPPY VALLEY RESERVOIR

REYNELLA EAST


Woodend Rd
Young St
Gravity
M2
Pump @ 40L/s to
quarry Storage
(400ML)
Southern Exp
Pembroke Dr
Lana St
Hop St
2ha
2
Market St
Quambi Ct
Pyalla Ct
Quay Ct
Pet St

YOUNG ST

ELIZABETH CRESENT RESERVE

Bains Rd
States Rd
Gravity
Tokay Cres
Harding Ct
Gunn Ct
Baulkham St
Hermitage Ave
Madeira Dr
Adam Rd
1ha
Pump to storage
at Wilfred Taylor
reserve
Cashel Pl

MADEIRA

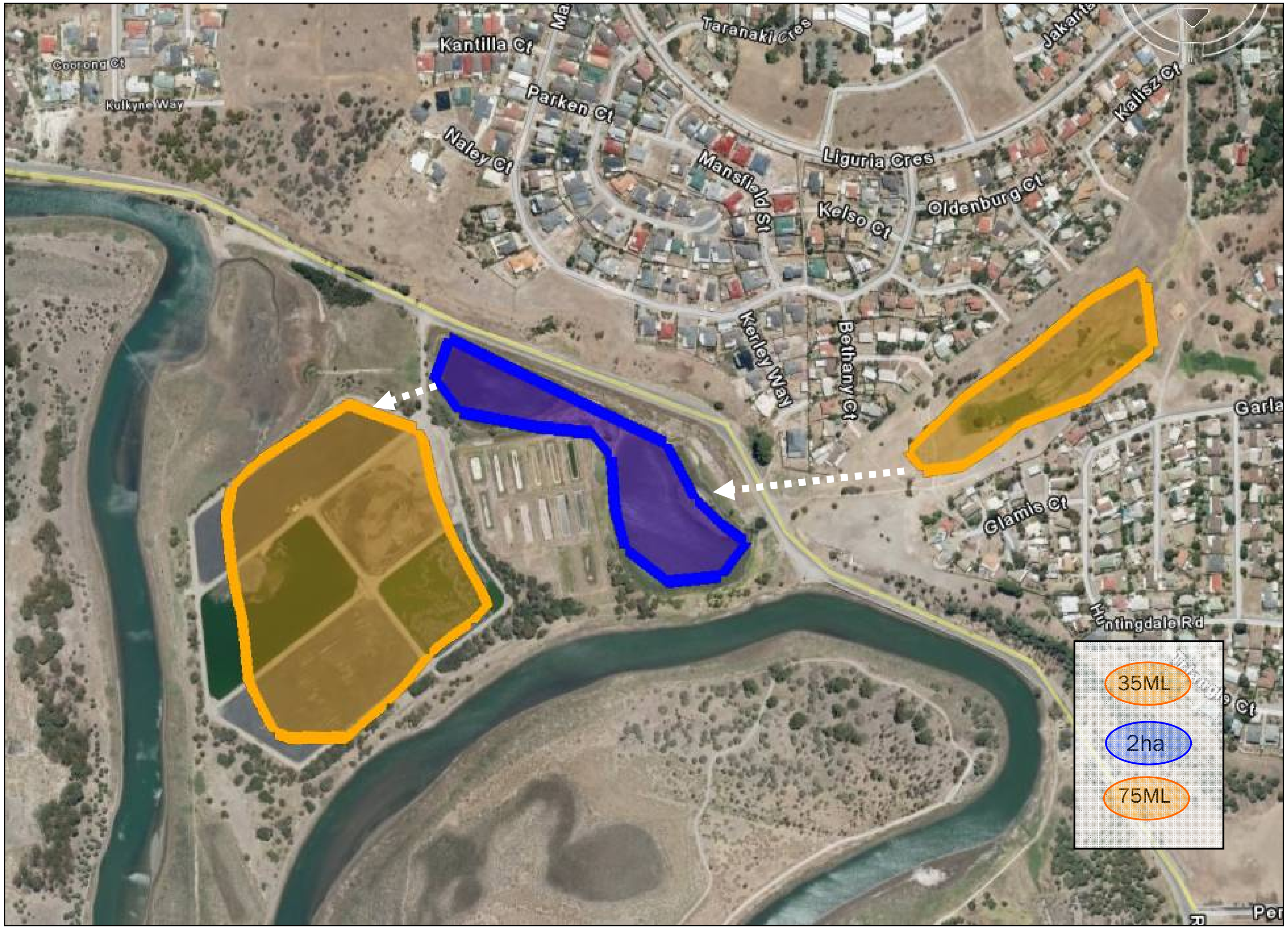
Commodore
Brodie Rd
Teusner Dr
Reserve Pde
Martin Rd
Jasper Pl
Conington
Abbott Ave
Burns Ct
Salisbury Ave
Ringwood
Pump to storage at Wilfred Taylor reserve or Christie
3ha

