CONFIDENTIAL ORDINARY COUNCIL MEETING

Released 28 November 2018

CONFIDENTIAL MATTERS

Strategic Planning Committee

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COMMITTEE REPORTS

STRATEGIC PLANNING COMMITTEE

Confidential Matters

Released 28 November 2018

16.1 GAWLER RIVER FLOODPLAIN MANAGEMENT AUTHORITY

Contact Person: Mr Sam Green

Why is this matter confidential?

Subject to an order pursuant to Section 90 (3) (b) of the Local Government Act 1999, this matter is confidential because it identifies land that may or may not be required to be acquired in future. As a consequence if this information was released to the public it may cause undue distress to residents and communities, when final solutions may have significantly less impacts. In the correspondence from the Executive Officer of the Gawler River Floodplain Management Authority the request has been made to consider the report 'in the strictest of confidence'.

A. COUNCIL/COMMITTEE TO MOVE MOTION TO GO INTO CONFIDENCE

No action – This motion passed in the open section of the Agenda

B. THE BUSINESS MATTER

See Attachment No:
1. Mitigation Options Findings Report – ***Confidential***
2. Mitigation Options Findings Report & Liability CONSIDERATIONS - ***Confidential***

Why is this matter before the Council or Committee?

Matters which cannot be delegated to a Committee or Staff.

Purpose

The Gawler River Floodplain Management Authority (GRFMA) has written to each of the constituent Councils seeking their response on the draft Mitigation Options Findings Report. The GRFMA has requested that the report be considered in confidence because of the sensitive nature of the report as it identifies properties that may be impacted or acquired if proposed structural flood mitigation options were to be pursued.

STAFF RECOMMENDATION

Council endorses that the following should be considered by the Gawler River Floodplain Management Authority (GRFMA) in regard to the final Mitigation Options Finding Report and the subsequent next steps in the Business Plan for the GRFMA Board:

1. Council receives the GRFMA Mitigations Options Findings Report (Attachment 1).
2. The non-structural option of a Total Flood Warning system is supported and should be a high priority for development by the GRFMA.
3. The implementation of Planning Controls to manage future development is supported and should be managed by the respective constituent Councils of the Authority, having regard to the impact of the Total Flood Warning systems and structural mitigations options.
4. Council's supports the structural mitigation option to upgrade to the Bruce Eastick Dam.
5. Consideration of implementing levees to protect Virginia is to be undertaken within the context of the overall stormwater infrastructure priorities identified in the City of Playford's City-wide Stormwater Management Plan.

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6. That given the magnitude of cost of the structural works, the Board uses its best endeavors to seek funding from Federal and State Governments to a minimum of 80% of the value of the structural works.
7. That the GRFMA endeavor to establish a cost sharing arrangement for Councils to consider for the structural and non-structural solutions.

COMMITTEE RESOLUTION 2542

Council endorses that the following should be considered by the Gawler River Floodplain Management Authority (GRFMA) in regard to the final Mitigation Options Finding Report and the subsequent next steps in the Business Plan for the GRFMA Board:

1. **Council receives the GRFMA Mitigations Options Findings Report (Attachment 1).**
2. **The non-structural option of a Total Flood Warning system is supported and should be a high priority for development by the GRFMA.**
3. **The implementation of Planning requirements to manage future development is supported and should be managed by the respective constituent Councils of the Authority, having regard to the impact of the Total Flood Warning systems and structural mitigations options.**
4. **Council's supports the structural mitigation option to upgrade to the Bruce Eastick Dam subject to appropriate engineering considerations.**
5. **Consideration of the construction of levees would only be considered by Council within the context of the overall stormwater infrastructure priorities identified in the City of Playford's City-wide Stormwater Management Plan.**
6. **That given the magnitude of cost of the structural works, the Board uses its best endeavours to seek funding from Federal and State Governments to a minimum of 80% of the value of the structural works.**
7. **That the GRFMA endeavour to establish a cost sharing arrangement for Councils to consider for the structural and non-structural solutions.**

Relevance to Strategic Plan

Strategy 2. Securing Playford's future and building value
Outcome 2.1 Well planned and sustainable City

Relevance to Public Consultation Policy

Public consultation is not required on this issue under Council's Public Consultation Policy.

Background

Council has a role under the Local Government Act 1999 "*to take measures to protect its area from natural and other hazards and to mitigate the effects of such hazards*" and "*to provide infrastructure for its community and for development within its area (including infrastructure that helps to protect any part of the local or broader community from any hazard or other event, or that assists in the management of any area)*". These roles place an obligation on Council to manage stormwater and associated flooding risks.

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On the 15th March 2016 at a Closed Informal Gathering, Council received a presentation on "Managing the Risk of Flooding in the City of Playford". The presentation discussed the broad areas of focus in mitigating the risks of flooding, being:

- Prevention.
- Protection.
- Preparedness.
- Emergency Management.
- Recovery.

Council needs to consider all of the above mitigation options when managing stormwater and flooding within the City. The mitigation options are not independent of each other, but are complementary and may be in the form of non-structural measures, such as early warning systems and planning controls, or structural measures, such as stormwater management systems, levees and flood mitigation dams. For example, the risk of damages of flooding may be mitigated by planning controls via preventing development to occur in an area that is at risk of flooding, or alternatively, the construction of a flood mitigation dam may remove the risk of flooding, allowing development to occur in that area.

Council and the GRFMA have conducted significant investigations to identify the extent of flooding risks for the 3 key catchments in the City of Playford, being Smith Creek, Adams Creek and the Gawler River. Mitigation options have been identified by the GRFMA for the Gawler River, however, further work is required to understand the mitigation options for the Smith and Adams Creek catchments. The key issues identified in the current investigations are:

- Areas across the city are at risk of flooding and require mitigation.
- Development should be controlled in areas:
    - of medium to high risk of flooding.
    - that have no access during flooding ("islands").
- 'Total warning system' should be considered for Gawler River.
- Stormwater infrastructure upgrades are required across the city. The priority of implementation needs to defined and priorities through the City-wide Stormwater Management Plan.
- Levees and expansion of dam are an option to mitigate flooding from the Gawler River.

Council, through its Development Plan, currently controls development within medium to high risk areas of flooding and has some policies relating to access and egress from areas isolated due to flooding ("islands"). Prior to Council considering strengthening current Development Controls, the impact of other mitigation options should be explored, including the establishment of a "total warning system" and additional structural options for the Gawler River.

Council needs to determine the level of risk it is comfortable with and then determine the most appropriate mitigation option(s) to achieve the desired risk level. This paper deals with potential mitigation options proposed for the Gawler River, proposed by the Gawler River Flood Management Authority (GRFMA). The purposes identified in the charter of the GRFMA are:

- *to co-ordinate the construction, operation and maintenance of flood mitigation infrastructure for the Gawler River. This is the core business of the Authority;*
- *to raise finance for the purpose of developing, managing and operating and maintaining works approved by the Board; and*
- *to provide a forum for the discussion and consideration of topics relating to the Constituent Council's obligations and responsibilities in relation to the management of flood mitigation for the Gawler River.*

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Previous works carried out by the GRFMA included the construction of the Bruce Eastick Flood mitigation dam located on the North Para River and modifications to the spillway of the SA Water Reservoir located on the South Para River. The construction of these flood mitigation works aimed to reduce the combination of these flows at their junction, being the Gawler River located within the Town of Gawler. The aim of these works was to integral in the total solution of achieving a 100yr standard of protection for the Gawler River Floodplain. However, subsequent analysis of the estimation of the quantum of the flow expected in the 100yr event identified that the construction of this infrastructure only achieved a flood protection standard in the order of a 40yr standard in the upper reaches.

Part of the original strategy of flood mitigation works in the lower parts of the catchment (Virginia, Angle Vale, Lewiston and Two Wells) proposed the construction of levee banks. The construction of levees was seen as a cost effective way of managing the floodwaters spilling from the Gawler River in the lower reaches of the catchment. These works were not implemented once the GRFMA was made aware of the revised estimate of the 100yr flows in the catchment. The GRFMA within its Business Plan decided that further investigation and revision of the original strategy of flood mitigation works was required. Accordingly the GRFMA have now completed investigations to determine options of improving the flood management of Gawler River.

The key elements of the investigations were;

- to assess whether the 100yr level of flood protection was applicable for the catchment;
- to review the flood hydrology (estimate of the 100yr flow), given that an additional 10 years of flow data is available from the previous assessment; and
- to consider structural and non-structural options of flood management.

The full report is attached to this report. A summary of the key outcomes and an assessment of the findings are presented below.

<u>Review of the 100yr standard of protection</u>

A review was carried out nationally and internationally of the standard of protection for new developments and there was a high level of consistency with adopting a 1 in 100yr level of protection. A lower level of protection for new developments would be difficult to justify, however for existing areas a lower level may be justified through a cost / safety / benefit optimisation process, that is, identifying what the community can realistically afford.

<u>Review of the flood hydrology</u>

With the additional 10 years of flow data that is available since the last review, the updated analysis of the peak flow has resulted in a new 100yr estimate slightly lower than previous (635 cubic metres per second rather than 643 cubic metres per second). Future estimates will be based upon the additional years of data and the flow events that are experienced during that time. In essence, the more history and information that is available on the flows, the more statistically confident we can be about estimating what may be a 100year flow.

<u>Review of structural and non-structural options of flood management</u>

The objective of the study was to examine what measures could be put in place to improve the safety of the community, build their resilience to flood events and reduce potential future flood damages.

In assessing the options, a range of considerations were made against each structural and non-structural option to determine their effectiveness under a range of performance, social, economic and environmental criteria. The following is a ranked list of the structural and non-structural mitigation options.

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Rank	Mitigation Option
1	Total Flood Warning
2	Planning
3	Mitigation Dam
4 equal	Strategic Levees
4 equal	Composite (Partial Dam and Levees)
6	Do Nothing
7	Floodway / Channel Works

Analysis of Issues

Commentary on the mitigation options and their respective ranking

The non-structural options are identified as the recommended option for implementation. The reason behind this is quite simple - they are generally a low cost option and provide opportunities to inform the community who live on a floodplain how best to manage their own safety and minimise damages in the event of a flooding event. A flood warning system would provide this and would be expected to be carried out across a catchment, if not on a regional basis. A potential method of delivering this would be through the existing frameworks such as SAFECOM and the zone emergency management for the regions.

The Planning option is also identified as it looks to manage any new development proposed within the floodplain area with the aim of not creating any additional risk to public safety or damages caused by inappropriate development. Planning controls are subject to changes in the hazards associated with floodplains and will change in future, especially with the advent of structural measures that significantly reduce flood hazards to a level where the risks of development are well within the bounds of industry practice. For example, if a suitable solution could be found to reduce the hazard of the current eastern-most flow path from the Gawler River that heads toward the Virginia town centre, then proposed planning controls could be relaxed.

Strengthening of Planning controls also need to consider the impact of the effectiveness of the early warning system. Council has received additional advice on planning controls from AWE, above and beyond that provided by the GRFMA. The advice indicated that Council should strengthen the planning policy in areas that become isolated “islands” during a flood event. This recommendation is to reduce the risk associated with traveling through flood waters. The implementation of an early warning system may enable the safe evacuation of the “islands”, minimising the risk to the community, while still allowing development to occur in these areas.

The upgrade of the Bruce Eastick dam is identified as the next ranked option. Its affect is to significantly reduce the risk of flooding to properties and dwellings, particularly in the area of Lewiston in the District Council of Mallala. The risk to Virginia is unchanged to that of the current situation, however, there is a reduction of flooding of horticulture land to the east of the railway line.

The investigations have considered the construction of strategic levees to manage the location and extent of flooding, in particular, protecting the township of Virginia. It is acknowledged that levees are not the most resilient mechanism to manage break-out flows from the Gawler River as there will always be a small risk of failure either structurally, or by overtopping in a larger event. In managing the location and extent of flooding there is the potential for a marginal increase in flood depths in the areas that receive the re-directed flows. It is acknowledged that the alternative of construction of a channel and culverts at key transport infrastructure (Port Wakefield road and rail) are quite costly, especially if major land acquisition is required for the channel.

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In considering the use of strategic levees, it is suggested that analysis of other potential flooding areas within the City of Playford is conducted prior to determining the relative priority of installing levees in the Virginia area.

The 'do nothing' option is not considered appropriate as an option. Outcomes of the enquiries into the 2011 and 2012 floods in Queensland and Victoria clearly identify that a 'do nothing' approach is not an option.

The floodway channel option identified to cater for the major spill north of the River that heads though Lewiston to Gawler is agreed to be unrealistic in managing the quantum of flow anticipated and the rank is appropriate. However, as identified earlier the combination of flow channels and levees for the southern break-out that flows toward Virginia should be considered as part of the next analysis step in the determination of this option.

Costs and Funding

The report does provide indicative costs for the options outlined above, but is silent on the funding mechanisms required to achieve the mitigation options listed. Whilst the GRFMA has asked constituent Councils to comment only upon the findings report, it is considered that commentary should be provided on the funding mechanisms and the potential financial implications in delivering / administering the options presented.

For the non-structural options, planning controls are administered generally by Councils and given the history of developing planning policy relating to the floodplain it has been accepted that this is borne by the respective Council. The Total Flood warning system could be considered as being shared between the constituent Councils on the basis of the administration cost share arrangements with funding sought from State Government in the set up and delivery of this program.

The costs of the structural options are significant and beyond the financial capacity of the constituent Councils to deliver such work without funding from the State or Federal Governments. It is suggested to inform the GRFMA that for the delivery of such a capitally significant program that the target of funding proportion that should be sought from the other levels of Government should be at least 80% of the cost of the works. This proportion is similar to that achieved in the funding of the capital works of the Bruce Eastick flood mitigation dam and the spillway improvements.

It is also acknowledged that discussion needs to occur through the GRFMA Board on potential cost sharing arrangements on the balance (20% funding) for the delivery of the structural options presented. Proposals for the cost sharing arrangements between constituent Councils should then be presented to those Councils for their subsequent consideration.

General

The consideration of the Mitigation Options Findings Report by constituent Councils needs to consider the commentary / recommendations provided by those Councils in ensuring that the process of determining the most effective way of delivering flood protection to the community continues. Whilst the findings report will most likely raise concerns of some Councils in their ability or willingness to financially contribute to further flood mitigation options, nevertheless the process of seeking funding and determining cost share arrangements between Councils should occur if funding is achieved from State and Federal Governments.

The GRFMA has provided legal advice regarding the risks to the constituent Councils and the GRFMA if no action is taken (Attachment 2).

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Options

Option 1

Council endorses that the following should be considered by the Gawler River Floodplain Management Authority (GRFMA) in regard to the final Mitigation Options Finding Report and the subsequent next steps in the Business Plan for the GRFMA Board:

1. Council receives the GRFMA Mitigations Options Findings Report (Attachment 1).
2. The non-structural option of a Total Flood Warning system is supported and should be a high priority for development by the GRFMA.
3. The implementation of Planning Controls to manage future development is supported and should be managed by the respective constituent Councils of the Authority, having regard to the impact of the Total Flood Warning systems and structural mitigations options.
4. Council's supports the structural mitigation option to upgrade to the Bruce Eastick Dam.
5. Consideration of implementing levees to protect Virginia is to be undertaken within the context of the overall stormwater infrastructure priorities identified in the City of Playford's City-wide Stormwater Management Plan.
6. That given the magnitude of cost of the structural works, the Board uses its best endeavors to seek funding from Federal and State Governments to a minimum of 80% of the value of the structural works.
7. That the GRFMA endeavor to establish a cost sharing arrangement for Councils to consider for the structural and non-structural solutions.

Option 2

Council endorses that the following should be considered by the Gawler River Floodplain Management Authority in regard to the finalisation of the Draft Mitigation Options Finding Report and the subsequent next steps in the Business Plan for the GRFMA Board:

1. ___________________________
2. ___________________________
3. ___________________________

Analysis of Options

Option 1

This option generally supports the findings contained within the Mitigations Options Findings Report developed by the GRFMA and recommends a logical process to increase flood awareness and resilience of the community whilst endeavouring to find a cost effective structural solution with least impact upon the community. The recommendations put forward by this Council will inform the GRFMA Board in its deliberations on the finalisation of the Findings Report. The intention of each of the points identified in the recommendation and likely next steps is as follows:

1. The non-structural option of a Total Flood Warning system is supported and should be a high priority.
   It is suggested to the GRFMA Board that the Total Flood Warning System should be investigated and developed by the Board in partnership with key lead State Agencies that are responsible for flood disaster. It would be likely that the Barossa and Northern Adelaide Zone Emergency Management Committees would also be involved in the development and adoption of this process. It would be expected that the Board would seek funding from these State Agencies in the development and on-going management of the scheme.

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2. The implementation of Planning Controls to manage future development is supported and should be managed by the respective constituent Councils of the Authority, having regard to the impact of the Total Flood Warning systems and structural mitigations options.
   It is expected that the GRFMA Board will provide up to date information to Councils on the flood depth and flood hazard mapping for the Gawler River so that the constituent Councils can update their respective Development Plans. Council will need to consider the appropriate level of risk within the flood prone areas and the potential impact that the Total Flood Warning System has on reducing that risk, especially associated with access and egress from areas isolated by flooding.

3. That preference for the structural option should be an upgrade Bruce Eastick Dam
   The Mitigation Options Report has identified that the Bruce Eastick Dam can be upgraded, and that the proposed update significantly improves the level of protection downstream, especially for Lewiston and Two Wells. The expanded dam would also reduce the impact of flooding in the horticultural areas in the Virginia Triangle, east of the railway line and eliminate the number of "islands" in this area. The upgraded dam will not change the impact on the township of Virginia.

4. Consideration of levees to protect Virginia
   Council is about to commence a City-wide Stormwater Management Plan, on the completion of flood mapping of the major catchments within the City. The Plan will identify all the potential flooding risks within the City, determine appropriate mitigation options to reduce the risk of flooding and associated costing and priorities the implementation of the mitigation options. The implementation of levees to protect the Virginia should be considered in terms of all of the risks within the City and relative priorities and return on investment in reduced flooding damages.

5. That given the magnitude of cost of the structural works, the Board use its best endeavors to seek funding from Federal and State Governments to a minimum of 80% of the value of the structural works.
   The previous structural works on the Gawler River were significantly funded from State and Federal Governments. The approximate percentage of this funding was 80% of the value of the capital works. It is proposed that the GRFMA Board seek this level of funding again, given the inability of the constituent Councils to raise such funds.

6. That the GRFMA endeavor to establish a cost sharing arrangement for Councils to consider for the structural and non-structural solutions.
   Previously the GRFMA decided upon a cost sharing arrangement for the construction of the Bruce Eastick Flood mitigation dam and the spillway modifications. The cost sharing percentages were only for those items. A new cost sharing arrangement needs to be developed for the solutions proposed within the findings Report.

<u>Option 2</u>

Any option suggested by Council would need to be mindful of the purpose of the GRFMA and the responsibility of constituent Councils for management of the Gawler River Floodplain. This may include reprioritising the suggested mitigation options and propose alternative funding arrangements.

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Financial Implications

The study identifies various options that may be implemented. Any consideration by the Board of the GRFMA of strategies or works to be implemented will require consideration by the constituent Councils of the funding source and apportionment.

The will be required to be identified in the GRFMA's next iteration of its 3year Business Plan in 2016 / 2017.

Preferred Options and Justification

Option 1 as outlined above is preferred. The Background and Analysis of Issues section of this report has outlined a risk based assessment of the options available to the GRFMA and its constituent Councils.

