• Impacts on existing trees.

7.2.4 Incorporation of water sensitive urban design into reserve upgrades

There are a vast number of reserves across the study area. Many are irrigated and most are heavily utilised for both formal and informal recreational purposes.

While it is not recommended that reserves that are used for recreational purposes be replaced with water sensitive urban design features (such as large biofiltration systems or wetlands), a strategy of incorporating water sensitive urban design into planned reserve upgrades is recommended. As part of this strategy, Council should include consideration of small-scale, localised diversions of stormwater into the reserve for irrigation purposes in conjunction with identifying opportunities for the replacement of some areas of irrigated turf with native species which require minimal watering. There is the potential for these works to improve water quality (Goal WQ1), promote beneficial reuse of runoff (Goal RU2) and enhance the biodiversity and aesthetics of the reserve area (Goal RA3)

The opportunity for raising public awareness and/or community education via way of involving local groups and educational signage should also be considered.

7.2.4.1 Oval Corridor reserve

Collectively, Chambers Reserve, Don Ferguson Reserve and Colin Sellars Reserve are known as the ‘Oval Corridor’ reserve. These reserves, located within the Henley Fulham Catchment, have been identified as one area where there is the potential to incorporate water sensitive urban design into a reserve upgrade. It is a green corridor which runs from Henley Grange Memorial oval (in the south) to Grange Road, in the north. The width of the corridor varies from 30 to 60 metres.

The corridor currently comprises irrigated and non-irrigated areas, with numerous native trees of varying sizes scattered along the corridor. Recent plantings of native trees were observed at the southern end of the reserve (refer Figure 7.7 and Figure 7.8).

There are recreational facilities (such as sports courts) within the corridor and a shared use path extends along the northern section of the reserve. During a site visit, it was observed that the reserve was being heavily utilised by the community.

Figure 7.7 An irrigated section of the Oval corridor. The existing trees which line the reserve and the shared use path can be seen.

Figure 7.8 A non-irrigated section of the Oval corridor. Note an informal path and newly planted trees on the right-hand side.

WGA (2010) presented a preliminary concept for the incorporation of water sensitive design into the Ovals Reserve Corridor. The concept included the following components:

- Revegetation using species of local provenance to increase biodiversity and reduce irrigation demand.
- Creation of different planting zones along the corridor based on pre-European landscapes.
- Diversion of stormwater into the reserve to created mini wetlands, infiltration zones and dry land swale systems. The potential to 'break open' existing stormwater pipes that currently cross the reserve was identified. This would provide water quality improvement benefits, in addition to increasing biodiversity along the corridor.
- Extend the shared use path along the length of the corridor.
- Localised stormwater harvesting at Beck Street.
- The creation of zones where stormwater can pond, thereby providing flood attenuation benefits.

Subsequent geotechnical and environmental investigations along the corridor (Coffey, 2010) identified contamination within the upper layers of soil, that not only exceed the EPA's criteria for Waste Derived Fill, but also exceed the National Environmental Protection (Assessment of Site Contamination) Measure 1999 (NEPM) maximum recommended concentrations of Benzo(a)pyrene and Total PAH for a recreational park. The presence of contamination will need to be considered in future plans for upgrading the reserve.

Consistent with the recommendations for the incorporation of water sensitive urban design into reserve upgrades, it is recommended that Council consider the following for the Ovals Reserve Corridor:

- Revegetation of areas not used for recreational purposes with species of local provenance and low irrigation requirements.
- Localised diversion of surface runoff to support the areas of planting.

The works described above should aim to minimise impacts on the existing trees within the reserve and should be cognisant of the contamination which has been identified. Works should also be undertaken in a manner so as to not have any adverse hydraulic impacts on the upstream stormwater network.

7.2.5 Grange Lakes channel upgrades

The Grange Lakes system is an open channel stormwater drain which extends from Grange Road to Trimmer Parade and conveys flows from the Henley-Fulham catchment to West Lakes. The downstream sections of the channel are concrete lined, while the upstream reaches take on a more natural, meandering form with earth banks. The banks appear to have a steep drop-off into the channel and are lined with exotic grasses, with some reeds (refer Figure 7.9 and Figure 7.10). There is no vegetation within the channel. There are trash nets at the upstream end of the channel (refer Figure 7.11). The natural section of the channel also contains a wide basin like area which acts as a sedimentation zone (refer Figure 7.12). Council periodically removes the build-up of sediment from this basin.

Figure 7.9 The Grange Lakes natural section of channel – note the exotic grasses and erosion on the bank, with steep drop off into the water.

Figure 7.10 The Grange Lakes natural section of channel – note the tall reeds and exotic grasses.

Figure 7.11 Trash nets at the upstream end of the Grange Lakes channel

Figure 7.12 The basin area on Grange Lakes which acts as a sedimentation zone.

There is the potential to increase the water quality improvement, in addition to biodiversity, amenity and public safety, along the natural section of the Grange Lakes channel. In furthering the design of the works, careful consideration should be given to ensuring that the works do not adversely impact the hydraulic conveyance of the system, thereby resulting in upstream flooding.

It is recommended that (where space permits) the edges be regraded to provide a flat bench (nominally 1V:8H and 2.5 m wide). This flat bench can then be planted with aquatic species of local provenance. This will help to create habitat, improve biodiversity, improve public safety, improve amenity and provide some water quality benefits.

While it is recommended that the channel be maintained as an ephemeral watercourse, investigations should be undertaken to identify areas suitable for construction of deeper pools, which will provide continuity of habitat for water birds during extended dry periods.

Consideration should be given to increasing the volume of the sedimentation zone, and the construction of shallow macrophyte zones perpendicular to the flow path to provide increased water quality improvement.

These proposed works are generally consistent with the concept design developed by WGA (2010) and address Goals WQ1 and RA3 of this SMP.

The scope to undertake water quality improvement works along the downstream (concrete lined) section of the Grange Lakes channel is more limited as conversion of the concrete lined channel to a natural watercourse would impact the conveyance of the channel. WGA (2010) identified the option of terminating stormwater pipes which discharge into the drain further away from the channel, with conveyance of flows to the channel via open swale. This is recommended where space permits.

7.2.6 Permeable paving

Permeable paving, also known as porous paving, is a load bearing pavement structure which can be used on trafficable surfaces including roads with low traffic volumes, footpaths, carparks and pedestrian areas. It is best suited to areas that are relatively flat (DPLG, 2010).

Permeable paving typically comprises a permeable surface layer overlying an aggregate storage layer and provides many runoff management benefits including:

- Reduction in peak discharges and volumes.
- Increased groundwater recharge.
- Water quality improvement as a result of infiltration.

It is recommended that Council consider the use of permeable paving as part of capital works (e.g. construction/rehabilitation or carparks). An education campaign, informing the general public of the benefits of using permeable paving on their sites (e.g. driveways) should also be considered. This would align well with the requirements of the new Planning and Design Code, which contains provisions for permeable paving.

Installation of permeable paving addresses Goal WQ1.

7.3 Non-structural water quality improvement strategies

The structural water quality improvement strategies described above are aimed at treating water after it has been 'contaminated'. The principles of water sensitive urban design dictate that non-structural strategies, aimed at reducing the peak flow rates, volumes and contaminant concentrations of runoff, should be considered higher up in the hierarchy of controls.

Council's Biodiversity Action Plan includes a focus on education and citizen science (Action Area 4). It is recommended that the non-structural water quality improvement strategies be delivered within the framework of the Biodiversity Action Plan.

7.3.1 Microplastics investigation

Sampling undertaken as part of the AUSMAP program identified very high concentrations of microplastics on the beaches of West Lakes. A recording of 9,517 particles/m^2 at Towpath Reserve on the shores of West Lakes in 2019 is the highest recorded concentration within Australia. The source of the microplastics in West Lakes is not currently known.

It is recommended that Council work with the AUSMAP program to undertake further investigations to identify the source of the microplastics (including consideration of stormwater discharges) and to understand the patterns of export of the microplastics to the Port River environment.

This is considered a high priority and will be the first step in addressing Goal WQ2. The investigation could incorporate an element of community education and/or citizen science in conjunction with Council's Biodiversity Action Plan.

7.3.2 Sediment controls for development

While no information could be found in the literature, anecdotally high levels of development within a catchment significantly contribute to the sediment load discharged to receiving environments. There have been reports from the operators of managed aquifer recharge schemes that sediment loads as a result of development in the upstream catchment impact the schemes' harvestable volumes.

While effective sediment controls are often implemented during the construction of larger developments, small infill development does not always have the same levels of control. This results in visible sediment on the road network in the vicinity of the development (examples of which are shown in Figure 7.13). This sediment is then washed into the stormwater network, contributing to the sediment loads in the receiving environment.

It is recommended that Council implement and monitor tougher controls on all development within the catchment to reduce the sediment loads being discharged to the Coastal Waters via West Lakes. Given the recognised impact that sediment has on the coastal waters, this is considered a high priority action which addresses Goal WQ1 and could be undertaken by existing Council staff.

Figure 7.13 Examples of development sites, with visible sediment at the entrance to the site and on the downstream road network.

7.3.3 WSUD in the backyard

It is recommended that Council encourage 'WSUD in the backyard' both for existing residences, but more importantly for in-fill development. Examples of measures could include rainwater tanks (with effective reuse), permeable paving and small-scale raingardens. Potential benefits that could be achieved by a WSUD in the backyard approach include reduced peak flows and runoff volumes, beneficial reuse of runoff (Goal RU2) and improved water quality (Goal WQ1).

Implementation of WSUD in the backyard will require community buy-in. It will require a community awareness and education campaign, which aligns with key actions (Education and Citizen Science) identified by Council's Biodiversity Action Plan.

