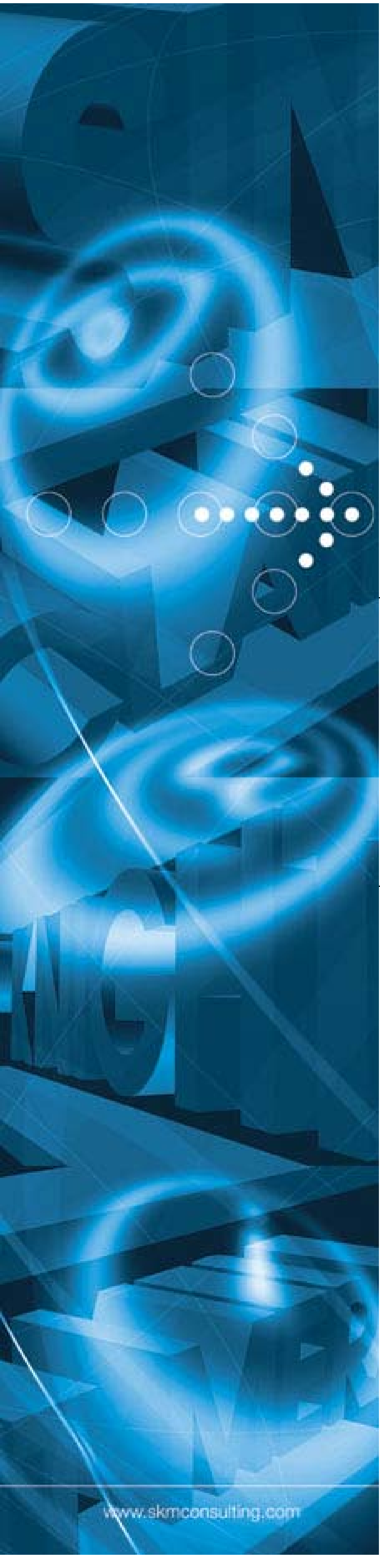

Shepparton Mooroopna Floodplain Management Study

Floodplain Management Plan
Stage 2 Technical Report

October 2002

LAWSON AND TRELOAR PTY LTD
Coastal, Ocean and Water Resources Consulting Engineers

SINCLAIR KNIGHT MERZ

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1. Introduction

Following the Spring 1993 floods, a Scoping Study was prepared (SKM, 1998) that identified the need for a comprehensive study for Shepparton-Mooroopna. In June 1999, Sinclair Knight Merz was commissioned by the Greater Shepparton City Council (GSCC) to undertake a comprehensive floodplain management study for Shepparton-Mooroopna. The Goulburn Broken Catchment Management Authority (GBCMA) has also played a lead role in managing this study. The study forms the basis on which the Floodplain Management Plan was developed.

The main objective of the floodplain management plan is to minimise the economic and social impacts of flooding on the community. It has been achieved through this study by investigating the existing nature of flooding and investigating a range of flood mitigation measures and their merits. The mitigation measures investigated included both structural (eg. levees, floodways) and non-structural options (land use planning, emergency response).

The study was coordinated and guided by a technical steering committee (TSC) comprising representatives from relevant agencies. The committee met throughout the course of the study. Its role was to review work to-date, provide guidance to the consultant, and make resolutions regarding the consultant's findings and study outcomes. A community reference group (CRG) consisting of residents nominated by the community. The CRG has played a pivotal role of providing feedback on the study direction and outputs during the course of the study.

The plan has been developed in two stages to enable the application of risk management principles. The advantage of this approach is it improves community understanding of existing risks (ie. likelihood and consequences) to allow the community to make informed decisions (eg. selection/approval of risk treatments or commonly known as flood mitigation options) to be made based on a sound understanding of flood risk principles. By streamlining the study, the approach also has the advantages of ensuring decisions are made with all necessary information and in an effective sequence.

The use of the risk management framework is in line with best practice principles as outlined in the Victoria Flood Management Strategy (DNRE/DoJ 1998). Key elements of the two stages are as follows:

- **Stage 1** - Investigation of flooding, determining the likelihood and consequences for existing conditions.
  - Data collection – collection of data relevant to study (eg. topographic information, historical flood levels, etc),
  - Community consultation - providing information to and seeking flood related information from the community,
  - Hydrologic analysis – analysis of streamflow information to assess the likelihood of the floods of a given size occurring (ie, flood peaks and volume),
  - Hydraulic analysis – computer modelling of flood behaviour to estimate flood extent and levels resulting from a given flood under existing conditions.
  - Flood damage assessment – assessment of economic damages to the community from flooding under existing conditions,
  - Flood mapping for emergency response – mapping on a cadastral base of a range of flood events (output from the hydraulic analysis) to enable improved emergency management and response during floods,

  - Planning scheme information – providing GSCC and GBCMA with suitable outputs to aid the revision of the planning scheme related to flooding under existing conditions.

- **Stage 2** – Investigation of measures to reduce economic and social consequences from flooding
  - Community consultation - providing information to and seeking feedback from the community on the existing flooding risks (likelihood and consequences), and possible measures to reduce economic and social consequences from flooding,
  - Preliminary identification and assessment of possible mitigation measures – broad assessment of flood mitigation measures identified through community consultation,
  - Detailed assessment of mitigation measures – assessment includes hydraulic, economic, environmental and social impacts due to mitigation measures,
  - Development of a floodplain management plan for Shepparton Mooroopna.

This report documents the components of **Stage 2** of this study. Documentation of **Stage 1** is provided in a separate report (SKM, 2002a).

2. Community Consultation

Similarly to **Stage 1**, a resident questionnaire was distributed in June 2001 to explain the nature of flooding detailing the flood risks (ie. likelihood and consequences). With this information in mind, the questionnaire was designed to gather feedback on risk treatments (or more commonly known as mitigation measures) of both a structural and non structural nature. As per **Stage 1**, the questionnaire was distributed to 18,000 properties with a target of approximately 12,000 residents. Responses were received from 663 residents (6% of total target).

Appendix A contains a copy of the **Stage 2** questionnaire.

Two questions related to the nature of flood mitigation measures preferred by the community. Question 2 asked the community to rank eight structural and non-structural measures in order of importance. The results, in order of importance to the community, were as follows:

1) Floodways
2) Waterway capacity works
3) Levees or flood walls
4) Land use planning controls
5) Improved flood warning
6) Flood proofing or raising
7) Community Education
8) Land acquisition

Question 4 was aimed at obtaining the community's suggestions of possible mitigation measures/schemes.

A number of comments were made in the questionnaire responses which required addressing via feedback to the general community through the CRG. The issues raised and responses are shown in **Table 2-1.**

- **Table 2-1 Issues raised and response to Stage 2 questionnaire**

Issues	Response
Existing environmental values not to be adversely impacted by any mitigation measure/scheme	Clearly communicate assessment of environmental impacts will be undertaken
Impacts on flooding due to the Goulburn Valley Highway bypass	Clearly communicate VicRoads will be required to demonstrate the floodplain impacts of the bypass
Levees can lead to a false sense of security	Clearly communicate levees are designed for a given flood magnitude and will overtop for larger events
Local flooding due to stormwater drainage	Clearly communicate this study is concerned with mainstream flood.
Flood response plans – sandbagging, evacuation procedures, etc	Clearly communicate a comprehensive flood response plan will be reviewed as part of this study.

From the feedback obtained a list of mitigation measures for preliminary assessment was developed. The preliminary assessment of mitigation measures is outlined in **Section 3**. Part of this assessment included identification of measures warranting detailed assessment.

Further consultation with the CRG was undertaken during the detailed assessment of structural mitigation options (See **Section 4**).

3. Flood Mitigation Measures

3.1 General

There are number of flood mitigation measures available that may be included in the development of a Floodplain Management Plan. These measures are derived to suit local flood and floodplain conditions. They are commonly sub-divided into “structural” and “non-structural” categories.

Flood mitigation options are then derived as collections of individual mitigation measures. Further discussion and an assessment of the options is provided in **Section 4**.

Sections 3.2 and **3.3** discuss in general the structural and non-structural mitigation measures available.

The following discussion identifies flood mitigation measures and their application to Shepparton Mooroopna.

3.2 Structural Measures

Structural measures, whether large or small in scale, are usually the main elements of flood mitigation options, supplemented where appropriate with non-structural measures.

3.2.1 Upstream Flood Storage

Flood storage is a common flood mitigation measure in many circumstances. In flood management for rural communities however, it is not always feasible or as cost effective as other mitigation options. If feasible, however, it has a number of advantages. These include the following:

- it lies outside the area of interest and is therefore potentially invisible to the area it is protecting,
- it has the potential to be a complete mitigation option in itself or at least significantly reduce the requirements for additional measures within the area it is protecting.

Flood storage is achieved by constructing an embankment across the valley. An outlet would be designed to allow daily and minor flood flows through unimpeded but throttle flood flows sufficiently to protect Shepparton-Mooroopna from floods up to the design standard. This type of storage remains empty in non-flood periods. Such storages are most effective as near as possible to the area it is to protect. It is possible to combine them with permanent water bodies that have recreational or water supply functions, although this is not relevant in this instance.

The area behind the embankment would be temporarily inundated during the flood. The feasibility of this option is therefore dependent on low value, flood resilient and/or building free land being available. It is also dependent in the environmental impacts of reduced inundation (such as reduced deposition of fertile alluvium on farmland) on all land downstream of the storage.

The structure would require the acquisition of private land for its footprint. Areas where the flooding regime is changed upstream of the structure would also require acquisition of private land or least a flood easement. The structure may also be constrained by existing infrastructure (main roads, bridges, *etc.*). It is therefore unlikely to be cost effective. Furthermore, it is understood that there are few areas of "low value, flood resilient and/or building free land" upstream of the study area.

3.2.2 Levees

Construction of levees or floodwalls can be undertaken to restrict the extent of flooding, and thereby confine the area subject to damage. Levees are usually earth embankments, and can be landscaped to present an attractive appearance through grassing, planting with native shrubs, and/or variation to the alignment, width and height of the embankment. Floodwalls are usually constructed of concrete and/or stone, are more expensive but are convenient where space for levees is restricted or cost of land acquisition is high.

It is important to note that levees are not necessarily large imposing structures. Often considerable flood relief or benefit can be achieved by local surface re-shaping, including raising road formations.

To determine the design levee height, a freeboard is usually added to the estimated design flood level to be contained by the levee. This allows for a number of factors, including settlement over time; erosion due to wear if trafficked; provision of a safety margin for inaccuracy in estimation; wave action or superelevation of water levels near bends. In Victoria, the usual practice is to allow 600 mm freeboard above the design flood level.

If the levee is designed to be overtopped, however - eg. if its purpose is to delay flooding and/or provide only low level protection - it will not be appropriate to add freeboard and the levee will be constructed only to the designated design flood level.

The main advantage of levees is that they provide a physical barrier to the floodwaters for areas that were subject to flooding. Substantial economic and social benefits can be achieved. There are, however, a number of potential disadvantages to set against the clear benefits derived. For example:

- in floods larger than the "design standard" (ie. the designated design flood), levees may be overtopped. Water ponded behind levees can result in damages and hardship greater than would otherwise have occurred. Furthermore, development may have occurred within the area protected and/or the awareness of flood risk and preparedness for flood events may diminish because of the works. On the other hand, if warning times permit, sandbagging along the levee can provide extra relief on a temporary basis,
- failure of levees can produce the same adverse effects as overtopping and can be sudden and catastrophic. Damage and hazard may be aggravated in the proximity of levee breaches. While failure should not occur if construction standards are good, over time the condition of levees can decline if sound, regular maintenance is not provided,
- levees produce some loss of floodplain storage and obstruction to flood flows. This can increase flood levels and velocities on the flooded side of the levees and increases the flood peak flows (and therefore levels) downstream. Flood level increases will also propagate for some distance upstream,
- levees can create a visual obstruction. Although they can be landscaped to improve appearance, some people object on aesthetic grounds,
- levees can be seen as an inequitable solution by those land owners located outside the leveed areas.

3.2.3 Floodways

Floodways provide additional flood flow paths. They can have a dual function. First, they can reduce flood levels by providing additional flow carrying capacity. Second, they can act to divert flow away from areas susceptible to flooding and damage.

Ideally, floodways should make use of existing natural depressions in the floodplain. One of the main limitations of such floodways is their often limited effectiveness in significant flood conditions where the bulk of the flow is carried in the floodplain. In these events, floodways provide little flow capacity. Their benefit is usually in small to medium type floods.

3.2.4 Waterway Management Works

Waterway management works can include local widening, deepening, re-shaping and clearing of channels and verges. It also includes clearing of in-channel debris and mostly non-native riparian vegetation.

Such works increase the flow capacity of the channels and floodplain, although the benefits are dependent on the existence or severity of channel and floodplain constrictions. Local works are likely to have only local benefits. However, waterway management works have the potential to cover significant lengths of the waterway.

Generally the benefits of waterway management works will be most evident in small to medium floods. In larger floods, where the waterway carries only a small proportion of the flow, improvements will provide only minor benefit.

Waterway management works do have disadvantages. There are environmental and geomorphologic issues associated with both the clearing of vegetation and the reshaping or enlarging of channels. Removal of large trees should be avoided, for example. For the same reasons, reshaping of land surfaces, sediment removal and alteration to river cross-sections should to be done sparingly, and with consideration for the likely hydraulic and geomorphologic consequences. Tampering with the beds and banks of streams can trigger hydraulic responses that are undesirable. In any given area, works should be selective – excessive clearing or channel reshaping will inevitably have adverse impacts. Waterway management also has a high maintenance cost.

3.2.5 Individual Property Protection

It is possible and appropriate to protect single buildings or small clusters of buildings on an individual basis. This type of individual treatment is not feasible on a broad scale, but is useful for a number of cases, including:

- isolated buildings,
- buildings for which no other mitigation measure is feasible,
- buildings, which have been adversely, affected by other mitigation measures.

Individual treatment is best restricted to buildings which flood above floor, and only those which are habitable/occupied or might serve some emergency response function.

The types of protective measures that can be undertaken include:

- ring banks or levees,
- raising of floor levels (applicable mainly to timber structures),
- water-proofing of walls below flood levels by use of suitable construction materials,

- sealing of openings (eg. doors, typically involving the fastening of panels at times of flood danger).

Some of the measures described above are more suited to different classes of building. For example, water-proofing and sealing are generally considered more appropriate for commercial and some industrial premises, and raising of floor levels is best suited to timber houses.

Individual protection is somewhat of a last resort as collective protection is always preferred.

3.2.6 Improvements to Hydraulic Structures

Any structure (eg. road and rail embankments) that intersects a flow path will potentially act as a barrier or constriction to flood flows and impact on flood levels, most commonly by increasing water levels upstream of the structure. Measures to improve the efficiency of such structures are common components of flood mitigation options.

3.3 Non-Structural Measures

Non-structural measures are commonly important components of flood mitigation. Most non-structural measures involve on-going best practice activities that support any mitigation scheme over the long term. As an alternative to structural measures, they are increasingly the more usual measures found in Floodplain Management Plans.

3.3.1 Catchment Management

Catchment management works within the Goulburn-Broken catchment are encouraged, as they are consistent with flood mitigation goals.

Management activities such as revegetation of riparian strips, assisted by fencing and other measures to limit stock access to streams and low-technology bank protection measures, will retard runoff as it moves along the waterways in the catchments. The end result is reduced flood peaks downstream of the works.

The flood volume and flood peaks in a catchment are in part a function of the vegetation cover within a catchment. Land clearing since European settlement has significantly altered the condition and flood response of many catchments. Catchment revegetation could in time, among its many benefits, reduce flood volumes in the long term. However, in major floods reductions in peak flow would be insignificant.

Generally, it is the GBCMA that is responsible for ensuring the catchment is managed and protected to the benefit of landholders and the environment. Whilst catchment management works lie outside the scope of this floodplain management study, catchment revegetation and waterway improvements are part of the GBCMA's core activities.

3.3.2 Land Use Controls

The Victoria Planning Provisions (VPPs) allow for zoning of land and the application of restrictions on the type of land use and permitted activities in areas prone to flooding.

The VPPs distinguish land subject to inundation (LSIO) from floodways. Floodways are further divided into urban floodway zones (UFZ) and floodway overlay (FO).

The intention of the floodway zones or overlay is to identify areas for which greatest flood hazard exists. This may be on the basis of the depth and/or velocity of flood flows, the frequency of flooding or because the designated floodway is important for conveyance of flow during major floods. Even partial blockage of floodways could aggravate problems elsewhere. Strict controls on buildings and earthworks in floodway areas are appropriate.

The VPPs provide guidelines for the appropriate uses and/or development of land in LSIO, UFZ and FO areas. The local authority (in this case Greater Shepparton City Council) can apply exemptions to LSIO and FO areas if it sees fit in order to streamline the planning process for some types of development. Exemptions for UFZ areas are limited to advertising signs. These planning measures are intended to be applied in conjunction with an incorporated local floodplain development plan (LFDP) document at Clause 81 of the Planing Scheme. If no LFDP is in force, applications for development in floodway areas must be accompanied by a flood risk report addressing a number of issues specified in the VPPs. A more detailed discussion of land-use controls is provided in **Section 4.4.1**.

3.3.3 Property Purchase

It is often the case that past development has proceeded in areas now considered inappropriate for such development. This may be due to a lack of knowledge of the risk of flooding at the time of the development, a revised assessment of the risk of flooding, historical experience of land inundation post-development, or simply a revised assessment of what risk is acceptable.