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Gawler River Floodplain Management Authority

A Findings Report for the Gawler River Flood Mitigation Scheme

MITIGATION OPTIONS FINDINGS

FINAL

March 2016

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1 Executive Summary

The following points summarise the key findings from the investigation of updated hydrology and floodplain mapping for the Gawler River.

Locality

The Gawler River system comprises the North Para and South Para which join at Gawler to form the Gawler River. The catchment is over 1000km^2 and extends from Mount Adam to the sea at Port Gawler.

Hydrology Update

There have been some significant changes to the catchment since 2007 with major developments being approved and upgrades to council infrastructure. There has also been nearly ten years of additional data collection that has been used here in to improve the reliability of the flood estimates. This promoted a review of the flood hydrology.

The hydrology review and update has resulted in a minor reduction in peak flow estimates for the Gawler River. The peak flow at Gawler Junction during a 1 in 100 ARI event is now estimated to be 635 m^3s^{-1}.

The review has demonstrated that a shorter duration storm event should be used as the design flood event. This effectively reduces the volume of flood waters that need to be managed.

The North Para River remains the primary focal point for managing major flood flows.

Floodplain Modelling and Mapping

The base Mike Flood model has been updated to incorporate major changes in the landscape of the Gawler River floodplain. The model has also been refined to further improve its representation of culverts and the major railway lines traversing the floodplain. The flood extents remain similar but slightly less than for the 2007 mapping. A small area of Angle Vale township is no longer considered to be at risk of flooding from the Gawler River during a 1 in 100 ARI flood event.

Desired Level of Flood Protection

The 1 in 100 ARI event is considered to be the minimum desirable level of flood protection for new development as well as for much of the existing floodplain development. In cases where the failure mechanism may be sudden (e.g. failure of a levee), a higher level of protection should be considered especially for new developments.

Flood Damages

The present value of potential flood damages from a 1 in 100 ARI flood has been estimated to be $182 million. The Average Annual Damages from flooding is estimated to be $7.40 million. The Present Value of these Average Annual Damages (calculated over a 30 year timeframe @ 7% discount rate) is $109 million.

Public Safety

Over three thousand residential properties are at risk of flooding with a flood hazard rating of medium or higher in a 1 in 100 ARI flood event. A further 1600 properties are likely to incur nuisance but low hazard flooding.

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Flood Mitigation Measures

Non structural measures such as a total flood warning system and more effective and consistent planning measures to manage new development are the most cost effective mitigation options. Both provide no regrets approaches and should be actioned immediately.

Two structural flood mitigation strategies are considered to be practical and cost effective means to reduce the flood damages and public safety exposure. Of these, a enlarging the existing Bruce Eastick North Para Flood Mitigation Dam on the North Para offers the greatest level of protection with least impacts and is rated as the most favoured structural mitigation option.

Strategic levees to protect Two Wells, Gawler and Virginia are an alternative, less costly (but less effective) structural flood mitigation solution.

Given that enlarging the Bruce Eastick North Para Flood Mitigation Dam is the most effective structural solution for addressing flooding issues downstream, a structural feasibility assessment for the best method of raising the dam wall is required to confirm technical feasibility and further refine cost estimates for enlarging the dam.

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2 Introduction

Flooding of the Northern Adelaide Plains associated with the Gawler River is a significant constraint for further development within the region and an ongoing risk to existing development.

The Gawler River Floodplain Management Authority (GRFMA) has commenced this project to further review the available flood mitigation options (both structural and non-structural), in particular the potential for a second and/or further flood control dams. Whilst previous investigations have reviewed potential dam locations, this was mostly done prior to the hydrology review and floodplain mapping of 2007.

This working paper outlines the flood mitigation options that have been considered as well as those that offer the greatest potential.

The analysis is supported by the hydrology review work which is separately reported in detail in AWE (2014), the results of which are summarised herein. The project has also included an update to the 2007 floodplain mapping to incorporate outcomes from the hydrology review as well as to reflect changes in the catchment that have taken place since 2007.

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3 Overview of Flooding Issues

3.1 Flooding Behaviour

Floods in the Gawler River are driven by flows from the upstream rural catchments of both the North Para and the South Para. These two river systems join immediately downstream of the town of Gawler. The catchment upstream of Gawler is a little over 1000 km^2 with the North Para catchment being the larger of the two main inflows comprising nearly 600 km^2.

The Gawler River itself is a perched river system and hence receives very little inflow from the land through which it flows on its way to the sea near Port Gawler.

The capacity of the Gawler River channel falls from east to west and varies also with the dynamics of the flood hydrograph. This characteristic is consistent with a naturally perched river system. Near Gawler the capacity of the river is around 400 m^3s^{-1}. This rapidly diminishes to the west. Near Boundary Road it is 200 m^3s^{-1}; Baker Road Ford 100 m^3s^{-1}; and down to 10 m^3s^{-1} immediately upstream of Buckland Park Lake.

Major overtopping in large floods occurs along much of the river length. Significant flooding commences within Gawler township from both the North and South Para. Mitigation works within Gawler and works associated with Mark 1 of the Gawler River Flood Management Project (which involved constructing the Bruce Eastick North Para Flood Mitigation Dam on the North Para and modifications to the South Para Reservoir) have reduced the extent of this flooding for a 1 in 50 ARI event whilst eliminating major flooding for events around the 1 in 20 ARI and less. Flooding at the 1 in 100 ARI event is largely unaltered by the works undertaken to date. However flooding from the 1 in 20 ARI still occurs in the lower reaches of the Gawler River (west of Virginia) due to the limited capacity in this area.

In a 1 in 100 ARI event, flooding within the township of Gawler can be expected but this would be contained within the main river valley. Downstream of Gawler flood waters can be expected to break out of the river channel shortly downstream of the Northern Expressway river crossing. Floodwaters upstream of the river crossing are contained within the river channel and levee system recently installed as part of the Northern Expressway bridge crossing.

Downstream of the Northern Expressway river crossing, a series of major breakouts can be expected to Boundary Road. The majority of the floodwaters would spill to the north from this area (approximately two thirds of the flood) and result in flooding of Lewiston before reaching Two Wells. As the flood waters approach Two Wells they would enter Salt Creek and cause flooding in the Two Wells township.

Further but smaller breakouts would occur downstream of Boundary Road. The worst of these would be adjacent to Pederick Road where flood waters would spill to the north and south of the river. Spills to the north would flow westwards (approximately parallel to the river) towards Port Gawler. Over bank flow to the south would flow towards and through Virginia township and surrounding horticultural areas, then flow further west, overtopping the Port Wakefield Road before flowing around the Buckland Park housing development (once it has been established) to the sea.

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3.2 Results of Hydrology Review

A review of the hydrological analysis of the Gawler River for the 2007 floodplain mapping study was undertaken.

The review identified the following:

- There was an additional eight years of flow data (2006-2013) available for the Gawler River system. However, due to system augmentations (Bruce Eastick North Para Flood Mitigation Dam and South Para Spillway modification) only Yaldara, Penrice and South Para flow monitoring stations were able to have the data record extended to review the flood frequency analysis.
- The flood frequency analysis showed little change from the 2007 peak flow results for the North Para with both Penrice and Yaldara seeing a minor reduction in the estimated 1 in 100 ARI flow (approximately 7% at Penrice and <1% at Yaldara).
- The flood frequency analysis for the South Para indicated a significant reduction from the 2007 peak flow results. The 1 in 100 ARI flow is now estimated to be 158 m^3s^{-1} in comparison to the previous estimate of 215 m^3s^{-1} (refer Hydrology Report, AWE 2014). This is simply because additional flow recordings over the last ten years have enabled a more reliable flood frequency analysis to be undertaken.
- It was not possible to update the flood frequency relationships at Gawler Junction because the gauge has been decommissioned. However, given the reduction in peak flow estimates for both the North and South Para upstream it is likely that a revised peak flow estimate at Gawler Junction would be less than the 2007 estimate.
- Comparison of flood volumes from historical data was compared against the RRR model hydrograph volumes. This indicated that the 24 hour design storm provided the best match for flood volumes at Yaldara and Gawler Junction with all volumes within 15% at Gawler Junction and 20% at Yaldara. Longer duration storms would result in substantially higher volumes and increase the discrepancy between modelled results and the flood frequency analysis.
- The 24 hour design storm provides a good match (all stations for all ARI events within 17%) with the flood frequency analysis peak flows for a range of ARI events and is considered to provide the best overall match to observed floods. Hence it should be adopted as the design storm.
- The new IFD data from the update to Australian Rainfall and Runoff was checked against the intensity values adopted in the 2007 hydrology. Generally the differences were within 5% except for Mount Adam where there was a maximum difference of 13.8% for the 1 in 100 ARI storm event. There is no need to update the intensity values in for the design storms as the parameter selection was based on flood frequency analysis. Any increase to intensity would be counteracted by a change to the loss model parameters.
- Soil properties for the Greenock Creek catchment were reviewed and the findings generally supported two different flood producing mechanisms (medium intensity on wet winter catchments, or more intense summer rainfall on a dry catchment). This supported the variable loss model for the part of the catchment covered by the Yaldara loss model, including the Greenock Creek catchment.

Flood hydrographs for the North Para, South Para and the Gawler River near Gawler are provided in Figure 3-1.

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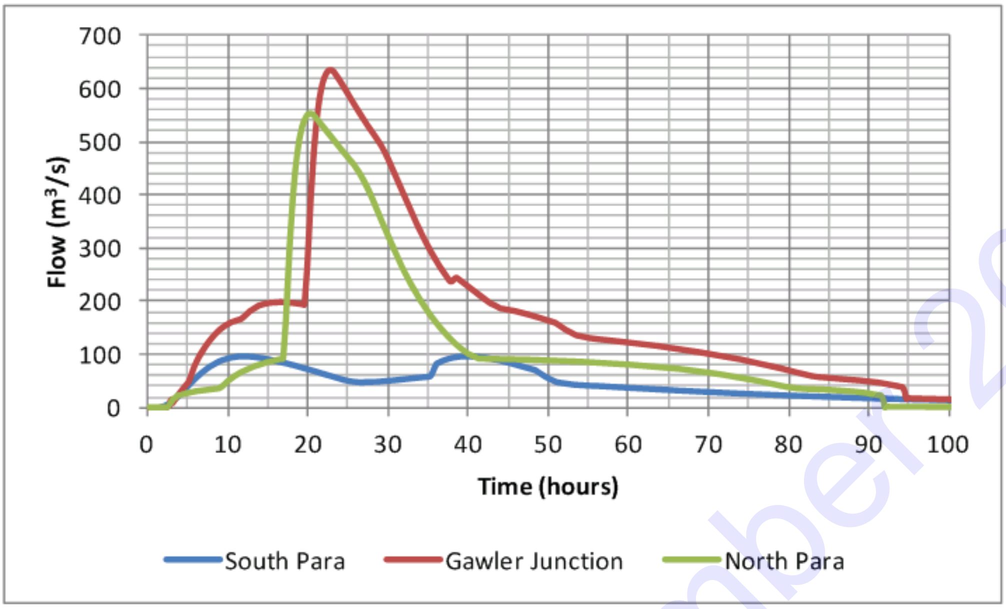

FIGURE 3-1 : NORTH PARA, SOUTH PARA AND GAWLER RIVER DESIGN HYDROGRAPHS - 1 IN 100 ARI

3.3 Floodplain Hydraulic Model Update

3.3.1 Introduction

The original floodplain model was developed as a 2D MIKE21 hydraulic model. For this update project, additional one-dimensional floodplain features such as culverts were included in the model and therefore a coupled 1D-2D MIKE FLOOD model was developed. The river and floodplain flow was represented in the 2D model grid and culverts were represented as 1D model elements, linked to the 2D model at their upstream and downstream end.

3.3.2 Model Resolution

The resolution for the updated hydraulic model was maintained at 15m as was used for the original Gawler River modelling, modelling of the adjacent Light River floodplain and Smith Creek rural areas modelling.

The model grid was extended to the west to incorporate breakout flow paths through Two Wells and toward Middle Beach. The grid was also shifted slightly in order to match up with the 15m Light River model DEM which enabled the Light River DEM data to be incorporated.

The topography was built up in layers, from older to newer datasets, as summarised in Table 1.

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TABLE 1 : MIKE FLOOD TOPOGRAPHY LAYERS

Layer	Dataset	Details
1 (Bottom)	Gawler River LiDAR (1m)	Grid shift issues in the original Gawler model and an inconsistency in grid origins between the Gawler River and Light River models were addressed by reverting back to the 1m LiDAR DEM and re-sampling a 15 m DEM on the same grid as the Light River model. The Bruce North Para Flood Mitigation Dam was removed from the topography as it was close to the upstream boundary. The effect of this dam will be captured in the hydrological assessment. The Northern Expressway and basins north of river were included within the model. Details from the old Gawler model were updated to include as constructed information for the basins and associated levee (on the southern side of he river).
2	Light River model DEM (15m)	Used as is, except at boundaries – boundaries clipped out of grid.
3	Smith Creek DTM (1m)	Used as is.
4	Buckland Park Ultimate	The Buckland Park ultimate DEM had fill areas raised to a flood-free level and approximate channel details.
5	Buckland Park Stage 1	Actual fill levels and final channel designs for Stage 1 were superimposed on the ultimate design to give better detail in the stage 1 area.
6	SA Greyhound Club Redevelopment	Design levels for tracks and building floors and existing site levels were combined to produce a DEM of developed conditions.
7	Eden Development Two Wells	Fill areas and channels/basins were included directly in the M21 grid. Fill areas were raised to 12.9 m which is the design fill level for the eastern edge of the development. This is well above the 200 year flood level for the site so further detail was not required.
8	Liberty Development Two Wells	Fill areas and channels/basins were included directly in the M21 grid. Fill areas were raised to 10.6 m which is the design fill level for the eastern edge of the development. This is well above the 200 year flood level for the site so further detail was not required.
9	Donaldson Road Development Two Wells	Areas to be filled and the basin were included in the M21 grid as per the Proposed Land Division plans. Roads were raised to 11.8-12.2 m AHD as per the plans.
10	Gullacci Development Two Wells	As constructed levels were converted to a grid and stamped into the model. However level information was not available across the entire development. Manipulation of the Mike 21 grid was undertaken to ensure all fill areas were included.
11	Gawler River Road	Levels were adjusted to as constructed levels which were available for a section of the road.
12	Gawler Skate Park	DEM generated from design contours and strings.
14	Hillier Development	Fill area raised in M21 grid above flood level. Reserve area lowered to 41.2 m AHD.
15	Gawler Par 3 Golf Course Levee	Levee alignment and heights were digitised from plans and added to the grid.

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Layer	Dataset	Details
16	Gawler Footbridges	Proposed footbridges were incorporated over the Gawler River and its tributaries. These footbridges are part of the planned *Gawler Urban Rivers Shared Path*. Four of the key footbridges were incorporated into the model as 1D elements, with the deck height added to the 2D grid.
17	Northern Expressway Levee Survey	Survey of the Northern Expressway levee was incorporated into the model. This levee aims at stopping breakout flows to the south of Gawler River and is located upstream of the recently constructed Northern Expressway. The levee crest was incorporated in the 2d model topography.
18	Northern Expressway Survey	Survey of the recently upgraded Northern Expressway crossing of the Gawler River was incorporated into the 2d model. This also includes surrounding detention basins and earthworks.
19 (Top)	Breaklines and Channel	Breaklines from existing models were collated and stamped onto the grid. Road/levee embankments were treated by sampling the maximum level within 15m of the breakline and applying that maximum level to the grid. Railway embankments were treated similarly, but the embankments were lowered in places to account for wash-out of ballast when overtopping occurs. The Salt Creek crossing in two Wells was lowered as per the original Light River modelling. The Gawler and South Para crossings in Gawler township were lowered by approximately 0.2m. The rail lines elsewhere were not lowered. The Gawler River channel definition from the original Gawler model was stamped into the model grid. The Smith Creek channel was also stamped onto the grid.

3.3.3 Culverts

Culverts were adopted from design drawings and the previous Light River and Smith Creek models. All culverts were transferred from the Light River model, whereas culverts were selectively transferred from the Smith Creek model. This was because the Smith Creek model contained minor drainage pipes as well as major culverts. Minor culverts were not included in this model as the 15m grid spacing is too coarse to include minor culverts. Priority was given to including culverts through major embankments such as the rail line, Port Wakefield Road and the Northern Expressway. Culverts were also given priority if they were considered to be in an area where significant flow may occur.

A number of additional culverts were identified that were considered likely to impact on flow behaviour in large floods, but which had not previously been included in the models. These were surveyed by Australian Water Environments and included in the current model.

The four proposed footbridges from the planned Gawler Urban Rivers Shared Path were also included as 1D elements.

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A number of bridge span openings were not included as 1D elements but were included as openings in the 2D grid, particularly for major bridge crossings of the Gawler River and some large floodplain culverts and bridge spans, where the structure width was greater than 15m and the culverts/bridge openings were unlikely to flow full.

A total of 111 bridge/culvert crossings were included in the model. The Light River culverts and most of the Smith Creek culverts were previously benchmarked against an independent method (HY-8 culvert calculator) and entry/exit loss coefficients were adjusted as necessary. MIKE 11 default entry/exit loss coefficients were adopted for the remaining culverts. A map of culverts included in the model is provided in Appendix A.

Railway lines (near Virginia and Gawler) were included in the model as earthen embanks, however it was assumed that the ballast would not be an effective barrier to flow (ie the ballast would become buoyant and displaced if water levels reached the underside of the railway sleeper). This approach was consistent with recent floodplain mapping for the Light River and reflects a further refinement on the modelling approach that was applied for the 2007 Gawler River floodplain mapping process.

3.3.4 Model Boundary Assumptions

Inflow boundaries were applied for the North Para and South Para upstream of Gawler. These hydrographs were extracted from the hydrologic model downstream of Turretfield and at the South Para SE Gawler gauging station.

An ocean level boundary was applied along the western and southern model edges. A level of 1.5 m AHD, equal to the Highest Astronomical Tide was applied.

3.4 Updated Floodplain Inundation Maps

The updated flood extent for the 1 in 100 ARI event is provided in Figure 3-2. There are a few minor variations from the 2007 mapping, viz:

- The flood extent is generally a little less at the edges;
- Areas of approved development in the floodplain have been raised above the flood level;
- There is less flooding near Angle Vale for the 1 in 100 ARI event and the township is no longer considered to be at risk for the design flood event; and
- There is a minor breakout around the Northern Expressway - but the volume is very small and hence the impact remains localised.

