Tatura Flood Plain Management Plan

Final Report

Prepared For: Greater Shepparton City Council

Prepared By: WBM Engineering and Environmental Consultants

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1 INTRODUCTION

1.1 Background

Greater Shepparton City Council (GSCC) commissioned WBM Oceanics Australia (WBM) to undertake a floodplain management study for the township of Tatura in 2002. The Tatura Township is situated 17 km South of Shepparton in central Victoria and lies within the Mosquito Depression East Arm floodplain. Figure 1-1 shows the general location of the township in relation to its catchment and surrounding features.

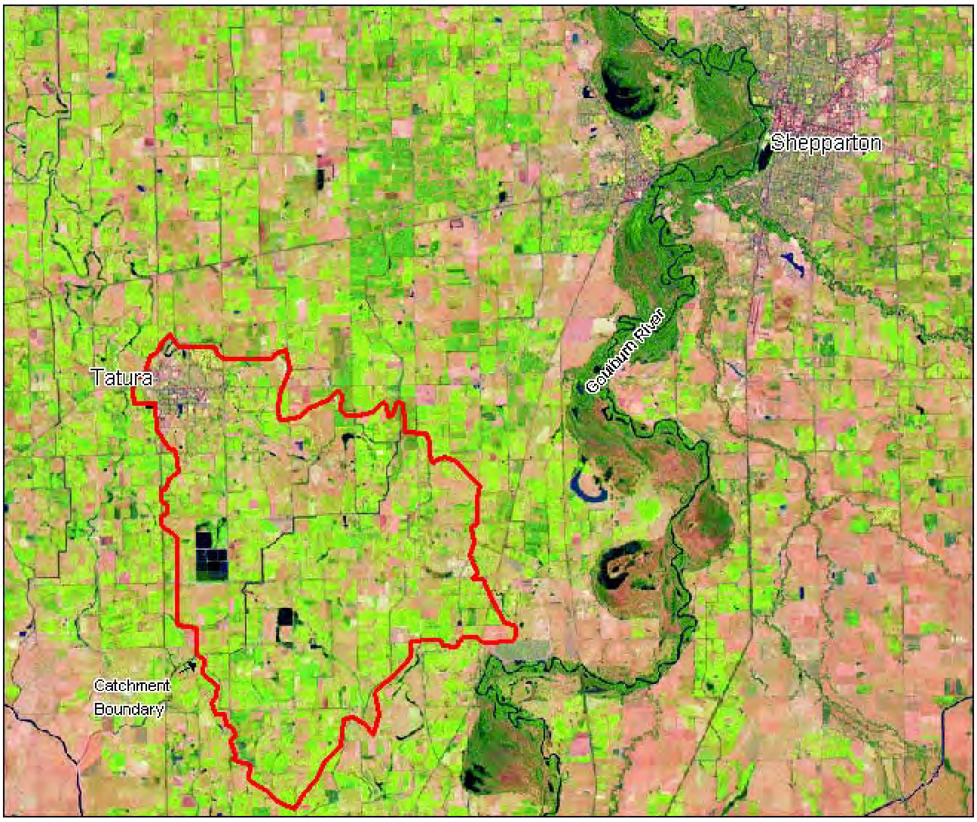

Figure 1-1 Locality Plan

The objectives of the study were to identify, analyse and document flooding and flood risk at Tatura, and assess potential floodplain management options using a risk management approach, based on detailed hydrological and hydraulic analysis. Key outputs from the study include recommended structural and non-structural floodplain mitigation measures, detailed flood inundation and planning maps, coupled with a progressive consultation program to ensure stakeholder ownership of the outcomes.

1.2 Catchment Description

The Mosquito Depression East Arm is a sub catchment of the Mosquito Depression which is a tributary of the Golburn River. At Tatura, the Mosquito Depression East Arm drains a catchment of 6150 ha of rural pasture and orchards and comprises a network of shallow and wide interconnecting drainage paths on a low grade. Anthropogenic activities and infrastructure within the catchment have altered the natural condition of the drainage system and the hydrologic response of the catchment.

Important features of the upstream catchment include agricultural storages, irrigation channels, flood protection levees, road embankment and culverts, and shallow interconnecting floodways. The catchment has been identified as quite unique in terms of the attenuation that these features provide to all flood events (Sinclair Knight Merz, 2000).

Upstream of Tatura, the Mosquito Depression East Arm exists as two distinct branches; one from the South and one from the East. The Southern and Eastern Branches are of similar length and have comparable catchment areas, however agricultural storages and levees in the Eastern branch impede the arrival of peak flows at the town boundary by days.