To address this, property can be purchased, ideally complemented with land uses changes. Property purchase is a useful mitigation measure in areas where:

- current land-use is incompatible with the flood risk,
- floodway areas should be reclaimed
- buildings adversely affect flood flows,
- structural alternatives (such as those described above) are physically not feasible or adversely impact on flood levels.

Subsequent leasing of the land may be considered with limitations on permitted activities.

In general, property purchase is not appropriate for land and development on floodplains subject to only occasional inundation.

There are disadvantages to this measure. Affected properties might contain older and more historic buildings and have significant heritage value. In addition to such social issues, purchase and removal of these buildings can significantly inflate the cost to a community for flood mitigation.

3.3.4 Land Management Incentives

Incentives can be provided to foster good land management practices on private land. Some of the catchment management measures described above can be instituted via incentives to relevant landholders.

Within the town, residents can be encouraged to keep their properties clear of stockpile or debris and to construct open or collapsible fencing. Such measures improve flow conveyance in flood times and remove or reduce impacts on water levels, particularly upstream.

Incentives may be provided in a variety of ways. One way is by the application of rate discounts or differential rating. Another possibility is provision of subsidies for materials and/or services used in activities contributing to best practices for management of riparian areas.

3.3.5 Emergency Response and Flood Warning

Efficient and well-planned emergency response procedures are essential. This in turn relies on quality information on flood inundation and flood behaviour, such as the flood inundation maps and associated flood information prepared for this study (See **Stage 1**, SKM 2002a). These provide information for a range of flood magnitudes on properties affected, access routes and breakout points. As a result, flood response prior to and during an emergency can then be targeted to where it is most effective.

Emergency response should also be linked to the “Greater Shepparton Public Health Plan. The floodplain management plan should call on provisions of the municipal public health plan when establishing flood recovery methods and more generally by providing as sense of improved personal safety in times of flood (see also **Section 3.3.6**).

3.3.6 Community Awareness and Preparedness

The trauma created by flooding and the difficulties associated with effective flood response highlight the need for sustained community awareness of the flood risk. Residents and commercial enterprises need to be prepared, with an understanding of effective actions they personally can take to avoid flood hazard and minimise flood damages and loss.

An organised program of community education, rehearsals and reinforcement is essential to sustain awareness and maintain preparedness.

The importance of community awareness and preparedness is emphasised by the health goals of the “Greater Shepparton Public Health Plan”. Under Health Goal 1, “Sense of Belonging and Connectedness”, Community issue 1.2 states “Diverse factors threaten the personal safety of people of all ages and distance individuals from the community. Such factors diminish sense of wellbeing and contribute to distrust of others and social isolation”. Flooding and flooding impacts is one such factor, but one that can be addressed and minimised by improving awareness and preparedness.

It is important to emphasise that measures undertaken under a floodplain management plan can substantially reduce the flood risk, but cannot eliminate it. This must be clearly understood. If effective protection against flooding is provided against floods up to the flood of 100 year ARI, for example, there remains a 1% probability of larger floods occurring in any year which may overwhelm the measures provided. Also, if structural measures are not well maintained nor non-structural measures well sustained, there is also a chance of the system failing in even smaller floods.

There is also potential for the implementation of a floodplain management plan to encourage complacency in the community because the perception of reduced risk can produce a delusion of the elimination of risk.

These issues demonstrate the importance of maintaining, following the implementation of a floodplain management plan, an awareness of flood risk in the community and a preparedness to react effectively.

3.4 Preliminary Selection and Assessment of Flood Mitigation Measures

A preliminary assessment of the feasibility of mitigation measures suggested by the community and CRG was made considering the cost, practicality and effectiveness. From this assessment measures/schemes requiring further investigation were identified. **Table 3-1** outlines the results of this preliminary assessment.

■ **Table 3-1 Preliminary Assessment of Flood Mitigation Measures**

Measure Suggested	Type of Measure	Issues affecting feasibility	Warrants further investigation
Mooroopna Floodway - constructed floodway between Mooroopna and Goulburn River north of the Causeway	Structural	- Size of floodway & in turn cost to achieve reduction in flood levels - Any social and environmental impact on adjacent land	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Levee banks along Goulburn River in South Mooroopna - levee adjacent to Archer Street and Toolamba Road	Structural	- Levee height versus costs to achieve benefit - Availability of land to site the levee - Upstream and downstream adverse hydraulic impact - Any social and environmental impact on adjacent land/ landholders - Local drainage from behind levee	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Levee banks along Goulburn River in North Mooroopna - levee adjacent to Mooroopna Wyuna Road between McFarlanes Lane to Paisley Crescent	Structural	- Levee height versus costs to achieve benefit - Availability of land to site the levee - Upstream and downstream adverse hydraulic impact - Any social and environmental impact on adjacent land/ landholders - Local drainage from behind levee	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Levee banks along Broken River in South Shepparton - levee adjacent to Lincoln Drive and Broken River Drive	Structural	- Levee height versus costs to achieve benefit - Availability of land to site the levee - Upstream and downstream adverse hydraulic impact - Any social and environmental impact on adjacent land/landholders - Local drainage from behind levee	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Levee banks along Goulburn River in Boulevard Area - levee adjacent to Boulevard	Structural	- Levee height versus costs to achieve benefit - Availability of land to site the levee - Upstream and downstream adverse hydraulic impact - Any social and environmental impact on adjacent land/ landholders - Local drainage from behind levee	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Realignment of No. 12 irrigation supply channel to create a floodway	Structural	- Change to existing infrastructure - Cost associated with realignment compared with reduced flood damage (ie reduce flood levels)	**Yes** - Hydraulic, economic, social & environmental impact assessment
Increased Capacity of Railway and/or Causeway openings	Structural	- Costs associated with widening opening compared to reduced flood levels and benefits - Environmental impacts due to change flow regime	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Improved Land Use Planning	Non-structural	- Existing developments - Development pressure	**Yes** - Land use planning map completed
Remove/change operation Loch Garry	Structural	- Distance downstream of study area - Impact on downstream properties	**No** - Investigation shows no impact within the study area – refer to **Section 3.5**

Measure Suggested	Type of Measure	Issues affecting feasibility	Warrants further investigation
Clearing vegetation from waterways	Structural	- Environmental impacts would be significant - Ongoing maintenance would be significant	**No** **-** Significant environmental impacts
Improved Flood Warning/ Emergency Response	Non-structural	- Lack of flood awareness - Comprehensive flood response plan	**Yes** - Economic & social impact assessment required - Review flood response plan Flood response maps
Construction of Upstream storages on the Goulburn River and/or Broken River	Structural	- High costs - Significant social and environmental impacts	**No** - Significant cost and environmental impacts
Diversion of Goulburn River to Waranga Basins or along Eastern Goulburn Main Channel	Structural	- Flood volumes significantly larger than existing channel capacity - High costs - Significant environmental impacts	**No** - Significant cost and environmental impacts
High Capacity Pumps located near confluence of Goulburn and Broken with pipeline to downstream	Structural	- Flood volumes significantly larger than pump capacity - High costs - Significant environmental impacts	**No** - Significant cost and environmental impacts

3.5 Operation of the Loch Garry Regulator

There have been numerous suggestions to remove or alter the Loch Garry operation rules to facilitate lowering flood levels within the Shepparton-Mooroopna area.

The Loch Garry Regulator is located some 20 kilometres downstream of Shepparton (near Bunbartha). The regulator is a 48 bay structure each bay being 2.2 metres wide. The structure has a total of 460 drop boards. It is operated in accordance with a formal agreement between landholders and Goulburn-Murray Water. Under the agreement the removal of the boards commence 24 hours after the Shepparton Gauge exceeds 10.36 metres (34 feet), which is about a 2.5 year ARI flood. For each rise of 31 millimetres (0.1 feet) above 10.36 metres, 23 boards are removed, and all boards are removed once 10.96 metres (36 feet) is reached, which is about a 7 year ARI flood.

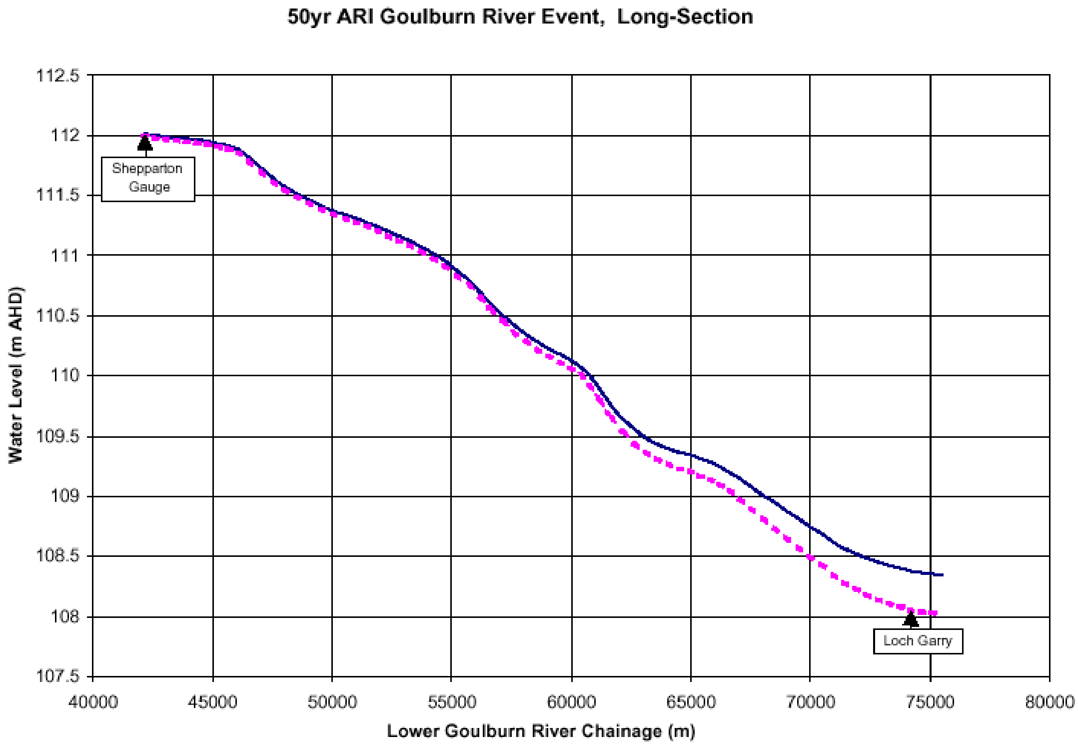
It is suspected that the link to Shepparton Gauge levels and the 24 hour delay in removing boards has led to a belief that Loch Garry influences flooding within Shepparton Mooroopna.

Hydraulic analysis was carried out to determine the upstream influence Loch Garry has on increased flood levels. The analysis determined that:

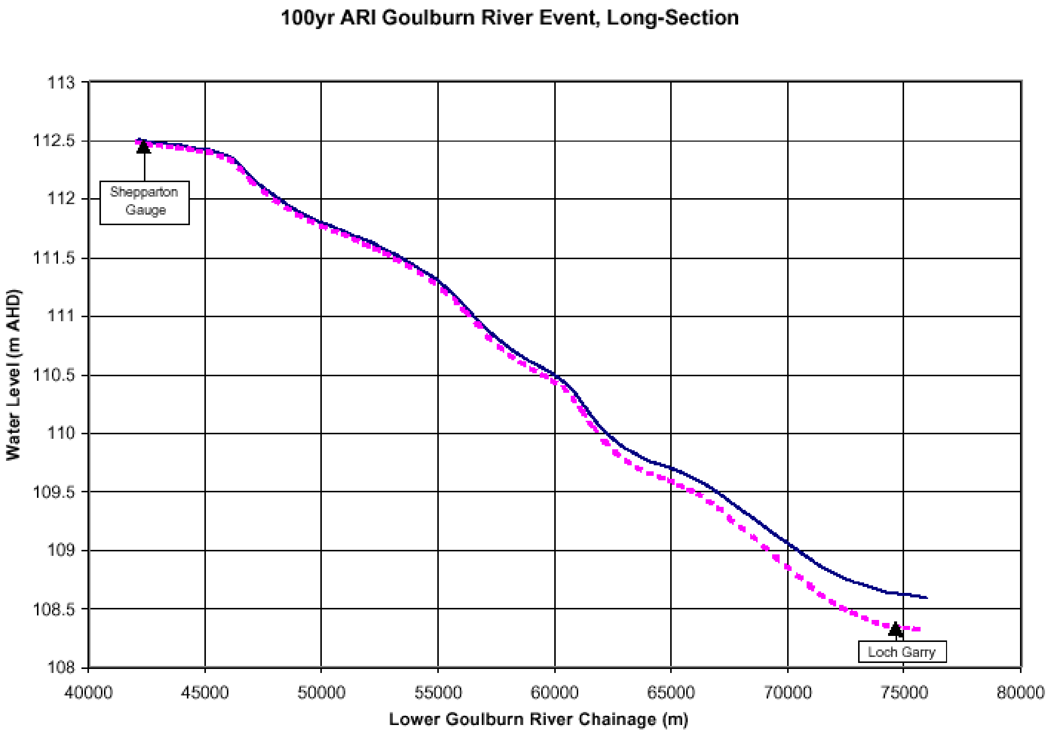
- The maximum increase in flood levels at Loch Garry is 450 millimetres, which diminishes upstream.
- The influence of the increased flood levels at Loch Garry ceases by the time it reaches Medland Road, which is downstream of the Shepparton Mooroopna Study Area.

Figure 3-1 and **Figure 3-2** graphically demonstrates the influence of Loch Garry on flood levels in the Goulburn River between Shepparton and Loch Garry. The dashed line represents the effect of removing Loch Garry.

- **Figure 3-1 Goulburn River Flood Levels – 50 year ARI event**



- **Figure 3-2 Goulburn River Flood Levels – 100 year ARI event**



4. Detailed Flood Mitigation Option Assessment

4.1 Overview

The flood mitigation assessment involved the development and comparison of a number of flood mitigation options. The assessment included both structural options and stand-alone non-structural measures.

The following eight structural options were assessed:

- Option 1 – Kialla Levee
- Option 2 – South Shepparton Levee
- Option 3 – South Mooroopna Levee
- Option 4 – Boulevard Levee
- Option 5 – Combination of the above levee options
- Option 6 – East Mooroopna Floodway
- Option 7 – Realignment of Channel 12
- Option 8 – Increased waterway opening in causeway and railway line crossing.

Figure 4-1 shows the indicative levee alignments for Options 1 to 5 and the floodway alignment for Option 6. **Figure 4-2** shows both the existing and revised Channel 12 alignment under Option 7. These alignments have been used for evaluation purposes and do not represent final alignment if options are to be incorporated in the floodplain management plan.

Two non-structural measures were assessed as follows:

- Planning scheme amendment (Land use planning)
- Emergency response and flood warning

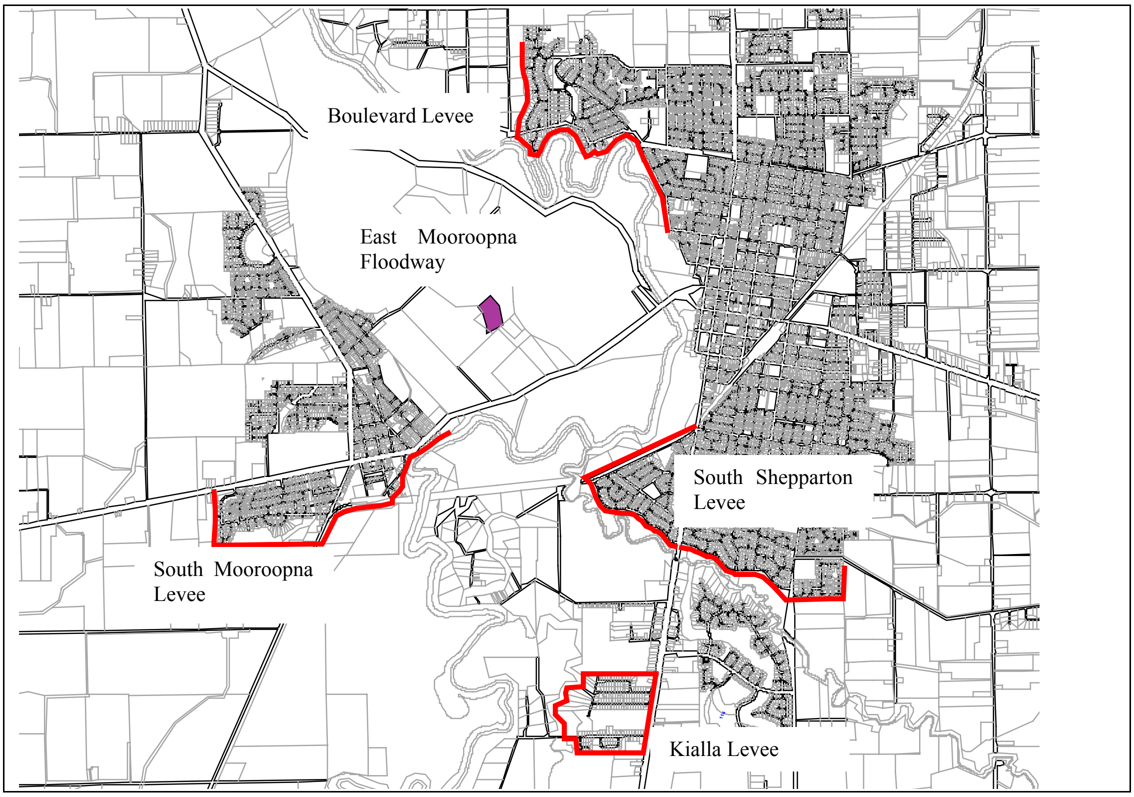
The options or measures were assessed on the basis of their absolute and relative impacts under key assessment components. The components of the assessment are:

- Hydraulic
- Economic
- Environmental
- Social

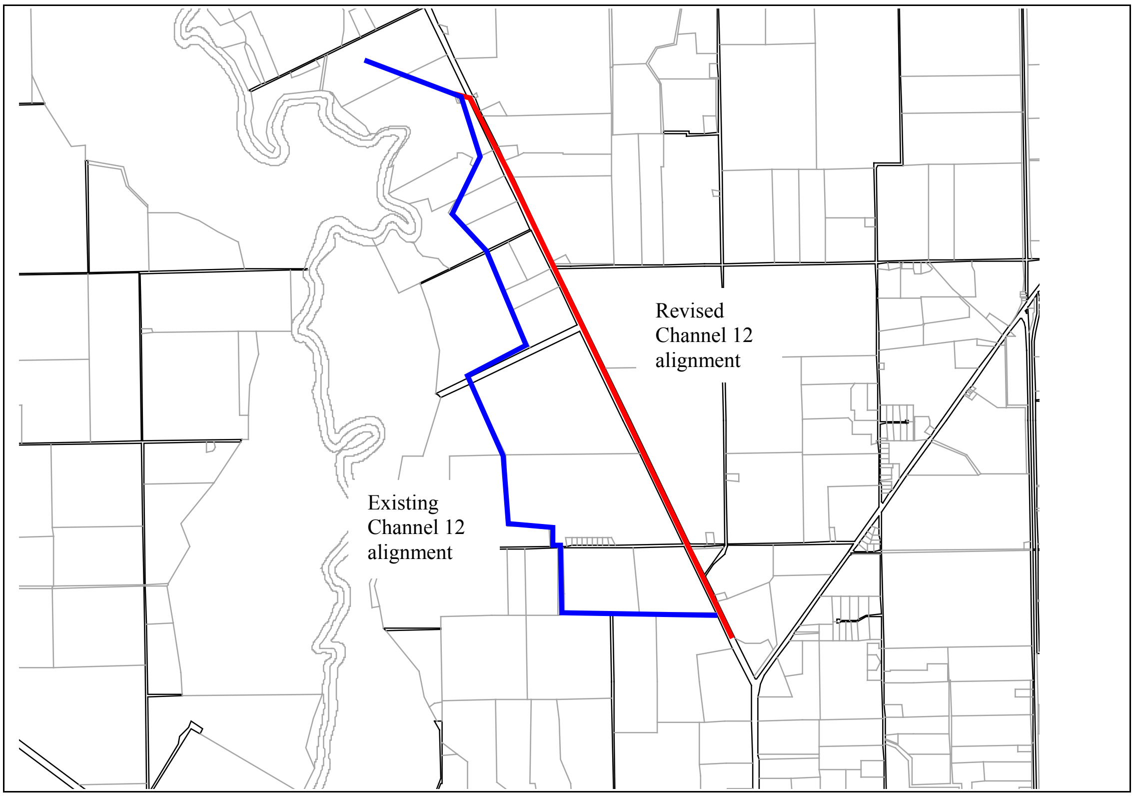
The primary tools in the assessment process were the various models – hydrologic, hydraulic and flood damages – which provided estimates of the benefits and disbenefits in terms of changes in flows, flood levels and/or affected properties resulting from each option.

Section 4.2 outlines the methodology employed in the assessment of the mitigation options. The assessment of the structural options is provided in **Section 4.3** with the assessment of non-structural options provided in **Section 4.4**.

■ **Figure 4-1 Mitigation Options 1 to 6**



■ **Figure 4-2 Mitigation Option 7 - Channel 12 Realignment**



4.2 Assessment of Options

The assessment considered the impacts, both positive and negative, of the options using the four main assessment components:

1. The *hydraulic assessment* considers changes in flood level/depth, flood extent, flows and velocity across the study area.

2. The *economic assessment* compares the monetary cost of each mitigation option against the reduction in flood damages achieved by its implementation. For each mitigation option, the assessment determined:
   - the mitigation costs (both capital and ongoing maintenance),
   - the number of buildings protected,
   - the economic benefit – ie. the reduction in Average Annual Damages (AAD),
   - the benefit-cost ratio.

   A benefit cost ratio above unity (greater than 1) indicates that benefits outweigh costs. A benefit cost ratio below unity indicates that costs outweigh benefits. In the latter case the option becomes difficult to justify, particularly for subsequent funding for implementation. The ratio provides a means by which the options can be ranked on economic grounds. For the economic analysis, a 30 year project life and 6% discount rate were assumed.

3. The *environmental assessment* considers the impacts of each option largely on the natural environment. In this instance, potential environmental impacts include the changes in river morphology and the aesthetic and ecological consequences of removing vegetation.

4. The *social assessment* considers the impacts of each option on the health, safety and social and commercial activities of the community. Potential positive social impacts are the reduced flood hazard and reduced personal risk and trauma and the protection of additional commercial properties. Potential negative impacts are the aesthetic impact of levees and inequality in flood protection. Whilst the social impacts are more subjective and not readily quantifiable, the change in flood damages (economic assessment) due to a given option is a useful and quantified measure of social impacts (positive or negative) of that option.

In this assessment economic and hydraulic (and to some extent social) impacts were the initial indicators of the merits of options. If a given option were plausible economically and hydraulically (and socially acceptable), more thorough social and environmental assessment could be undertaken.

In all assessments, a Goulburn River dominant flood scenario was used. A Broken River/Seven Creeks dominant scenario would yield slightly different property damage estimates (as demonstrated via **Tables 7-1** and **7-2** in the **Stage 1** report (SKM, 2002a)), but have little effect on the benefit/cost of each mitigation option.

4.3 Structural Mitigation Options

The following provides a discussion of the assessment of each structural mitigation option considered. The levee Options 1 to 5 were evaluated assuming a 100 year ARI design standard. The levee height included a freeboard of 600 mm above the 100 year ARI design flood level. This freeboard allowance is in line with standard design practice. The provision of levees with a lower design standard (eg. 20 year ARI) would not be feasible given that total monetary flood damages only start to become significant above a 20 year ARI event. This is illustrated in **Figure 7-1** in the **Stage 1** report (SKM, 2002a).

Appendix B contains further results from the hydraulic assessment of mitigation options.

4.3.1 Option 1 - Kialla Levee

This option involved the construction of a ring levee encompassing Vickers Street, Furphy Avenue and Balmoral Street. The levee would prevent flooding of properties contained within. Details of the levee assessment are as follows:

- Length ~ 2.70 km
- Average height ~ 2.10 m
- Estimated costs ~ $1.2 million
- Reduction in AAD ~ $70,000
- Benefit/Cost ~ 0.8

A hydraulic assessment of the flooding impacts for the 100 year ARI flood showed the levee increased water levels east of the Goulburn Valley Highway by 20 mm to 50 mm**.** **Figure 4-3** shows the *difference* in the 100 year ARI water surface levels between Option 1 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

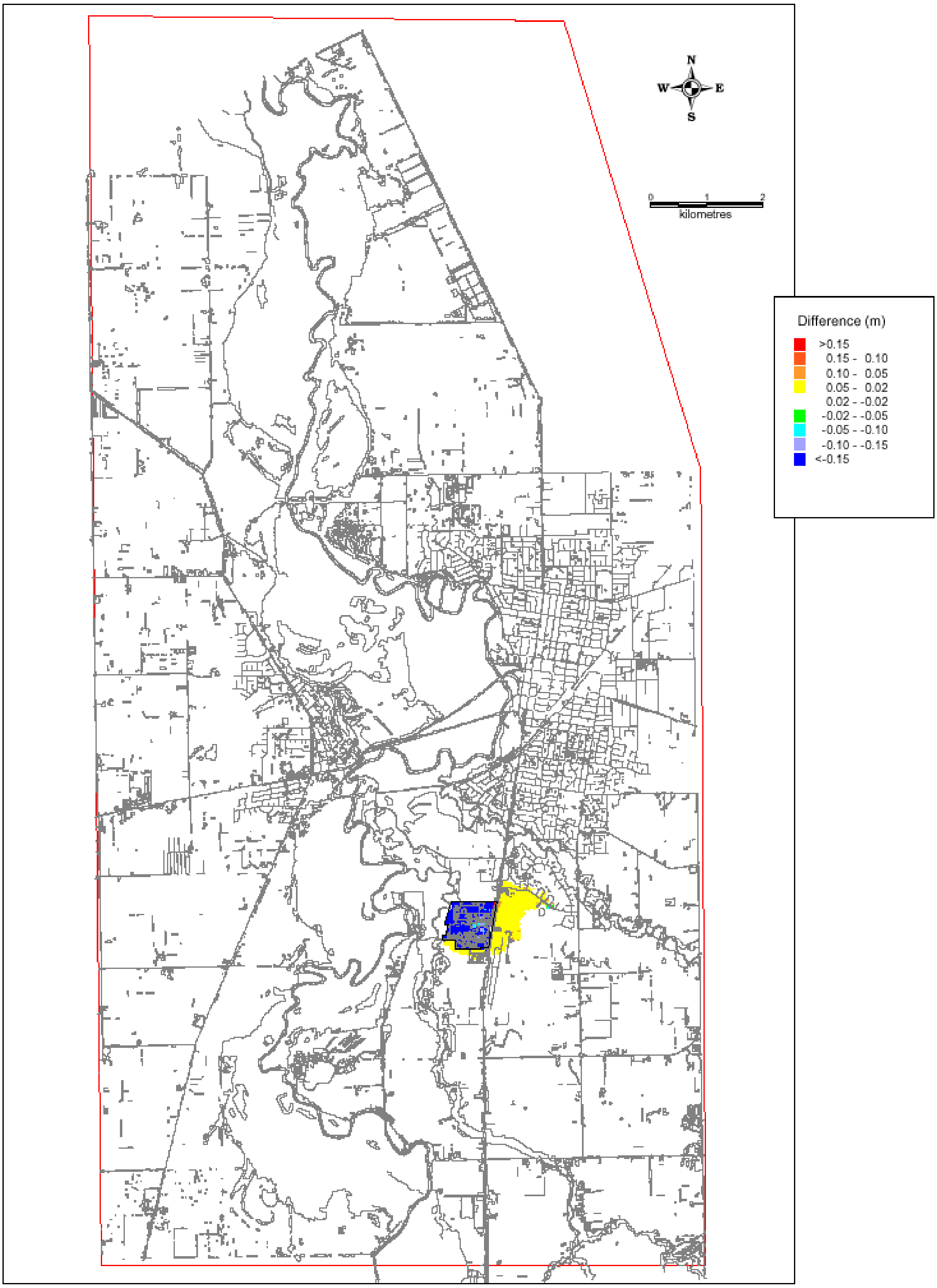
Table 4-1 shows the effect of Option 1 on the number of properties affected, both above floor levels and total, for the 100 year ARI event over the entire study area.

- **Table 4-1 Option1 Kialla Levee – Properties Affected (100 year ARI event)**

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	2,126	6,451
Reduction in number of properties	**34**	**121**

Social and environmental impacts and advantages and disadvantages of levee options generally are discussed in **Section 3.2.2**. A conclusion on the merits of all levee options in provided in **Section 4.3.6**.

■ **Figure 4-3 Option 1 Kialla Levee – Water Surface Level Difference (100 year ARI event)**



4.3.2 Option 2 – South Shepparton Levee

This option involved the construction of levee along Lincoln Drive, Broken River Drive. In addition, a low level bund is required along the northern side of the railway line from the Broken River to Goulburn Valley Highway. This bund prevents backwater flooding from the Goulburn River. Some stormwater works are required to prevent flooding through the stormwater drainage system. These works would prevent properties in the Shepparton South area flooding from the Broken River and backwater flooding from the Goulburn River.

Details of the levee assessment are as follows:

- Length ~ 4.8 km (includes railway bund)
- Average height ~ 1.50 m
- Estimated costs ~ $1.4 million
- Reduction in AAD ~ $130,000
- Benefit/Cost ~ 1.3

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the levee increased water levels in the Kialla Lakes Residential Estate (south of Broken River) and adjoining properties by 50 mm to 100 mm. **Figure 4-4** shows the *difference* in the 100 year ARI water surface levels between Option 2 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

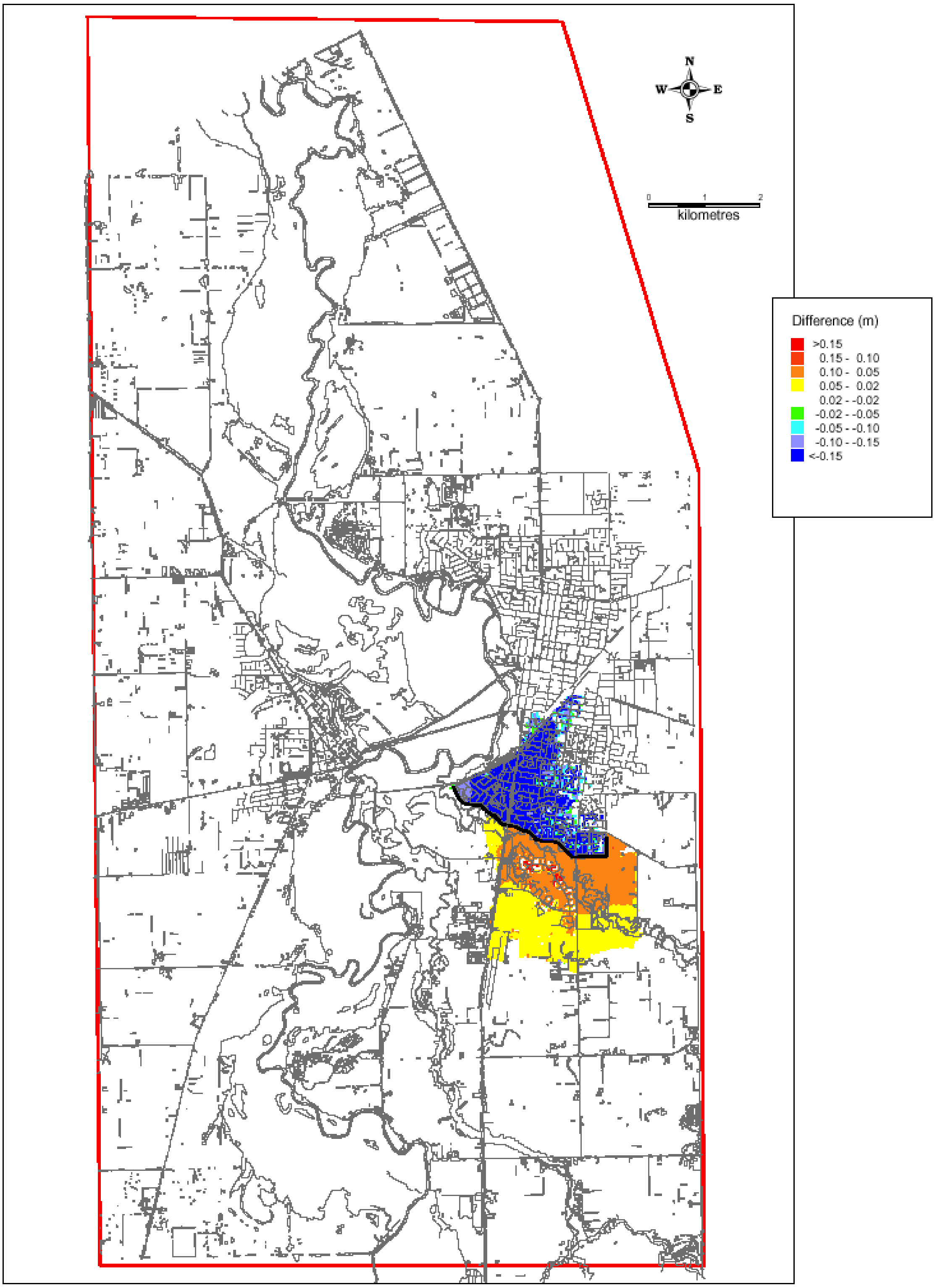
Table 4-2 shows the effect of Option 2 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

- **Table 4-2 Option 2 Shepparton South Levee - Properties Affected (100 year ARI event)**

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	1,814	5,896
Reduction in number of properties	**346**	**676**

Social and environmental impacts and advantages and disadvantages of levee options generally are discussed in **Section 3.2.2**. A conclusion on the merits of all levee options in provided in **Section 4.3.6**.

■ **Figure 4-4 Option 2 Shepparton South Levee – Water Surface Level Difference (100 year ARI event)**



4.3.3 Option 3 – South Mooroopna Levee

This option involved the construction of a levee along the southern edge of the Mooroopna township from the Midland Highway (western edge of Mooroopna) to Toolamba Road. From Toolamba Road the levee continues north along the railway line then along the back of the Archer Street properties to the Midland Highway (eastern edge of Mooroopna). Some rural drainage works are required to divert the Ardmona Drain to the west of Mooroopna. This option prevents the breakout of the Goulburn River across the railway line through Mooroopna. For this option backwater flooding will still occur in Mooroopna via the Mooroopna golf course area.