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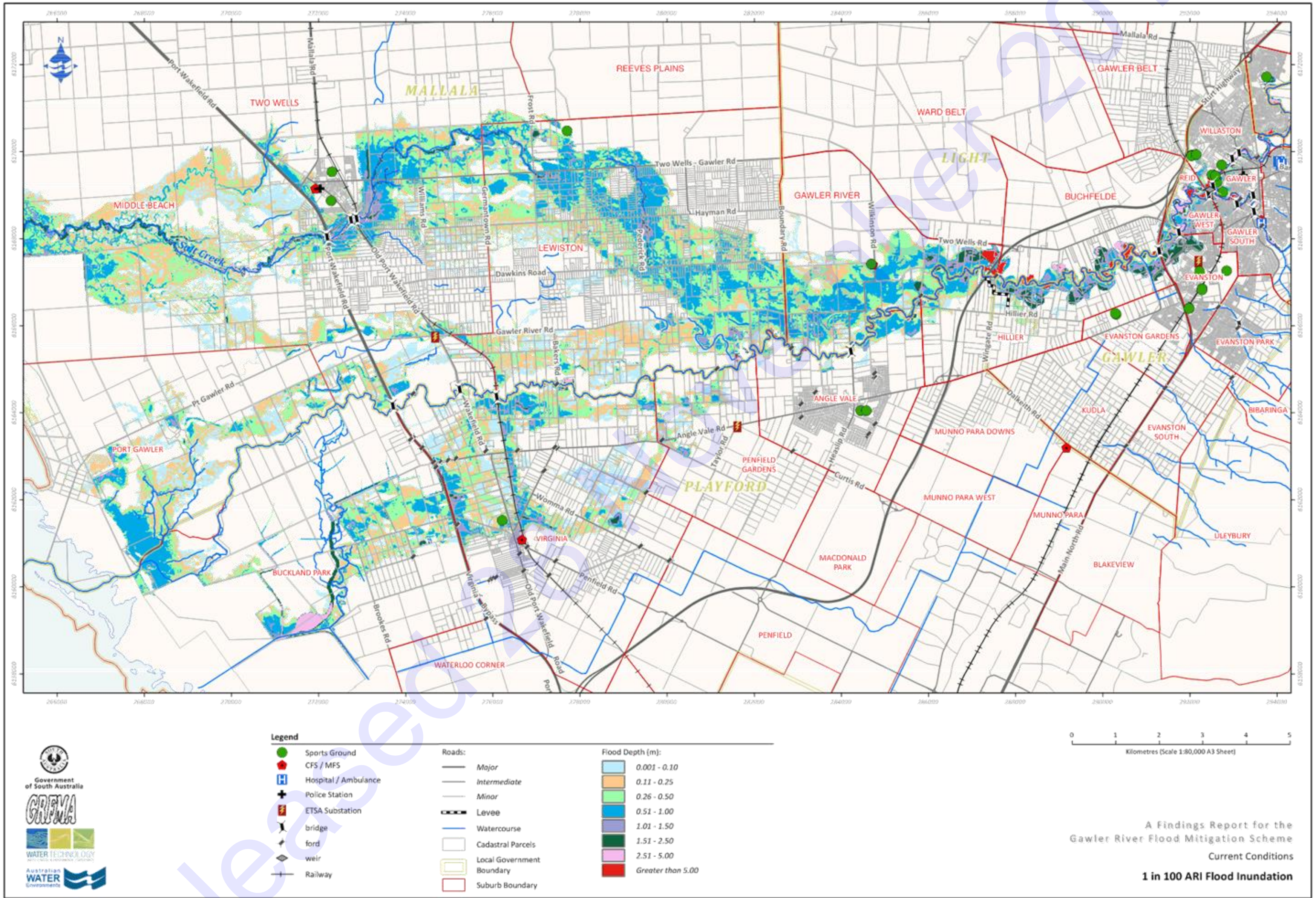

14147 D020 v4 Gawler River Flood Mapping 150501
Last Updated: 1/05/2015

Figure 3.2

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3.5 Scale of Impacts

Flood damage estimates have been updated with the new floodplain inundation mapping that has been prepared. The damage estimate process has mirrored the approach previously adopted for the Gawler River (AWE, 2004 and AWE, 2009). These previous assessments have been updated to allow for significant changes in land-use and cost implications. The methodology and results are outlined in Appendix B. A high level summary is provided in Table 2.

TABLE 2 : FLOOD DAMAGES SUMMARY

Flood Frequency (ARI)	Estimated Damages
1 in 10	$15m
1 in 20	$24m
1 in 50	$102m
1 in 100	$182m
1 in 200	$212m
Average Annual Damage	$7.40m
Present Value of Damages*	$109m

**Calculated over a thirty year timeframe using a discount rate of 7% per annum. Note: a lower discount rate will result in higher damage costs. Similarly, a longer timeframe for evaluating damage cost will increase the present value of damages.*

The numbers are likely to under estimate the true potential cost of flooding because they only include physical damage to property and infrastructure as well as flood response and clean up costs and do not place a value lost business or social/emotional damages.

Table 2 above introduces the terms Average Annual Damage and Present Value of Damages. The present value is calculated by capitalising the average annual damages. A variety of assumptions can be made in that process, but the selection of discount rate is perhaps the most critical. In today's economic climate a lower discount rate than 7% could be argued, however this will result in an even higher estimate in damages and hence we have stayed with the relatively high rate of 7% (which is consistent with other public infrastructure rates used in the past).

The average annual damage is calculated for all potential floods, by multiplying the potential flood damages for any given flood by the likelihood of that flood occurring. Effectively it is the area under a curve of potential damages associated with floods of different likelihood. The flood damages summarised in Table 2 were used to calculate the Average Annual Damages. In order to complete the calculation an assumption needed to be made for the Probable Maximum (or 0% likelihood) Flood. The damage cost associated with the Probable Maximum Flood was assumed to be $450 million.

The average annual damages curve is presented in Figure 3-3.

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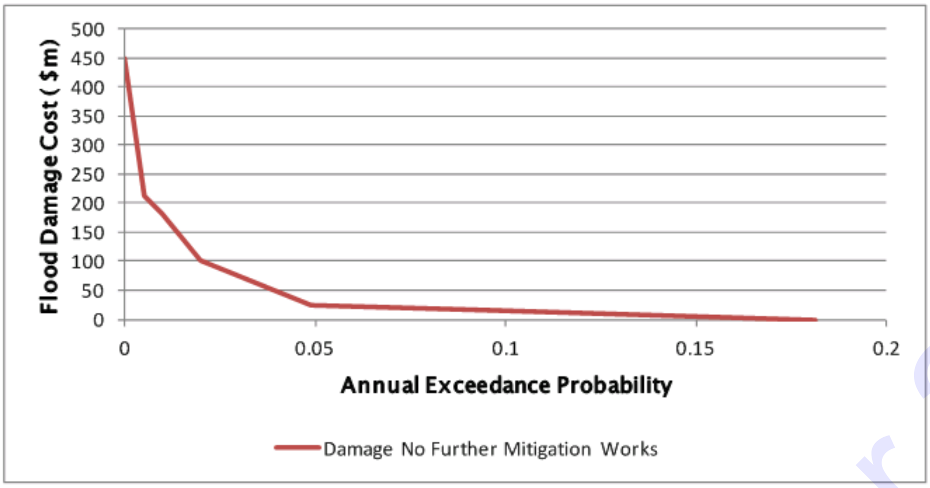

FIGURE 3-3 : AVERAGE ANNUAL DAMAGE CURVE FOR FLOODING FROM THE GAWLER RIVER

The costs presented in Table 2 are significant and are as a result of a large number of residential and commercial properties that would be affected as well as the large areas of crops and agricultural production that would also be impacted. Indicative statistics on the numbers and areas of property affected are presented in Table 3.

TABLE 3 : PROPERTIES AFFECTED BY FLOODING

Flood Frequency (ARI)	Number of Residential Properties*	Number of Commercial and Industrial*	Agriculture/crop areas affected (ha)
1 in 20	180	51	1993
1 in 50	1504	151	3943
1 in 100	3087	213	6032
1 in 200	3686	315	6559

**Includes over floor property inundation only.*

Table 4 below illustrates the flood hazard exposure for residential properties. Flood hazard is term that helps to describe the direct risk to people. Flood hazard is described in terms of being either low, medium, high or extreme. Flood hazard for any particular point of inundation of the floodplain is calculated from the product of depth and flow velocity. Conceptually very deep water flowing very fast will present the greatest hazard but shallow, very fast moving water can also be dangerous, as can deep but slow moving water. The categories are summarised in Figure 3-4.

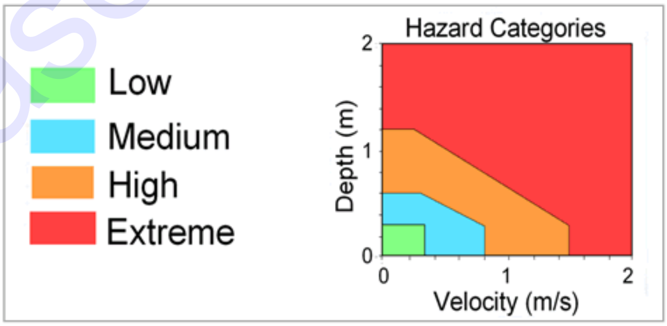

FIGURE 3-4 : FLOOD HAZARD CATERGORIES

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TABLE 4 : HAZARD RATINGS FOR PROPERTIES POTENTIALLY AFFECTED BY FLOODING

Flood Frequency (ARI)	Number of residential properties within each hazard rating			
	Low	Medium	High	Extreme
1 in 50	1056	785	483	236
1 in 100	1559	1451	1179	457
1 in 200	1814	1652	1419	615

Furthermore much of the area represents prime agricultural land which is expanding as well as being part of the 30 year growth area for Adelaide. The high level of flood risk of the area is limiting this potential for future growth.

3.6 Desirable Levels of Protection

Decisions on the desirable level of flood protection are generally made based on the nature of the flooding behaviour within a catchment and the level of exposure created for a range of flood events.

There is a high level of consistency in adopting a 1 in 100 ARI (1% AEP) level of protection for new development both in Australia and overseas. Indeed the South Australian Government was a leader in setting this quasi standard through the South Western Suburbs Drainage Scheme which was established in the mid 1960s. This scheme resulted in a 1 in 100 ARI level of protection for properties previously at risk of flooding from the Sturt River. This standard has been reinforced through consideration of the likelihood that a landholder may be flooded within their lifetime (adopted by the statisticians as 70 years), refer Table 5. (DIPNR, 2005; QRA, 2011).

This level of protection has remained as an aspirational minimum level of protection and it is generally accepted that adopting a lower level of protection for new development should only occur in exceptional circumstances where it can be demonstrated the situation is indeed exceptional. In the case of the Gawler River it is difficult to see how the flooding behaviour and impacts could be described as being exceptional and a lower level of protection justified for new development.

The situation is often less clear with respect to existing developed areas. In these cases there is a wide range of design levels of protection that have been adopted in South Australia as well as elsewhere. Typically the 1 in 100 ARI is considered initially as the desirable level of protection to be achieved but this then varied through a process of cost / safety / benefit optimisation. This can result is a higher level of protection being provided (e.g. the River Torrens Linear Park) or lower levels of protection (e.g. Second Creek). But typically the 1 in 100 ARI level will still be the preferred level to be achieved (e.g. Sturt River, Brown Hill Creek, Dry Creek, Little Para River for example).

The percentage likelihood of floods of various sizes occurring within a 70 year timeframe is summarised in Table 5.

TABLE 5 : LIKELIHOOD OF A FLOOD OCCURING WITHIN A 70 YEAR TIMEFRAME

Flood ARI	Likelihood of the flood occurring at least once	Likelihood of the flood occurring at least twice
1 in 50	75 %	41 %
1 in 100	50 %	16 %
1 in 200	30 %	5 %

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In addition to ensuring new development is not placed at risk, damages to existing property need to be minimised and the issues of public safety and social/community costs associated with flooding need to be considered. The number of impacted properties shown in Table 3 are therefore also an important consideration.

Whilst it is considered impractical to provide protection against all floods it is important that very large and severe flood events are also considered so that emergency response services can be fore armed on what to expect so they are better equipped to respond.

It is also important that any flood management measures, be these associated with new development or existing landscapes, recognise the variable, unpredictable nature of floods and uncertainties associated with their estimation. This requires that a level of resilience be built into the management measure.

Resilience is more readily built into some management measures than others. Management measures that result in a rapid failure when their design standard is exceeded are considered less favourable than those which result in a slower more gradual exposure to flooding when a design standard is exceeded.

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4 Mitigation Options

4.1 Non Structural Options

There are a range of non-structural measures that can assist in minimising the impacts of flooding in the future. Non-structural measures are typically highly cost effective and can be implemented over much shorter timeframes than structural options. Whilst not preventing the flooding per say they can greatly reduce the cost and trauma associated with major flood events.

4.1.1 Flood Preparedness

Flood preparedness is a cost effective non-structural means of reducing damages as a result of a flood. Flood preparedness is about helping people to be aware of the flood risk and how best to respond to it. Flood preparedness programs in this context are considered in four phases: flood awareness, flood warning, response and recovery. They form the key elements of a total flood warning system (Commonwealth of Australia, 2012).

These programs can be very effective. Whilst they don't prevent flooding they can substantially reduce the damages (and intangible losses) that otherwise would occur. Figure 4-1 below (from BTE, 2001) illustrates this point. The effectiveness of these programs increases with people's experience and awareness as well as the warning time they are provided with.

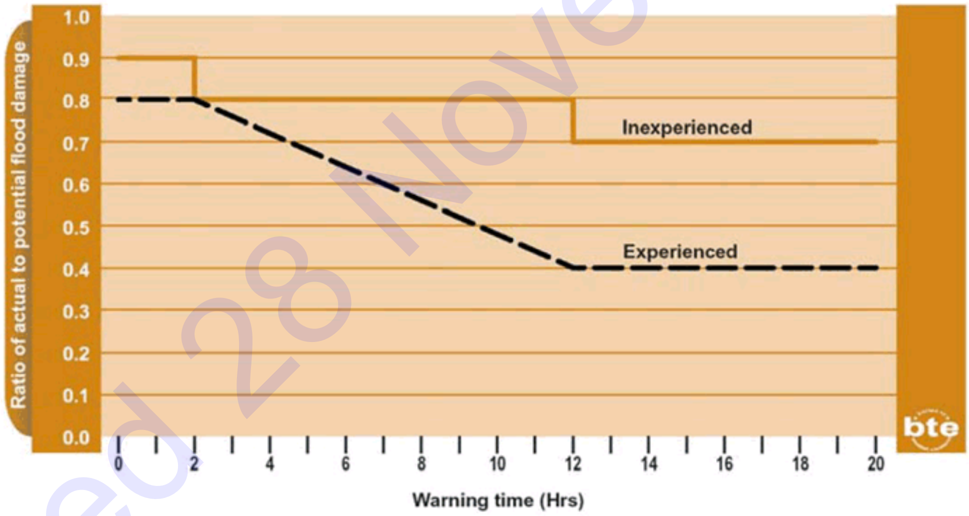

FIGURE 4-1 : EFFECTIVENESS OF FLOOD WARNING SYSTEMS

Fortunately in the case of the Gawler River, people can typically be provided with 12 or more hours warning of an oncoming flood. Hence a total flood warning system has the potential to be particularly effective for people on the Gawler River floodplain.

An effective flood preparedness system as a mitigation measures incorporates a high level of flood management resilience. This is because it does not change the way in which flood waters move across the landscape and involves keeping landholders updated on flood behaviour and informed of effective measures to minimise flood damages. Landholder response follows a consistent path which is predetermined in the flood preparedness plan. The level of response escalates as the flood severity increases, with predetermined decision points. If the flood behaviour varies from the

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expectations (based on modelling and mapping), landholders still have the foundation information they need to respond. If a landholder fails to respond effectively then the consequences are limited to their own property and their failure does not create a cascading effect across the floodplain.

4.1.1.1 Flood Awareness

A flood awareness program is an important aspect of reducing the risk of flood damage. A community awareness program, similar to SA State Emergency Service's (SES) highly successful community education and awareness raising 'Floodsafe' program would be effective. A program such as this may include awareness activities such as informing the community through discussions with individual households, local councils' newsletters, public presentations, articles in local media, information included on council websites and information about a flood emergency kit.

A coordinated education program is one means of ensuring this information is effectively disseminated. The development of such programs is essential for ensuring that landholders can respond effectively to the onset of flooding.

For example, the education program may work with the commercial premises within the main flow path to ensure that their storage of goods vulnerable to water damage is well above ground level – or that the sides of greenhouses can be raised to reduce the scale of damages. The education program should also target residential properties.

Any education program would need to be an ongoing program, to ensure as the population changes that new residents and business owners are aware of the flood risk to their assets.

The awareness activities may also include conducting a finished floor level survey of properties adjacent to the main flood flow paths and using this information to further target the education program to those businesses or residents which are most at risk.

4.1.1.2 Flood Warning

There is currently a very effective flood monitoring system in place for the Gawler River catchment. This consists of a series of automatic rain gauges and water level recorders, with data accessible in real time via the web.

Whilst there is a technical recording and reporting system readily available experience elsewhere has been that the effectiveness of these systems is heavily influence by people's awareness of it and how to interpret the information.

Hence educating the community who live within and near the area of floodplain about flood warnings and providing a recognised point of contact for the community, council and emergency services will increase the potential effectiveness of warnings and the rainfall and streamflow information that is being collected and disseminated.

An awareness program along the lines outlined above is therefore critical for an effective flood warning system.

4.1.1.3 Flood Response

The flood response phase (and to a lesser extent the recovery phase) is highly influenced by the experience or knowledge of people of the likely behaviour and nature of a flood event. There are a range of actions people can do with their property before and during a flood that can substantially reduce the damage costs. Many of these measures are very simple and easily implemented. To be effective landholders potentially affected by flooding need to be aware of their options and response strategies.

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The response of emergency services during a flood is obviously also a key factor in reducing flood damages and threats to public safety. Integrated disaster response plans are an important means for helping to ensure emergency services can effectively respond. Whilst not wishing to suggest that current response services are deficient (because they are not), the regular review of these plans and the conduct of "dry run" flood response exercises can be effective ways of ensuring emergency response staff and volunteers are aware of the issues, hazards and opportunities that might be presented to them during a real flood event. Such initiatives should be actively supported.

In addition to supporting emergency service planning and training, councils may wish to have internal training of its field staff to ensure flood response equipment, for example sand bags, are available at short notice and that staff have the necessary training to assist emergency personnel to install them effectively at buildings which are likely to be at risk.

4.1.1.4 Flood Recovery

The recovery phase post flood is critical to reducing social disruption and long lasting health issues associated with trauma (and in extreme cases disease). If residential or commercial properties experience flooding, in particular over floor flooding, it is costly and can cause significant stress and trauma.

In addition to responding to the initial emergency condition, it is important that councils have plans in place to work with other agencies to assist affected residents and businesses once floodwaters have receded.

Experience with recent flooding in rural communities north of Adelaide has been that where councils maintain a presence (e.g. through ongoing assistance with the cleanup and recovery phase) and maintains an ongoing dialogue communities appear to be better equipped to move forward in a constructive and positive manner (O'Broin, 2014).

4.1.2 Development/Planning Controls

The Development Plan is a statutory document that controls and manages all forms of development. It sets out a range of development zones, maps and rules (objectives and principles) to help ensure that development is undertaken in a well managed way and takes account of relevant environmental, infrastructure, urban design, heritage and community needs.

Planning controls within council Development Plans provide a framework to plan and build in a manner that incorporates stormwater management. All councils in the floodplain area have information in their Development Plans to help guide development.

AWE reviewed the status of the planning system of the key councils that are impacted by Gawler River flooding to understand the status of the planning system in their councils (with respect to Gawler River flooding), along with the emerging development issues and frustrations they have had to contend with in updating their Development Plans. This process involved reviewing the councils' Development Plans, planning assessment information, websites and interviewing council planning staff. Discussion about their experience in the flood warning system and identifying any opportunities was also included.

Planning controls provide a moderate level of resilience as a flood management measure. These measures will typically involve setting floor heights above the predicted flood level for the design flood. If applied correctly this measure will not substantially change the flood behaviour across the floodplain and increased resilience can be achieved by incorporating a freeboard allowance above the design flood water level. The higher the freeboard the greater the resilience. A weakness in this measure is that it can create the false impression for a landholder that their property is flood free yet the surrounds of their property may be flooded and may also be flooded by a larger flood event.