BRODIE ROAD

Woocalla St
Borraga St
Gumeracha Rd
Roopena St
Galloway Rd
Pump @
200L/s
Treated flow to
Christies
Beach WWTP
Bagshaw Rd
Morrow Rd
Copernicus Rd
A15
2ML
1ha
Brown Rd
Cocking Rd
Brodie Cres

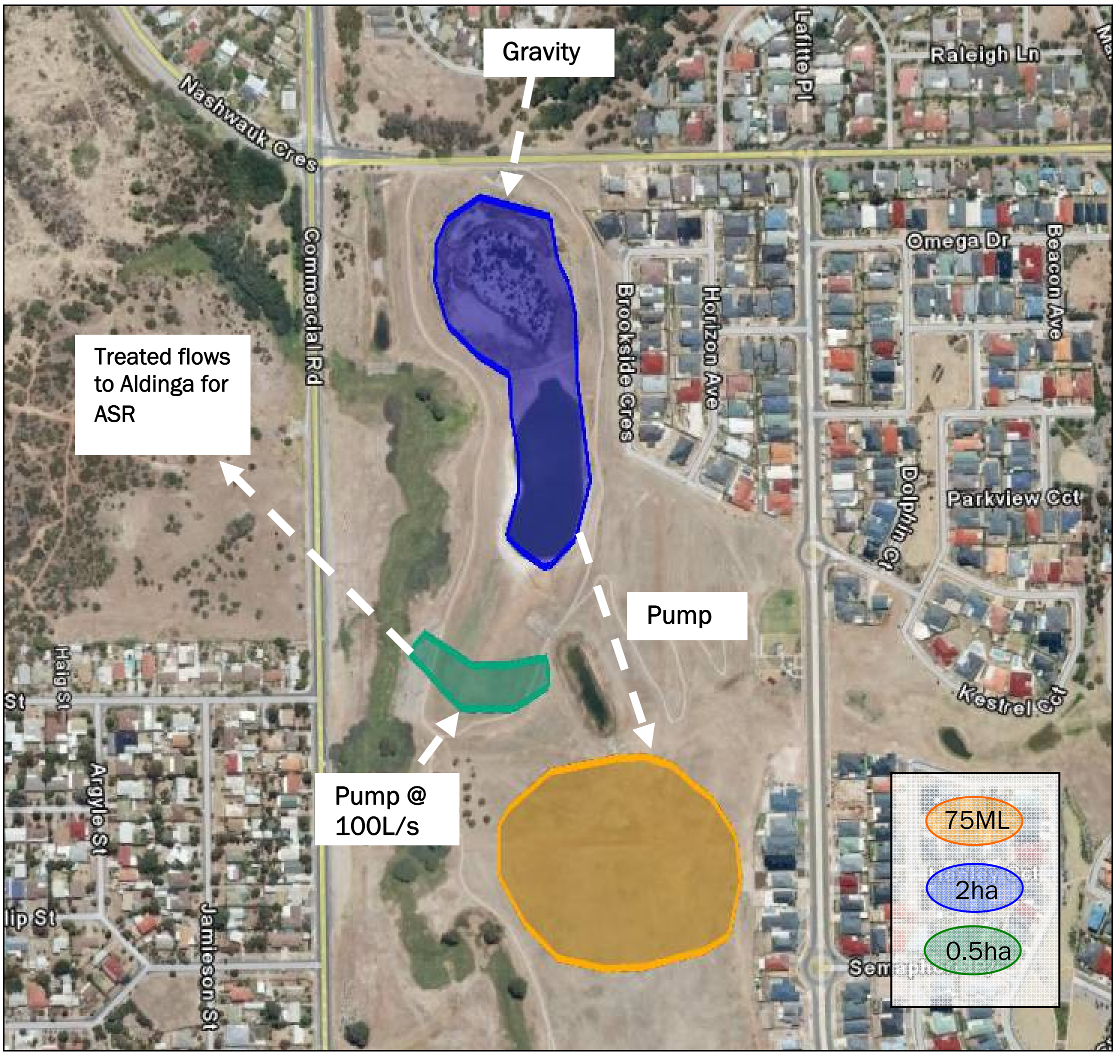
MORROW ROAD

ONKAPARINGA RECREATION PARK



GARLAND RESERVE

ONKAPARINGA RURAL FLOWS



PEDLER CREEK