Details of the levee assessment are as follows:

- Length ~ 3.9 km
- Average height ~ 1.40 m
- Estimated costs ~ $3.0 million
- Reduction in AAD ~ $330,000
- Benefit/Cost ~ 1.50

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the levee increased water levels upstream of the levee significantly. Increases in the water levels through the Kialla Lakes, Kialla and South Shepparton areas are between 50 mm to 100mm. **Figure 4-5** shows the *difference* in the 100 year ARI water surface levels between Option 3 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

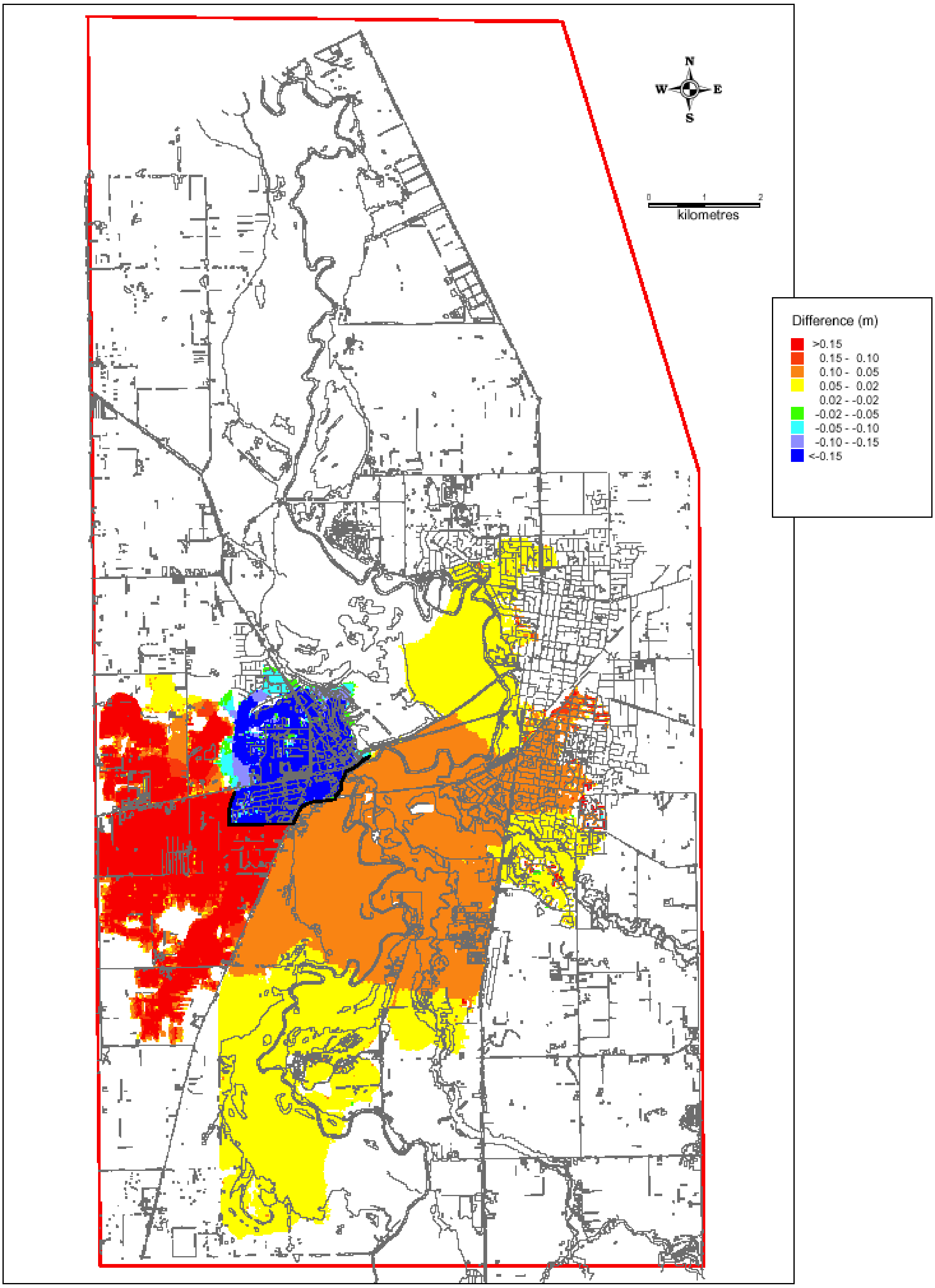
Table 4-3 shows the effect of Option 3 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

- **Table 4-3 Option 3 Mooroopna South Levee – Properties Affected (100 year ARI event)**

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	1,468	5,816
Reduction in number of properties	**692**	**756**

Social and environmental impacts and advantages and disadvantages of levee options generally are discussed in **Section 3.2.2**. A conclusion on the merits of all levee options in provided in **Section 4.3.6**.

- **Figure 4-5 Option 3 Mooroopna South Levee – Water Surface Level Difference (100 year ARI event)**



4.3.4 Option 4 – Boulevard Levee

This option involved the construction of a levee from adjacent to the northern end of De Lisle Avenue south to the north bank of the Goulburn River. The levee continues along the north bank of the Goulburn River behind the existing properties to the corner of The Boulevard and Knight Street. This option prevents the breakout from the Goulburn River across The Boulevard and through the existing residential area. Some backwater flooding will still occur along the existing floodway parallel to Hovell Crescent.

Details of the levee assessment are as follows:

- Length ~ 3.6 km
- Average height ~ 1.40 m
- Estimated costs ~ $1.0 million
- Reduction in AAD ~ $100,000
- Benefit/Cost ~ 1.50

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the levee increased water levels upstream of the levee. Increases in the water levels of 20 mm to 50 mm occurs within the floodplain adjacent to Gemmills Swamp. **Figure 4-6** shows the *difference* in the 100 year ARI water surface levels between Option 4 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

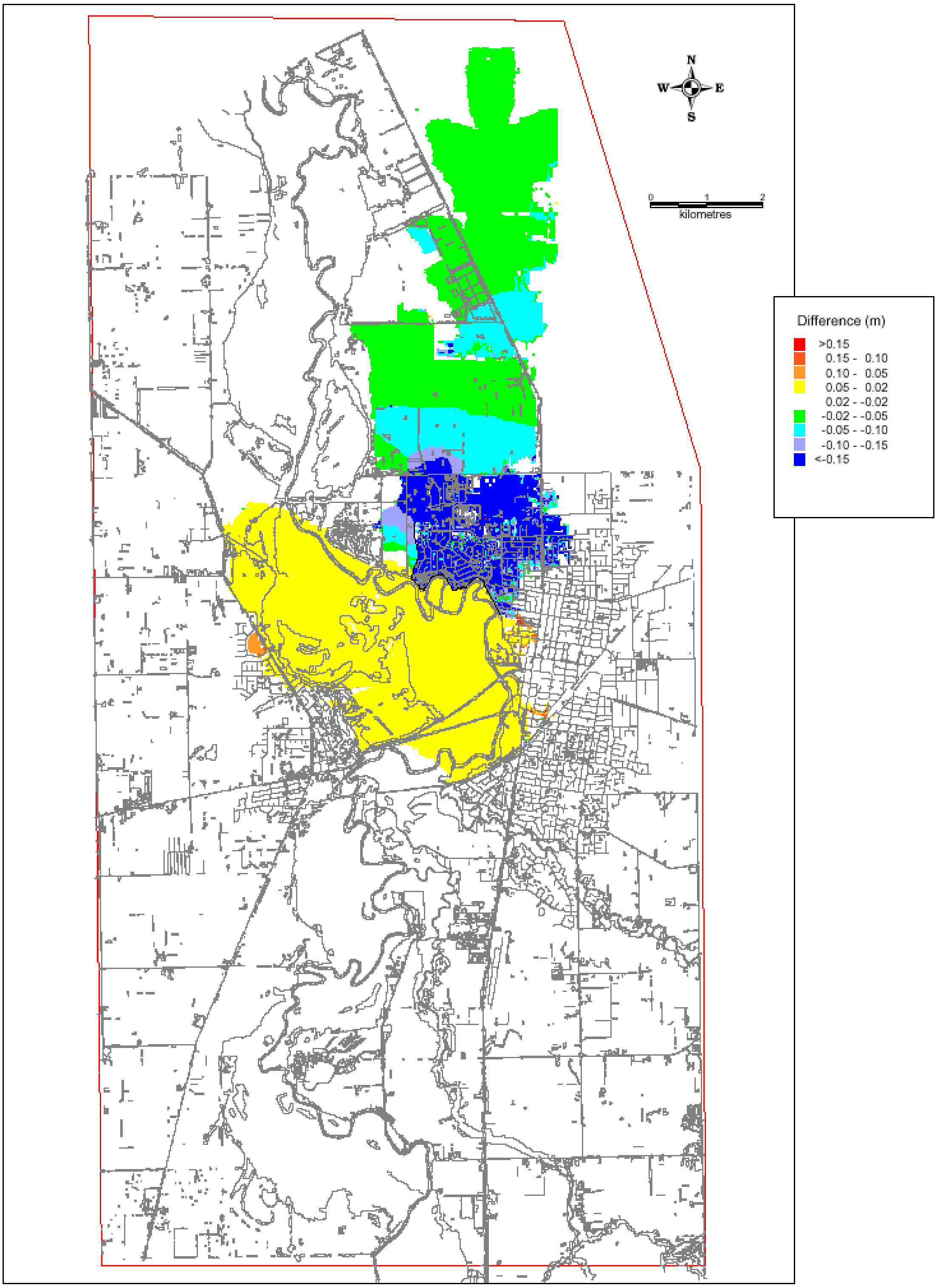
Table 4-4 shows the effect of Option 4 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

- **Table 4-4 Option 4 Boulevard Levee – Properties Affected (100 year ARI event)**

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	2,050	4,993
Reduction in number of properties	**110**	**1,579**

Social and environmental impacts and advantages and disadvantages of levee options generally are discussed in **Section 3.2.2**. A conclusion on the merits of all levee options in provided in **Section 4.3.6**.

■ **Figure 4-6 Option 4 Boulevard Levee – Water Surface Level Difference (100 year ARI event)**



4.3.5 Option 5 – Combined Levees

This option combined the levees outlined in Options 1 to 4.

Details of the levees assessment are as follows:

- Total Length ~ 15 km
- Estimated costs ~ $6.6 million
- Reduction in AAD ~ $560,000
- Benefit/Cost ~ 1.10

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the levees increased water levels over the area upstream of the Boulevard levee. Significant increases in the water levels of 100 mm to 150 mm occur in the residential areas of Kialla and Kialla Lakes. **Figure 4-7** shows the *difference* in the 100 year ARI water surface levels between Option 4 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

Table 4-5 shows the effect of Option 5 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

- **Table 4-5 Option 5 Combined Levees – Properties Affected (100 year ARI event)**

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	831	3,937
Reduction in number of properties	**1,329**	**2,635**

Social and environmental impacts and advantages and disadvantages of levee options generally are discussed in **Section 3.2.2**. A conclusion on the merits of all levee options in provided below.

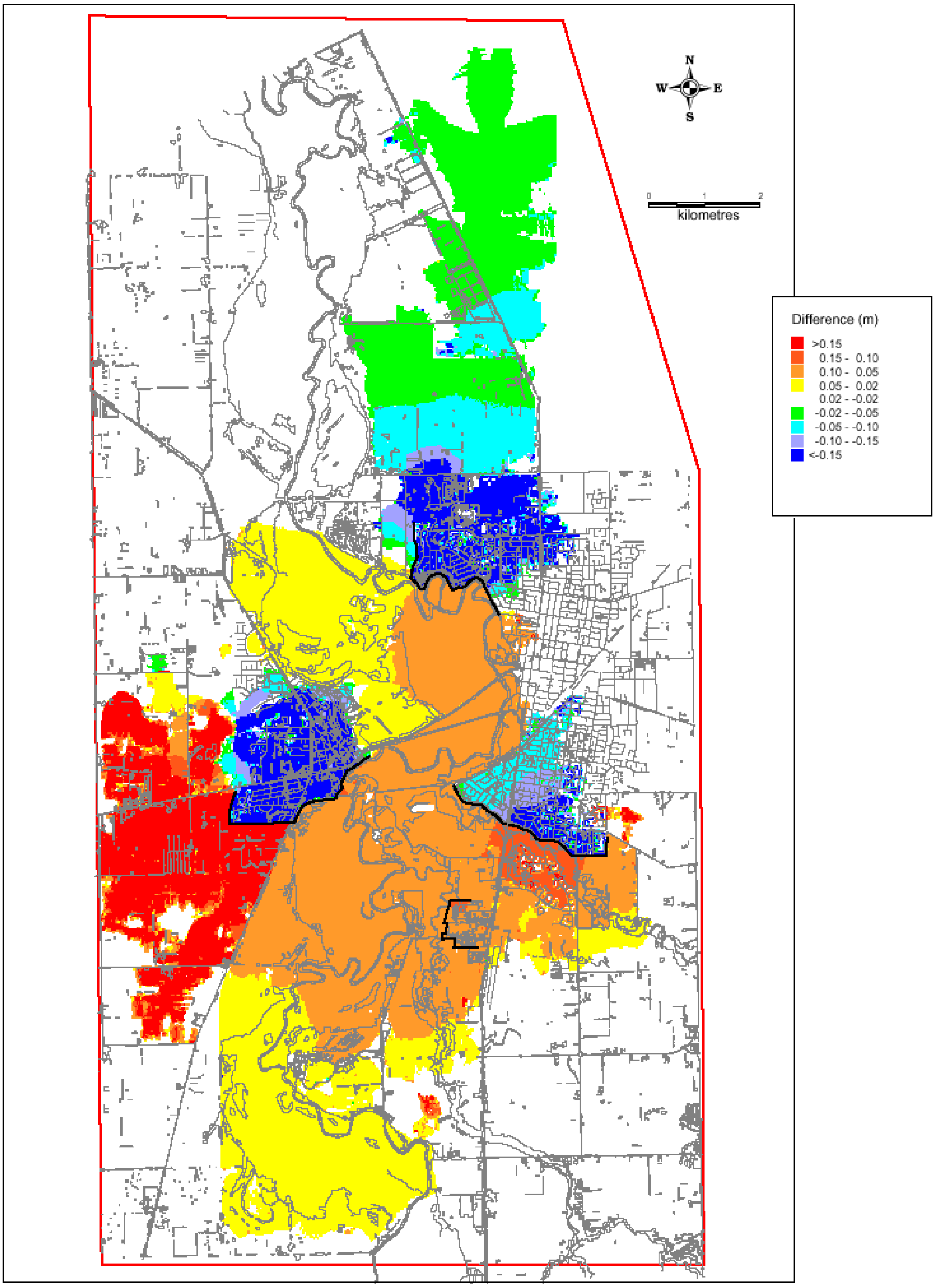
4.3.6 Levee Options - Conclusions

The levee options (Options 1 to 5) were presented to both the TSC and the CRG in April 2002, where it was considered that the increases in the water surface levels (see **Figure 4-3** to **Figure 4-7**) would be unacceptable to adjacent affected landholders. On this basis, levee options have not been considered further.

In addition, the construction of the South Mooroopna and Boulevard levees would involve siting the levees in close proximity to existing residential properties. Adverse social impacts would arise from the levee locations and include the visual impacts and inconvenience.

Given the adverse flooding impacts and community feedback via the CRG, Options 1 to 5 are not recommended for inclusion in the Floodplain Management Plan. Further and more detailed social and environmental assessment is therefore unnecessary.

- **Figure 4-7 Option 5 Combined Levees - Water Surface Level Difference (100 year ARI event)**



4.3.7 Option 6 – East Mooroopna Floodway

This option involves the construction of a floodway through a ridge adjacent to the Ibis piggery. The floodway exploits the significant difference in flood level between the old Mooroopna Hospital and Gemmill's Swamp. To improve the efficiency of the floodway the widening of the Geraghty's Bridge opening in the causeway by 25 m (approximately doubling the existing opening) was considered as part of the works. This option removes an obstruction to the flow on the western floodplain.

Details of the floodway assessment are as follows:

- Length ~ 330 m
- Width ~ 200 m
- Depth of excavation ~ 0.9 m average; ~ 1.5 m maximum
- Volume excavated ~ 64 000 m^3
- Widening of Geraghty's Bridge by 25 m
- Estimated Cost ~ $1 .8 million
- Reduction in AAD ~ $75,000
- Benefit/Cost ~ 0.6

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the floodway decreased water levels in the floodplain from the causeway to the Boulevard by 20 mm to 50 mm. Localised increases in the water levels of 20 mm to 50 mm occurred at the floodway outlet adjacent to Gemmill's Swamp (Note: increases do not occur in the vicinity of existing properties). **Figure 4-8** shows the *difference* in the 100 year ARI water surface levels between Option 6 and existing conditions. A positive number indicates an increase in water level due to the proposed floodway.