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They can therefore be highly vulnerable to a more severe flood than the design flood or in the event that the design flood behaves unexpectedly.

4.1.2.1 Development Plans, Planning Policy Library and Planning Reform

Councils' Development Plans include planning provisions, zonings and maps to help guide appropriate development in the floodplain.

Following the 2007 floodplain mapping work, a number of councils have been updating their Development Plans to manage development in the floodplain. However progress in this area has been stalled and inconsistent across the catchment.

To encourage best practice and to provide a consistent development plan format across the state, the Department of Planning and Local Government prepared the Planning Policy Library (version 6, 2011). The Library includes a range of principles of planning control, such as those relating to flood hazards. Councils that have undergone conversion of their Development Plan into the Better Development Plan (BDP) format should therefore have such flood hazard policies. Councils within the Gawler River floodplain area that have undergone a BDP conversion include:

- Light Regional Council (in 6 November 2014);
- District Council of Mallala (in 31 January 2013);
- The Barossa Council (in 18 August 2011); and
- City of Playford (in 9 December 2010).

The State Government is also going through a process of reviewing the state's planning system to seek opportunities to make it more effective, efficient and enabling. An Expert Panel was established to facilitate the reform process. It released its second report in August 2014 'Our Ideas for Reform' for discussion. This identified 27 reform ideas that aim to improve the system's ability to respond to changes such as investment activity, sustainability and community interests. One of these reform ideas is to have a consistent state-wide menu of planning rules, such as developing a consistent approach to guiding development in flood prone areas.

The Development Plans for the District Council of Mallala, Light Regional Council and City of Playford include a constraints map which shows the extent of the Gawler River floodplain. These maps are likely to be based on the mapping undertaken in 1993. Those councils refer to different flood hazard zones in their Development Plans but the Development Plans do not contain a map of such. The Town of Gawler includes flood prone areas and hazard flood risk areas. Council planning staff for the above four councils all have access to the 2007 flood maps to assess development applications.

These four councils include the 1 in 100 ARI event as the flood trigger for non-complying development in the floodplain.

Councils' Development Plans also require a freeboard allowance of 300 mm or greater above the 1-in-100 ARI flood event level (and some also include the additional words: 'or natural surface level, whichever is greater').

This free board is usually applied to dwellings and commercial buildings. There is an argument to adopt a lesser free board for outbuildings and agricultural operations. It is also possible to raise buildings on piles or piers so that building contents can be above flood levels but flood waters can pass underneath unimpeded.

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4.1.2.2 Current Status of Development Planning Amendments (DPAs)

The District Council of Mallala commenced a DPA for flooding however that is on hold until the revised flood mapping is made available. The council has also tried to update its flood policy into the new Better Development Plan format. This has resulted in removal of the flood hazard maps.

The City of Playford has a Statement of Intent and draft planning policies however these are on hold until the revised flood mapping is made available.

Light Regional Council is awaiting Ministerial approval for its flood prone DPA which is expected in 2015. This DPA will include the 2007 mapping and the flood hazard zones. The general hazard module is being updated in the Development Plan and this also includes updated information regarding non-complying development in the various zones. Council has included a new policy to address access in the floodplain so that development would be deemed 'non-complying' if it requires traversing across land that is in a high flood risk area.

4.1.2.3 Planning Issues in the Floodplain

Some councils have experienced issues relating to the protection of development, such as requiring a minimum floor level height. Some feedback from the community indicated that they are not happy to build house extensions that are at a different level to the original dwelling (i.e. above 300mm above the 1 in 100 ARI).

Access to development within the floodplain is an issue when assessing development applications, particularly when the development is not shown as being flooded on the flood maps but it requires accessing the property across land that will be flooded. Some councils are unsure if the Development Plan is strong enough to refuse proposed development based on access. As mentioned above, Light Regional Council has recently developed a new policy to deal with this issue.

Another issue in managing development in the floodplain are greenhouse developments. These appear to be being constructed throughout the floodplain but often have no planning approval. Some greenhouses have caused local drainage issues through stormwater discharge from the development. The developments increase the stormwater runoff and in areas of flat topography the runoff pools in local drains for a long time as well as detrimentally affecting the road surface.

4.1.2.4 Gawler River Floodplain Information on Council Websites

Some of the councils provide a link to the Gawler Council website which has information about the Gawler River Floodplain Management Authority with maps such as the Gawler River 1:100 Year ARI Flood Hazard Map and the Gawler River 1:100 Year ARI Flood Inundation Map.

Some of the councils include information sheets on flooding for the public to review when preparing development applications. However this information varies in detail amongst the councils and is not available on all the websites.

Some councils provide links to documents on their websites however these links do not function properly or the documents have out of date information about flood mapping projects.

4.1.2.5 Practical Impediments to Effective Planning

Managing the expectations of landowners can be difficult. Landholder awareness levels are typically low and often the council will require the development application to have an engineering report to demonstrate that it meets council's flood protection requirements. Whilst necessary, this increases the cost to landholders and they are not always accepting of this requirement.

There is a lack of state-wide guidance on managing developments in floodprone areas and there is a lack of consistency amongst councils. Whilst councils acknowledge the resource limitations at the

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state government level, a greater investment in this area by state government would improve planning decisions. For example; developing and issuing planning bulletins to provide better guidance for councils on flood management and development assessments in flood prone areas.

The preparation of Development Plan Amendments requires significant effort, including undertaking investigations and community consultation. This is very time consuming and can be costly as well. These factors make it difficult for council to include the most up to date flood mapping in their Development Plans. Opportunities for streamlining this process for flood prone area amendments should be evaluated.

Keeping abreast of changes to engineering standards, such as road trafficability criteria, can be difficult for council staff but it is important that such information is up-to-date when assessing development in the floodplain. Having access to specialist technical knowledge was seen as valuable in assisting in Development Plan Amendments as well as for individual development assessments, however for some councils this requires external support as it is not contained in-house.

There is a general lack of adequate resourcing provided at the local government level to support the planning assessment process. This means that tasks such as undertaking inspections and checking for compliance are not always satisfactorily completed.

It is also important that a consistent set of development principles be established across the floodplain. These principles should also make provision for the uncertainties associated with actual real time floods and how these might vary from the idealised design floods considered herein.

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4.2 Structural Options

4.2.1 Flood Mitigation Dams

Flood mitigation dams reduce the peak flow rate of flood waters passing downstream. As the flood passes through the dam, the dam is progressively filled as the flood flows entering the dam are greater than the flows that the dam allows to flow out of it. Under the design flood condition this process continues until the dam is full. By the time the dam is full the outflow rate begins to exceed the inflow rate (because the peak inflow rate has now dropped). The dam then slowly drains, hence the flood water associated with the peak flows of the hydrograph are temporally stored in the dam.

For a flood mitigation dam to be effective it is essential that adequate available storage space remains in the dam for an oncoming flood. Hence flood mitigation dams are typically empty for most of the time and have very little impact on "normal" flows.

Flood mitigation dams can be very effective, but can only reduce flows from that part of a total catchment upstream of the dam. Furthermore, if they are managed incorrectly they can make flooding worse (if they use gated spillways).

Flood mitigation dams are considered to have a moderate to high level of resilience. Whilst they are designed not to fail structurally (if they did the consequences could be catastrophic), the degree of protection provided by them diminishes quickly as the design level of protection flood is exceeded. Flood mitigation dams nevertheless will still result in less damage than otherwise would be the case because the outflow from these dams will always be less than the inflow. However they can also cause landholders to believe that they are completely flood free when this is not the case.

The design flow hydrographs for the North and South Para (Figure 3-1) illustrate that the management of flows on the North Para remains the highest priority.

A thorough analysis of potential dam sites has been undertaken as part of this current investigation. A number of sites along the North Para and the major tributaries of the North Para are suitable for the construction of flood mitigation dams.

However, sites in the upper reaches (such as upstream of Penrice) are too far upstream of Gawler to be of benefit because of the large catchment area contributing to flow between Penrice and Gawler. Flood mitigation dams on the major tributaries of the North Para (eg Jacobs Creek) are also not very effective because they too do not address flows across a large enough portion of the catchment.

Ideally a flood mitigation dam needs to be located as close to (but upstream of Gawler) to provide maximum benefits. This is partly the reason for the location of the existing Bruce Eastick North Para Flood Mitigation Dam.

Consequently, four sites along the North Para were initially identified as potential flood mitigation dam sites. These sites are:

- At the Bruce Eastick North Para Flood Mitigation Dam site (ie enlarge the existing dam);
- Upstream of Rosedale;
- Downstream Location 1, which is about 2.6 km downstream of Rosedale; and
- Downstream Location 2, which is about 9.5 km downstream of Rosedale.

The site upstream of Rosedale was found to offer limited protection because it could not provide a sufficient volume of flood storage As a result, enlarging the Bruce Eastick North Para Flood Mitigation Dam and the two potential sites downstream of Rosedale were short listed for more detailed investigation.

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A partial detention system was also considered to assess the merit of having a smaller detention dam complimented by additional works downstream. This option results in some flows over the Bruce Eastick North Para Flood Mitigation Dam spillway during a 1 in 100 ARI event with a peak flow of 188 m^3s^{-1} (down from 566 m^3s^{-1}). The maximum flow at downstream of the Gawler Junction with the South Para (Gawler River) is 276 m^3s^{-1} (down from 635 m^3s^{-1}). The design hydrograph for this partial mitigation event is illustrated in Figure 4-2.

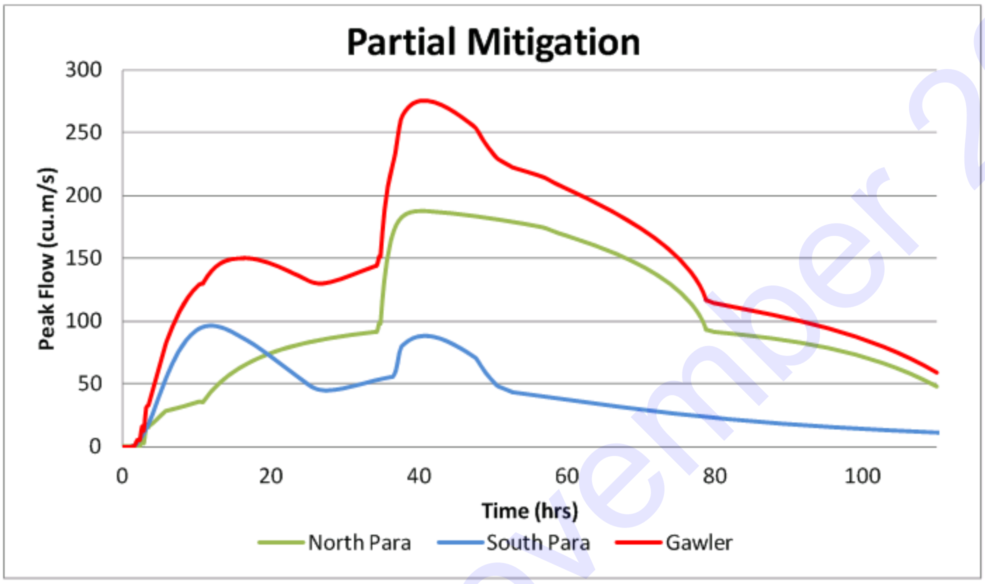

FIGURE 4-2 : PARTIAL MITIGATION HYDROGRAPH WITH SMALLER FLOOD MITIGATION DAM

The partial mitigation option results is an inundation extent similar to the current situation but at a much reduced depth (typically between 300 mm to 400 mm). The township of Two Wells is no longer subject to flooding, with the exception of a handful of properties that are the most flood-prone at present. Breakouts to the south of the Gawler River remain unchanged from the unmitigated or current situation.

4.2.2 Retarding Basin Downstream of Gawler

A retarding basin installed downstream of Gawler was evaluated. A retarding basin would effectively operate in a very similar manner to a flood mitigation dam but would be constructed by excavating a large area of the floodplain to provide additional floodplain storage. Given the large volume of the flood, a very large excavation would be required. It was determined that given the very flat terrain, the area required to install an effective retarding basin would be substantial, potentially covering an area of around 10 km^2. This would make the option very costly and have a high degree of social and environmental disruption. Consequently it is not considered to be a viable mitigation alternative for the Gawler River.

4.2.3 Levees

Levees can be very effective flood mitigation measures for dealing with localised breakouts from river systems. Levees do, however, have a number of inherent features that make them hydrologically and hydraulically less attractive than either retarding basins or flood mitigation dams.

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If levees are over topped or their design standard exceeded, they are liable to rapid failure and under these circumstances they can exacerbate flooding issues. If over topped they can also trap floodwaters and hence prolong the duration of flooding which can result in a worse situation than would otherwise be the case. If the design flows for flood mitigation dams or retarding basins are exceeded they simply become ineffective but they do not result in a worse situation.

Also, whilst levees can prevent flood inundation they do so by containing the flow, causing higher water levels upstream and higher stream velocities adjacent to and downstream of the levees. Levees can, therefore, exacerbate flooding both upstream and downstream and require a higher degree of maintenance to keep them in good working order.

Hence, whilst they are a widely used measure in many locations, they are considered to have a low level of resilience and are they are not without their challenges. Their level of resilience can be improved by applying a higher design standard to them and also be incorporating a controlled failure mechanism within their design, so that if they are overtopped then this occurs through a predetermined mechanism. It is also important to ensure that their function is supported through a regular and comprehensive maintenance program.

It is worth noting that levees have already been used along the Gawler River in the following locations:

- As part of the Northern Expressway Road crossing;
- Along many sections of river in Gawler;
- Along sections of the lower Gawler River; and
- Being a perched river system the Gawler River has a series of natural levees along most of its length.

Whilst levees can create a number of problems, they can also be very cost effective if these issues are well managed. They have been considered in a number of ways for the Gawler River:

- To provide strategic protection of higher density development areas; and
- To work in conjunction with partial mitigation further upstream.

The centres where higher density development is present and levees could be used to assist in protecting these areas were considered to be as follows:

- Gawler Township – six sections of levee totalling 5 km in length;
- Virginia – two sections of levee, one 3.3 km long, the other 2.6 km long; and
- Two Wells – one levee 2.4 km long.

Note that in the updated flood hydrology a small area near Angle Vale is no longer considered at significant risk of flooding, this is a significant variation from the floodplain mapping prepared in 2007. Hence a levee is not proposed in that area.

4.2.4 Bypasses and Floodways

Two alternative flood bypass or floodways have been considered.

- Option 1 – Follow the main break out alignment through to Salt Creek; and
- Option 2 – Follow an alignment alongside the main river channel.

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In both cases the channel area required is substantial. The floodway would need to be over 35 km long with a cross sectional area of approximately 500 m^2. This would, for example, result in a channel being excavated into the floodplain (in the case of Option 1) of 1 m deep and 500 wide.

In the case of Option 2, it would involve levees either side of the main river channel some two metres high but set back from the main channel by approximately 150 metres. Irrespective of the large amount of physical works required to construct the floodway, there is not a simple alignment possible that could avoid the numerous (over 1000) properties that would be directly impacted by the floodway works and its functionality.

Flood bypass systems are typically most effective when the flow paths are short and through undeveloped landscapes. This is not the case for the Gawler River and hence these options are not considered worthy of further consideration.

4.2.5 Channel Modifications

Options for increasing the efficiency of the main river channel in conveying flood flows have also been considered.

Weedy and overgrown vegetation in a main river channel can cause a significant reduction in the flood carrying capacity of a river channel. Consequently, removal of overly dense and obstructive vegetation and replacement with grass lined banks can often improve the flood carrying capacity of a river system. This has been achieved in many other locations (e.g. River Torrens Linear Park) so this approach was tested for the Gawler River.

Sensitivity analyses were undertaken to simulate the effect of channel clearing. An increase in flood conveyance capacity was achieved, but this was typically less than 10% and hence very minor in relation to the large imbalance between flood flows and channel capacity.

The main reason for this outcome is that the limited channel capacity is largely as a result of the limited physical cross section of the channel as it progresses downstream. This situation is further exacerbated by the highly meandered form of the Gawler River as it crosses the northern Adelaide Plain. These are the primary reasons that the channel capacity diminishes rapidly from 400 m^3s^{-1} near Gawler to less than 100 m^3s^{-1} near Virginia. Hence channel clearing is unlikely to be very effective.

Consideration was also given to increasing the channel capacity by channel widening, refer Figure 4-3.

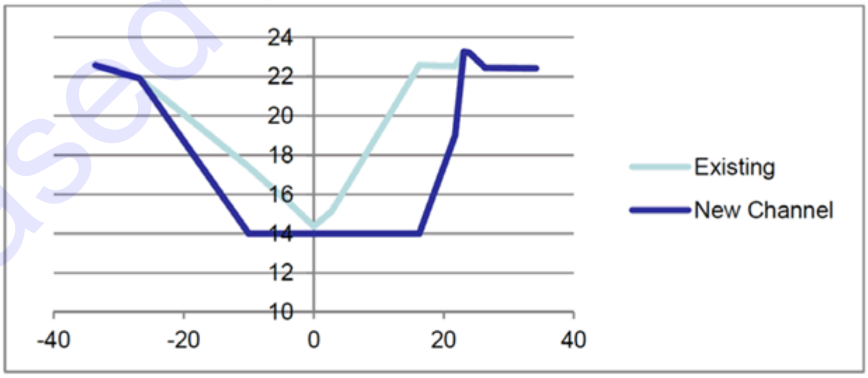

FIGURE 4-3 : CHANNEL WIDENING ILLUSTRATION (DIMENSIONS IN METRES)

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It was estimated that approximately 8,500,000 m^3 of soil would need to be removed to provide sufficient capacity. The cost of this is would be prohibitive notwithstanding the likely native vegetation, other environmental, cultural and social disruption issues.

Therefore channel widening is not considered to be a viable option.

4.3 Mitigation Options Summary Matrix

Each of the options and strategies outlined above were considered with respect to their effectiveness under a range of performance, social, economic and environmental criteria.

The results are summarised in the table that follows. The higher the score the more favourable the option or rating for each category. The options were then ranked from 1 (most favourable) to seven (least favourable). The prioritisation process has involved placing an emphasis on actions that are effective but do not necessarily rely on structural works. These are typically the most resilient and cost effective; refer to the option ranking presented below in Table 6.

TABLE 6 : MULTI-CRITERIA ASSESSMENT SUMMARY OF MITIGATION OPTIONS

Category	Option							Weights
	Do Nothing	Total Flood Warning	Planning	Strategic Levees	Floodway / Channel Works	Mitigation Dam	Composite (Partial Dam and Levees)	
Public Safety	1	4	3	3	3	4	4	3
Option Resilience	1	4	4	2	3	4	4	2
Damage Reduction	1	2	2	3	4	4	4	3
Cost of Works	5	5	5	3	0	1	1	3
Environmental	3	2	2	2	0	2	2	1
Public Concern	4	4	2	3	1	3	2	2
Ongoing Maintenance	4	4	5	2	1	3	1	2
Economic Development	1	2	2	4	2	5	4	1
Weighted Total	43	61	56	47	33	54	47	
Unweighted Total	20	27	25	22	14	26	22	
Rank	**6**	**1**	**2**	**4**	**7**	**3**	**4**	

A brief summary of the criteria follows:

- Public Safety: Measured by the number of properties that would be protected from medium and higher hazard ratings.
- Option Resilience: The capacity of the mitigation option to perform over a range of flood magnitudes and frequencies. Includes consideration of performance of an option should its design standard be exceeded.
- Damage Reduction: Reduction in flood damage costs.
- Cost of Works: Whole of life costs associated with any works or ongoing recurrent expenditure (e.g. includes cost of repeating education and awareness programs in subsequent years).