It is recommended that Council work with Water Sensitive SA (WSSA) in the roll out of the campaign. WSSA has a range of relevant online resources (refer Figure 7.14) and also runs a community training program. A WSUD in the Backyard campaign

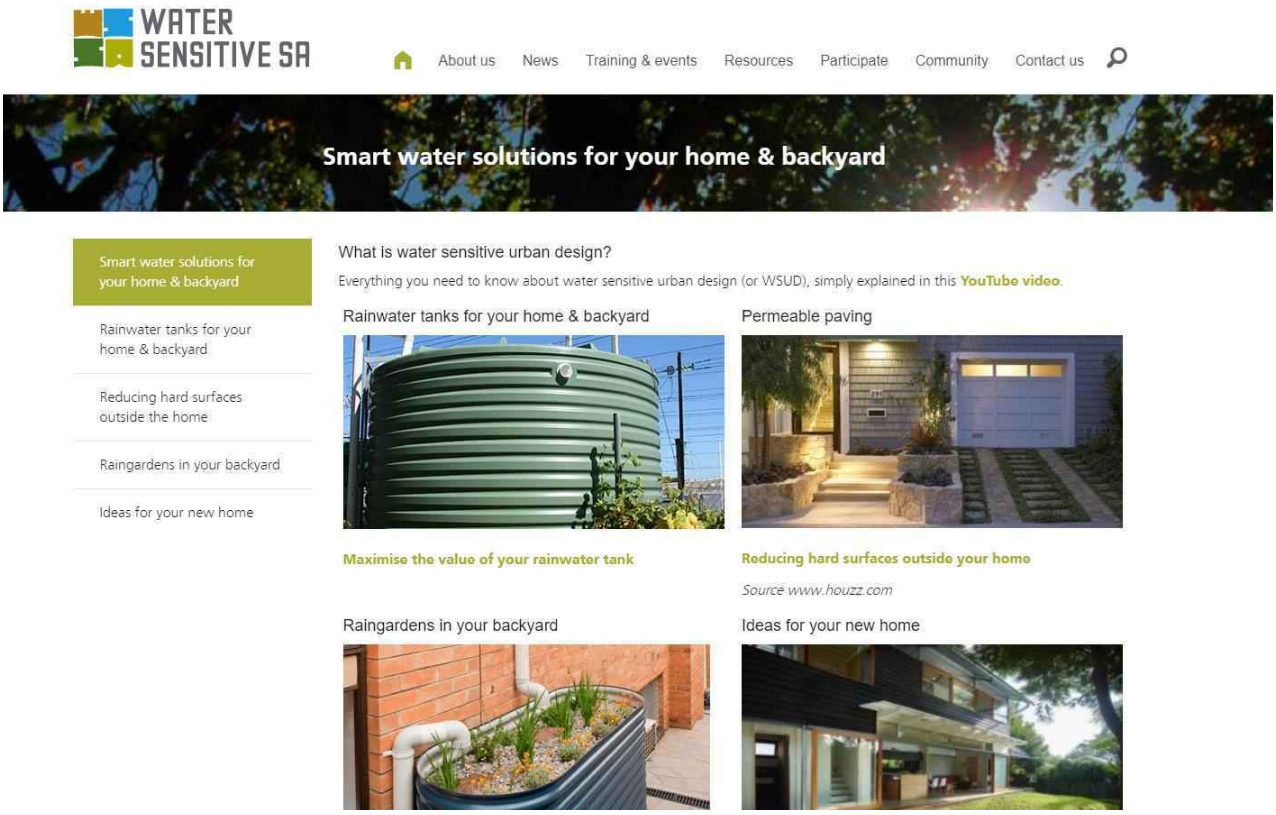


Figure 7.14 Online resources relating to WSUD in the backyard (Water Sensitive SA)

7.4 Summary of water quality actions

Table 7.9 contains a summary of the identified actions, a budget cost and priority.

Table 7.9 Summary of water quality improvement actions and priorities

Project ID	Description	Budget cost	Priority	Goal addressed
Q1	Gross pollutant traps	$300,000 each	High/Ongoing	WQ1
Q2	Street scale infiltration measures	$50,000 per year	High/Ongoing	WQ1, RU2
Q3	Street scale biofiltration (raingardens)	$25,000 each	High/Ongoing	WQ1, RU2
Q4	Oval Corridor reserve WSUD upgrades	$200,000	Low	WQ1, RU2, RA3
Q5	Grange Lakes channel upgrades	$500,000 with $5,000 annual cost	Medium	WQ1, RA3
Q6	Permeable paving	Part of capital works projects (no additional cost)	Ongoing	WQ1, RU2
Q7	Microplastics investigation	$20,000	High	WQ2
Q8	Sediment controls	$20,000 per year (nominal, assumed to be enforced by existing Council staff).	High	WQ1
Q9	WSUD in the backyard	$20,000 allowance each year	Medium	WQ1, RU2

8 Stormwater harvesting and reuse

The beneficial reuse of stormwater is one of the key objectives of the SMP (Goals RU1 and RU2). Not only does the reuse of stormwater reduce the volumes of water (and associated pollutant loads) being discharged into the receiving environment, but the use of fit-for-purpose water instead of mains water can also result in costs savings for Council.

8.1 Existing water reuse

There are number of existing water reuse schemes within the study area. These are described in the following sections. An overview of the existing recycled water network within the study area is shown in Figure 8.1.

8.1.1 Waterproofing the West

Council is the owner and operator of the Waterproofing the West (WPW) scheme, which includes a managed aquifer recharge (MAR) scheme within the study area, at Cooke Reserve. The Cooke Reserve site captures stormwater runoff from the urban catchment. Prior to injection into the aquifer, runoff is treated within biofiltration wetlands located along the edge of the West Lakes Golf Course, adjacent to Frederick Road.

WPW was commissioned to reduce Council’s reliance on potable water, particularly for irrigation of reserves. The scheme incorporates a distribution network of approximately 53 km, which is now connected to a large number of reserves and recreation areas within the northern and central portion of the Council. The scheme was designed with an ultimate distribution network almost double this length connecting more Council reserves, schools and industrial premises. The scheme has a target design harvest volume of 2,400 ML/a, however only 15 of the planned 25 injection/extraction bores have been constructed to date (based on available budget at the time of construction), and Council estimates that the current maximum supply volume is in the order of 1,200 ML/a.

Council is currently reviewing the demand, supply, operational efficiencies and return on investment of the WPW scheme. As part of this, increasing the number of bores will be considered.

8.1.2 Grange Golf Club

The Grange Golf Club was the first golf club in Adelaide to adopt a water reuse scheme. The scheme was developed in order to supply an alternative source of irrigation for the golf course. The scheme began operating in 2009, diverting runoff from the City of Charles Sturt’s stormwater network. Two diversion structures (located at Trimmer Parade and Brebner Drive) are used to pump stormwater to a series of wetlands adjacent to the eastern boundary of the course. Following treatment in the wetlands, the captured stormwater is injected into the T1 aquifer via two injection/extraction bores. Typical injection volumes within recent years are in the order of 50 ML/a, with limiting factors including catchment yield and artesian conditions.

8.1.3 Royal Adelaide Golf Club

As with the Grange Golf Club, the water harvesting scheme within the Royal Adelaide Golf Club sources stormwater runoff from the adjacent catchment. Harvested water is used for irrigation of lawns and gardens within the club. An injection volume of 150 ML was achieved in 2018/2019. This scheme is currently limited by aquifer conditions, with artesian conditions experienced in 2019.

8.2 Water reuse opportunities (managed aquifer recharge)

It is recommended that the assessment of opportunities associated with additional managed aquifer recharge schemes within the catchment focus on extending the existing schemes and/or increasing inflows to the existing schemes as opposed to the creation of new water reuse schemes.

Based on usage information provided by Council it is understood that the current demand for recycled water (based on existing connections) is approximately 510 ML/a. This is less than half of the existing supply volume of the WPW scheme (1,200 ML/a).

There are a large number of reserves within the West Lakes catchment that are not currently connected to the existing recycled water network. Work undertaken by Tonkin previously identified that extension of the existing alternative water supply network to additional reserves within the Council area could replace potable water usage by approximately 180 ML/a (Tonkin, 2020b). This estimate is based on irrigation demand information provided by Council. It is recommended that Council consider extending the WPW network to increase the reuse of stormwater runoff within the catchment. Consistent with the recommendations of Tonkin (2020b), Council should also liaise with Port Adelaide Enfield Council to identify opportunities for supply beyond the Council area.

While there may be opportunities for small scale harvest and reuse at some locations within the catchment (such as at the downstream end of Grange Lakes), it is not considered that the investment required to undertake the necessary investigations and then implement small (one or two well) managed aquifer recharge systems will stack up compared to augmentation of the existing system.

8.3 Water reuse opportunities (small-scale)

A number of the water quality improvement strategies will also provide opportunities for small-scale stormwater capture and beneficial reuse (Goal RU2). These include small-scale reuse opportunities such as rainwater tanks (with effective reuse) and passive reuse of water through WSUD features.

It is recommended that Council encourage these small-scale schemes through community awareness and education programs and consideration of grants to partially offset the costs of the rainwater tank installation.