Table 4-6 shows the effect of Option 6 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

■ Table 4-6 Option 6 East Mooroopna Floodway – Properties Affected (100 year ARI event)

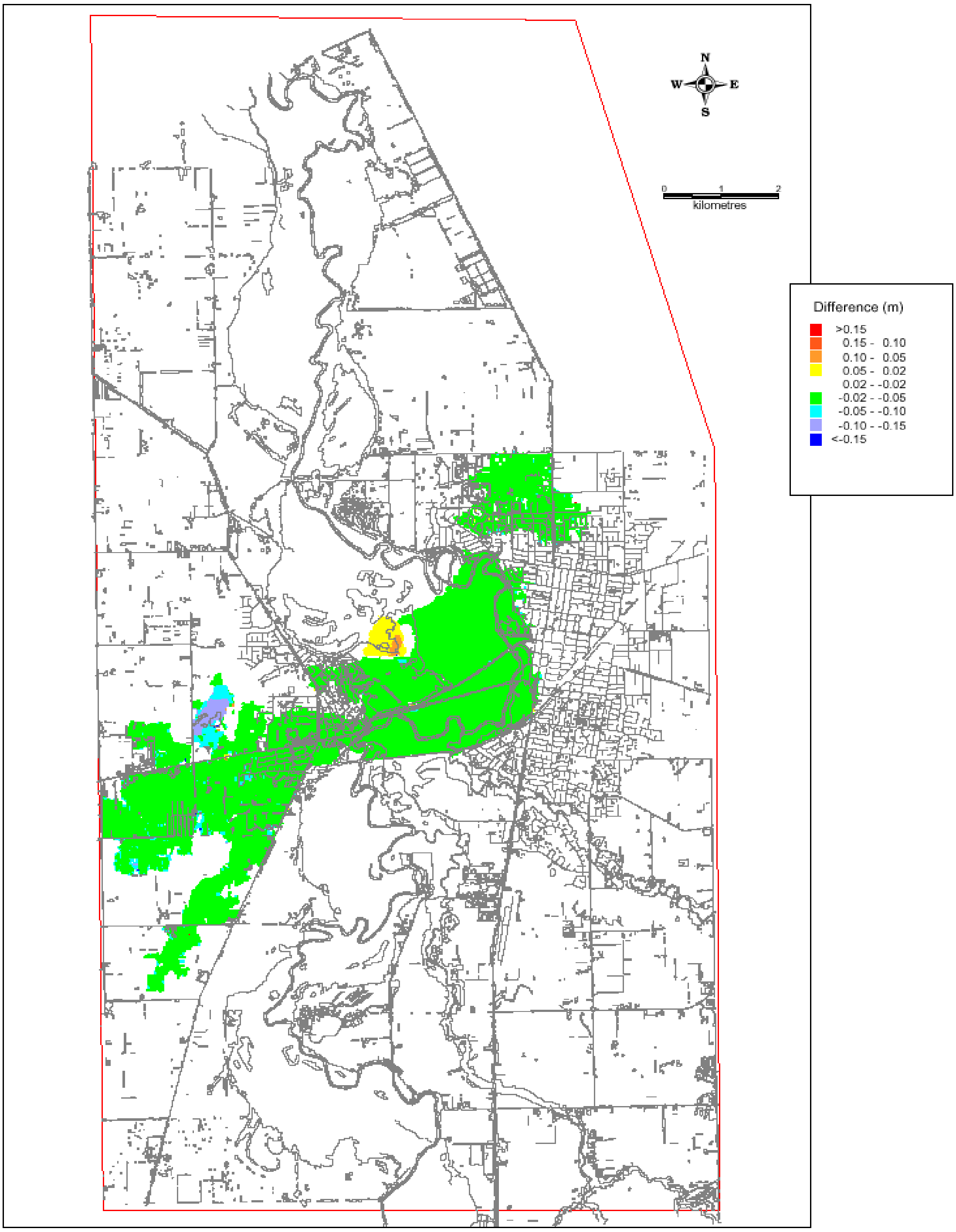
Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	2,061	6,447
Reduction in number of properties	**99**	**125**

The floodway is located on a portion of the floodplain which is inundated in flood events greater than 20 year ARI. For flood events with ARIs less than 20 years the floodway has no effect on flood behaviour. Given this relatively low frequency when the floodway will operate it is considered the environmental impact on Gemmill's Swamp will be minimal.

For the 100 year ARI event, peak flow velocities through the floodway are about 1 m/s. These velocities are unlikely to result in scouring of a grassed floodway. As indicated above the floodway will not operate in flood events with an ARI of less than 20 years. Due to the low frequency of inundation and the significant distance from the floodway to the Goulburn River, the risk of avulsion (ie, a change in river course) of the Goulburn River along the floodway is considered low. Further comment on floodways is provided in **Section 3.2.3**.

Due to the low benefit cost ratio, the East Mooroopna Floodway is considered uneconomic and is not recommended for inclusion in the Floodplain Management Plan.

- **Figure 4-8 Option 6 East Mooroopna Floodway - Water Surface Level Difference (100 year ARI event)**



4.3.8 Option 7 – Realignment of Channel 12

This option involves the realignment of the Channel 12 along the western side of the Barmah-Shepparton Road. Currently the banks of Channel 12 form a barrier to the flood flow in the area to the south of the Sewerage Treatment plant. Channel 12 is used for the distribution of irrigation water by Goulburn Murray Water.

Details of the floodway assessment are as follows:

- Length of channel to realignment ~ 5.6 km
- Estimated Cost ~ $1.2 million
- Reduction in AAD ~ $40,000
- Benefit/Cost ~ 0.5

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the realignment of Channel 12 decreased water levels in the area north of Wanganui Road to the existing Channel 12 alignment by up to 150 mm. Smaller decrease of 20 mm to 50 mm are seen in the area south of Wanganui Road to the Boulevard. Increases in the water levels occur downstream of the existing alignment adjacent to the Sewerage Treatment Plant. **Figure 4-9** shows the *difference* in the 100 year ARI water surface levels between Option 7 and existing conditions. A positive number indicates an increase in water level due to the proposed realignment.

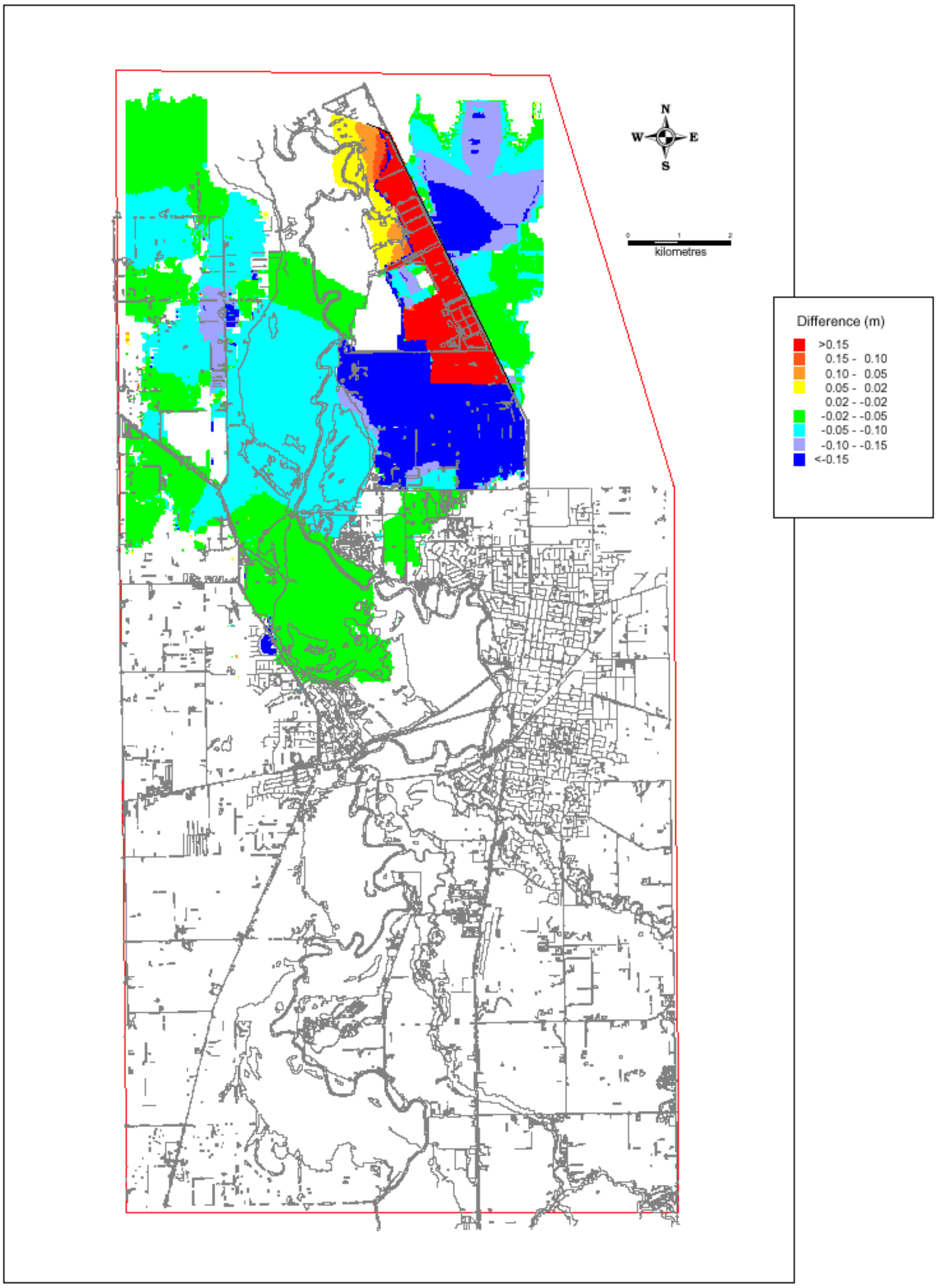
Table 4-7 shows the effect of Option 7 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

- **Table 4-7 Option 7 Channel 12 Realignment – Properties Affected (100 year ARI event)**

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	2,140	6,492
Reduction in number of properties	**20**	**80**

Due to the low benefit cost ratio the Channel No. 12 realignment is considered uneconomic and the option is not recommended for inclusion in the Floodplain Management Plan.

■ **Figure 4-9 Option 7 Channel 12 Realignment - Water Surface Level Difference (100 year ARI event)**



4.3.9 Option 8 – Increased Bridge Openings in Causeway and Railway Line

This option involves increasing the bridge openings through both the causeway and the railway line. The hydraulic analysis for existing conditions has shown that both the causeway and railway cause a significant increase in flood levels immediately upstream of both structures. These increases are due to the constriction to the flood flow formed by the two structures. This option aims to reduce the increases in upstream flood levels by increasing waterway openings.

This option considered a doubling of the bridge openings in both the causeway and railway line. This would involve the replacement of existing bridges with new extended bridge structures. The details of the increased openings are as follows:

- Causeway (openings number west to east)
  - Geraghty's Bridge - increased by 25m
  - Ah Wong's Bridge - increased by 50m
  - Boolbadah Floodway Bridge - increased by 75m
  - Daish's Bridge - increased by 25m
  - McGuire's Bridge - increased by 100m
  - Dainton's Bridge (Goulburn River) - increased by 75m.
- Railway
  - Goulburn River - increased by 175m
  - Broken River - increased by 75m

Details of the causeway and railway openings are as follows:

- Estimated Cost ~ $20 million
- Reduction in AAD ~ $240,000
- Benefit/Cost ~ 0.16

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the widening of causeway and railway openings decreased water levels in the area between the causeway and railway by 100 mm to 150 mm. Larger decreases in water levels occur immediately south of the railway. North of the causeway, increases in water levels of 20 mm to 50 mm occur in The Boulevard area. Immediately downstream of the causeway increases in water levels are between 50 mm to 100 mm. **Figure 4-10** shows the *difference* in the 100 year ARI water surface levels between Option 8 and existing conditions. A positive number indicates an increase in water level due to the proposed wider openings.

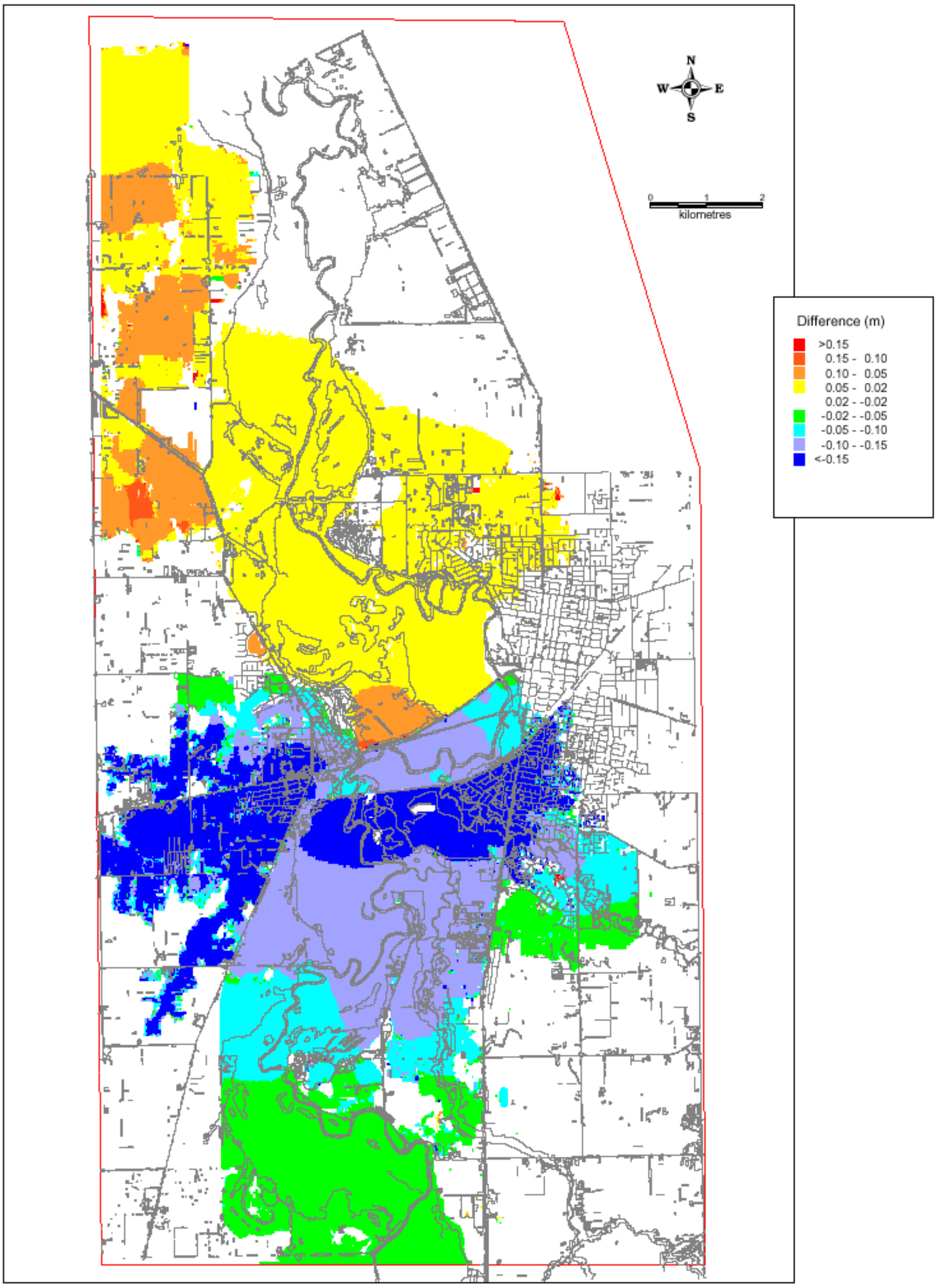
Table 4-8 shows the effect of Option 8 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

■ Table 4-8 Option 8 Causeway and Railway Opening – Properties Affected (100 year ARI event)

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	1,322	5,917
Reduction in number of properties	**838**	**655**

This option results in a significant reduction in properties flood affected and incurring flood damages. However due to the high capital cost the benefit cost ratio is low. On this basis increasing bridge causeway and railway openings is considered uneconomic. The option is not recommended for inclusion in the floodplain management plan.

■ **Figure 4-10 Option 8 Causeway and Railway Increased Waterway Openings - Water Surface Level Difference (for 100 year ARI event)**



4.4 Non-Structural Mitigation Measures

4.4.1 Planning Scheme Amendments (Land-Use Planning)

Amendments to the current planning scheme are aimed to ensure that future land use and development are compatible with flooding risks as identified by this study. **Stage 1** (SKM 2002a) outlines the approach adopted by this study in providing improved planning information to the GSCC and GBCMA.

Improved land use planning does not immediately reduce flood damages for existing properties/infrastructure, but does provide an effective means of reducing flood damages in the longer term.

In addition, the improved information for land use planning would facilitate more effective assessment of applications.

4.4.2 Emergency Response and Flood Warning

As outlined in **Stage 1** (SKM 2002a), flood inundation maps and property listings have been developed for a range of gauge heights at Shepparton. The flood inundation maps show the flood extents, flood depths, flood elevations contours and properties inundated above floor level and the property listings identified the address of properties inundated above floor for a range of gauge heights at Shepparton.

The flood response plan for Shepparton–Mooroopna (Flood sub-plan of the Municipal Emergency Management Plan) has been reviewed as part of this study and the review is presented in **Appendix C**. The revised flood response plan will incorporate the flood inundation maps and property listings.

The revised flood response plan represents a significant improvement over current emergency management and response by providing detailed information about infrastructure (roads, etc) and properties affected for a given gauge height at Shepparton. As a consequence it is likely that there will be a reduction in flood damages experienced, as authorities/residents will be able to take appropriate preparatory actions (ie. lifting of valuable property above flood level, sand bagging, etc).