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- Environmental: Impacts on biodiversity and stream stability.
- Public Concern: Level of likely acceptance of the measure.
- Ongoing Maintenance: The costs and practicalities associated with ongoing maintenance liabilities.
- Economic Development: The opportunity for future economic growth as a result of the mitigation measure being implemented.

Both weighted and unweighted consideration was given to the various criteria that have been used.

The ranking in either case remained the same with flood warning systems being the highest ranked option. This option preformed the best in terms of damage reduction, public safety and option resilience.

A flood mitigation dam upstream of Gawler was the highest ranked structural option. The floodway/channel works option performed the least favourably.

The combined partial mitigation dam and levee alternative was also rated. This option explored the potential for reducing the footprint of the short listed flood mitigation dam options. Whilst conceptually appealing, this option still results in large breakouts that would inundate Lewiston and surrounding areas and hence is not rated as favourably as a number of other options.

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5 Short Listed Structural Flood Mitigation Options

Two forms of structural mitigation options were considered in more detail and modelled to test their effectiveness. These were:

- A flood mitigation dam upstream of Gawler but also downstream of Rosedale
- Strategic levees and associated works in Gawler, Two Wells and near Virginia.

Of the these options enlarging the existing Bruce Eastick North Para Flood Mitigation Dam provides the greatest level of flood protection whilst potentially having the least environmental and social impacts, although the impacts created are largely outside of areas that are currently considered to be at risk of flooding. A description of the structural flood mitigation options follows.

5.1 Flood Mitigation Dam Upstream of Gawler

Three potential sites were investigated in detail. Two of these would involve constructing a new dam. One site was identified 9.5 km west of the settlement of Rosedale, the other approximately 2.6 km to the west of Rosedale. The third option was to enlarge the existing Bruce Eastick North Para Flood Mitigation Dam near Turretfield.

Each of the options would provide the same levels of flood mitigation.

The dam would be empty for nearly all the time. Normal flows would pass through all of the dam options relatively unimpeded but for larger floods, water levels in all options would gradually rise until the dam was filled. If either of the two new dam options were pursed then these would act in tandem with the existing Bruce Eastick North Para Flood Mitigation Dam. This is less efficient that enlarging the existing Bruce Eastick North Para Flood Mitigation Dam and providing flood mitigation at one specific location.

Constructing a new dam also increases the area of impact upstream of the dam. These impacts would be less for the dam site 9.5 km west of Rosedale in comparison to the site further upstream (2.6 km west of Rosedale).

The flood mitigation dam would need to provide approximately 28,000 ML of temporary flood storage for the 1 in 100 ARI flood event.

For each of the three dam options, consideration was given to providing partial mitigation so that the storage volume and area affected behind each dam could be minimised. This was found to be effective in reducing the areas affected behind each dam but also resulted in significant reductions in the level of flood protection provided downstream. It was also determined that any cost savings would be relatively minor.

Further work was also carried out to optimise the outlet configuration for all three dams. When the entire dam outlet and storage arrangement is optimised, the full flood mitigation benefits can be achieved whilst the water storage volume and hence inundation area behind the dam can be minimised.

Concentrating the detention storage at one location was also found to provide significant efficiencies. Hence enlarging the existing Bruce Eastick North Para Flood Mitigation Dam proved to be the optimal mitigation dam solution.

A high level review of the geotechnical report for the existing dam site confirmed the site suitability for dam construction.

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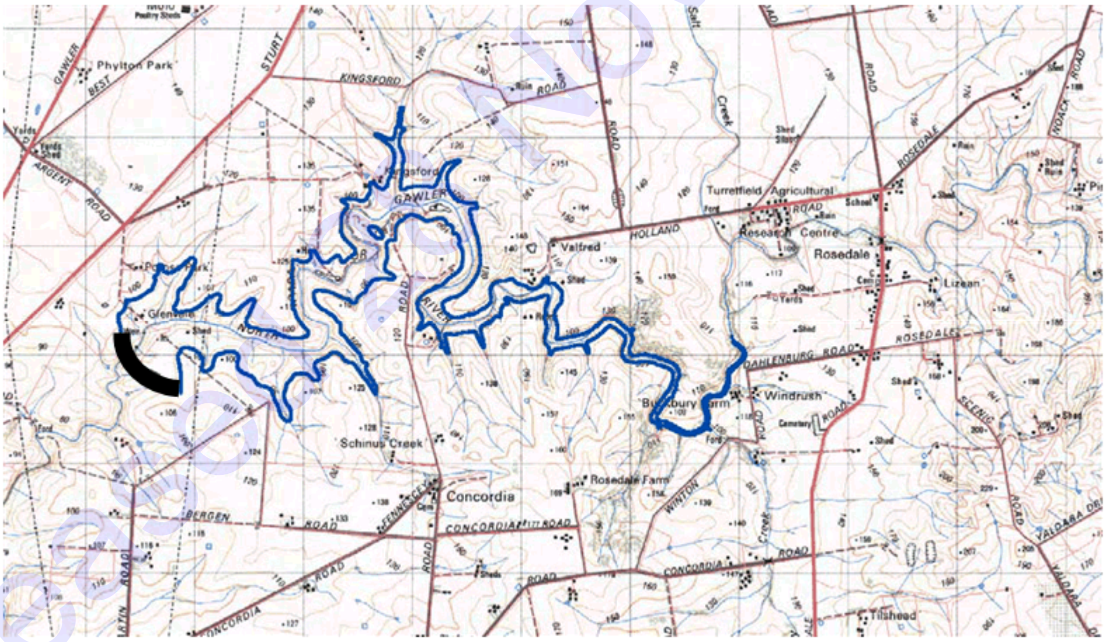
The dam would need to be raised in height by approximately 10 metres. A structural feasibility assessment is required to determine the actual preferred method for raising the dam wall height should the Authority wish to pursue this option, but for this stage of the assessment process, for costing purposes, it has been assumed that the dam would be raised by firstly widening the base of the dam (along the stream) by approximately 8 metres and the using the same construction method and dam shape and type to build upwards (at a vertical to horizontal slope of 5 to 4) to effectively increase the height of the dam wall. A new stepped downstream face of the dam would thereby be constructed and step up to a new higher elevation. The stilling pool would then be relocated downstream.

The resulting maximum water surface elevation (WSE) behind an enlarged Bruce Eastick North Para Flood Mitigation Dam is summarised for the full mitigation and partial mitigation scenarios in the table that follows.

TABLE 7 : BRUCE EASTICK NORTH PARA FLOOD MITIGATION DAM OPTIMISATION RESULTS

Mitigation Scenario	Maximum Discharge (m^3/s)	Maximum Water Level during a 1 in 100 ARI flood (mAHD)
Maximised Flood Mitigation	100	91.8
Partial Flood Mitigation	188	88.7

The flood inundation extent for the optimised outlet and storage configuration for an enlarged Bruce Eastick North Para Flood Mitigation Dam is provided in Figure 5-1.



Bruce Eastick Dam
WSE = 91.8 m

FIGURE 5-1 : FLOOD INUNDATION EXTENT AT BRUCE EASTICK NORTH PARA FLOOD MITIGATION DAM (MAXIMUM WSE 91.8 MAHD - 1 IN 100 ARI FLOOD)

The extended storage volume - depth relationship table for an enlarged dam is provided in Table 8.

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The relationship was developed from a DTM prepared in part using soft photogrammetry techniques by Aerometrex Pty Ltd, utilising aerial photography from 2011 with a vertical resolution of +\- 100 mm at one sigma (67% of values lie within that error range), with the balance being drawn from the statewide five metre contour data supplied by the Department for Environment Water and Natural Resources.

TABLE 8 : ENLARGED BRUCE EASTICK NORTH PARA FLOOD MITIGATION DAM DEPTH STORAGE VOLUME RELATIONSHIP

Water Surfaces Elevation (m AHD)	Storage Volume (Megalitres)
60	15
65	220
70	1,100
75	3,450
80	7,530
85	14,000
90	23,800
95	37,800

At 91.8 mAHD the stored water would have a maximum surface area of 266 hectares. (In comparison the existing maximum storage area for the existing dam is 128 hecatares).

The optimised mitigation option would detain a sufficient volume of floodwater such that flows up to the 1 in 100 ARI event would be contained within the functional range of an enlarged Bruce Eastick North Para Flood Mitigation Dam. That is; the water level in the dam would be near the crest of the dam spillway with slight overtopping.

This configuration would result in a peak flow of 100 m^3s^{-1} (down from 566 m^3s^{-1}) along the North Para at Gawler during a 1 in 100 ARI event; and downstream of the junction with the South Para (Gawler River) of 169 m^3s^{-1} (down from 635 m^3s^{-1}). The design hydrographs are plotted below in Figure 5-2.

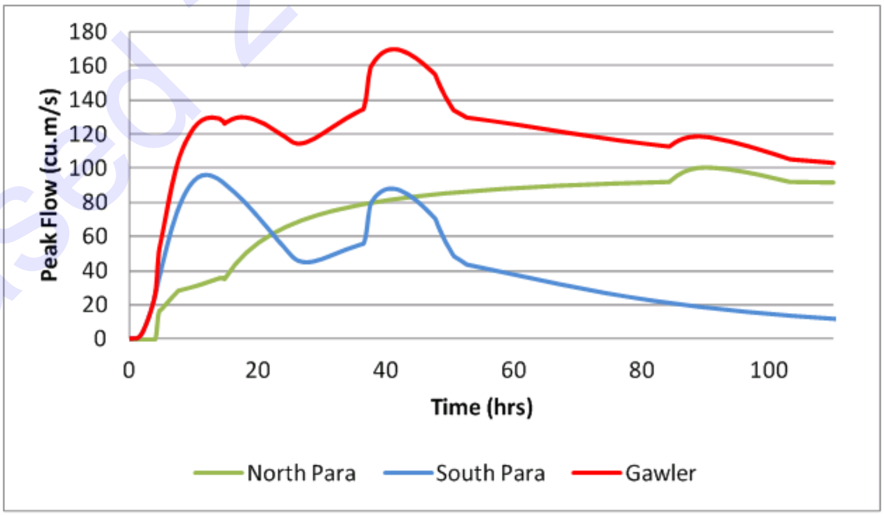

FIGURE 5-2 : OPTIMISED HYDROGRAPH WITH ENLARGED BRUCE EASTICK NORTH PARA FLOOD MITIGATION DAM

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The enlarged Bruce Eastick North Para Flood Mitigation Dam option substantially reduces the flood extent downstream. There remains a small breakout downstream of the Northern Expressway but this is much reduced and generally would be inconsequential. There is no flooding of the Two Wells township and Salt Creek flows remain contained within the channel.

A breakout remains on the lower Gawler River near Virginia, but whilst the agricultural area there remains under threat, the township itself is outside of the design flood extent with only a handful of properties expecting shallow flooding (below floor level). The flow paths west of Port Wakefield Road remain largely unaltered, due to the very small channel capacity of Gawler River there.

The enlarged dam would be very effective in reducing flood damages downstream. A 1 in 100 ARI flood inundation map for the Gawler River, assuming the upgraded dam was in place, is provided in Figure 5-3.

The dam would reduce the present value of flood damages from $109m down to $58m and reduce the average annual damages down to $3.93m. The benefits in terms of reduced exposure to flooding are summarised below in Table 9.

TABLE 9 : PRE AND POST FLOOD MITIGATION IMPACTS SUMMARY – FLOOD MITIGATION DAM OPTIONS 1 N 100 ARI EVENT

	Number of properties affected within each hazard rating			
	Low	Medium	High	Extreme
Residential without Dam	1559	1451	1179	457
Residential with Dam	485	359	230	153
Commercial / Industrial without Dam	132	92	72	49
Commercial / Industrial with Dam	64	46	43	34

The dam would also reduce the area of agricultural and grazing land inundated from 3770 ha down to 1410 ha. The affected horticultural area would also be reduced from 2170 ha down to 870 ha. Benefits would be achieved for the 1 in 200 ARI event as well of course for the 1 in 50 ARI flood where flooding upstream of the Port Wakefield Road will be largely avoided. Whilst the benefits of a flood mitigation dam are substantial there are some adverse impacts associated with it, as follows:

- The cost of enlarging the dam – which has been estimated to be approximately $40 million;
- The dam would cause inundation of land behind it. Whilst this would be insignificant for most of the time and for all floods less than 1 in 10 ARI, in larger floods this would be more substantial. In a 1 in 100 ARI flood new areas would be inundated;
- There are potentially 22 private properties affected but only 4 of these are new properties. All of these new properties are located at the fringe of the inundation area and located at the fringe of the flooded extent hence the impacts can be considered minor. The remaining properties already have encroachment on them by the existing Bruce Eastick North Para Flood Mitigation Dam inundation extent. One of these may involve a private dwelling however it is anticipated that works around the dwelling could be undertaken to ensure it is not inundated in a 1 in 100 ARI flood event.
- Land easements (right to flood easement) would need to be negotiated with private land owners affected; and
- There would be an increase in the duration of flood flows,

The maximum inundation extent behind the existing and an enlarged dam during a 1 in 100 ARI event, along with properties potentially affected, is illustrated in Figure 5-4.

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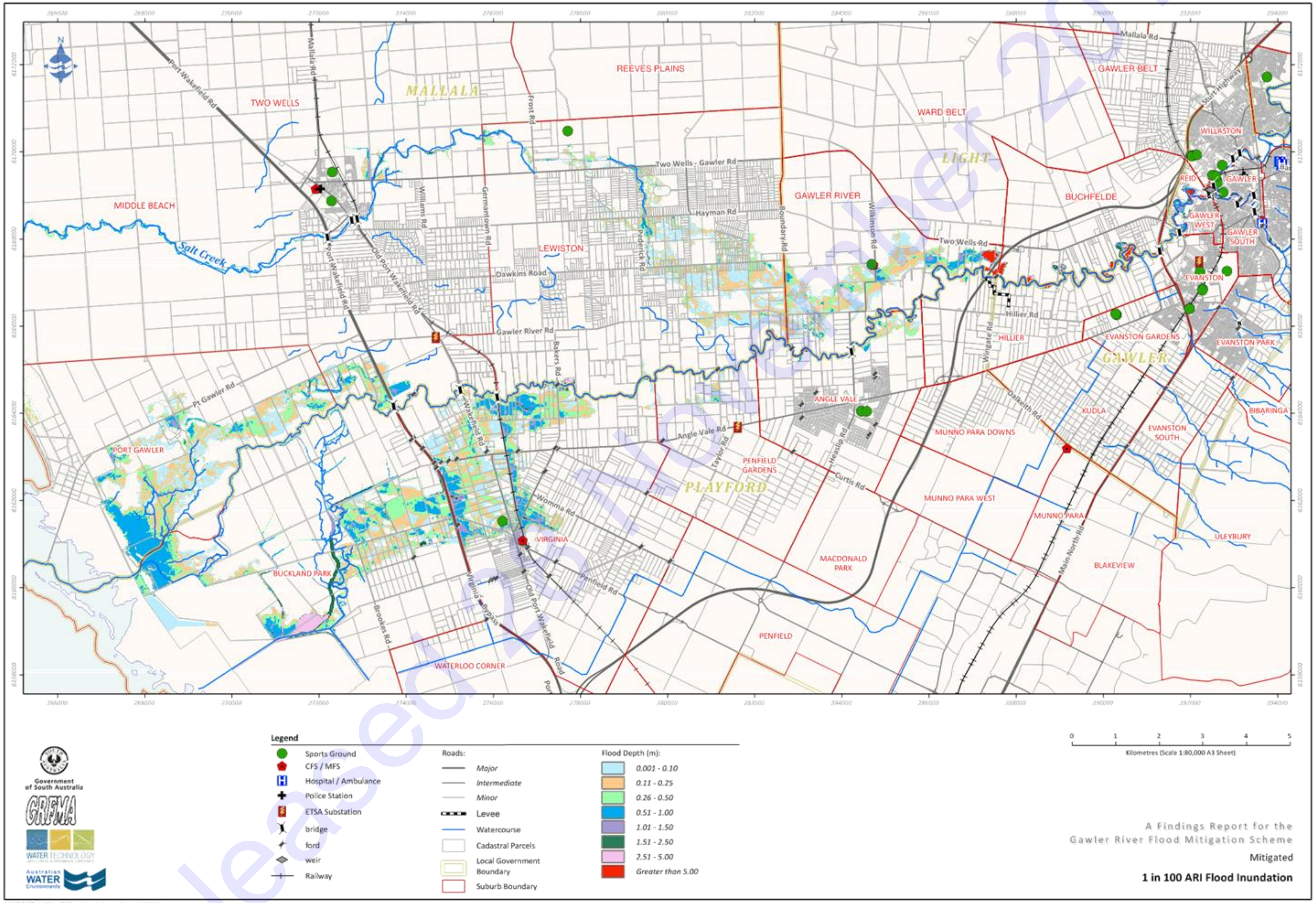

Figure 5-3

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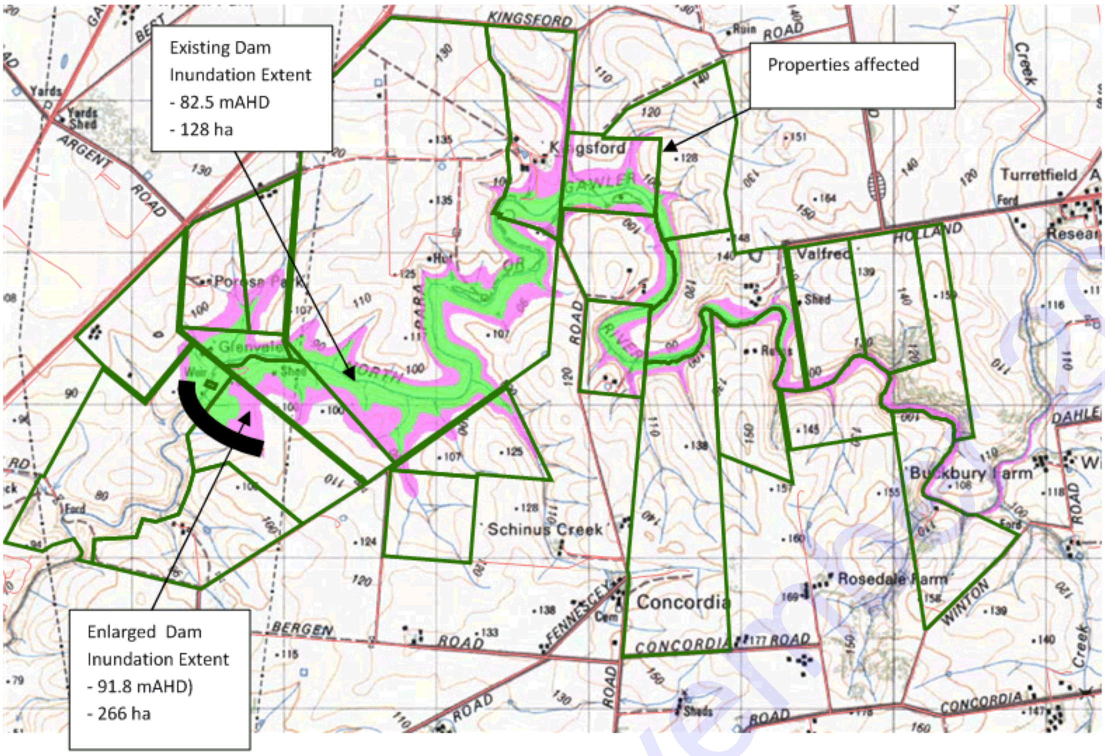

FIGURE 5-4 : INUNDATION EXTENTS AND PROPERTIES AFFECTED: 1 IN 100 ARI 82.5 MAHD AND 91.8 MAHD AT BRUCE EASTICK NORTH PARA FLOOD MITIGATION DAM

The net present value of the enlarged Bruce Eastick North Para Flood Mitigation Dam mitigation option has been estimated to be $11m with a benefit cost ratio of 1.3. The project is cost effective in purely monetary terms and well within the accepted range of flood mitigation projects where public safety is also a major concern. It should also be noted that the damage estimates only value export crops. If all crops are included, the Net Present Value and the Benefit Cost ratio would be significantly higher.