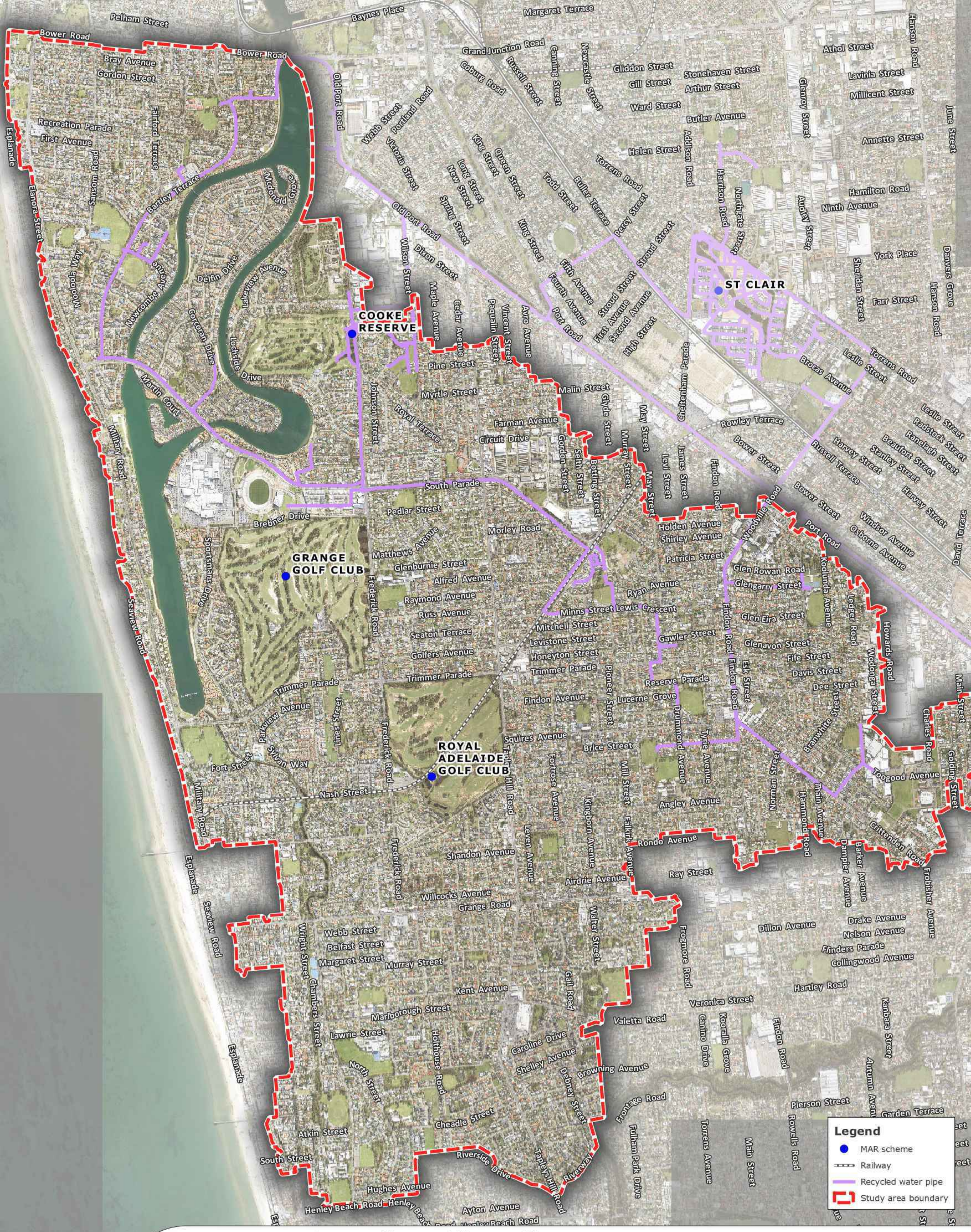
Council should also implement an internal policy which requires opportunities for the incorporation of WSUD to be considered for all Council funded capital works across the whole of Council (Goal RA2).

8.4 Summary of stormwater harvesting and reuse actions

Action RU1: Opportunities to augment the existing WPW scheme to be documented through identification of increased demands . This is a medium priority action and addresses Goal RU1.

Action RU2: Council to develop community awareness and education campaign to promote rainwater tank uptake and implementation of WSUD at a lot-scale. This will promote the beneficial reuse of water within the study area. This is a high priority action, and addresses Goal RU2.

Action RU3. Council to implement a policy which requires opportunities for the incorporation of WSUD to be considered for all Council funded capital works across the whole of Council (Goal RA2). This is a high priority action.



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Job Number: 20190818
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Data Acknowledgement:
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Roads and railways from Data SA, 2019
Distribution network from DEW, 2019

CITY OF CHARLES STURT

WEST LAKES STORMWATER MANAGEMENT PLAN
EXISTING WATER REUSE SCHEMES

Figure 8.1

9 Asset management

One of the objectives of the SMP is to ensure that sustainable management of stormwater infrastructure, including maintenance, is undertaken. The following sections provide guidance for the management of assets within the study area.

9.1 Existing infrastructure condition assessment

Council has a number of existing asset management plans, including a Water Assets Management Plan which has recently been subject to a periodic review. It is recommended that Council undertake a review of existing asset management plans relating to stormwater assets and identify where there are any gaps. Council should ensure that they have good information on the condition and likely remaining life of key infrastructure. Similarly Council should ensure that existing asset management plans consider the long-term sustainable management of infrastructure with respect to the projected changes in climate over the life of the asset.(Goal RA1). Detailed inspections of existing infrastructure, including CCTV and physical inspections, will enable an informed estimation of the residual design life for key components of the drainage system to be made. For underground drainage infrastructure, priority should be given to CCTV inspection of drains that have at least two of the characteristics described in Table 9.1.

Table 9.1 Criteria defining CCTV inspection priority

Drain characteristic	Discussion
Large drain size (larger than 750 mm diameter)	Large drains comprise the highest value component of Council’s drainage assets and the unplanned replacement of a section of large drain would have a large impact on Council’s financial resources.
Old drain	The older the drain the more likely that it will be nearing the end of its service life.
Prominent location	Some drains are located in prominent locations such as the centre of a commercial area or within an arterial road. Failure of these drains could result in major traffic disruptions and the potential for flood damages is highest.
Box culverts	Experience shows that box culverts can fail well before the end of their design life, increasing the need to understand their current condition.

9.2 Asset maintenance plan

A number of recommendations of this SMP include infrastructure that will require regular maintenance to ensure that it will continue to function as intended.

Council has recently undertaken a review of their Water Asset Management Plan (AMP). The intended purpose of the plan includes ensuring that the infrastructure functions correctly and has enough capacity for existing use and future demand.

It is recommended that Council review the AMP in the context of the findings of this SMP to identify any impacts the outcomes of the SMP have on the AMP. They should also develop a maintenance plan to cover the long-term management of their drainage assets, particularly the assets that have a high maintenance frequency (Goal RA2). The maintenance plans would be expected to align with Council’s existing asset management plans, and would need to include the following key details:

- The location and description of the asset.
- The likely frequency (or event trigger, such as a heavy rainfall event) that maintenance will be required.
- The type of maintenance that will be required (such as removal of silt, weeding).

Council will also need to allow for adequate resourcing and budgets to maintain the additional infrastructure that may be constructed as part of the implementation of the recommendations of this SMP.

9.3 Summary of asset management actions

Asset maintenance plans for all infrastructure, including WSUD, should be developed as infrastructure is built. It is therefore considered a high priority action.

The Water AMP should be reviewed against the outcomes of this SMP. The focus should be on identifying gaps in the existing AMP, and in particular knowledge about the state of key existing infrastructure and potential impacts of climate change on the sustainable management of assets. This is considered a high priority action.

10 Consultation

The objectives of stakeholder consultation for the SMP are to:

- Communicate the SMP and its aims to stakeholders.
- Obtain stakeholder input to the SMP, specifically the identification of key stormwater management issues and opportunities.
- Obtain stakeholder feedback on structural and non-structural stormwater management measures developed for the SMP.

The following key stakeholders have been identified:

- City of Charles Sturt (Council as well as the broader community)
- Stormwater Management Authority
- Green Adelaide
- Department for Infrastructure and Transport
- Environment Protection Authority South Australia

It is recommended that the following tasks be undertaken to inform the identified stakeholders about issues that may affect them:

- Media release published on Council's website
- Display the draft SMP at Council's libraries and office
- Letter to landholders that may be affected by proposed management actions, informing them of the recommendations of the SMP.
- Development of feedback forms.

10.1 Development of this draft SMP

This draft SMP has been developed in collaboration with a range of stakeholders within Council and has been reviewed by DIT, the SMA and Green Adelaide.

10.2 Council consultation

Formal Council review and consultation will be undertaken on this draft SMP.

10.3 Community consultation

The draft SMP will be issued for community consultation following approval from Council.

11 Consolidated stormwater management plan

11.1 Summary of actions, costs, benefits and priorities

A summary of the recommended actions along with a recommended priority and associated costs and benefits is provided in Table 11.1.

The flood mitigation (structural and non-structural) measures presented in this SMP will not only reduce the magnitude of flooding but will also provide social benefits, including improved public safety and continuity of community services. The strategies presented in this SMP also consider opportunities to improve water quality (and therefore the receiving water environmental values), promote beneficial reuse of runoff, enhance biodiversity and promote a sustainable approach to asset management.

11.2 Timeframes for implementation

The actions detailed in this plan will be implemented over a period of many years, as budget and funding opportunities allow.

Highest priorities are for measures that have the greatest reduction in flood damages, with a greater weighting given to measures that can demonstrate other benefits.

It is recommended that the following target timeframes be adopted for the prioritised works:

- High priority – within 5 years
- Medium priority – 5-10 years
- Low priority – greater than 10 years.

A suggested 10-year capital works plan is provided in Table 11.3.

11.3 Responsibilities for implementation and maintenance

The implementation and maintenance of the structural measures identified in this SMP will generally be the responsibility of Council. The exception is works associated with the West Lakes outlet, which will be responsibility of DIT. The economic analyses undertaken as part of this SMP consider recurrent annual maintenance costs, which will be Council's responsibility. Annual maintenance costs will generally be associated with the maintenance of underground storage tanks, open basins and raingardens.

11.4 Potential funding contributions

Council will be responsible for funding the proposed works documented in this SMP and it is recommended that Council allocate funds for the high priority works within their long-term financial plans.

Stormwater management projects that are in accordance with an approved SMP and that have at least 40 ha of contributing catchment upstream of the location of the proposed works are eligible for SMA funding. The SMA may contribute up to 50% of capital costs. The eligibility of projects for SMA funding is provided Table 11.2. It should be noted that eligibility for SMA funding does not guarantee funding.

Other sources of potential funding may include Green Adelaide (particularly for works promoting WSUD within the community). The State and Commonwealth governments may also offer grants periodically to facilitate specific works such as flood disaster planning and relief and the incorporation of WSUD.