The benefit of improved flood response/warning can be assessed by adjusting the ratio – the Damage Reduction Factor (DRF) - of actual damages to potential damages. As outlined in **Section 6** of the **Stage 1** report (SKM, 2002a) the ratio was set to 0.7 to evaluate the flood damages for existing conditions.

The RAM (NRE, 2000) provides some guidance on appropriate DRFs under improved emergency response/flood warning. It is considered reasonable that a DRF of 0.6 be adopted to evaluate the effectiveness of the revised flood response plan.

Based on the revised DRF the average annual damages (AAD) reduces from $1.09 million under existing conditions to $990,000 with the implementation of the revised flood response plan.

The flood inundation maps for emergency response, outlined in **Stage 1** (SKM 2002a), have been based on inflows from the Goulburn River, Broken River and Seven Creeks. To utilise these flood inundation maps requires flood forecasts for the three streams at locations immediately upstream of the study area.

The Bureau of Meteorology (BoM) in consultation with Goulburn-Murray Water (G-MW) currently provides quantitative flood forecasts (flood height and timing of peak) at the following gauges relevant to this study:

- Goulburn River at Murchison
- Goulburn River at Shepparton

Through consultation with BoM (A Baker, *pers comm.* 2002), the Murchison gauge on the Goulburn River is considered too far upstream of the study area to be fully effective. It is therefore recommended a telemetered stream gauge be installed near the upstream limit of the study area. A gauge at this site would also have the advantage of capturing inflows from the Castle, Creightons and Pranjip Creek catchments. It may be possible to re-establish the discontinued gauge on the Goulburn River at Kialla West. This would also require establishing new instrumentation.

A basic service for Orrvale on the Broken River is provided but this can be inaccurate in larger flood events as a result of the unknown magnitude of breakouts between Casey's Weir and Orrvale. Further investigations are required to quantify these breakouts with an aim to improve the accuracy of forecasts at Orrvale.

Additional quantitative flood forecasts (flood height and timing of peak) would be required for the Seven Creeks at Kialla West. The additional forecast for Seven Creeks at Kialla West could be made by using information for Seven Creeks at Euroa and the relationship developed as part of this study's hydrological analysis. A small amount of extra investigation is required to assess the suitability of this developed relationship for flood warning purposes. Alternatively, the existing Euroa URBS Flood Forecasting model could be extended to Kialla West (A Baker, *pers comm.* 2002).

BoM is currently finalising the development of an URBS runoff routing model for flood prediction for the Goulburn Catchment to Seymour. This model could be extended to Shepparton and then include quantitative prediction at all gauges relevant to the Shepparton Mooroopna study. The existing models for the Broken River to Benalla and Seven and Castle Creeks to Euroa would be incorporated into this lower Goulburn model.

To complement the URBS model development, BoM recommends that telemetry at a number of gauging stations be upgraded. The Goulburn River at Murchison and Goulburn River at Shepparton and Broken River at Orrvale gauges have older style telephone telemetry (telemark) which requires manual interrogation. Sevens Creeks at Kialla West has a modem interface which allows automatic interrogation of the gauge at the preset times. It is recommended that all critical gauges (Shepparton, Murchison, Kialla West and Orrvale) be upgraded to Event Radio Reporting Telemetry Systems (ERTS). It is further recommended that a new ERTS based stream gauge be commissioned on the Goulburn River at the upstream limit of the study area. Communications infrastructure at the new Yarrawonga radar site could be used to transfer data in real time to the BoM Flood Warning Centre in Melbourne. ERTS telemetry is preferred to telephone telemetry because there are no telephone polling or rental costs and greater resolution data is provided. Data from all relevant rain and stream levels sites would be displayed on the BoM's publicly accessible website (A Baker, *pers comm.* 2002).

BoM would be willing to contribute toward the capital costs of upgrading the existing sites subject to ongoing costs being met by local beneficiaries (ie: GSCC, GBCMA and G-MW). Also, BoM can assist with radio path testing to determine the suitability of the suggested telemetry upgrade approach for the existing four sites and the proposed new site. Ongoing maintenance procedures at the two new sites should include the development of high stage rating tables. It is likely that a small amount of hydraulic modelling work would be required at the two new sites to develop synthetic rating tables. These relationships would be required for the interim period until measured rating relationships are developed.

Opportunities to use FM88 and automated mass dialling to aid in flood warning have been explored (N McPherson, *pers comm.*, 2002). FM88 radio exists in the Shepparton-Mooroopna area although it is assumed an upgrade of station facilities to accommodate the flood warning process is necessary. Automated mass dialling, whilst appealing in principle, is more problematic. Telstra has established systems, effectively pilots, in the smaller communities of Euroa and Benalla but these are not cost effective in their current form. It is anticipated that the cost to maintain an effective system would be $10,000 to $15,000 *per annum*, although such a system has never been established. An alternative, originating from the Police Department of Western Australia and called PC Cops, uses the principal of automatic dialling but is understood to be currently limited in range (eg. street scale) and calls are sequential rather than concurrent.

Importantly, it is believed beneficial to use only one means of mass-communication for flood warning to ensure consistency of flood warning messages. On this basis a focus on FM88 is recommended, although opportunities and developments in automated dialling are worth tracking and exploring.

Flood warning arrangements will be documented as part of the flood response plan (Flood sub-plan of the Municipal Emergency Management Plan).

5. Floodplain Management Plan

5.1 Outline of Recommended Plan

The investigations in this study have been brought together as the Floodplain Management Plan for Shepparton-Mooroopna. This study has been conducted in line with best practice principles using a risk management framework (DNRE/DoJ 1998).

The recommended plan is in line with the Goulburn Broken CMA Regional Floodplain Strategy (SKM 2002b) and contains the following elements:

- *Planning Scheme Amendment*
  - It is recommended the Greater Shepparton City Council amend its planning scheme to include the revisions to the planning zones and overlays as outlined in **Stage 1** (SKM 2002a).
  - It is recommended the Goulburn Broken Catchment Authority declare the 100 year ARI flood levels outlined in **Stage 1** (SKM 2002a).

- *Flood Warning Arrangements*
  - It is recommended that BoM in conjunction with G-MW continue to provide quantitative flood forecasts for the Goulburn River at Murchison and Shepparton.
  - It is recommended the future role of G-MW in providing forecasts for Shepparton and other locations be resolved.
  - It is recommended that a new gauging station be established on the Goulburn River adjacent to the upstream study limit and BoM provide quantitative flood forecasts for this gauge.
  - It is recommended that the accuracy of the current flood forecasts for the Broken River at Orrvale be improved by further investigation of Broken River breakout between Casey's Weir and Orrvale.
  - It is recommended that BoM provide additional quantitative flood forecasts for the Sevens Creeks at Kialla West.
  - It is recommended that the communication infrastructure for gauges at Murchison, Shepparton, Kialla West and Orrvale be upgraded to Event Radio Reporting Telemetry Systems.
  - It is recommended that GSCC review existing roles and investigate further opportunities for Emergency Radio FM88 to assist in flood warning arrangements.
  - It is recommended that GSCC explore the viability of automatic telephone dialling as an alternative to deliver flood warnings to individual properties.

- *Flood Response and Recovery*
  - It is recommended the Greater Shepparton City Council revise its flood response plan (which requires amendment of the Municipal Emergency Management Plan - flood sub plan). This flood response plan outlines:
    - the roles and responsibilities of the relevant authorities,
    - means of disseminating flood warnings,
    - emergency works and actions (eg. evacuation, sand bagging, road closures, etc),
    - performance monitoring of emergency response and management (evacuations, road closures, injuries etc),

    - arrangements for flood recovery,
    - arrangements for counselling to address social trauma,
    - arrangements for financial flood relief.

  - The flood response plan should also be cognisant of the "Greater Shepparton Public Health Plan."

- *Flood Monitoring*
  - It is recommended the Greater Shepparton City Council and the Goulburn Broken CMA establish an agreement to cover the following flood monitoring aspects:
    - triggers and methods for data collection of rainfall, peak flood flows, peak flood levels, flood extents (including on ground survey, aerial photography and satellite imagery) and flood damages (includes damage to bed and bank, structural damages etc),
    - procedures for the storage of flood data collected during flood events.

    Note: This agreement will be based on the existing Flood Assessment Manual prepared for GBCMA Flood Response Action Plan (SKM 2002b).

- *Flood Preparedness and Community Awareness*
  - It is recommended the Greater Shepparton City Council in conjunction with the Goulburn Broken CMA develop a program to increase community awareness of existing flood risks, flood emergency response and flood warning arrangements. The program should consist of the following elements:
    - Community flood guide outlining contact phone numbers, context of local flooding issues, flood warning arrangements and useful tips for reducing damage and enhancing safety.
    - Contribution to media articles regarding flood issues.
    - Public exhibition of this study's outcomes in Council's foyer.

- *Information Management Systems*
  - It is recommended the Greater Shepparton City Council in conjunction with the Goulburn Broken CMA develop information management systems to facilitate the access and use of the flood information from previous studies, this current study and collected during flood events. The information management systems may include the following elements:
    - Customised GIS database/interface to facilitate the collation and access to the topographic, property, flood data collected as part of this study. All spatial study outputs (flood inundation maps etc) should also be included in the GIS database.
    - Training for GSCC and GBCMA staff in the use of the GIS database.
    - Establishment of a central location for hard copies of reports and maps.

This floodplain management plan recognises the principals of the VicHealth document "Leading the Way - Councils creating healthier communities", particularly the principal of integrated planning. In this regard, the floodplain management plan should call on provisions of the municipal public health plan when establishing flood recovery methods and more generally by providing a sense of improved personal safety in times of flood.

It should be noted that following the detailed assessment of structural mitigation options, no structural mitigation works are recommended for the plan.

From the assessment in **Section 4.4.2**, the flood warning arrangements and flood response elements alone would reduce the average annual damage (AAD) from $1.09 million to $990,000. This represents a benefit of $100,000 per year. It is reasonable to expect that the other elements of the recommended plan would also lead to further reductions in flood damages.

5.2 Costs Associated with Recommended Plan

The cost breakdown of the recommended plan, as outlined in **Section 5.1**, is shown in **Table 5-1**. Also provided is an indication of the priority of the recommended plan's elements.

■ **Table 5-1 Recommended Floodplain Management Plan – Costs**

Element	Cost	Priority
Planning Scheme Amendment		
- Adopt Planning overlays and zones	$6,000	Very high
- Declare 100 year ARI flood levels	$3,000	Very high
Flood Warning Arrangements		
- Clarify arrangements with GM-W	$2,000	Very high
- Establish gauging station on the Goulburn River adjacent to the upstream limit of the study area.	$50,000 $10,000 p.a (maintenance)	High
- Improve accuracy of forecast at Orrvale	$7,000	High
- Provide quantitative flood forecast for Sevens Creeks at Kialla West	$10,000	High
- Upgrade communication infrastructure for Murchison, Shepparton, Orrvale and Kialla West	$30,000	High
- Emergency Radio, FM88	$12,000	High
- Automatic Telephone Dialling Viability	$3,000	Medium
Flood Response		
- Develop flood response plan - Link to municipal public health plan	$10,000	Highest
Flood Monitoring		
- Develop/review monitoring plan	$3,000	High
- Data collection as required	$10,000 (indicative)[1]	High
Flood Preparedness and Community Awareness		
- Develop community flood response plan	$7,000	Medium
- Printing and distribution of community flood response plan	$10,000	Medium
Information Management System		
- GIS development	Part of current Study	Very high
- Training	$3,000	High
Total		
- Capital cost (excl. data collection)	**$156,000**	
- Recurrent cost	**$10,000 p.a**	

1. Cost is dependent on size of flood events.

5.3 Funding and Implementation

The implementation of improved flood warning would be subject to a funding bid being successful at State and Commonwealth level. Typical local contributions is one-third of the capital cost. Other programs can be implemented from the GSCC recurrent budget with technical assistance from the GBCMA and other relevant agencies.

5.4 Assumptions and Qualifications

The following points should be noted:

- Future flood events may well vary from those theoretically derived.
- Whilst various structural measures have been considered as components of mitigation options, these have been assessed to a level of detail consistent with the development of a floodplain management plan.

The analysis and overall approach has catered for the particular requirements of Greater Shepparton City Council (as specified in the study brief and subsequent agreements) and may not be applicable beyond this scope. For this reason, third parties should not utilise the outcomes of this investigation without further input and advice from Sinclair Knight Merz or Lawson & Treloar.

References

Baker, A. Personal Communications, Bureau of Meteorology, 2002.

Department of Infrastructure/Department of Natural Resources and Environment (2000): *Victorian Planning Provisions Practice Notes – Applying the Flood Provisions in Planning Scheme.* Department of Infrastructure. 2000.

Department of Natural Resources and Environment/Department of Justice (1998): *Victoria Flood Management Strategy.* Department of Natural Resources and Environment. 1998.

Department of Natural Resources and Environment (1998): "Advisory Notes for Delineating Floodways". Floodplain Management Unit, Natural Resources and Environment.

McPherson, N. Personal Communication. Neville McPherson, CT Management. 2002.

Sinclair Knight Merz (2002a) *Shepparton Mooroopna Floodplain Management Study – Stage 1 Technical Report*. Consulting report for the Greater Shepparton City Council. Sinclair Knight Merz, WC01082. October 2002.

Sinclair Knight Merz (2002b): *Flood Data Assessment Manual*. Consulting report for the Goulburn Broken Catchment Management Authority. Sinclair Knight Merz WC01036.300. February 2002.

Sinclair Knight Merz (2002c): *Regional Floodplain Strategy.* Consulting report for the Goulburn Broken Catchment Management Authority. Sinclair Knight Merz WC01036. June 2002.

Appendix A Stage 2 Community Consultation

Appendix B Hydraulic Analysis of Structural Mitigation Options

Figure B-1 Option 1 Kialla Levee - Water Surface Elevations (100 year ARI event)

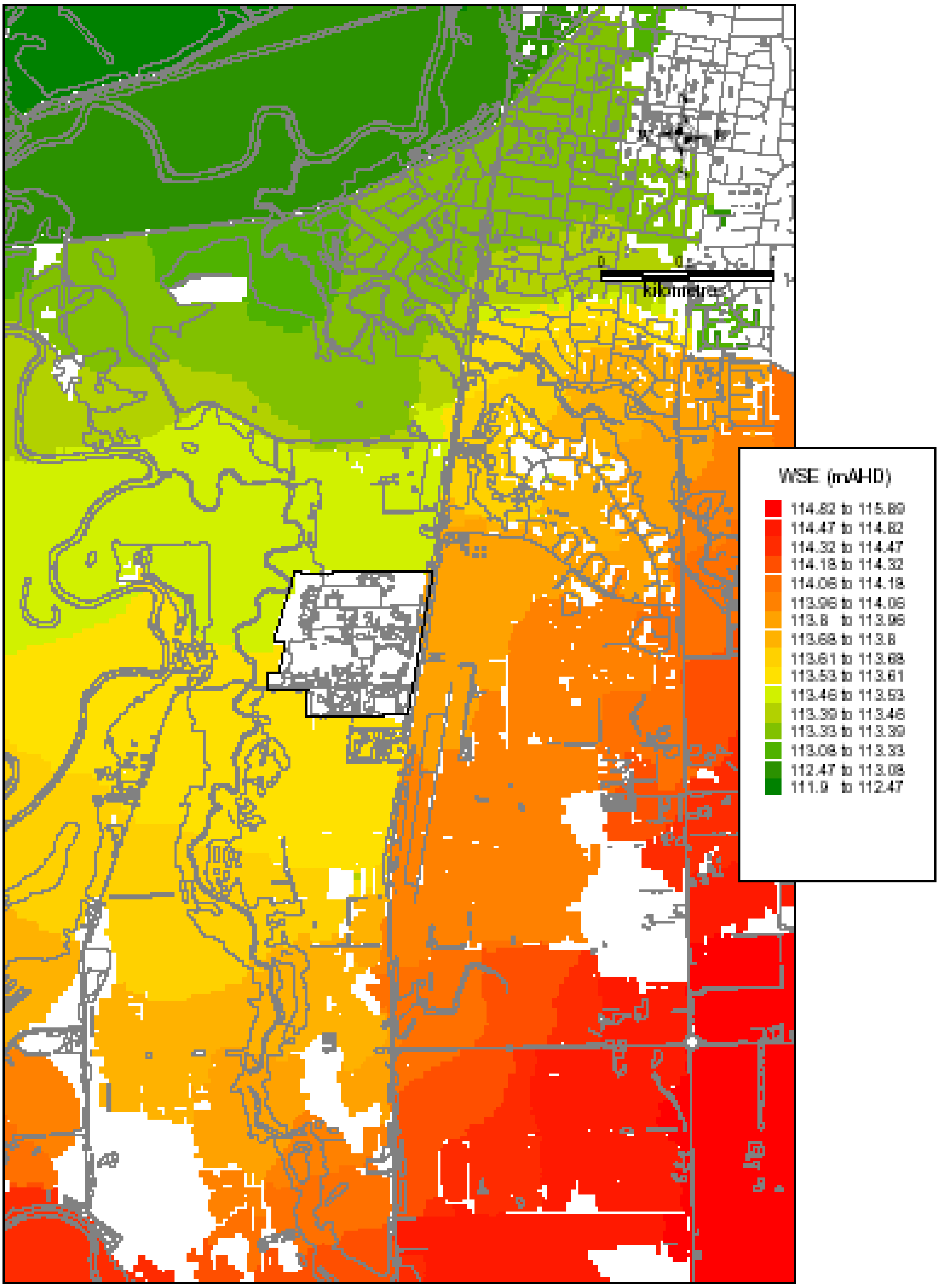


Figure B-2 Option 2 Shepparton South Levee - Water Surface Elevations (100 year ARI event)