The partial mitigation option results is an inundation extent similar to the current situation but at a much reduced depth (typically between 300 mm to 400 mm). The township of Two Wells is no longer subject to flooding, with the exception of a handful of properties that are the most flood-prone at present. Breakouts to the south of the Gawler River remain unchanged from the unmitigated or current situation. Given the reduced benefits achieved and the limited increase in impacts between the partial mitigation (1 in 100 ARI top water level of 88.7 mAHD) and full mitigation option (1 in 100 ARI top water level of 91.8 mAHD), the partial option is not considered a priority for further consideration for the enlarged Bruce Eastick North Para Flood Mitigation Dam option.

5.2 Strategic Levees to Protect Higher Density Development (Residential and Horticulture Areas)

Three sets of strategic levee were considered for protecting areas of higher density development where these works were considered likely to be effective and not create significant impacts to people and property further downstream.

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As outlined in section 4.2.3, three areas were targeted for protection: Gawler, Two Wells and Virginia. The levees were located so as to minimise disturbance to natural flow paths whilst maximising the level of protection afforded to higher density residential and horticultural areas.

The following figures outline the alignments used for the initial assessment process. A brief description of the levee alignment is also provided for each.

5.2.1 Virginia Township and Horticultural Areas

This levee system would be formed in two parts:

1. Lower Virginia levee located primarily along Angle Vale Road, immediately east of Port Wakefield Road; and
2. Upper Virginia levee located primarily along the Carclew Road alignment.

The lower Virginia levee would be constructed to the east of Port Wakefield Road and could be used to constrain the extent of inundation from southerly flowing breakouts downstream of the railway line to keep them north of Angle Vale Road. The levee would follow the alignment of Angle Vale Road, with its eastern end starting approximately 600 metres east of the railway line. Cost estimates have assumed that this section of the levee would be formed by raising Angle Vale Road by between 200 to 500mm. The levee would turn southwards at Port Wakefield Road with a channel effectively being created along the eastern side of Port Wakefield Road. The levee would extend along the alignment of Supple Road as far south as the Park Road intersection. It would be approximately 3.4 km long.

A low level bund (500 mm) may need to be provided around the electricity sub-station (or this infrastructure raised) near the Angle Vale Road / Port Wakefield Road intersection. A set of culverts (assumed in the model to be 0.9 m high by 3.1 m wide) would be inserted under Port Wakefield Road.

Minor widening of the separately proposed Buckland Park channel immediately to the west of the Port Wakefield Road would be required.

The levee would need to be constructed in conjunction with the upper Virginia levee to be effective. It may also be necessary to provide some detention storage for the local flows to deal with a coincidental event. The design of the levee will need to provide for local drainage water to get through the levee from the east when not in flood. Also this is an area of localised elevated groundwater levels and hence this will need to be taken into account and managed.

The location of the lower Virginia levee and channel works is shown in Figure 5-5.

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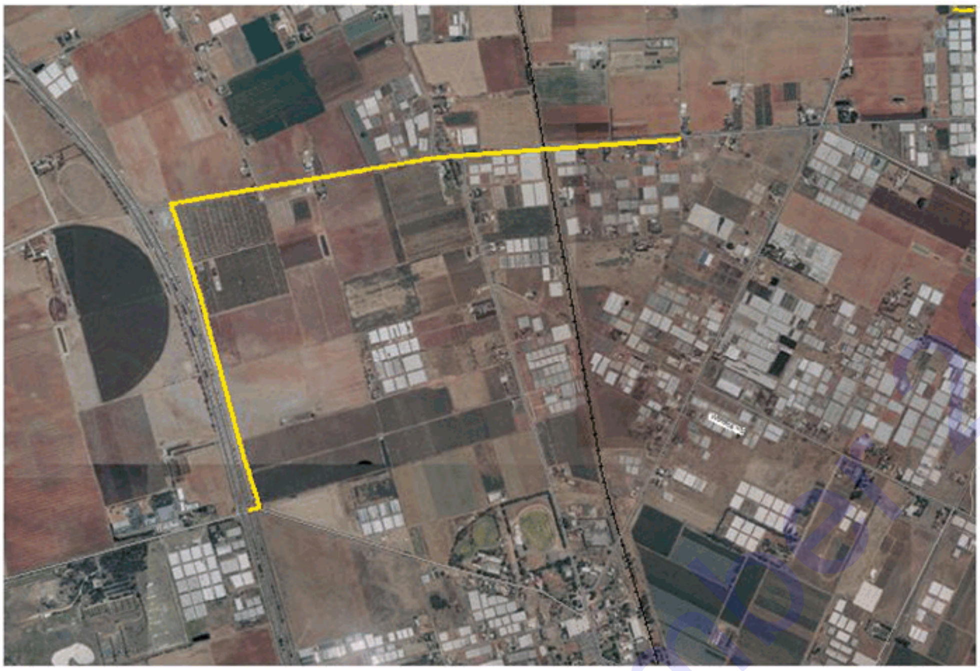

FIGURE 5-5 : LOWER VIRGINIA LEVEE AND CHANNEL WORKS

The upper Virginia levee is intended to direct flood waters that would breakout to the south from the Gawler River near the Hayman Road alignment. Presently these floodwaters would flow west, then south parallel to Carclew Road, or flow over Carclew Road with both flows progressing further in a south westerly direction into the Virginia township. The levee assessed for costing purposes would start approximately 400 metres east of Hayman Road and follow the alignment of Carclew Road, before turning west to follow Burt Road as far west as the Johns Road intersection. In all, the levee would be 2.6 km long. The levee would effectively be formed by raising Carclew Road and Burt Road (both unsealed roads) by an average height of 500 mm. Flood waters behind this levee would be directed towards the lower Virginia levee which would then steer those waters further west and on towards the coast in a controlled manner.

The location of the upper Virginia levee is shown in Figure 5-6.

The upper and lower Virginia levees together have been estimated to cost $14m.

These two levees have been located to minimise impacts to private land and to utilise the natural primary flow paths of floodwaters across the floodplain in this area. They would protect 250 residential properties from flooding for all events up to the 1 in 100 ARI event. They would also protect over 300 ha of agricultural (mostly horticultural) land.

The unit cost of the Virginia levees are high in comparison to the levees at Two Wells and Gawler because it has been assumed they would be formed by rebuilding the roads at a higher level rather than being built on open space areas. This attracts a significant cost penalty. If the works were done as part of a scheduled road upgrade then the cost could be defrayed over a wider stakeholder base.

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FIGURE 5-6 : UPPER VIRGINIA LEVEE LOCATION

5.2.2 Two Wells Southern Levee

A levee around the southern side of Two Wells could be used to protect the existing township and industrial area to the north of town from flooding of Salt Creek as a result of over bank flows from the Gawler River (and also the Light River). The levee alignment modelled in this scenario is consistent with the draft Stormwater Management Plan for Two Wells which is presently being developed. The levee system is approximately is 2.4 km long, as shown in the following figure, and has been estimated to cost a little under $2m.

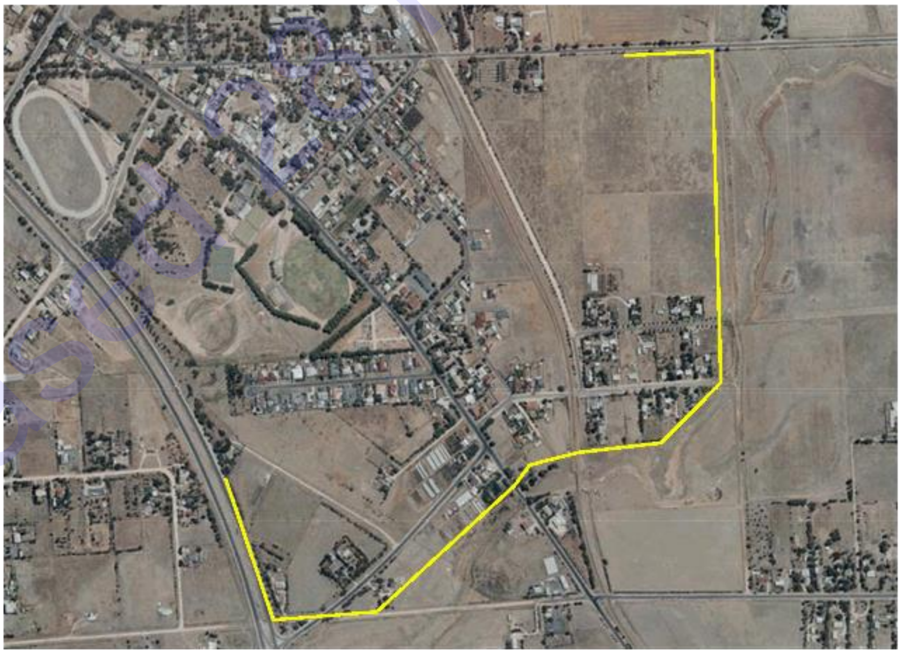

FIGURE 5-7 : TWO WELLS SOUTHERN LEVEE LOCALITY PLAN

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5.2.3 Gawler Township Levees

A series of six levees have been assessed to protect Gawler from flooding for all events up to and including the 1 in 100 ARI flood event.

The location of the levees is illustrated in Figure 5-8. The levees are located primarily on public land and along side road reserves. The levees would be primarily of earthen construction (4.7 km) and typically 600 mm in height. In some short sections the levees would need to be a little over one metre in height. There are three or four areas where there would be insufficient room to construct an earth levee. In these locations it has been assumed that a low retaining wall (typically less than 600 mm) would be incorporated into the existing landscape or rear of allotment fences. These sections are relatively short and are expected to total up to 250 metres in length. A short section (60 m) of Kelly Road would also need to be regraded to accommodate the assessed levee alignment.

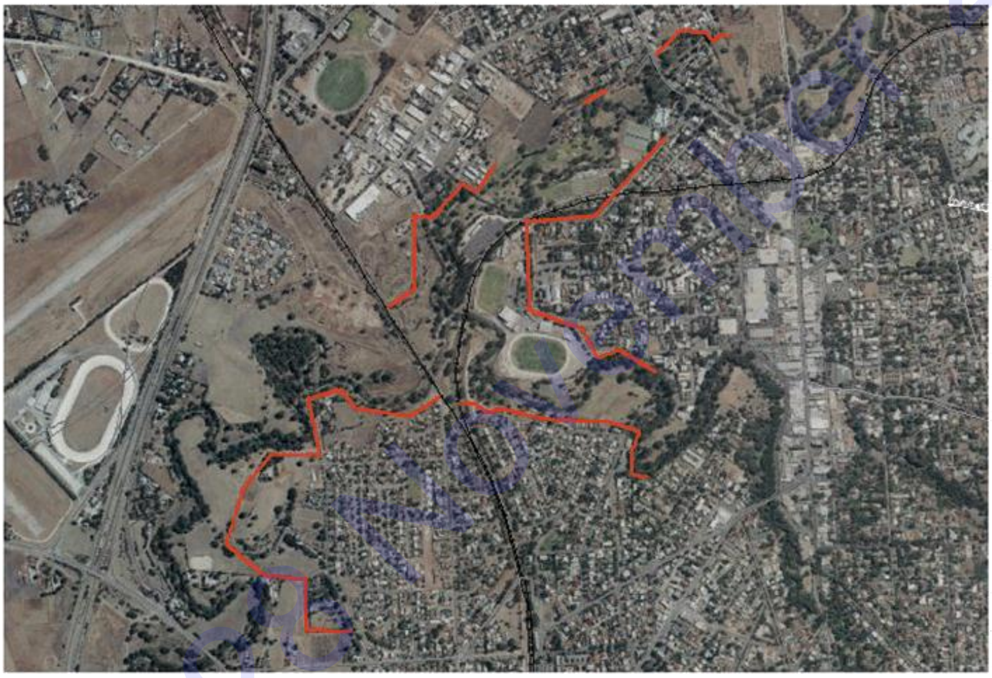

FIGURE 5-8 : STRATEGIC LEVEES WITHIN GAWLER

The levee system within Gawler has been estimated to cost $3m.

5.2.4 Damage Reduction from the Strategic Levees Package

The strategic levees would reduce the present value of flood damages from $109m down to $85m and reduce the average annual damages down to $5.77m.

The benefits in terms of reduced exposure to flooding are summarised below in Table 10.

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TABLE 10 : PRE AND POST FLOOD MITIGATION IMPACTS SUMMARY 1 IN 100 ARI – STRATEGIC LEVEES OPTION

	Number of properties affected within each hazard rating			
	Low	Medium	High	Extreme
Residential without Levees	1559	1451	1179	457
Residential with Levees	1086	933	689	316
Commercial / Industrial without Levees	132	92	72	49
Commercial / Industrial with Levees	79	62	46	42

The levees would make minimal change to the area of agricultural and grazing land inundated from 3770 ha down to 3690 ha. The affected horticultural area would be slightly reduced from 2170 ha down to 1765 ha.

The net present value of the strategic levee option has been estimated to be $5m with a benefit cost ratio of 1.25. The project is cost effective in purely monetary terms and relatively attractive when public safety is also considered. It should also be noted that the damage estimates only value export crops. If all crops are included the Net Present Value would be around $33m and the Benefit Cost ratio would be 1.72.

Whilst the benefits of the strategic levees outweigh the cost of their construction there are some impacts associated with them that would need to be managed. The most significant of these is in an increase in flood depth, albeit less than 100 mm in most cases. Whilst there would be an increase on some properties, most importantly no new properties would be flooded: simply the depth on a number of properties would be slightly greater. These areas are confined mainly to agricultural and horticultural land and it is not anticipated that any new areas of over floor flooding would be created.

A depth difference plot comparing the with and without levees scenarios is provided in the figures that follow for each of the areas targeted.

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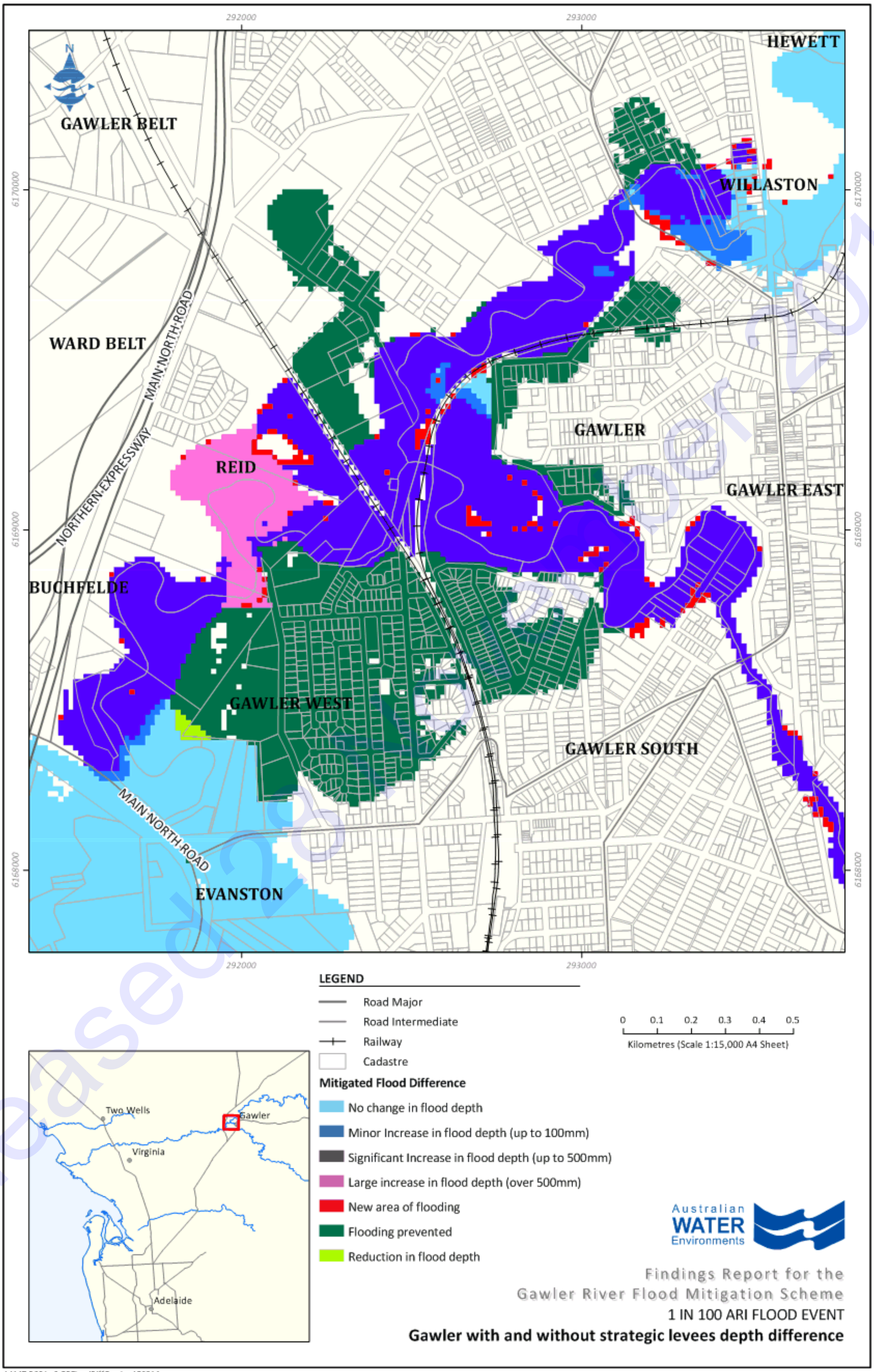
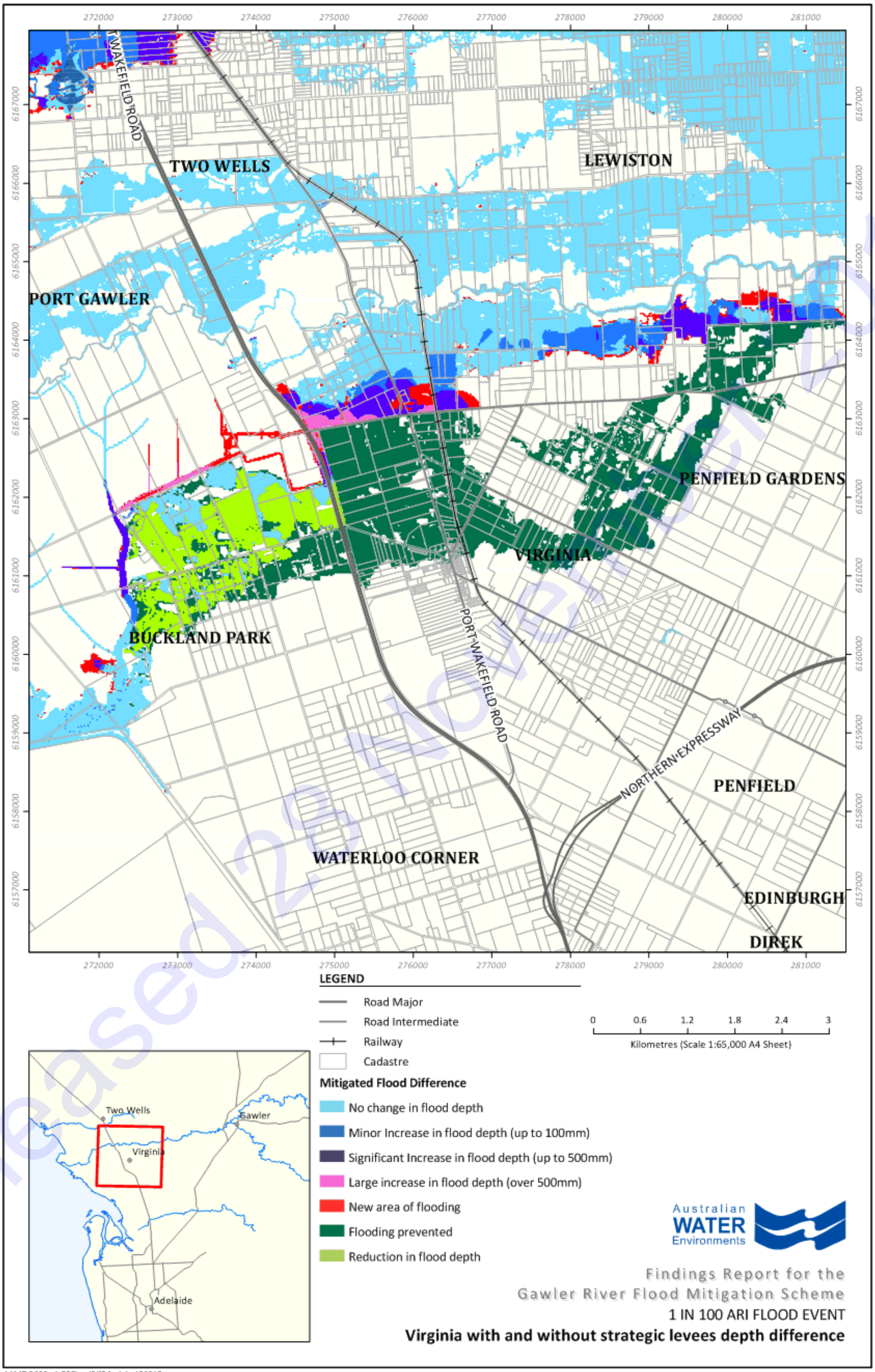