Table 11.1 Summary of recommended options

Priority	Project/Activity title	Budget estimate	SMA funding eligible	Flood mitigation benefit	Water quality benefit	Other benefits
High	F1 Gleneagles Reserve storage	$12,726,000 ($2,000 annually)	Y	Eliminates above floor flooding of private property in the 20% AEP event in a known flooding hotspot	Could consider infiltration during detailed design	Limited disturbance of open space Opportunities for localised infiltration/reuse Can be staged
High	F2 Nedford Reserve detention basin	$248,000 ($2,000 annually)	Y	Significant reduction (~180 mm) in flood depths within the road corridor in the 20% AEP event	High – landscape to provide water quality improvement	Possibility for landscaping for improved amenity and biodiversity
High	F3 Beatrice Avenue and Trimmer Parade pipe upgrades	$9,117,000	Y	Eliminates above floor flooding of private property in the 20% AEP event along the alignment of the upgrade (previously 7 properties subject to above floor flooding)	Minimal	Opportunity to incorporate WSUD with inlets
High	F11 Education and awareness	$70,000	N	Likely to reduce flood impacts on community	-	Public can better respond to flooding. Better community resilience to flooding.
High	F12 Flood mapping outputs	$20,000	N	Provide up to date information of flooding within the catchment	-	Better planning outcomes. Public can better respond to flooding via greater preparedness.
High	Q7 Microplastics investigation	$20,000	N	-	Understanding of source of Microplastics so that the levels can be reduced	-
High	Q8 Enforce sediment controls for development	-	N	-	Lower TSS discharged to receiving environments	Low cost (developer responsibility). Will also improve aesthetics in areas of heavy development and may reduce required frequency of street sweeping.
High	Q1 Gross Pollutant Traps	$300,000 each ($20,000 annually)	N	-	Reduce loads of gross pollutants and sediments to receiving environment	-
High	Q2, Q3, RU1 Commence ongoing programs to promote incorporation of street scale infiltration and biofiltration into Council works	Low initial investment	N	-	Reduced loads of sediment and nutrients to the receiving environments	Aligns with the promotion of small scale projects promoting beneficial reuse of water. Reduced volumes of flows, improved amenity associated with urban greening and offset of the urban heat island effects.
High	AM1, AM2 Asset management – review of existing plans and plans for new assets	$40,000	N	-	Will help to ensure existing/proposed WSUD measures function as intended	Reduced costs associated with proactive (as opposed to reactive asset management). Ability to better plan for asset management.
High (2050)	Bower Road Causeway upgrade and Consideration of Pumps	N/A	Work to be undertaken by DIT	Required to lower lake levels as sea level rises	None	None

Priority	Project/Activity title	Budget estimate	SMA funding eligible	Flood mitigation benefit	Water quality benefit	Other benefits
Medium	F4 Crittenden Road to Grange Lakes pipe upgrades	$24,172,000	Y	Eliminates above floor flooding of private property in the 20% AEP event along the alignment of the upgrade (previously 8 properties subject to above floor flooding)	Minimal	Opportunity to incorporate WSUD with inlets
Medium	F5 Matheson Reserve underground tank	$18,960,000 ($2,000 annually)	Y	Eliminates above floor flooding of private property in the 20% AEP event in a known flooding hotspot (previously 4 properties subject to above floor flooding)	Could consider infiltration during detailed design	Limited disturbance of open space Opportunities for localised infiltration/reuse Can be staged
Medium	F6 Recreation Parade detention basin	$3,765,000 ($2,200 annually)	Y	Eliminates above floor flooding of private property in the 20% AEP event in a known flooding hotspot (previously 2 properties subject to above floor flooding) Significant reduction (~200 mm) in flood depths within the road corridor in the 20% AEP event	Consider plant selection to provide water quality improvement	Possibility for landscaping for improved amenity and biodiversity
Medium	F7 Sansom Road pipe upgrades	$6,640,000	Y	Eliminates above floor flooding of private property in the 20% AEP event along the alignment of the upgrade (previously 4 properties subject to above floor flooding)	Minimal	Opportunity to incorporate WSUD with inlets
Medium	F8 Golfers Avenue pipe and pump upgrades	$3,197,000	Y	$648,000 (in combination with Priority F3 and F9) Improvements to flooding in roadways (particularly Frederick Road and Lily Avenue) in the 20% AEP event	Minimal	Opportunity to incorporate WSUD with inlets
Medium	Q5 Grange Lakes Channel Upgrades	$500,000 ($5,000 annually)	N	Minimal	Reduced loads of sediments and nutrients discharged to receiving waters	Improved biodiversity and visual amenity
Medium	Q9 WSUD in the backyard	$20,000 allowance each year	N	-	Reduced loads of sediments and nutrients discharged to receiving waters	Promotes beneficial reuse of water. Community education opportunities.
Medium	Additional connections to existing MAR schemes to increase water reuse	Variable	N	-	Reduced loads of sediments and nutrients discharged to receiving waters	Reduced volumes of water discharged to the receiving waters. May be financial gains from offsetting potable water with fit-for-purpose. Promote urban greening and offset head island effect.
Low	F9 Frank Mitchell Reserve underground tank	$15,049,000 ($2,000 annually)	Y	$648,000 (in combination with Priority F3 and F8) Significant reductions (~300 mm) in flood depth within the road corridor in the 20% AEP event	Low	Limited disturbance of open space
Low	F10 Market Corner pipe upgrades	$392,000	N	$111,000 (in combination with Priority F7) Minor reductions in flood depth within the road corridor	-	-
Low	Q4 Oval Corridor Reserve WSUD upgrades	Variable	N	-	-	Improved amenity and biodiversity. Opportunity to incorporate WSUD for small-scale beneficial reuse.

11.5 Achievement of stated SMP goals

An assessment of the level to which the proposed SMP objectives are attained by the recommended priorities described in the report is provided in Table 11.2.

Table 11.2 Attainment of objectives

Goal	Achieved	Discussion
Flood management		
F1a.	Partial	Over-floor flooding in a 1% AEP event reduced from 896 to 581 residential properties (2.4% of the study area). The SMP addresses the most pronounced areas of flooding. Residual areas of flooding are shown in the flood maps. Achieving a 1% AEP standard of protection across the entire SMP area is an aspirational target that can be worked towards over a long timeframe (not economically viable within a 10-year planning horizon).
F1b.	Partial	The strategies provide improvement to flood depths in the 20% AEP event in the most pronounced areas of flooding. There are very few areas remaining with flood depths in excess of 150 mm (i.e. above kerb height).
F1c.	Yes	The results of the flood mapping can be used to ensure a 1% AEP standard of protection for new developments.
F1d.	Yes	The modelling undertaken as part of the SMP development can be used to ensure new development have a stormwater network that provides a 20% AEP level of service.
F2	Yes	No private property is subject to high or extreme hazard (i.e. category H4 or higher) in a 1% AEP event.
F3	Yes	Community awareness and education is a recommended action.
Water quality improvement		
WQ1	Partial	Recommended measures will improve the water quality discharged to West Lakes. The achievement of the stated goals will depend on the extent to which the strategy is implemented.
WQ2	Partial	Investigation into the source of microplastics is identified as a high priority action. This will be the first step in achieving the targeted reduction. Once the source is known, a strategy to reduce the concentrations can be implemented.
Beneficial reuse of stormwater		
RU1	Yes	Opportunities to augment WPW scheme identified.
RU2	Yes	Direct recommendation to consider small-scale implementation.
Desirable planning outcomes		

Goal	Achieved	Discussion
RA1	Yes	Flood maps have been prepared and can be incorporated into the Planning and Design Code.
RA2	Yes	Recommendation for Council policy to require consideration of WSUD opportunities in the planning phase of all capital projects.
RA3	Yes	Recommended works in Grange Lakes.
Asset management		
AM1	Yes	Recommended that all existing stormwater assets be identified and recorded.
AM2	Yes	Details of asset maintenance plans provided.

Table 11.3 Indicative 10-year capital works plan (values in millions)

Priority	Works	21/ 22	22/ 23	23/ 24	24/ 25	25/ 26	26/ 27	27/ 28	28/ 29	29/30	31/32	Total per project
F1	Gleneagles Reserve storage (Stage 1)	5.0										**5.0**
F2	Nedford Reserve detention basin	0.25										**0.25**
F3	Beatrice Avenue and Trimmer Parade pipe upgrades		4.5	4.5								**9.0**
F4	Crittenden Road to Grange Lakes pipe upgrades				4.0	4.0	4.0	4.0	4.0	4.0		**24.0**
F6	Recreation Parade detention basin										3.8	**3.8**
F11, F12, Q8	Education, awareness, planning and enforcing sed controls	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	**0.55**
Q2/Q3/Q6	Street scale biofiltration measures and permeable pavement		0.2	0.2	0.2	0.2	0.2					**1.0**
Q7	Microplastics investigation	0.02										**0.02**
Q1	GPTs		0.3	0.3	0.3	0.3	0.3	0.3				**1.8**
Q5	Grange Lakes								0.25	0.25		**0.5**
	Total per year	5.37	5.05	5.05	4.55	4.55	4.55	4.35	4.30	4.30	3.85	**45.9**

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Appendix A – Assessment of development potential

MEMO

To	Olivia Oliver, Tonkin
From	Simon Channon, Anna Pannell
Date	14 October 2019
Project Number	19ADL-0214
Regarding	West Lakes catchment development potential

This memo summarises the findings of an investigation to determine development potential in the West Lakes catchment to inform the development of the West Lakes Stormwater Management Plan.

2070 is a long development horizon. To predict what may change within the catchment over this time requires making numerous assumptions. The assumptions described in the following sections have been made with regard to the planning context provided in the current Development Plan and 30 Year Plan for Greater Adelaide.