The branches converge at the town to form a series of meandering and interlinking shallow depressions. Floodwaters enter Tatura via four flow paths to the South and East, and drain through the township to the Northwest before joining the main branch of the Mosquito Depression.

1.3 Study Area

The Study Area comprises the township of Tatura and rural residential areas to the South and East as shown in Figure 1-2.

An extensive underground pipe network drains runoff from developed areas within the town to the Southern and Eastern Branches of the Mosquito Depression East Arm. Drainage reserves have been designated through the Eastern Branch, however significant development has occurred within the flood prone Southern Branch.

The town is cut diagonally by the Toolamba and Echuca railway embankment, which acts as constriction to flows along the Southern Branch. Flows are conveyed via an underpass of approximately 3.2 m wide and 1.8 m high. The majority of the towns flood affected properties are located along the Southern Branch in the area upstream of the embankment.

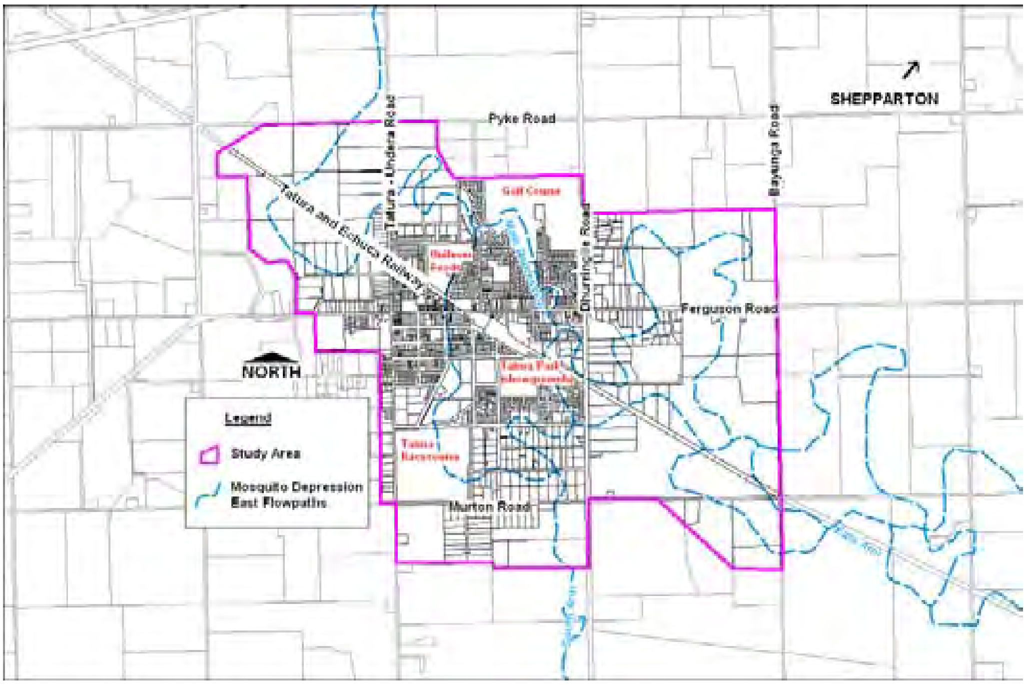

Figure 1-2 Study Area

1.4 History of Flooding

The townships first experience with suburban flooding occurred around the 1950s, when flood waters rapidly rose in the area that is now Lake Bartlett and broke across Martin Street flooding shops and businesses in the depressions natural course. The 1955 event is considered to be the largest flood on record. Flooding occurred again in 1956, 1958, 1974 and 1993.

In 1974 a less severe flood was contained by locals utilising portable and tractor mounted pumps to pump flows down Service Street into the Eastern Branch. (Arthur Knee, personal correspondence 2001).

After the construction of a sewerage system for the township, large amounts of fill became available and many low lying allotments within the floodplain were raised. The State Rivers and Water Supply Commission became concerned about development within the floodplain and planning controls were put into place. Council constructed banks of culverts within the Eastern Branch and developed a flood response plan that utilised penstocks at Lake Bartlett to hold back flows in the Southern Branch while flows within the town receded. Once sufficient capacity within the town's drainage network had returned, penstocks were to be opened allowing the Southern Branch flows to drain away via the natural depression. Flood management has also involved cutting through roads and the deployment of pumps once the capacity of penstocks has been exceeded.

1.5 Study Objectives

The objectives of the study are to identify, analyse and document flooding and flood risk at Tatura. This will help guide future actions for proactive and reactive management of flooding events by:

- developing maps and tools that can be used for emergency response and planning purposes; and

- identifying appropriate flood mitigation measures to minimise and manage flooding risks in the future.