14147 D021 v2 GRFloodDiffGawler 150914
Last Updated: 15/09/2015

Figure 5-9



14147 D022 v1 GRFloodDiffVirginia 150915
Last Updated: 15/09/2015

Figure 5-10

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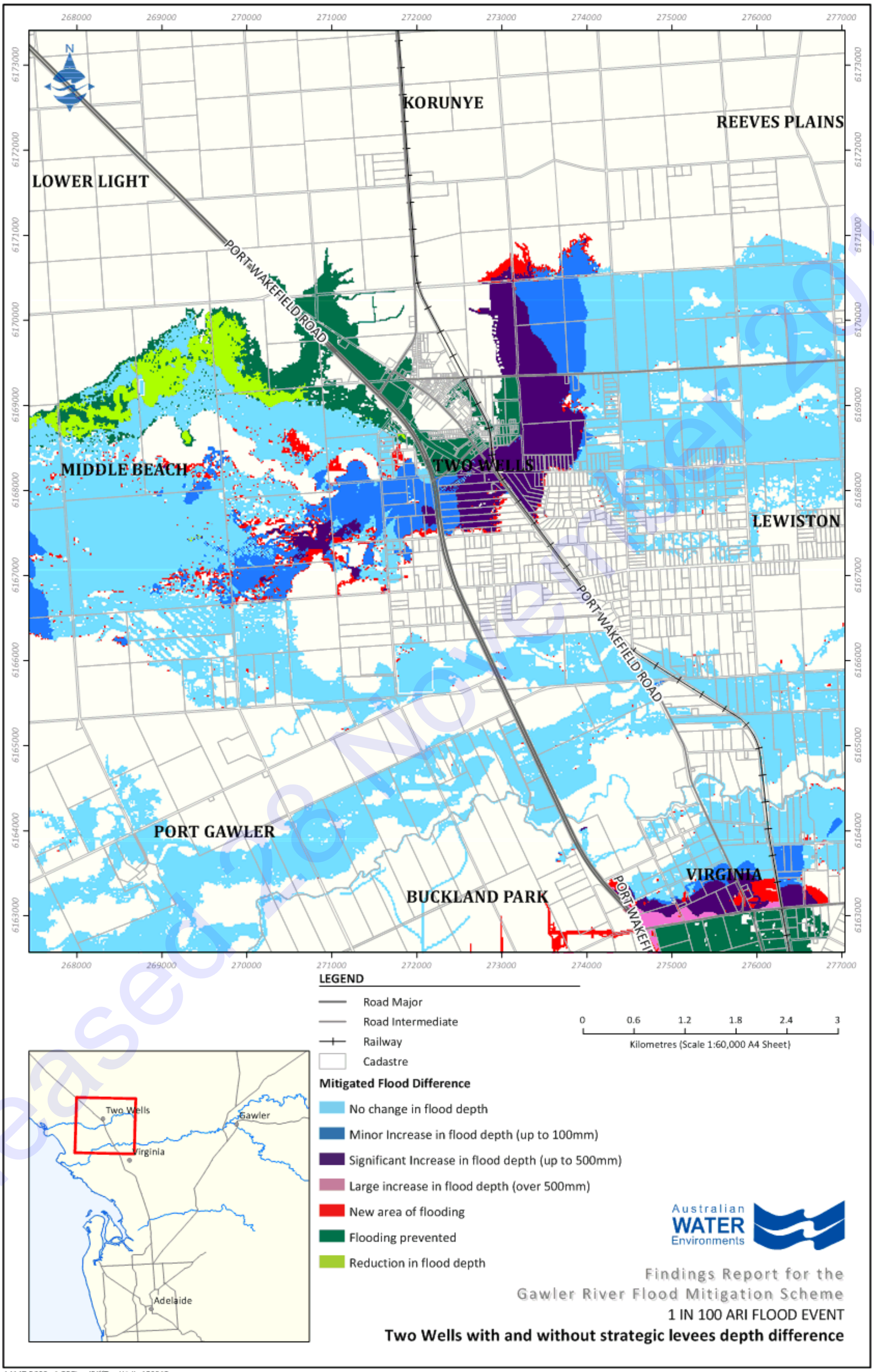

14147 D023 v1 GRFloodDiffTwoWells 150915
Last Updated: 15/09/2015

Figure 5-11

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6 Conclusions

Hydrology Update

The hydrology review and update has resulted in a minor reduction in peak flow estimates for the Gawler River. The peak flow at Gawler Junction during a 1 in 100 ARI event is now estimated to be 635 m^3s^{-1}.

The review has demonstrated that a shorter duration storm event should be used as the design flood event. This effectively reduces the volume of flood waters that need to be managed.

The North Para River remains the primary focal point for managing major flood flows.

Floodplain Modelling and Mapping

The base Mike Flood model has been updated to incorporate major changes in the landscape of the Gawler River floodplain. The model has also been refined to further improve its representation of culverts and the major railway lines traversing the floodplain. The flood extents remain similar but slightly less than for the 2007 mapping. A small area of Angle Vale township is no longer considered to be at risk of flooding from the Gawler River during a 1 in 100 ARI flood event.

Desired Level of Flood Protection

The 1 in 100 ARI event is considered to be the desirable and a realistic level of flood protection for new development as well as for much of the existing floodplain development.

In cases where the failure mechanism may be sudden (e.g. failure of a levee), a higher level of protection should be considered especially for new developments.

Flood Damages

The present value of potential flood damages from a 1 in 100 ARI flood has been estimated to be $182 million. The Average Annual Damages from flooding is estimated to be $7.40 million. The Present Value of these Average Annual Damages (calculated over a 30 year timeframe @ 7% discount rate) is $109 million.

Public Safety

Over 3000 residential properties are at risk of flooding with a flood hazard rating of medium or higher. A further 1600 properties are likely to incur nuisance but low hazard flooding.

Flood Mitigation Measures

Two structural flood mitigation strategies are considered to be practical and cost effective means to reduce the flood damages and public safety exposure.

Of these, enlarging the Bruce Eastick North Para Flood Mitigation Dam offers the greatest level of protection and creates the least impacts. This option is rated as the most favoured structural mitigation option. The enlarged dam would have a benefit - cost ratio of approximately 1.3. It would reduce the present value of damages from $109 million to $58 million. The works at the dam could cost in the vicinity of $40 million.

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Strategic levees to protect Two Wells, Gawler and Virginia are an alternative less costly (but less effective) structural flood mitigation option. Strategic levels would have a benefit – cost ratio greater than 1.25. The levees would reduce the present value of damages from $109 million down to $85 million.

The comparisons of the cost of implementing the various mitigation options and the financial benefits are summarised in the following table.

TABLE 11 : SUMMARY OF COST BENEFIT ANALYSIS OF FLOOD MITIGATION OPTIONS

	Strategic Levees	Enlarge the Bruce Eastick North Para Flood Mitigation Dam
Cost of Structure	$ 19 million	$ 40 million
Damage Reduction	$ 24 million	$ 51 million
Net Present Value	$ 5 million	$ 11 million
Benefit Cost Ratio	1.25	1.3

Whilst neither structural option is highly cost effective, both would be at worst cost neutral in purely monetary terms, and both can be considered very effective, viable options, particularly once public safety improvements and the social and emotional costs associated with flooding are considered.

Given that enlarging the Bruce Eastick North Para Flood Mitigation Dam is the most effective structural solution for addressing flooding issues downstream, a structural feasibility assessment for the best method of raising the dam wall is required to confirm technical feasibility and further refine cost estimates for enlarging the dam.

Non structural measures such as a total flood warning system and more effective and consistent planning measures to manage new development are the most cost effective mitigation options. Both provide no regrets approaches and should be actioned immediately.

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Appendix A : Culverts included in Mike Flood Model

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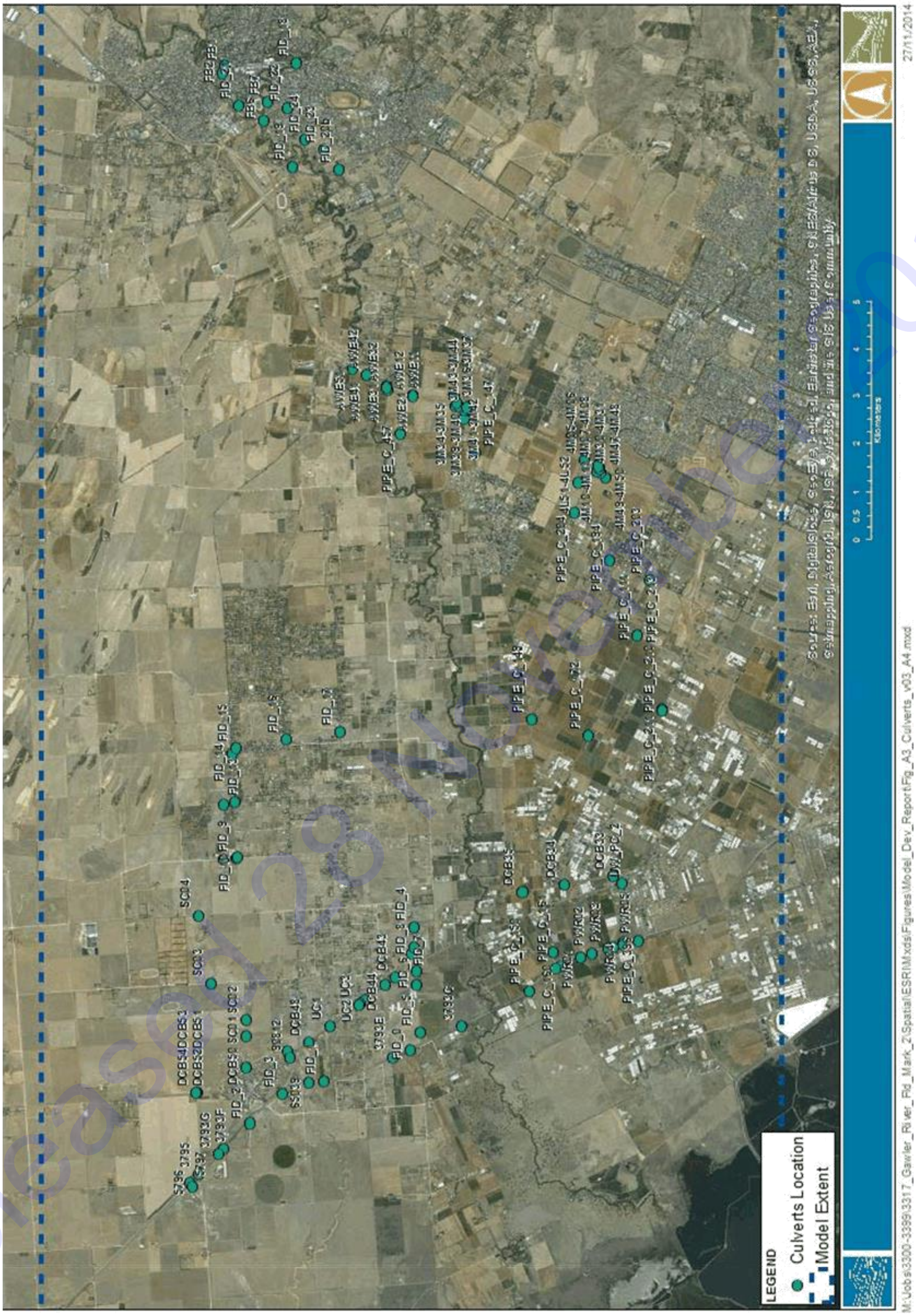

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Appendix B : Flood Damages Calculation Summary

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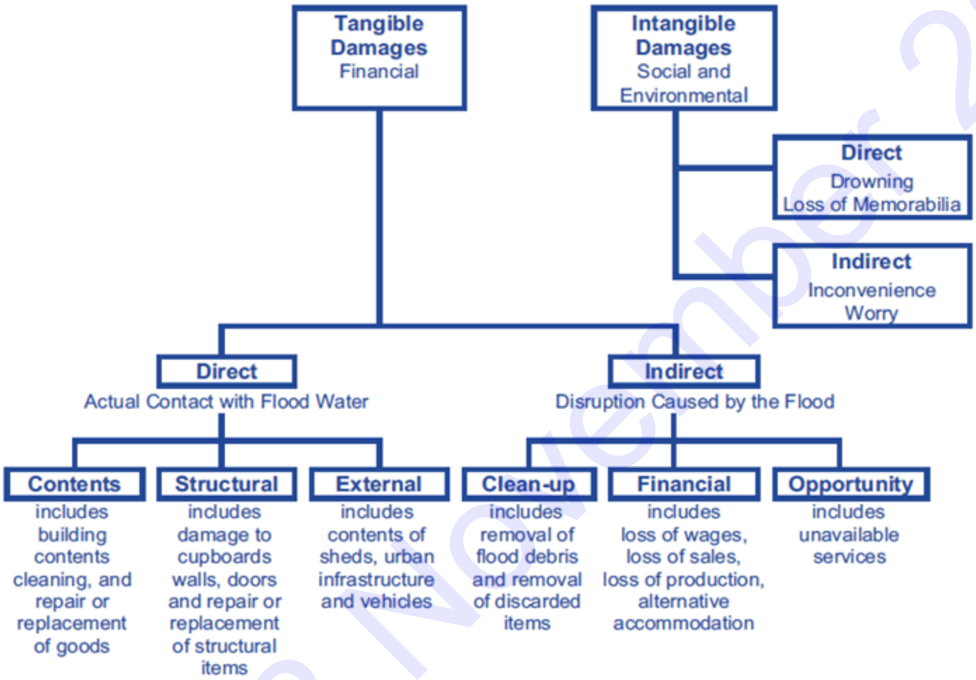
Introduction

The approach applied to estimating flood damages is consistent with Bureau of Transport Economics, 2001.

This approach allocates costs into two primary categories – tangible and intangible. Tangible damages are then further separated into direct and indirect costs.

The figure below illustrates the damage categorisation process. A description then follows along with a table of unit rates for different types of damages.



Source: Commonwealth of Australia, 2012

Direct tangible losses

Direct Tangible losses are the most straight forward and obvious. They are the losses that arise from the destruction of, or damage to, a man made physical asset. This includes losses as a result of damage to buildings, be they residential, commercial or industrial. They can be:

- private or public buildings;
- crops that are to be harvested for commercial sale and hence have a commercial value (whether or not they are naturally occurring);
- private or public infrastructure such as roads, railway lines, telecommunications, pipelines, electricity generation and distribution systems.
- vehicles and plant (e.g. mobile farm machinery);
- livestock; and
- the contents of buildings (e.g. furniture and fittings, retail stock, machinery and goods used for production of a commercial product).

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Indirect tangible losses

Indirect tangible costs are costs incurred as a consequence of the event occurring, but are not related directly to the physical damage that has occurred. These costs include such things as the:

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

Of the above items the most difficult and contentious to quantify is the disruption to business. The Bureau of Transport Economics (2001) provides the following guidance:

> *"The cost of lost business is often included in the estimated cost of a disaster. The impact of a disaster can be devastating for businesses directly affected by that disaster, and local communities can suffer as a consequence. However, when examining the impact of the disaster from a national perspective, business disruption costs typically should not be included. This is because business disruption usually involves a transfer between producers, without a significant loss in national economic efficiency. There may be occasions when the transfer between producers involves additional costs, which would be a valid indirect cost of the disaster. Business disruption costs would be included if the event affected the nation's economy through an increase in the level of imports or a decrease in exports".*

Intangible costs

This category includes all those items that can not be categorised as a direct or indirect tangible cost.

These costs include the:

- loss of life;
- costs associated with personal injury;
- increased medical costs / reduced life expectancy associated with increases in levels of sickness in a community following a disaster including stress related illnesses;
- disruption to households;
- loss of private memorabilia;
- loss of heritage values; and
- loss of items / features of cultural significance.

Intangible costs are those for which no market exists and hence there is no agreed method in place to quantify them. With respect to intangible losses the Bureau of Transport Economics (2001) advises that:

> *"The largest gap in the estimation of disaster costs is the inability to adequately estimate intangible costs. Evidence suggests that they are at least comparable with direct costs and possibly much larger. Research is needed to develop reliable methods to overcome this gap".*

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Direct tangible losses calculations

Losses to the following items have been considered in this latest analysis:

- Damage to buildings including their contents;
- Damage to infrastructure; and
- Damage to crops and stock losses.

Losses to vehicles have not been included as it was considered that mobile equipment could be readily relocated out of the flood zone given the relatively long lead time that could be provided by effective flood warning.