1. Assumptions regarding future development in the catchment by 2070

1. There will be no substantial changes to zone boundaries.
2. Future land use will be consistent with current zone intent.
3. Non-residential zones are unlikely to see any increase in permeable areas.
4. Recreation, open space and education land uses will not change.
5. No change in land use will occur within Residential Character Zones
6. Within existing Residential Zone, all residential, commercial, retail and industrial land uses could be developed (with the exception of existing aged care, flats and townhouses); if not by redevelopment at higher densities, through alterations and additions or other increases in impervious areas (i.e. new structures/paved areas)
7. No heritage places or Residential Character Zone properties will be developed

Residential zone development assumptions

8. 3 development scenarios have been used aligning with permeability provisions identified in the Planning and Design Code (P&DC):
   1. Low density development – only sites greater than 900m^2 are developed
   2. Medium density – only sites greater than 600m^2 are developed
   3. High density – sites greater than 400m^2 are developed.

The related P&DC provisions are described below: (draft Phase 3, 1 October 2019)

DTS / DPF 21.1

Residential development incorporates areas for soft landscaping with a minimum dimension of 0.5 metres provided in accordance with the following:

(a)

Dwelling site area (or in the case of residential flat or group average site area) (square metres)	% of site
<200	15%
201 - 450	20%
>450	25%

9. Given the development timeframe to 2070, it is assumed that all sites will be developed by 2070.

Even if land is not divided to create additional dwellings. It is assumed that the impervious area could increase through activities such as dwelling additions, new verandahs or other outbuildings and by an increase in paved/hard surfaces. New buildings will typically trigger a development application and therefore the above soft landscaping (permeable area) requirements will apply.

2. Other considerations for future development

Tree canopy will increase in line with 30-Year Plan target and City of Charles Sturt strategic plan priorities and strategies. The Draft Phase 3 P&DC also identifies tree planting requirements (refer page 2241).

3. Development zone permeability assumptions

Table 1 describes the zones that intersect the West Lakes stormwater catchments. Existing development plan provisions regarding permeability are described and where no guidance is provided, assumptions on the permeability of land within the zone are provided.

Table 1 Current land development zones and associated permeability guidance

Zone	Observations	Development Plan Site Coverage/Impervious Area Guidelines	Assumptions
Coastal Open Space Zone	Small portion in catchment. Largely open space but including a caravan park. Also expect footpaths/cycling trails.	No site coverage or permeability guidelines in the Development Plan but Zone intended to retain coastal landscape character.	Assume little if any development and therefore low impervious area and accommodating existing land uses and hard surfaces (30%)
District Centre Zone	The land is almost entirely developed and hard surfaced (roofs and car parks). There are some scattered trees in the car parks.	No site coverage or permeability guidelines in the Development Plan	Assume very high impervious area (~100%)
Education Zone	This Zone covers a school – more open space than built form.	No site coverage or permeability guidelines in the Development Plan	Assume medium level impervious area (~50%)

Zone	Observations	Development Plan Site Coverage/Impervious Area Guidelines	Assumptions
Home Industry Zone	Zone mainly contains dwellings and big sheds. Relatively high impervious areas.	No site coverage or permeability guidelines in the Development Plan.	Assume very high impervious area (~90%)
Local Centre Zone	The land is almost entirely developed and hard surfaced (roofs and car parks). There are some scattered trees in the car parks.	No site coverage or permeability guidelines in the Development Plan	Assume very high impervious area (~100%)
Mixed Use Zone	The land is almost entirely developed and hard surfaced (roofs and car parks). There are some scattered trees in the car parks.	Site coverage guideline that development should be limited to 60%. Landscaping should be a minimum of 10% of site area.	Assume very high impervious area (~100%)
MOSS/OS Zone	Zone runs along the River Torrens – generally no development in this area. No change to be expected.	No site coverage or permeability guidelines in the Development Plan.	Assume little if any development and therefore low impervious area (20%)
Neighbourhood Centre Zone	The land is almost entirely developed and hard surfaced (roofs and car parks). There are some scattered trees in the car parks.	No site coverage or permeability guidelines in the Development Plan	Assume very high impervious area (~100%)
Residential Character Zone	Low density area typically comprising larger homes on larger sites with lots of landscaping. Unlikely to be material infill development in the Zone given the desire to retain as is.	No site coverage or permeability guidelines in the Development Plan.	Assume high level impervious area (~80%)
Residential Zone	Residential area largely developed with infill development occurring throughout the zone (average of 1000 dwelling approvals per year over the past 10 years).	No site coverage or permeability guidelines in the Development Plan. Nearly all of the Zone is located in the area where the Residential Code applies that	Assume increase as per draft Planning and Design Code guidelines.

Zone	Observations	Development Plan Site Coverage/Impervious Area Guidelines	Assumptions
		permits up to 60% site coverage (roofed area).	
Special Uses Zone	Largely open space including schools and golf clubs. High proportion of open space.	No site coverage or permeability guidelines in the Development Plan.	Assume medium level impervious area (~50%)
Stadium Zone	Specific Zone covering the basketball stadium only – approximately 40% of site developed and the remaining open. Could be further developed.	No site coverage or permeability guidelines in the Development Plan.	Assume development potential will lead to higher impervious area (~85%)
Suburban Activity Node Zone	A predominantly residential zone that will have a mix of land uses. Very small area within the catchment.	No site coverage or permeability guidelines in the Development Plan.	Assume high impervious area (~85%)
Urban Core Zone	Zone set aside for intense urban development. Largely developed but will be developed to greater heights/densities.	No site coverage or permeability guidelines in the Development Plan.	Assume very high impervious area (~100%)
Urban Employment Zone	Typically developed industry zones. Covers a substantial area but generally hard surfaced already with buildings/car parks.	No site coverage or permeability guidelines in the Development Plan.	Assume very high impervious area (~100%)

4. Current sub catchment zoning

Table 2 summarises the sub catchment zoning for each of the 10 sub catchments which is assumed will not change by 2070.

Table 2 Sub catchments and current zoning

Sub catchments and zones	Area of sub catchment in each zone	% of sub catchment
Henley Grange sub catchment	**6021546**	
District Centre	62139	1.0%
Education	94604	1.6%
Local Centre	36468	0.6%
Metropolitan Open Space System	1	0.0%

Sub catchments and zones	Area of sub catchment in each zone	% of sub catchment
Mixed Use	42019	0.7%
Neighbourhood Centre	6295	0.1%
Residential	5546737	92.1%
Residential Character	227063	3.8%
Special Use	6222	0.1%
Meakin sub catchment	**4430446**	
Local Centre	19516	0.4%
Mixed Use	89237	2.0%
Neighbourhood Centre	10308	0.2%
Residential	3664029	82.7%
Special Use	336129	7.6%
Stadium	79355	1.8%
Suburban Activity Node	9159	0.2%
Urban Employment	222713	5.0%
Port Road sub catchment	**6611668**	
Commercial	6954	0.1%
District Centre	304180	4.6%
Home Industry	13989	0.2%
Industry	5822	0.1%
Local Centre	24312	0.4%
Mixed Use	331188	5.0%
Neighbourhood Centre	61877	0.9%
Recreation	1	0.0%
Residential	2162472	32.7%
Residential Character	1442416	21.8%
Special Use	578937	8.8%
Urban Core	77444	1.2%
Urban Employment	1602076	24.2%
Torrens East sub catchment	**5934740**	
District Centre	196247	3.3%
Industry	4564	0.1%
Local Centre	33611	0.6%
Metropolitan Open Space System	316378	5.3%
Mixed Use	452532	7.6%
Neighbourhood Centre	40586	0.7%
Open Space	53228	0.9%
Residential	3785958	63.8%
Residential Character	223862	3.8%
Special Use	60490	1.0%
Urban Corridor	1831	0.0%
Urban Employment	765451	12.9%
Trimmer Parade sub catchment	**4636999**	
District Centre	130710	2.8%

Sub catchments and zones	Area of sub catchment in each zone	% of sub catchment
Local Centre	4810	0.1%
Mixed Use	7382	0.2%
Neighbourhood Centre	62573	1.3%
Residential	3763063	81.2%
Residential Character	145677	3.1%
Special Use	381376	8.2%
Suburban Activity Node	43120	0.9%
Urban Employment	98286	2.1%
West Lakes Central sub catchment	**1039614**	
Local Centre	1785	0.2%
Residential	1037828	99.8%
West Lakes East sub catchment	**3466885**	
District Centre	5904	0.2%
Local Centre	13995	0.4%
Mixed Use	14871	0.4%
Neighbourhood Centre	28186	0.8%
Residential	2757109	79.5%
Special Use	49559	1.4%
Urban Core	269637	7.8%
Urban Employment	327624	9.5%
West Lakes North East sub catchment	**791230**	
Residential	260472	32.9%
Special Use	515828	65.2%
Urban Employment	14930	1.9%
West Lakes South sub catchment	**1687411**	
District Centre	268275	15.9%
Local Centre	1810	0.1%
Residential	400679	23.7%
Special Use	1011806	60.0%
Urban Core	4841	0.3%
West Lakes West sub catchment	**3305918**	
Coastal Open Space	152672	4.6%
Local Centre	32129	1.0%
Recreation	29	0.0%
Residential	3113948	94.2%
Special Use	7140	0.2%
Grand Total	**37926455**	**100.0%**

5. Current and future catchment conditions

Table 3 describes the current proportions of major land uses to inform catchment permeability considerations. This table has been prepared considering current zoning and land use.