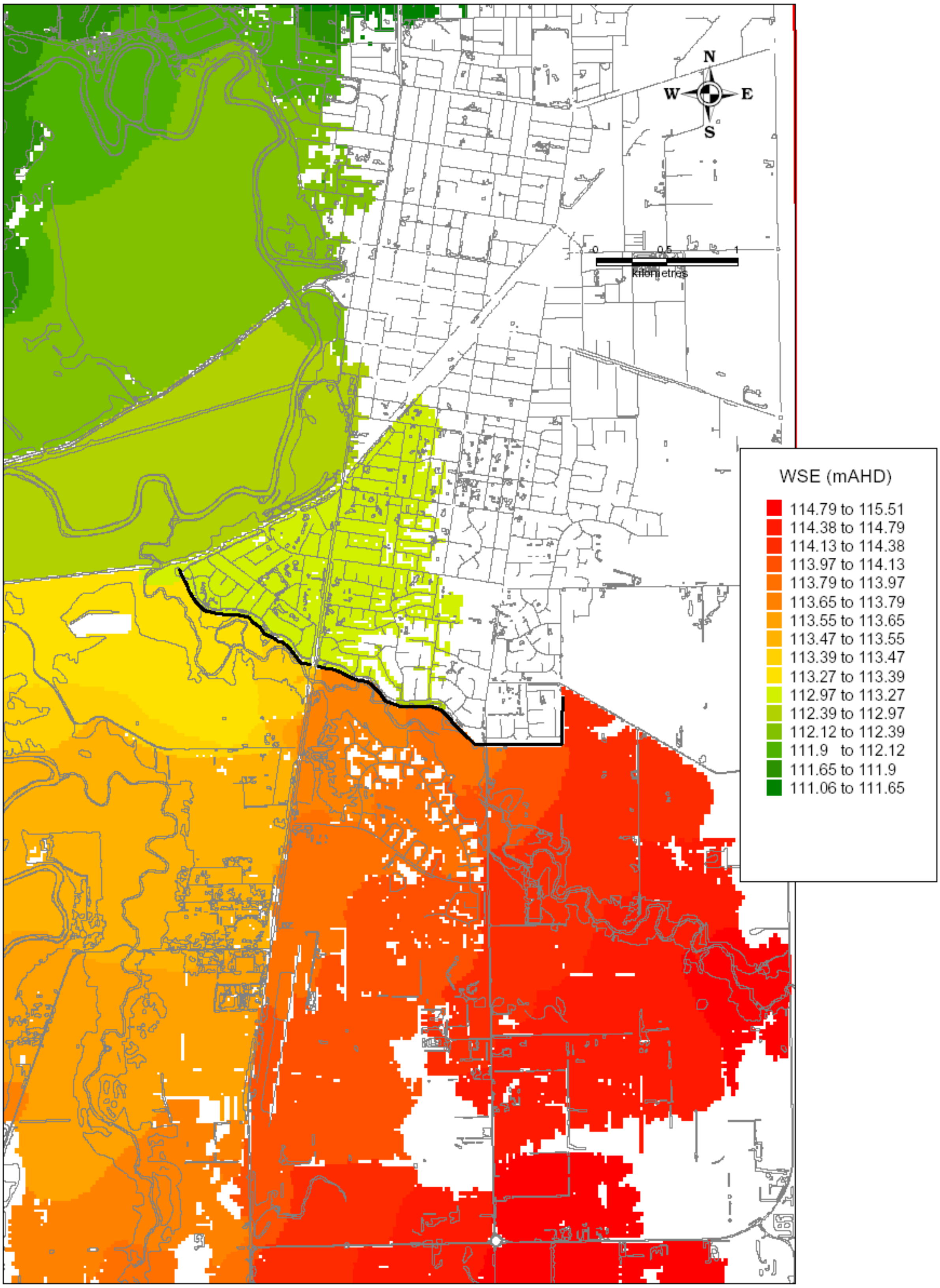


Figure B-3 Option 3 Mooroopna South Levee - Water Surface Elevations (100 year ARI event)

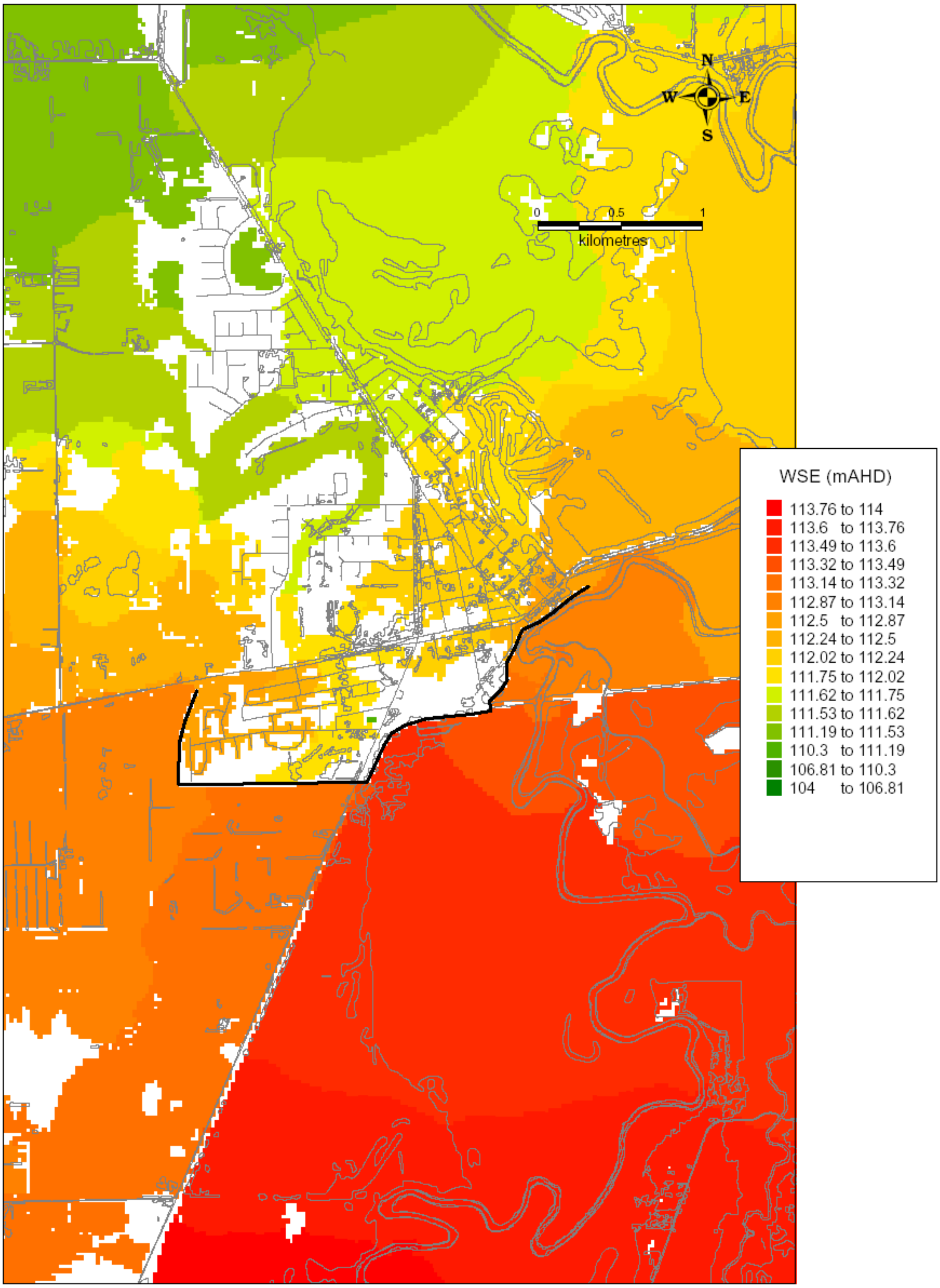


Figure B-4 Option 4 Boulevard Levee - Water Surface Elevations (100 year ARI event)

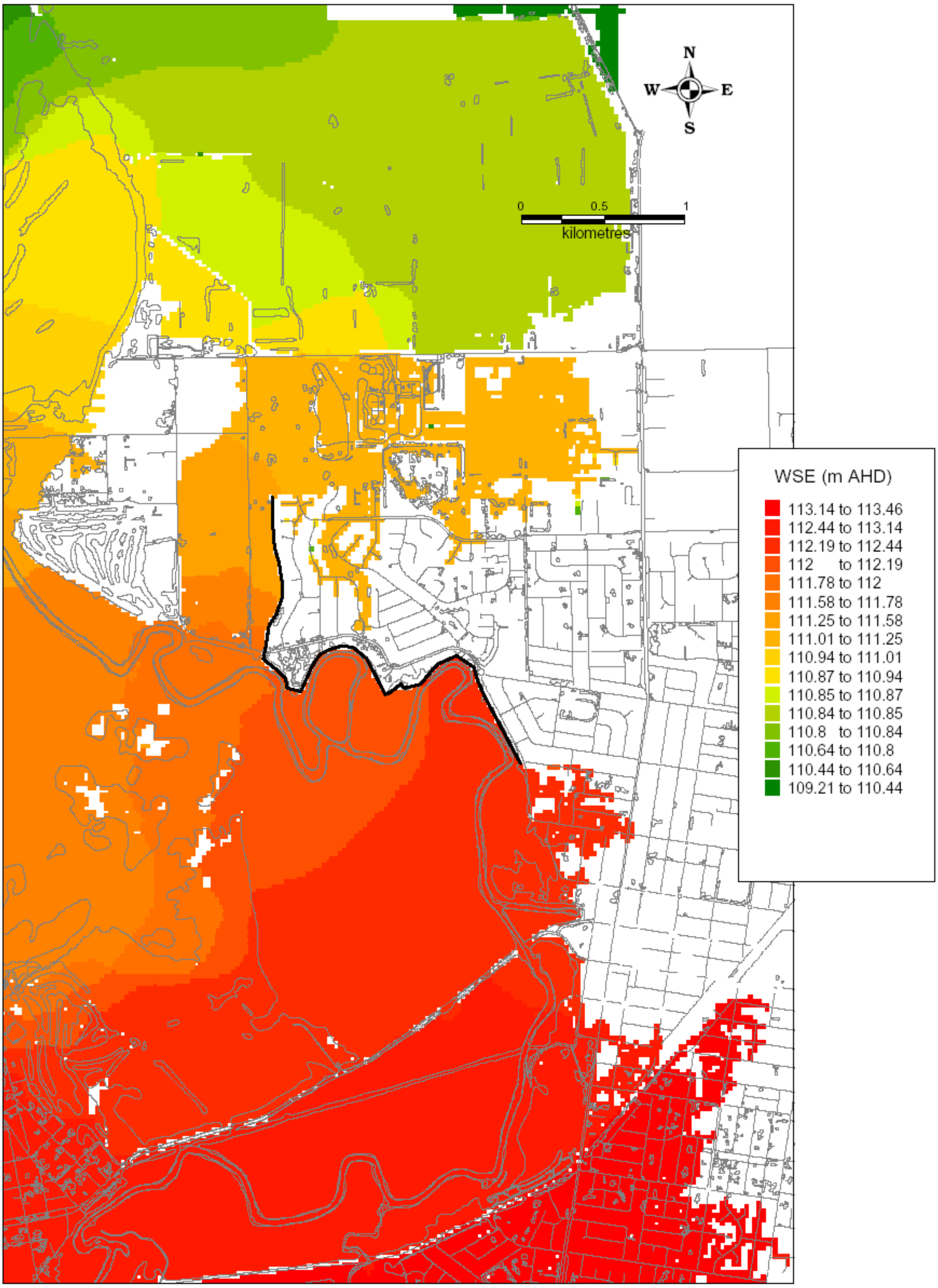


Figure B-5 Option 5 Combined Levee - Water Surface Elevations (100 year ARI event)

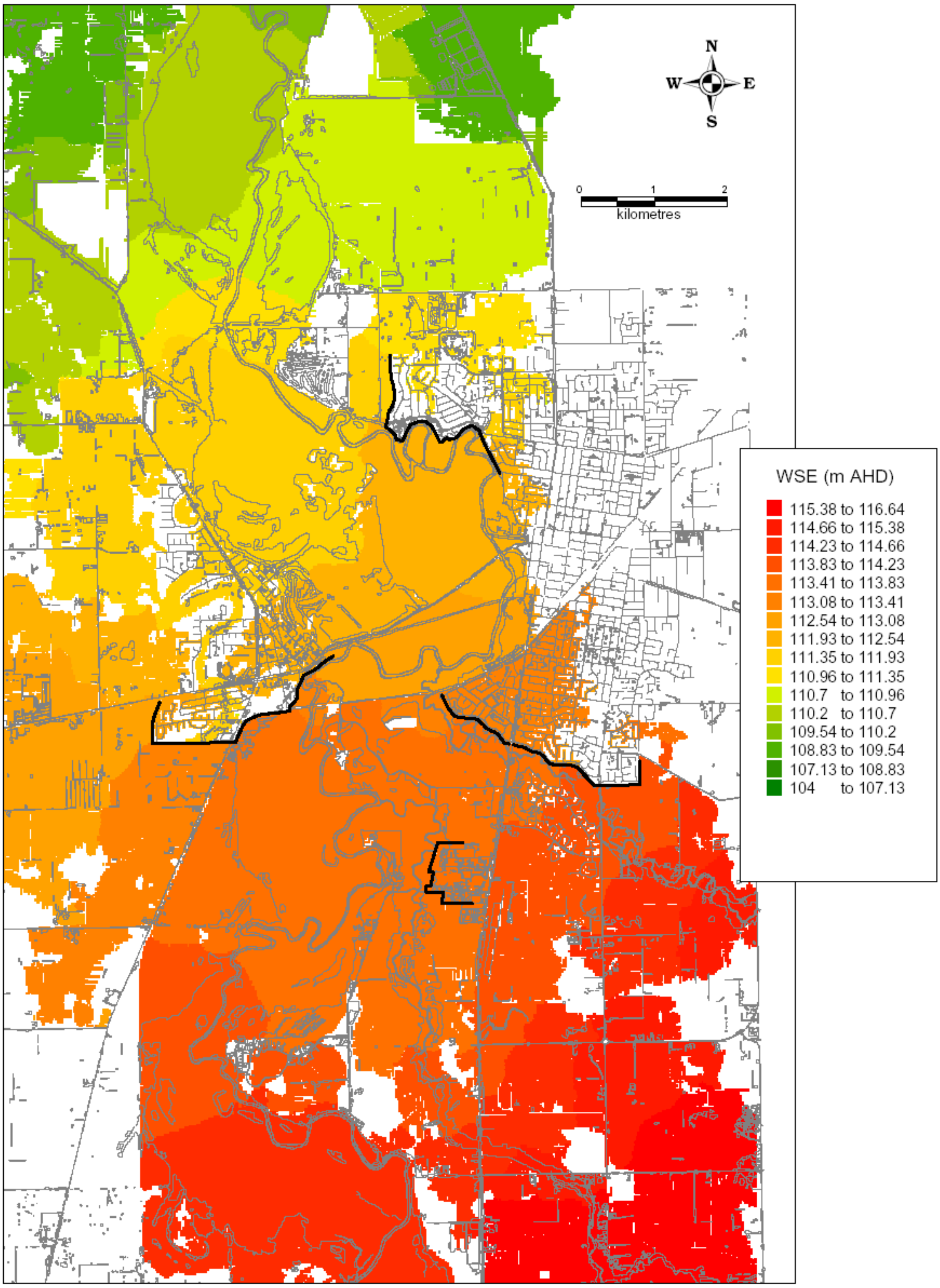


Figure B-6 Option 6 East Mooroopna Floodway - Water Surface Elevations (100 year ARI event)