Damages to buildings and their contents

Residential buildings

The number of residential buildings that potentially would suffer inundation for the 10, 20, 50, 100 and 200 year ARI events were separately estimated by overlaying the flood inundation maps for these events on landuse mapping and cadastre data sets. The estimates made in this way were verified and adjusted where necessary by inspecting aerial photography so that obvious cases where a property might be inundated but the house may not. Cases where properties were inundated by shallow water depths of less than 150 mm were also excluded as in these cases it was assumed that over floor flooding would not be incurred (and hence damages would be substantially less).

Ideally a stage damage curve relationship would have been developed for residential properties through a process of floodplain modelling and property inspections. This information was not available therefore damage estimates relied on a damage cost per inundated house of $20,500 which is recommended in Read Sturgess and Associates, 2000 (in BTE, 2001). This figure was converted to 2014 dollars by applying a CPI adjustment to convert from 1999 to 2014 prices. The cost of damage for properties where flooding occurred but the house was not inundated was assumed to be negligible (a conservative simplification of the expected estimated damages).

Large commercial buildings (excluding greenhouses)

BTE (2001) recommends that individual inspection of commercial buildings is the most effective means of quantifying damage costs. Where this is not possible, generic flood damage tables prepared by Smith (1994) and reported in BTE (2001) can be used. The costs to commercial properties has recently been reviewed in the western suburbs of Adelaide and reported in Wright (2000). The detailed work by Wright (2000) however, applies to the western Adelaide suburb of Keswick and the results are not considered of relevance to the rural nature of the Gawler River where most commercial building are likely to be related to storing, processing and package primary produce (or associated plant and equipment). For this reason the generic tables presented in BTE, 2001 were used.

The generic flood damage tables present a range of costs based on building type (based on five value classes), area and depth of inundation. For the purposes of this assessment the lowest value class was selected. The median area of all inundated commercial buildings was calculated to be 190 m2 (AWE 2004). A damage value of $7,443 per building was then adopted (and then adjusted to 2014 values by CPI). The same verification process as for the residential properties was used to exclude those commercial buildings for which over floor flooding was not anticipated.

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Greenhouses (building only, excluding the crop)

The area and location of individual greenhouses was estimated in AWE 2004. These data layers were applied to the new flood inundation areas and a revised cost estimate made.

The cost of construction of modern greenhouses estimated to be in the range of $20 to $40 per square metre excluding the cost of the land, water, and irrigation equipment, all of which would not be affected by floods. A cost value of $27 per square metre was adopted.

Public Infrastructure Damages

Transport infrastructure – Railway lines

A damage cost per kilometre of railway line affected by flooding of $200,000 and adjusted for CPI was adopted based on damage estimates for the Brown Hill and Keswick Creek catchments undertaken by Hydro Tasmania (2003).

Transport infrastructure – Roads

The damage rates proposed by Read Sturgess and Associates (2000) as reported in BTE (2001) were adjusted for CPI and applied.

A range of damage costs are available for different road constructions. The inundated road lengths were categorised into major sealed, minor sealed and unsealed roads.

Public services and utilities

The reported public infrastructure costs (water, power, sewer and telecommunications) as presented by Tonkin Consulting (2001) and Earth Tech Engineering (2002) were used to calculate a damage rate per unit length of inundated road (and adjusted for CPI). Most new services are placed underground and hence damage is likely to be minimal.

Damage to crops

Scholefield Robinson Horticultural Services (SRHS) undertook a comprehensive review of potential damages to crops in the AWE (2004) work. This involved:

- estimating the value of horticultural and agricultural production in the Northern Adelaide Plains region which includes the relevant area of the Gawler River;
- estimating the value of horticultural and agricultural exports to overseas from the region;
- identification of the main categories of horticultural and agricultural production susceptible to flooding and description of the types of losses that may result from flooding;
- formulation of a generic example of loss estimation; and
- estimation of as many as possible of the parameters required to estimate loss in each of the production commodities or categories.

Most of these estimates were formulated from the data provided by PIRSA other estimates were made from consultations within SRHS drawing on their collective experience as consultants to many clients in the region or with similar products.

Estimates of the value of exports overseas for horticultural crops were provided by PIRSA and for agricultural production were estimated by SRHS from their knowledge of each of the commodities and of the region. Estimated farmgate value of production for the year ending 30 June 2013 for categories of commodities was developed for the neighbouring Smith Creek horticultural areas by

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EconSearch. These sources of information were used to estimate unit rates for crop losses for various crops.

The original work by SRHS utilised a range of landuse data sets to collate the above apportionment of crops. For this revised damage estimate process it was assumed that the same mix of crops was being grown in the region as was estimated by SRHS in 2004.

In this latest damage estimate process more recent but coarser landuse data was used (2013 landuse data from Planning SA web site). In this data set primary production was split into agriculture, horticulture and livestock.

Areas ascribed as agriculture were assumed to be cereals; livestock - grazing; whilst horticulture was apportioned across the various crop types as per the 2004 proportions. Greenhouses were accounted for separately (because there was sufficient information to enable this from the earlier 2009 data coverages).

Indirect tangible damage estimates

Indirect costs are costs incurred as a consequence of the event occurring, but are not related directly to the physical damage that has occurred. These items are often not measured and can be difficult to accurately quantify.

Our approach to this task was to estimate these costs wherever possible.

The cost of lost business was not estimated. Given that most of the economic activity of the region is agricultural and relies on the production of one crop or in some case two or three, the effect of a flood will be to decimate the crop but not necessarily limit the production of a subsequent crop in the same year (if multiple crops can be grown) or in the years that follow, unless flood waters introduce a disease to the soils or other mode of crop damage. It was therefore considered that the estimate of crop damage under the Direct Tangible category adequately addressed crop and hence loss of business costs. Additional allowances under this category could be claimed to double count the actual loss.

BTE (2001) discuss the difficulty in estimating these losses at great length and conclude that wherever possible cost should be estimated directly but where this is not possible draw on their body of case study reviews to suggest that for flood damages, indirect tangible costs usually vary between 25 and 40 percent of the direct tangible costs.

The direct cost estimate method was applied herein. This resulted in a cost midway between the 25 and 40% methods.

Direct estimation of costs

Estimates of costs were made in the following categories:

- Emergency Response;
- Relief costs/grants;
- Clean up costs residential;
- Clean up costs commercial; and
- Emergency accommodation.

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Emergency response

Tonkin Consulting (2001) estimated the response costs for the 1992 floods. These estimates were adopted and adjusted for CPI. These costs were converted to a unit rate cost per inundated residential property (on the assumption that response costs would be proportional to the number of people and properties affected by the flood).

Relief costs and grants

These costs were estimated on the basis that on average a grant relief cost would amount to $2,500 per property as determined in AWE (2004) (and adjusted for CPI). This figure was determined following a review of recorded cost from the 1992 floods and grants made to assist landholders subjected to flooding of the Patawalonga Lake in 2004, (as reported in AWE (2004)). It was assumed that only properties with over floor flooding would receive a grant.

Clean up costs

Cleanup costs were estimated using the number of residential and commercial properties (including greenhouses) potentially affected by flooding. The rates used were guided by those presented in BTE (2001) and adjusted for CPI.

Emergency accommodation

Emergency accommodation costs were estimated by again using rates published in BTE (2001). It was assumed that only those properties with over floor flooding would require emergency accommodation.

Intangible costs

Intangible costs are all very difficult to estimate and in many cases no attempt is made to quantify them in monetary terms, but rather to simply acknowledge their existence and to take into consideration that they can be substantial, particularly in the case when costing marginal disaster mitigation schemes. An extract from BTE (2001) follows that provides an outline of the scale of these costs.

> *"Available estimates of intangible costs suggest that they are very substantial.*
>
> *A frequently quoted example is that of the Buffalo Creek flood of 1972, which resulted from the collapse of a dam at a coal mine. There were 125 people killed (Erikson 1976). Almost all of the survivors suffered psychological problems and 625 of them sued the company. Stern (1976) estimated the losses to households using the schedule of compensation and trauma scale resulting from the court case. In a conceptually similar study, Allee et al. (1980) constructed a scale of trauma suffered by residents in Tug Fork in the United States and estimated the costs by use of the Veteran's Administration Compensation Scheme. Both studies gave an estimate of loss approximately double the direct damage suffered by the households.*
>
> *In the UK, flood-affected residents were interviewed after a number of floods. They were asked to compare the different impacts of the flood in terms of their relative severity (Parker, Green and Thompson 1987, p. 104). Stress and loss of memorabilia generally ranked above the impact of damage to house and contents. For many people, the effect of having their gardens damaged is similar to the loss of memorabilia. Yeo (2000) reported that a number of respondents to National Hazard Research Centre surveys were sad at the degraded state of their gardens following floods in 1998.*

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One of the most comprehensive studies of the health effects of floods was that by Chamberlain, Hartshorn et al. (1981) of the 1974 Brisbane flood. The Chamberlain, Hartshorn et al. (1981) report showed that 14 months after the flood, 23 per cent of respondents to a survey had still not recovered from the effects of the experience.

Anecdotal evidence of other disasters indicates that the emotional and psychological effects can last for decades."

These few cases illustrate that there is little doubt that intangible costs faced by households as a result of flooding are very important."

TABLE 1 : FLOOD DAMAGE UNIT RATES TABLE

Item	Unit	Rate	Source
Direct Tangible Rates			
Major Road	km	$75,000*	BTRE, 2001
Minor Sealed Road	km	$24,000*	BTRE, 2001
Unsealed Road	km	$10,600*	BTRE, 2001
Services	km	$8,890*	BTRE, 2001
House over floor flooding	per house	$32,263*	BTRE, 2001
Commercial Building	per building	$11,715*	BTRE, 2001
Structural damage to Greenhouses	m^2	$27*	AWE, 2009
Grazing Land	ha	$374	Econ Search 2014
Crops (not irrigated)	ha	$350	Econ Search 2014
Irrigated perennial horticulture	ha	$13,951	Econ Search 2014
Irrigated oleaginous fruits	ha	$2,135	Econ Search 2014
Irrigated vine fruits	ha	$4,701	Econ Search 2014
Irrigated vegetables & herbs	ha	$65,906	Econ Search 2014
Greenhouse Crops	ha	$71,585	Econ Search 2014
Indirect Tangible			
Emergency Response	per property	$1,255	Actual costs from 1992 escalated
Relief Grants	per property	$3,596	Actual costs from 1992 escalated to 2014
Clean up Residential	per property	$3,927	Actual costs from 1992 escalated to 2014
Clean up Commercial/Industrial	per property	$3,798	Actual costs from 1992 escalated to 2014
Emergency Accommodation	per property	$676	Actual costs from 1992 escalated to 2014

**Escalated to 2014 with CPI (192.5 – from 1999 base of 122.3).*

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TABLE 2 : CURRENT FLOOD DAMAGE ESTIMATES FOR VARIOUS ARIS

ARI	200 ARI	100 ARI	50 ARI	20 ARI*	10 ARI*
Direct Tangible (export crops only)	$159,543,892	$138,504,076	$81,720,146	$22,048,312	$14,311,612
Direct Tangible (local and export crops)	$252,793,264	$225,199,275	$144,421,726	$54,922,783	$17,429,841
Indirect Tangible	$52,368,513	$43,756,455	$20,293,939	$1,984,172	$1,388,282
Total Tangible – export crops only	**$211,912,404**	**$182,260,531**	**$102,014,085**	**$24,032,484**	**$15,699,894**
Total Tangible – local and export crops included	**$305,161,776**	**$268,955,730**	**$164,715,666**	**$56,906,955**	**$18,818,123**

**Estimated from 2007 mapping.*

TABLE 3 : FLOOD DAMAGES SUMMARY

Flood Frequency (ARI)	Estimated Damages (Export Crops Only)
1 in 10	$15m
1 in 20	$24m
1 in 50	$102m
1 in 100	$182m
1 in 200	$212m
Average Annual Damage	$7.40m
Present Value of Damages*	$109m

**Calculated over a thirty year timeframe using a discount rate of 7% per annum. Note: a lower discount rate will result in higher damage costs. Similarly, a longer timeframe for evaluating damage cost will increase the present value of damages.*

The results presented in Table 3 adopt a direct calculation approach for Indirect Tangible losses (based on observed response costs) and hence are likely to be low.

Assumptions have also been made with respect to the exclusion of crop losses for crops that are sold locally. The damage (losses) to crops listed above only includes crops for the export market. Hence the potential damage costs could be much higher than those summarised above. If the value of local crop losses are included then the present value would be around $172 million.

As outlined above, the damage estimates above also make no allowance for Intangible losses. The literature suggests these could be substantial and if included would increase the above costs buy around 60%.

If these additional but less certain intangible costs were allowed for the present value of damages would be much higher again.

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Dear Dean

GRFMA – MITIGATION OPTIONS FINDINGS REPORT & LIABILITY CONSIDERATIONS

I refer to our telephone conversation regarding the above. You have requested advice regarding the potential liability issues arising for all Constituent Councils and the Authority if the 'structural' flood mitigation options identified in the AWE Mitigation Options Findings Report (the Report) are not implemented. By way of background, you have informed me that:

- one of the Constituent Councils has expressed concern that if it receives the Report at a formal meeting (i.e. for information purposes), this could result in the Council being liable for flood damage in its area if the flood mitigation options identified in the Report are not implemented; and
- the option identified as the most effective in the Report (the Rosedale Dam) is not seen to be viable by some of the Constituent Councils given its significant costs and since it involves the compulsory acquisition of at least 21 properties.

My advice is that the receipt of the Report at a formal meeting will **not**, of itself, result in a Council being liable for flood damage, even if none of the options are progressed or implemented. Further, a decision by one or more of the Constituent Councils not to progress the infrastructure options identified in the Report will not, alone, result in a Constituent Council or the Authority being held liable for any flood damage, particularly where the decision is supported by cogent reasons (i.e. such as resource limitations).

In the event of a flood and subsequent claim for damages against one or more of the Constituent Councils and/or the Authority, the question of liability (if any) will be determined on a case-by-case basis in accordance with the provisions of the *Civil Liability Act 1936* and common law principles (note that the Constituent Councils provide a statutory guarantee of the liabilities incurred by the Authority – refer clause 31, Schedule 2 of the LG Act). The following is relevant:

- the Report, which was commissioned by the Authority, quantifies the risks associated with flooding of the Gawler River based upon the available flood modelling data and proposes possible options to mitigate these risks. Upon receiving and considering the Report, a Constituent Council will, therefore, be deemed to have knowledge of the risks associated with the flooding of the Gawler River in its area. However, the Councils will likely already have varying knowledge of these risks given they have seen fit to establish

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the Authority for the purpose of coordinating appropriate action to mitigate them! On this basis, the consideration of the Report by a Constituent Council will not increase or otherwise impact that Council's risk of exposure to liability associated with flooding of the Gawler River;

- the Report does not impose a duty or obligation on the Constituent Councils to undertake one or any of the options identified therein. Rather, it identifies what, if any, steps *could* be taken (i.e. at the discretion of the Constituent Councils) to mitigate the flood risks. Indeed, there are other prudential considerations over and above the Report (i.e. such as those set out under section 48(2) of the LG Act) that will necessarily inform a decision regarding the viability of the structural options proposed (being the dam and levee options);

- it is not within the functions of the Authority (as set out in its Charter) to determine what flood mitigation infrastructure should be constructed in relation to the Gawler River but, rather, to *coordinate* its construction once a determination has been made and to raise funds for this purpose. Accordingly, the decision to progress any of the mitigation options is a matter for the Constituent Councils alone. This means that there are no grounds for the Authority to be held liable for flood damage if none of the options in the Report are progressed - such outcome is beyond the Authority's control;

- in assessing whether liability could reasonably be attributed to one or more of the Constituent Councils in the event of a flood and subsequent claim, the Court would consider the Councils' knowledge of the flood risks and their likelihood, whether any control measures could have reasonably been undertaken by the Councils to mitigate against or protect persons from those risks and if so, the nature and extent of them. The question as to what measures could have been reasonably taken will turn upon the particular circumstances. The limitations upon the Councils' resources are relevant in this regard as the Courts are required in to take into account the competing demands on those resources (see *Calvaresi v Beare* [2000] SASC 21); and

- by way of example, if flood damage to third party property resulted from any unreasonable failure by a Constituent Council to maintain drainage infrastructure, this would likely (based on applicable case authorities) have adverse liability implications for that Council. Conversely, where a Constituent Council is not sufficiently resourced to fund the infrastructure options in the Report and has otherwise done all that is reasonably within its power to mitigate the risks associated with rare flood events (i.e. such as implementing, to the extent it is practicable to do so, the 'non-structural' measures outlined in the Report) the likelihood of the Council being held liable for flood damage (or associated injury) in the event of a claim is, in my view, remote.

Regardless, it is not possible to prevent a person from pursuing a claim for damages against the Constituent Councils or the Authority in relation to loss or injury arising from a flood. As above, the success of such claim will turn upon the facts, including the degree to which the Councils' (or a Council's) actions (or failure to act) caused or contributed (if at all) to the relevant injury or loss and the Council's ability to have taken reasonable preventative action, to be measured having regard to its resources.

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I trust the above is sufficient for your purposes, however please let me know if you would require a more detailed response on our letterhead.

Yours sincerely
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C. COUNCIL/COMMITTEE TO DECIDE HOW LONG ITEM 16.1 IS TO BE KEPT IN CONFIDENCE

Purpose

To resolve how long agenda item 16.1 is to be kept confidential.

STAFF RECOMMENDATION

That pursuant to Section 90(2) and Section 91(7) of the Local Government Act 1999 the Council orders that the following aspects of Item 16.1 be kept confidential:

- Report for Item 16.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.
- Attachment(s) for Item 16.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.
- Discussion for Item 16.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme
- Decision for Item 16.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.

COMMITTEE RESOLUTION 2543

That pursuant to Section 90(2) and Section 91(7) of the Local Government Act 1999 the Council orders that the following aspects of Item 8.1 be kept confidential:

- **Report for Item 8.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.**
- **Attachment(s) for Item 8.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.**
- **Discussion for Item 8.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme**
- **Decision for Item 8.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.**

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Options

Option 1

That pursuant to Section 90(2) and Section 91(7) of the Local Government Act 1999 the Council orders that the following aspects of Item 16.1 be kept confidential:

- Report for Item 16.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.
- Attachment(s) for Item 16.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.
- Discussion for Item 16.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.
- Decision for Item 16.1 until the Gawler River Floodplain Management Authority releases the Findings report for the Gawler River Flood Mitigation Scheme.

Option 2

The Council/Committee determines a different timeframe for any "in confidence" aspects of agenda item 16.1 to remain in confidence.

Analysis of Options

Option 1

This item is excluded from the public on the basis that it relates to Section 90 (3) (b) of the Local Government Act 1999.

This matter is confidential because it identifies communities that may or may not be required to be acquired in future. As a consequence if this information was released to the public it may cause undue distress to residents and communities, when final solutions may have significantly less impacts. In the correspondence from the Executive Officer of the Gawler River Floodplain Management Authority the request has been made to consider the report 'in the strictest of confidence'.

The report, attachment, discussion and decision by this Council discuss the issue of the construction of flood mitigation dams that will, if built in accordance with the draft Flood Mitigations Options Report, impact significantly upon communities in the upper and lower reaches of the Gawler River. The recommendation put to the GRFMA suggests changes to the structural solutions that minimize this potential impact and subject to the deliberations of the GRFMA may address this by incorporating the preferred structural alternatives that minimize the community impact.

Option 2

The Council may determine that certain or all aspects of agenda item 16.1 remain in confidence.

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