Table 3 Current catchment conditions (2019)

Sub catchment	Total area m^2	Land area in cadastre m2	Land not in cadastre (ie road) m^2	% of subcat not in cadastre	Area open space or rec m^2	% open space or rec	Area residential land use in Res zone m^2	% residential	Area Res Character m^2	% Res Character	Area education land uses m^2	% education	% other land uses*
Henley Grange	6021550	4731794	1289756	21.4%	585521	9.7%	3187112	52.9%	148432	2.5%	261605	4.3%	9.1%
Meakin	4430450	3596487	833963	18.8%	514131	11.6%	2382494	53.8%			130467	2.9%	12.9%
Port Road	6611670	4671219	1940451	29.3%	88483	1.3%	1214823	18.4%	1019275	15.4%	83907	1.3%	34.3%
Torrens East	5934740	4707593	1227147	20.7%	429844	7.2%	2551013	43.0%	141149	2.4%	132122	2.2%	24.5%
Trimmer Parade	4637000	3719190	917810	19.8%	502220	10.8%	2436518	52.5%	119561	2.6%	70284	1.5%	12.7%
West Lakes Central	1039610	777395	262215	25.2%	73636	7.1%	576619	55.5%					12.2%
West Lakes East	3466890	2676971	789919	22.8%	217756	6.3%	1689707	48.7%			85021	2.5%	19.7%
West Lakes North East	791230	728340	62890	7.9%	336774	42.6%	163929	20.7%					28.8%
West Lakes South	1687410	1582748	104662	6.2%	1063927	63.1%	205550	12.2%			5577	0.3%	18.2%
West Lakes West	3305920	2542710	763210	23.1%	436649	13.2%	1668408	50.5%			61084	1.8%	11.4%

* Other land uses are predominantly in non-Residential zones.

Table 4 shows the potential increase in allotments by 2070 for three scenarios:

1. Low density development – only sites greater than 900m^2 are developed
2. Medium density – only sites greater than 600m^2 are developed
3. High density – sites greater than 400m^2 are developed.

Table 4 Future residential density calculations

Sub catchment	Current residential allotments	2070 high density scenario – allotments	2070 medium density scenario – allotments	2070 low density scenario – allotments
Henley Grange	4,927	12,533	8,152	5,310
Meakin	3,792	9,276	6,126	4,046
Port Road	2,024	4,694	3,047	2,162
Torrens East	4,030	10,057	6,544	4,309
Trimmer Parade	3,885	9,491	6,199	4,255
West Lakes Central	843	2,263	1,414	882
West Lakes East	3,017	6,253	4,238	3,122
West Lakes North East	246	677	435	256
West Lakes South	261	785	504	290
West Lakes West	2,606	6,127	4,041	2,730
TOTAL	25,631	62,156	40,700	27,362

For the high density scenario, there is potential for 62,156 allotments with an average area of 200m^2. Assuming 15% permeable this would mean the area of permeable cover on residential allotments across the whole catchment would equal 1,864,680m^2 (186ha).

For the medium density scenario, there is potential for 40,700 allotments with an average area of 300m^2. Assuming 20% permeable this would provide 2,442,000m^2 (244 ha) permeable cover on residential properties.

For the low density scenario there is potential for an additional 1,731 allotments (above current conditions). Assuming 25% permeable this would provide 2,736,200m^2 (274 ha).

The current allotments are assumed to have an average of 40% impervious. The average current allotment size across the catchment is 590m2. Based on these figures current residential properties provide 4,100,960m^2 (410ha) of permeable cover.

This assessment suggests that the area of permeable cover on residential properties could be expected to significantly reduce considering future likely development conditions.

Appendix B – Summary of modelling approach

Introduction

The approach to the hydrologic and hydraulic modelling that underpins the development of the West Lakes Stormwater Management Plan is summarised in the following.

The modelling is based on the modelling that was undertaken as part of the Western Adelaide Region Climate Change Adaptation Plan (Tonkin 2015), which in turn was based on the hydrologic and hydraulic modelling that was undertaken for the West Lakes TUFLOW Floodplain Modelling Project (Tonkin 2009).

Scope of modelling

Development of the flood modelling involved the following:

- Hydrological modelling of contributing catchments, including within and external to the study area.
- Obtaining details of the hydraulic structures, including pipes, culverts, pumps and areas of storage.
- Preparing a combined linked 1D–2D hydrodynamic flood model (using existing models prepared by Tonkin previously as a basis) to assess the extent of surface flooding within the study area for the predicted levels of development.
- Analysing the resultant flooding for the following storm events, assuming a 10% increase in rainfall intensity (climate change) with the 2070 level of development:
  - 63% AEP storm event (1 exceedance per year (EY))
  - 39% AEP storm event (0.5 EY)
  - 20% AEP storm event
  - 10% AEP storm event
  - 5% AEP storm event
  - 2% AEP storm event
  - 1% AEP storm event
  - 0.2% AEP storm event

Hydrological modelling

Modelling of runoff within the urban area was undertaken using the ILSAX hydrological model (in DRAINS). The ILSAX model requires the catchment to be divided into smaller sub-catchments, each of which is assigned a directly connected impervious area percentage, an indirectly connected impervious area percentage and a remaining pervious area.

The directly connected impervious area represents paved and roof areas within the catchment from which runoff is discharged directly to the street drainage system. The indirectly connected impervious area represents paved and roof areas within a catchment that are not directly connected to the street drainage system but may travel overland across a pervious surface before reaching the street. The pervious area largely represents the remaining grass and gardens areas.

For each sub-catchment, the model requires input of travel times, which when convolved with rainfall enables the generation of a runoff hydrograph using the time-area method.

A description of the parameters used to undertake the modelling within each of these models is provided in the following sections of this report.

Sub-catchment boundary delineation

Sub-catchment boundary delineation was performed for the study area using the digital elevation model. A single sub-catchment was delineated for each inlet to the urban drain system. The sub-catchments defined for the previous modelling were used as a starting point, with changes made to reflect the new DEM and changes to the drainage network since the previous modelling was undertaken.

Catchment imperviousness

Impervious area percentages were assigned to each allotment depending on land use.

The predominant land use within the Study Area is residential. A single scenario representative of the projected 2070 levels of development was modelled. Following review of development and the likely impacts of development on the impervious areas within the study area, it was assumed that all residential properties (excluding those in residential character zones) would be 80% impervious, comprising 65% directly connected areas and 15% indirectly connected areas.

The adopted percentages are shown in Table 1.1.

Table 1.1 Adopted impervious area percentages

Land Use	Directly Connected Impervious (%)	Indirectly Connected Impervious (%)
Residential	65	15
Driveways /Carparks	100	0
Commercial and Industrial	85	5
Schools	20	18
Public Institutions	70	10
Road Reserves	100	0
Public Reserves	1	5

Times of concentration

Times of concentration were calculated for each sub-catchment by summing together gutter flow and roof to gutter times. Gutter flow times were determined based on:

- The length of the travel path to the pit from the furthest upstream point in the catchment; and
- The slope of the travel path.

Slopes were calculated from the DEM. Overland flow charts (IEAust, 1977) were utilised where runoff within a sub-catchment would not travel to a pit via a gutter. A time of five minutes was allowed for the roof to gutter time of concentration for residential housing whilst ten minutes was used for large commercial/industrial buildings.

The golf courses within the catchment were split into a number of sub-catchments around low points within each golf course. The maximum travel time to the low point was calculated and used as the time of concentration for each sub-catchment, with the inflow hydrograph being applied at the low point of each sub-catchment.

Rainfall estimation

Consistent with the previous investigations undertaken within the study area, the hydrological modelling for the West Lakes SMP uses 1987 patterns of rainfall, and 1987 Intensity Frequency Duration (IFD) depths.

The rainfall intensities were increased by 10% to account for projections of likely future climate change.

Loss model

Runoff was estimated using an Initial Loss – Continuing Loss model. This model supposes an initial catchment wetting phase which absorbs rainfall (the initial loss) followed by a continuing, steady infiltration of rain over the pervious areas for the remainder of the event (the continuing loss). The initial and continuing losses are surface type dependent. The adopted loss parameters are presented in Table 1.2. The values listed are consistent with those used for modelling a range of urban catchments across Adelaide.

Table 1.2 Loss parameters used for urban catchments

Parameter	Value
Directly connected impervious area initial loss	1 mm
Indirectly connected impervious area initial loss	1 mm
Pervious area initial loss	45 mm
Pervious area continuing loss	3 mm/hr

Hydrograph generation

Hydrographs were generated using the industry standard DRAINS model. For each AEP event storm durations ranging from 15 minutes to 24 hours were run.

The hydrographs were then exported and used as a key input in the TUFLOW model.

Hydraulic modelling

Hydraulic modelling uses the outputs of the hydrological modelling to determine the extent, depth and behaviour of floodwater. The resulting outputs provide an estimate of areas subject to flooding.

A detailed flood model was created for the study area, which included both one and two dimensional components. The model was run to simulate storm events within the study area and generate flood inundation maps.

The model includes the external catchments which were identified as likley to influence flooding within the study area (Port Road and a section of the Torrens East catchment as identified in Section 2 of the SMP).

Modelling software

The hydraulic modelling was carried out using the TUFLOW modelling software. The software simulates depth averaged, two-dimensional free surface flows such as those that occur during floods. TUFLOW has the ability to dynamically link to the ESTRY one-dimensional (1D) model (if needed), which enables the creation of models containing both 1D and 2D domains.

For this study the TUFLOW HPC solver has been used to solve the full 2D shallow water flow equations. The HPC solver is a fixed grid 2D hydrodynamic solver that uses an explicit finite volume solution scheme that is 2nd order in space and 4th order in time. The solution scheme includes viscosity and sub-grid turbulence terms that other solution schemes do not. Consequently, the HPC solver is well suited to reproducing accurate flood behaviour.

The HPC solver is designed for efficient computation using Graphics Processing Units (GPUs); substantially reducing simulation time. This is advantageous when running large numbers of simulations due to the number of temporal patterns, AEPs or climate scenarios being considered.

Digital elevation model

A digital elevation model (DEM) of the study area was prepared using data from LiDAR survey undertaken in early 2019. LiDAR is a remote sensing method that uses laser pulses to measure the distance to features in the terrain. The laser pulses are obtained and processed to create a 3D model of the landscape. Tonkin reviewed the DEM to ensure it was free of major errors.

The lake was assumed to have an invert of -2 mAHD in the absence of accurate lake bathymetry. This invert is based on the level of the outlet gates. The assumed invert will have no impact on projected flood levels as the initial water level determines the Lake's capacity to store stormwater runoff.