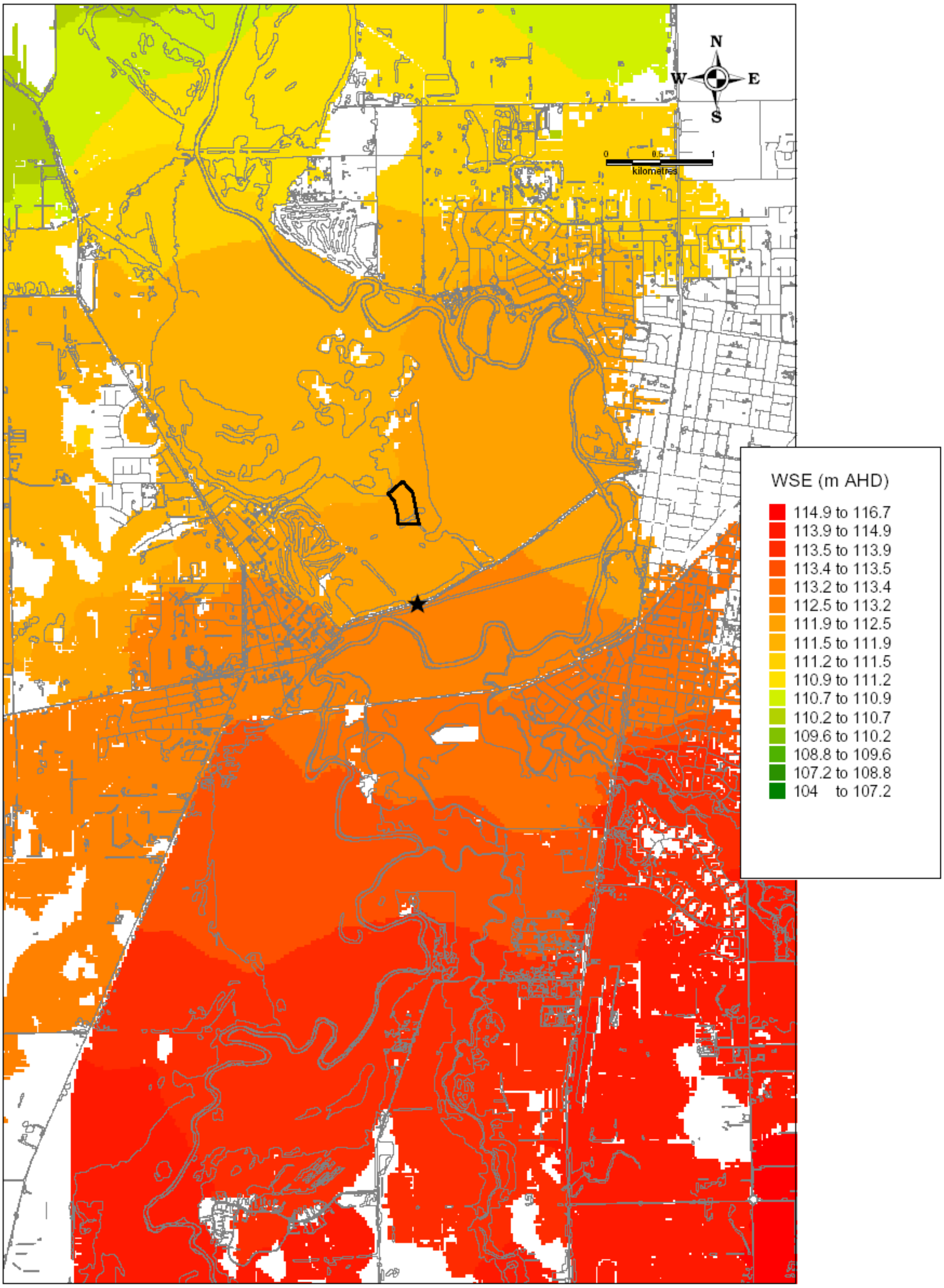
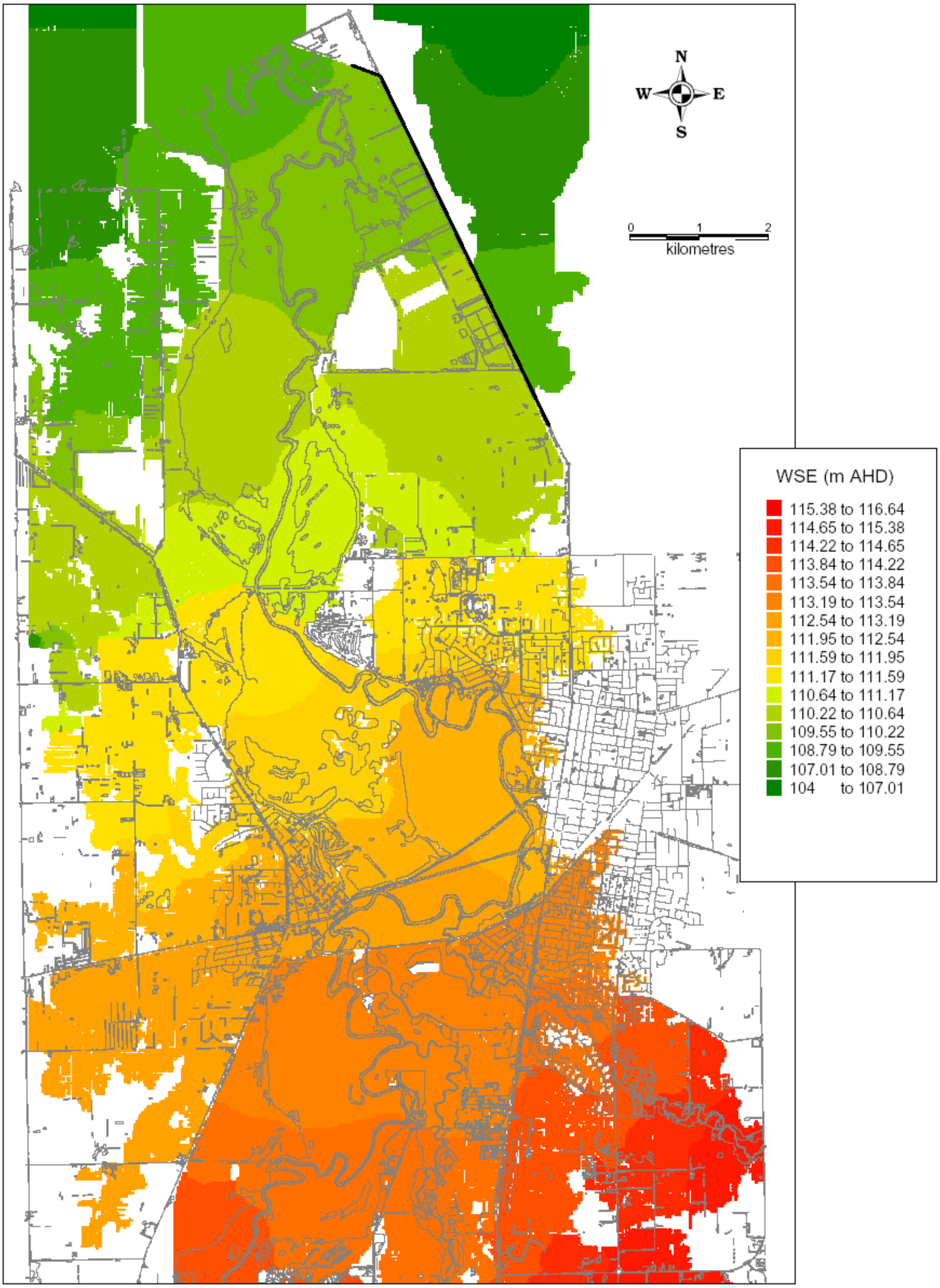
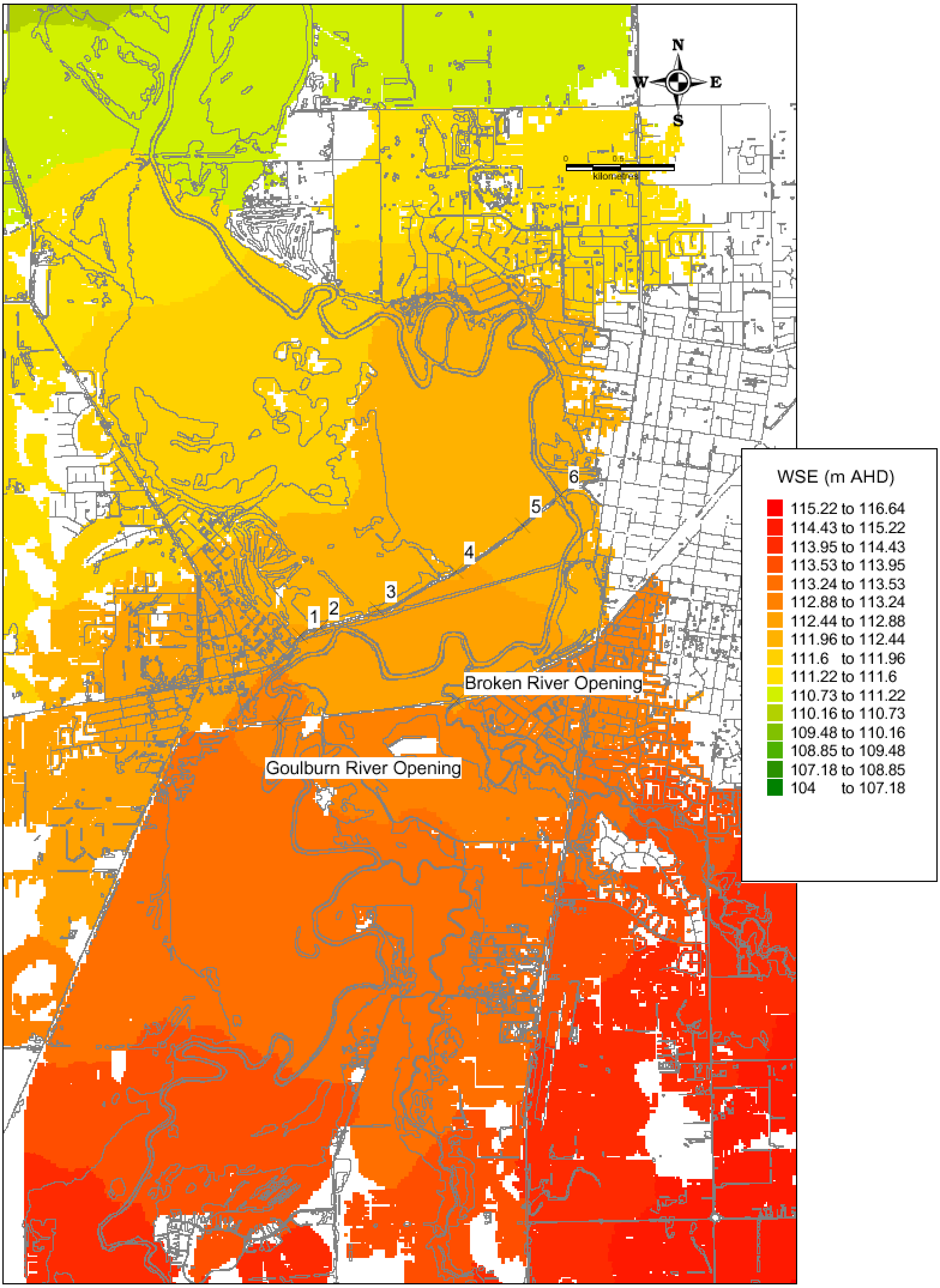


Figure B-7 Option 7 Channel 12 Realignment - Water Surface Elevations (100 year ARI event)



■ **Figure B-8 Option 8 Causeway and Railway Increased Waterway Openings - Water Surface Elevation (for 100 year ARI event)**



Appendix C Review of Flood Response Plan

A review of existing flood response documents was undertaken by GHD-GeoEng to complement the investigations undertaken in this study.

C.1 Introduction

A document titled "Flood Reaction Tasks" and dated 2001, was supplied by GSCC as the current version of the City's Flood Response Plan. An initial read of this document revealed that appreciable changes would be required in order to accurately reflect current organisational arrangements and an updated appreciation of local flood behaviour. For example, the document contains references to the extinct Rural Water Commission (RWC), flood related responsibilities assigned to Goulburn-Murray Water (G-MW) are more substantial than G-MW acknowledge and there is no acknowledgement of the Catchment Management Authority (CMA). The document also does not show its relationship to the City's Emergency Management Plan and/or wider flood management arrangements. Outputs and knowledge gained from the current study also need to be incorporated.

A copy of the GSCC Flood Plan (1995), produced as a Sub Plan to the City's Emergency Management Plan, was obtained from VicSES. While this document is difficult to read and lacks the detailed information contained in the Flood Reaction Tasks document, it appears to be structured to fit within the emergency management framework established within Council and other stakeholder agencies.

It is apparent that both the above documents have many paragraphs in common. It is unclear which document is the parent document although the former does contain a reference to the GSCC Flood Plan, 1996 (sic) and reference is made to the year 2000 in the introduction. In view of the information contained in it and the various references, it is suggested that the "Flood Reaction Tasks" document is the parent document but that it has gone through a number of edits to arrive at the current version.

There is no apparent reason for two documents that appear to serve a similar purpose. It could be surmised that the "Flood Reaction Tasks" document is an operational document that also contains some policy details and related matters while the "Flood Plan" is a policy document that contains some operational information. In our view this represents an unnecessary duplication and creates a significant potential for error and operational uncertainty stemming from incomplete or conflicting information, the latter from uncoordinated or uncontrolled update/maintenance of either or both documents.

It is understood that the Flood Plan has been prepared to a formula that fits with the City's Emergency Management Plan. In view of this and the more 'structured' nature of the Flood Plan, we have taken that document as being the base document and have directed our review and framed our comments accordingly.

C.2 General Comments

The Flood Plan is difficult to read due to inconsistencies in writing style and obvious grammatical and spelling errors. A severe edit to correct these and to improve readability would be a useful exercise. This would include a reformat to address layout, fonts, spacing, paragraphing, numbering, etc. Before this is done however, the writer/team needs to be clear on the identity of the document's audience and whether it is a public document. This will enable policy issues/statements to be identified, relocated and perhaps rephrased and an appropriate level of detail to be included with relevant references for further detail.

A statement on the intended audience and the public status of the Flood Plan should be included in the early parts of the document, perhaps in Part 1.

All relevant information contained in the Flood Reaction Tasks document should be incorporated in the updated Flood Plan. This will require a careful consideration of all sections of the former document and some rework of words/phrases/sentences/paragraphs that need to be cut across. Policy related text in particular will need to be considered for context, relevance and currency.

Prior to rewriting the existing Flood Plan, potentially useful plans and diagrams should be identified and collected. This includes:

- maps of the main flood-affected areas as per the Flood Reaction Tasks document, taken from the flood inundation and planning maps as produced by the current study,
- historic flood extent maps as available from GBCMA via NRE's Flood Data Transfer Project (FDTP),
- tables of gauge levels and flood impacts as per the Flood Reaction Tasks document, taken from the findings of this study,
- other information that can be gleaned from the 100 year ARI and historic flood extent maps.

An additional potentially rich source of information on flood matters relevant to updating the Flood Plan is the GBCMA. The CMA has specialist technical staff with a depth of experience and understanding of flood matters that would greatly inform the new Flood Plan. Documentation and study results held by the CMA, such as elements of the Regional Floodplain Management Strategy (2002), would be particularly pertinent to the task. For example, Program 6 (Emergency Response Planning) as well as Program 3 (Statutory Land Use Planning), Program 4 (Development Assistance Guidelines), Program 5 (Control of Works and Activities on Floodplains) and Program 7 (Flood Monitoring Actions) of the Strategy. The Strategy document also includes information on historical floods as do the digital datasets and reports emanating from the NRE initiated Flood Data Transfer Project (FDTP).

It should be noted that the information contained in the FDTP datasets requires interpretation. However, once done it could be fed into the regional emergency planning process. If done in detail, this could result in the identification of roads, bridges and houses affected in historical events along with the date and height of the floods together with a brief background to the event (ie. catchment wet/dry condition, dominant meteorological conditions, upper/lower catchment event, rainfall totals, maximum 24 hour totals, etc). The CMA has the credentials (but not necessarily the resources) to do this work.

It is suggested that much of the background, flood impact and flood response information (retained from the Flood Reaction Tasks document as well as new material) necessary for an effective flood plan could be formatted and included as stand-alone appendices, provided these were clearly identified as such and their existence and content included in a comprehensive index at the front of the plan. Each appendix (as well as the master document) should include a QA table that, as a minimum, records its update history, a version number, 'last modified' date and other pertinent details. In this way the Flood Plan could serve both policy and operational purposes without need for duplication while maintaining relevance for the various user groups. Further, operational and other staff could easily access/copy required information in the lead up to and during a flood event. There would be no need for a second document.

Detailed information contained in the "Flood Reaction Tasks" document provides a good starting point for the stand-alone (or operational) appendices. However, the information needs to be both updated with current knowledge and augmented with additional information. GBCMA and the outputs from this study are obvious major contributors to such an update.

Information relevant to emergency flood response activities now available as a result of this study includes:

- For all properties likely to be affected by flooding:
  - address,
  - location,
  - building floor level,
  - building type, size and condition.
- A comprehensive set of flood inundation maps for Shepparton-Mooroopna that show the areas likely to be inundated by a range of floods relative to the Goulburn River gauge at Shepparton as well as the likely depth of flooding in these areas.
- A listing of properties affected by flood, both below and above floor level, for a range of flood levels relative to the Goulburn River gauge at Shepparton and linked to the above maps.

An essential input to a recasting of the Flood Plan is resolution of G-MW's role in operational flood matters and GBCMA's role in flood monitoring and related tasks. For example, while G-MW agrees that its staff assists BoM in the flood forecast and warning process for Shepparton by providing real time information from its gauging network, it stresses that it has no role (statutory or otherwise) in providing flood warning advice. The City's existing Flood Plan and recent flood operations, where quantitative flood forecasts (flood height and timing of peak) have been provided by BoM following close consultation with G-MW, suggest that G-MW policy and operational realities may not be perfectly aligned. Further, GBCMA operate to a Flood Response Action Plan that is not recognised by the City's Flood Plan. As a minimum the Flood Plan should acknowledge the existence of the CMA's plan (and vice versa) as well as the availability of specialist expertise and experience within the CMA. These and related issues were raised in the GBCMA Regional Floodplain Management Strategy (2002) and have been touched on in this study. Their resolution, accompanied by robust and sensible custodial and authority arrangements, is critical to an effective and coordinated response to flooding in the municipality and to improving the current Flood Plan.