Model setup

Determining an appropriate cell size for the computation grid used by TUFLOW requires a compromise between the resolution of flood mapping and the simulation time and memory required to run the models. Smaller 2D cell sizes more accurately reproduce detailed topography and the hydraulic behaviour, but significantly increase the amount of memory and computational power required to run the model. An understanding of the specific requirements for each study is needed in order to select an appropriate 2D cell size.

A cell size of 4 m was adopted for the modelling. A review of the preliminary modelling results was undertaken to confirm that this cell size provides sufficient definition to adequately define the patterns of flooding within the study area.

The selection of an appropriate time step for the numerical solution scheme is critically important to the accuracy of the model output. Time steps that are too large may result in overestimation of the derivatives within the model which decreases the numerical accuracy of the computations. The choice of a smaller time step helps prevent numerical diffusion but increases the simulation time of models. An appropriate time step will balance simulation time with the model's stability and numerical accuracy.

For this study, use of the TUFLOW HPC solver meant that the timestep was adaptively selected by the solver as the simulation progressed.

Boundary and initial conditions

The adopted initial conditions and boundary conditions were the same as was used for the 2070 scenario that was modelled for the Western Adelaide Region Climate Adaptation Plan.

The downstream boundary condition at the outlet of West Lakes was set using a Mean High Water Springs tide cycle (based on recorded tide data) with a 0.5 m sea level rise added. Modelling of each flood event was undertaken such that the tide was timed to rise with the rising water level in the Lake system. This simulates the situation where the beginning of the main storm outflow coincides with the rise of the first high tide, a situation which is most likely to result in the highest flood level in the lake.

The initial water level in the lake was set to -0.34 mAHD. This was on the basis of water balance modelling that was undertaken as part of the Western Adelaide Region Climate Adaptation Plan.

The inflow hydrographs generated in DRAINS were applied at each inlet pit within the study area.

Surface Roughness

Within TUFLOW a land use (materials) layer is utilised to import surface roughness information into the model. A materials layer for the catchment was constructed by utilising cadastre data in conjunction with aerial photography. The following Manning's 'n' values were used:

- 0.2 (Houses/ residential areas);
- 0.3 (Medium density residential and commercial/industrial);
- 0.03 (Roads/ carparks);
- 0.035 (Grassed areas and bare ground);
- 0.045 (Parklands, scattered trees);
- 0.014 (Concrete lined open channels).

1D Drainage network preparation

The drainage network consists mostly of underground pipes and culverts with an open channel section along Grange Lakes.

The 1D network from the previous TUFLOW modelling was used as a basis for the West Lakes SMP model. During the model development phase, the pipe sizes and locations in the previously modelled network were compared to Council provided GIS data of the current stormwater network (conduits and inlet structures). The 1D network in the TUFLOW model was updated to reflect the information provided by Council.

Inlet pits were modelled using head-flow relationships to provide a good estimate of the inlet capacity of each pit. Different curves were created for single, double and triple side entry pits (SEPs) as well as 600×600 and 450×450 grated inlet pits (GIPs). This allowed the inflows to pass directly into the drainage network until the pit or pipe capacity was exceeded, with the excess spilling into the street network (2D floodplain).

Due to the broad scale objective of this flood study, no specific allowance has been made to account for pit blockages. Given that the capacity of the pipes is limiting across the study area, it is not considered that this will impact the results of the floodplain mapping and associated recommendations.

Limitations of the modelling

While every care has been taken with the preparation of the models and the choice of the adopted parameters, all hydrological and hydraulic modelling has an inherent level of uncertainty. This is due to a number of factors including the following:

- The accuracy and resolution of the DEM used and the interpretation of this information by the hydraulic model.
- Uncertainty in the rainfall pattern and catchment conditions prior to a flood. Actual flood events are dependent on the antecedent moisture conditions prior to rainfall, initial detention storage levels at the beginning of rainfall runoff and the intensity and uniformity of the rainfall event itself. The floods modelled by this study are based on design storm bursts which attempt to reproduce the expected average temporal pattern of a storm burst within specified rainfall zones (see AR&R for greater explanation). As such, individual rainfall events may exhibit a differing temporal pattern than those modelled.
- Estimation of input parameters to the model (such as runoff coefficients, times of concentration, Manning's roughness, entry and exit losses).
- Lack of gauging data available for calibration of the hydrologic and hydraulic models.
- Availability and quality of drainage infrastructure data.

The aforementioned limitations are considered typical of limitations associated with flood modelling and mapping, and in computer simulation of complex natural processes. It is not considered that these limitations will impact on the resultant flood mapping and recommendations for works.

Validation of the modelling

In the absence of recorded flow data to calibrate the model, the results of the initial floodplain mapping were compared with Council records of historical flooding complaints and Council staff’s knowledge of flooding ‘hotspots’. Reflecting the fact that the modelling considers an increased state of development relative to the existing catchment, the results of the modelling for the more frequent events (e.g. 0.5 EY) were considered.

In collaboration with Council, the modelling (in particular the pit and pipe network) was refined during the process of validation. The resultant floodplain maps are considered to provide an accurate representation of flooding issues within the catchment.

Floodplain map generation

During each model run, the peak flood depth and hazard category was recorded across the 2D model domain. Once modelling was complete, the results from each duration were spliced together to create a maximum depth and hazard envelope for each flood event.

Flood inundation and hazard maps were produced so that the impact of flooding could be visually analysed. The flood depth data was classified into discrete intervals to allow for easy discrimination of flood depths. Flooding less than 25 mm deep is not shown as it is not considered relevant to the wider flood map.

Appendix C – Flood inundation and hazard maps

Disclaimer

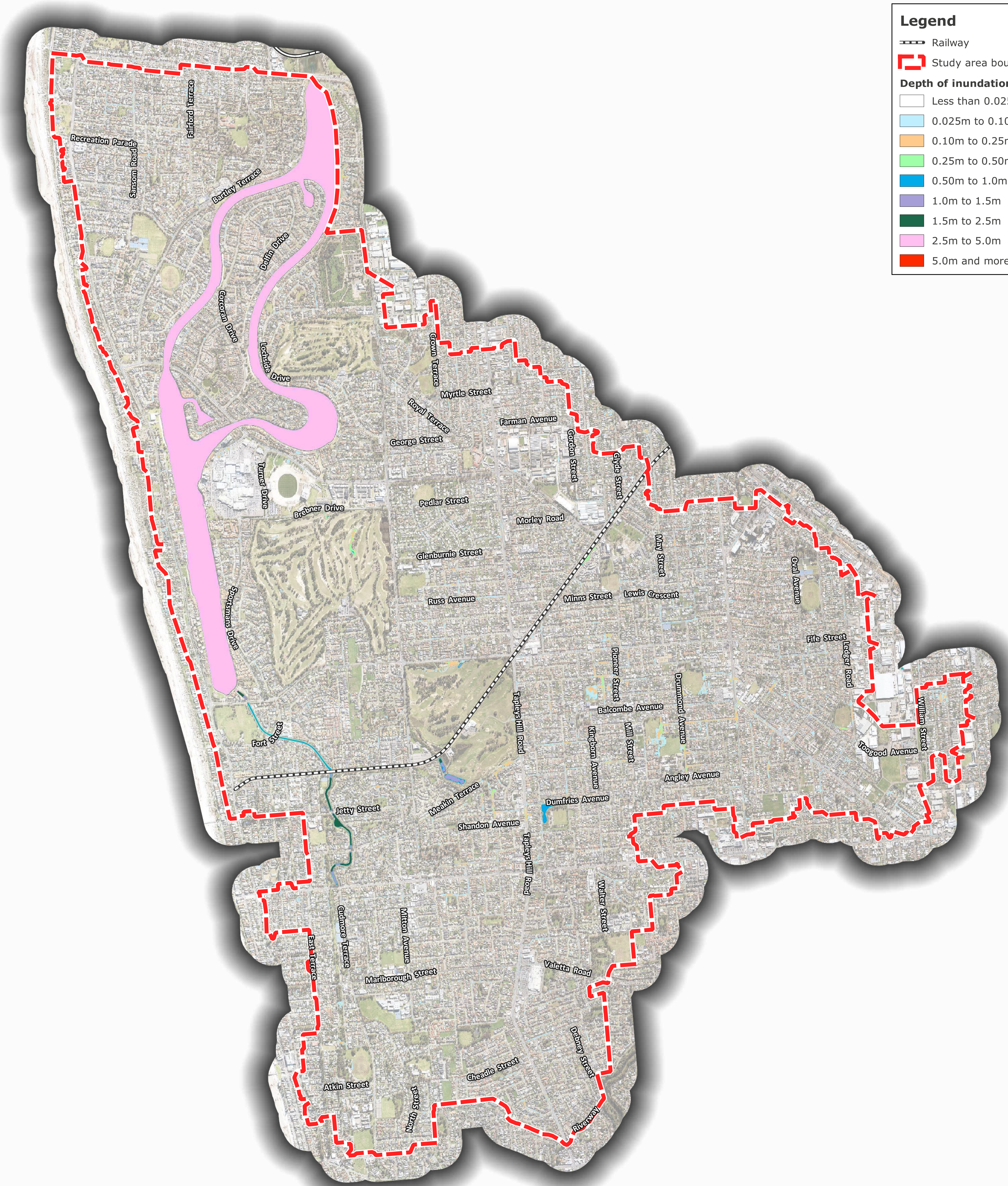
This map has been prepared to a standard of accuracy sufficient for broad scale flood risk management and planning. The flood extents are not based on actual historical floods. The map does not increase the risk or affect the level of flooding over an area or property. The limit of flooding shown on this map is not a boundary between flood prone and flood free land. Land outside the flood extent shown on this map could be affected by:

- Floods with a different Annual Exceedence Probability (AEP).
- Blockage in drainage systems, creeks or culverts caused by vegetation or other debris carried by floodwaters.
- Further development, earthworks and other changes to the catchment that alter the actual flood extents.

The flood extents shown are a prediction of land subject to a specific level of flood risk and do not necessarily indicate a threat to buildings located on that land. Confidence in the prediction is reduced in areas affected by flood depths less than 0.1 m, due to the effects of fences, walls, buildings and landscaping which affect the flow of floodwaters. Such effects, which require detailed modelling, are beyond the capabilities of the modelling process. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

This map is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damage alleged to be suffered by anyone as a result of the publication of the map, and the notations on it, or as a result of the use or misuse of the information provided herein.

More detail can be found in the report associated with this study.



Legend

- Railway
- Study area boundary

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 1,000 2,000 3,000 m

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Data Acknowledgement:
Aerial imagery from City of Charles Sturt, 2019
Roads and railways from Data SA, 2018

CITY OF CHARLES STURT

WEST LAKES STORMWATER MANAGEMENT PLAN
63% AEP FLOOD INUNDATION MAP
2070 DEVELOPMENT WITH CLIMATE CHANGE

Map 1

Disclaimer

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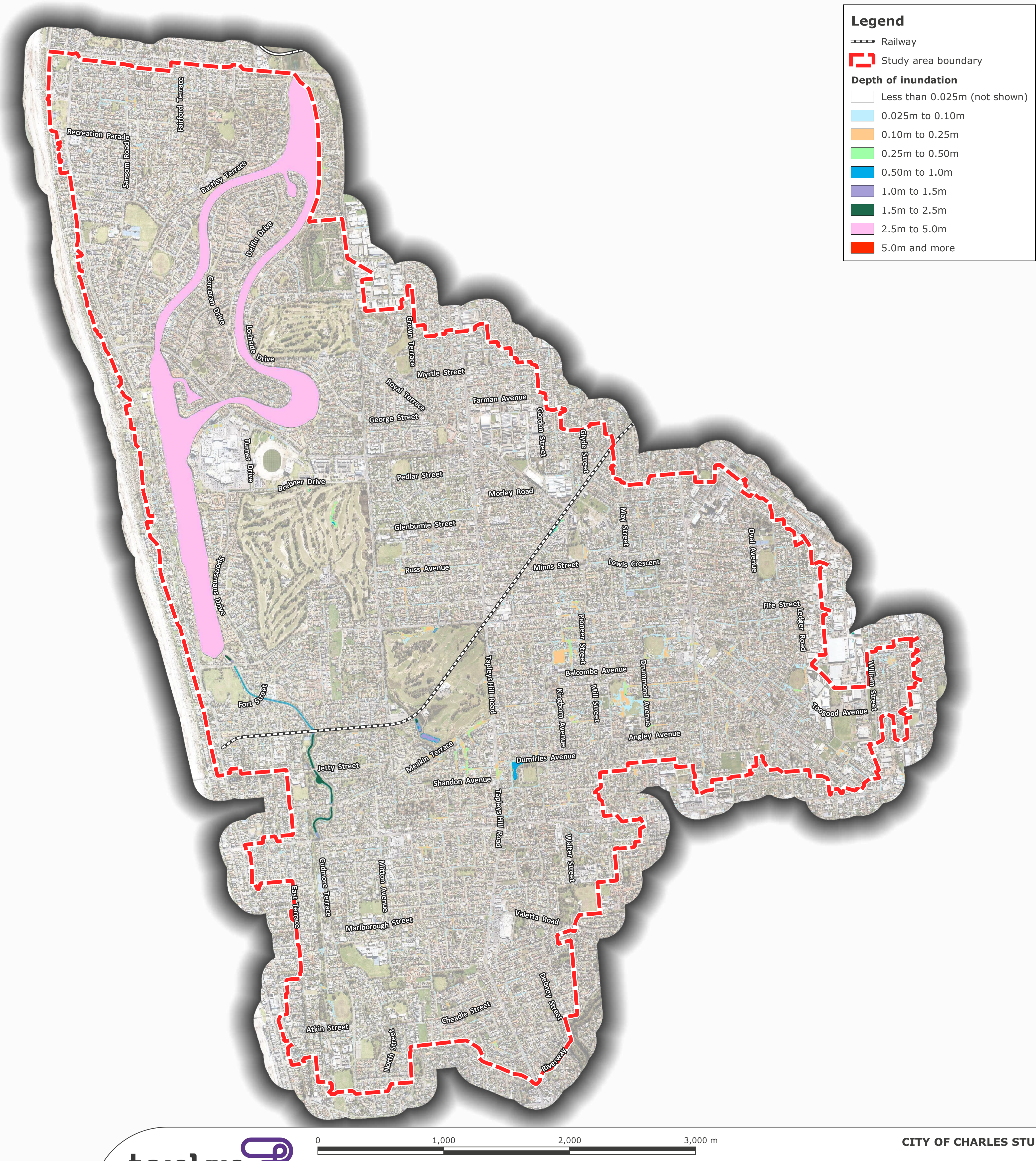

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Roads and railways from Data SA, 2018

CITY OF CHARLES STURT

WEST LAKES STORMWATER MANAGEMENT PLAN
39% AEP FLOOD INUNDATION MAP
2070 DEVELOPMENT WITH CLIMATE CHANGE

Map 2

Disclaimer

This map has been prepared to a standard of accuracy sufficient for broad scale flood risk management and planning. The flood extents are not based on actual historical floods. The map does not increase the risk or affect the level of flooding over an area or property. The limit of flooding shown on this map is not a boundary between flood prone and flood free land. Land outside the flood extent shown on this map could be affected by:

- Floods with a different Annual Exceedence Probability (AEP).
- Blockage in drainage systems, creeks or culverts caused by vegetation or other debris carried by floodwaters.
- Further development, earthworks and other changes to the catchment that alter the actual flood extents.

The flood extents shown are a prediction of land subject to a specific level of flood risk and do not necessarily indicate a threat to buildings located on that land. Confidence in the prediction is reduced in areas affected by flood depths less than 0.1 m, due to the effects of fences, walls, buildings and landscaping which affect the flow of floodwaters. Such effects, which require detailed modelling, are beyond the capabilities of the modelling process. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

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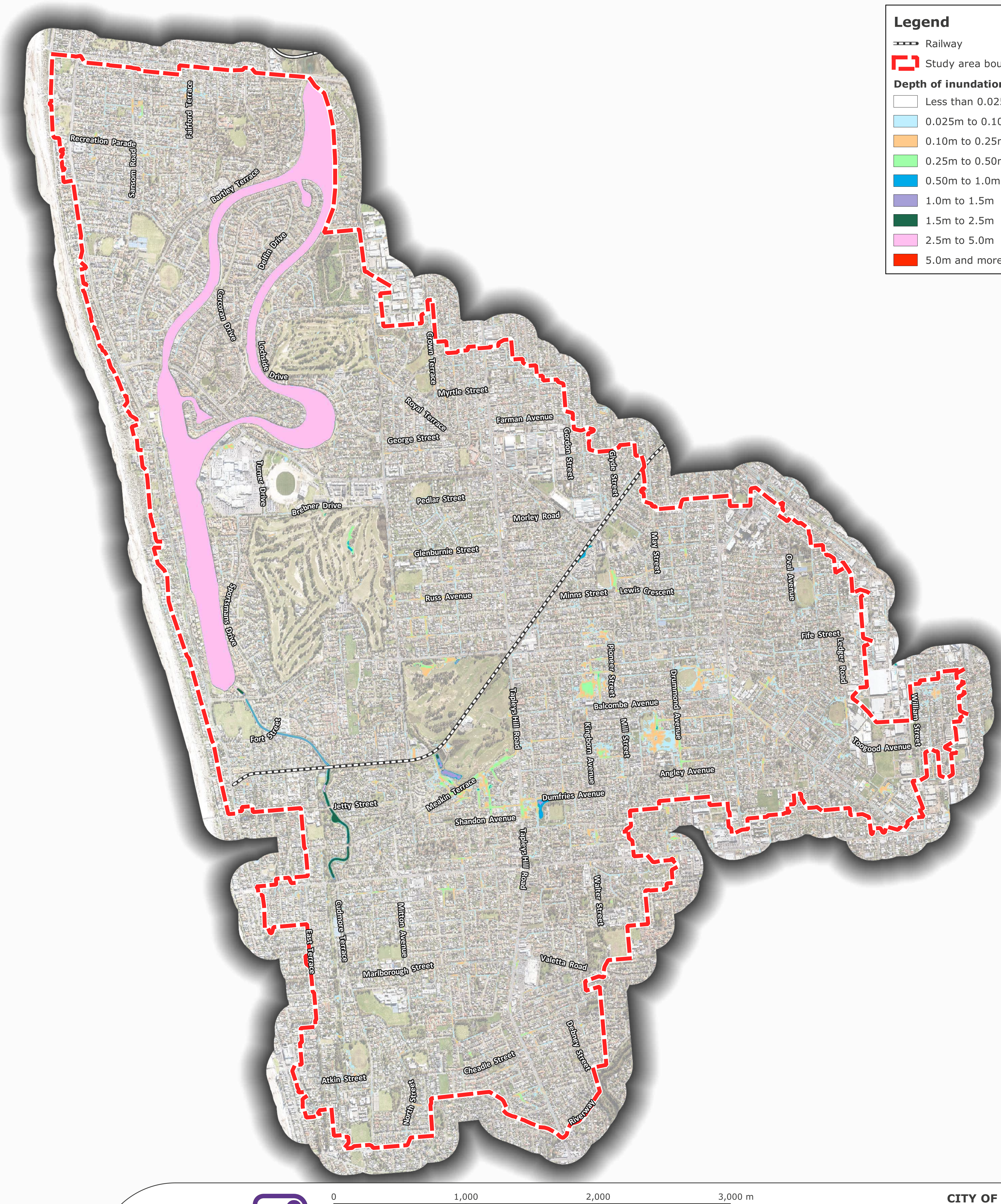

Legend

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- Study area boundary

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- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

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CITY OF CHARLES STURT

WEST LAKES STORMWATER MANAGEMENT PLAN
20% AEP FLOOD INUNDATION MAP
2070 DEVELOPMENT WITH CLIMATE CHANGE

Map 3