Key outputs for the study are:

- A GIS database containing:
  - survey data including ground photogrammetric points, generated 200 mm ground contours and a DEM;
  - survey data of property floor levels, type and condition with property description;
  - 100-year ARI flood level contours and DEMs of flood height and flood depth for all events;
  - surveyed flood level marks;
  - proposed planning map layers (LSIO, UFZ, FO); and
  - digital ortho photo.
- Project DVD with the above project data in ArcGIS with associated readme file explaining what's on it.
- A set of PDF files of the following:
  - final report and figures;
  - flood inundation maps; and
  - declaration of Flood Level map (No. 540229).
- All flood damage, hydrologic and hydraulic model input files including appropriate readme files.
- Flood animations

1.6 Study Approach

The approach adopted to carry out this study involved the following:

- the review and development of existing hydrologic analysis of the catchment;
- the development of a hydraulic model specifically tailored to most accurately reproduce flooding characteristics;
- the production of GIS flood inundation and planning maps;
- the application of a risk approach to define management priorities; and
- the evaluation of a range of structural flood mitigation options using multi-criteria analysis.

A two-dimensional hydraulic model covering the entire study area and incorporating the underground stormwater drainage system and major flow paths external to the township was developed.

Hydrological investigations have built on existing analysis, with specific consideration given to the topography and complex drainage interactions that influence that way in which flood waters are delivered to, and distributed through, the township.

1.7 Technical Steering Committee

A Technical Steering Committee (TSC) consisting of the members shown in Table 1-1 was established to oversee the project.

Table 1-1 Technical Steering Committee Members

Name of TSC Member	Association
John Gray	Councillor
Greg McKenzie and Gordon Cameron	Greater Shepparton City Council
Guy Tierney	Goulburn Broken CMA
Ian Gauntlett	DSE Floodplain Management Unit
Neville Whittaker	Goulburn Valley Water
Sam Green	Goulburn-Murray Water
Arthur Knee	Local Resident

Meetings held by the TSC throughout the study were used to discuss technical issues and approve key milestones allowing the study to progress.

1.8 Community Reference Group

A Community Reference Group (CRG) was identified through a community consultation questionnaire that was mailed out to all residents of Tatura in the early stages of the study. The questionnaire identified 61 residents who were interested in being part of the CRG. Members of the CRG were invited to attend meetings to discuss key decisions and findings throughout the study. The CRG meetings aimed to involve the community in the formulation of the Flood Management Plan and to gain an appreciation of how community perceives flooding, including the likely nature of management measures they may support.

The plan was made available to the public for comment in December 2005. No submissions were received by the closing date.

2 DATA COLLECTION

In executing this study an existing bank of data was drawn upon and additional data was collected.

2.1 Existing Data

Members of the TSC gathered the available relevant information for review by WBM. Flood data obtained included previous studies and flood photos held by stakeholders and the Tatura community. A summary of the information and data sets and their source is presented Table 2-1.

Existing data sets collected and reviewed were:

- **Previous investigations and reports** – Several previous studies have been carried out on the nature of flooding in Tatura. These studies cover the hydrology of the upper catchment, the hydraulics of the minor stormwater drainage system within Tatura and the feasibility of a designated floodway through the town. None of the existing studies address the extent of flooding throughout town in great detail.
- **Existing models** – As part of the previous studies mentioned above, a RAFTS hydrological model and MIKE11 hydraulic model of the Mosquito Depression was developed to provide design flows at Tatura.
- **Digital Minor Drainage Network –** As part of a previous study the details of the underground drainage network of Tatura was captured and made available in GIS format.
- **Survey data –** Availability and reliability of Survey data in the depression varied
- **Historical flood data** – Historical flood data at Tatura was limited to floodplain planning overlays that were determined from aerial photographs of the Depression during a flood and the recollections of Arthur Knee, who is a long-time resident of Tatura and held the position of Shire Engineer during the 1950s. Oblique flood photographs taken at ground level were also made available.
- **Rainfall data and stream gauge data**– No pluviograph data or stream gauge data exist for any storms within the study area.

Table 2-1 Background Data and Survey Information

Data Type	Source
General Data	
GIS and Digital Cadastral Map Base, 2003	Council
Digital Aerial Photogrammetry, 2D and 3D Feature Survey, QASCO, 2003	Council
Design rainfall data (non-historical)	Australian Rainfall and Runoff, 1999
Historical flood data/levels	GBCMA, Council and Community
1950s flood levels preserved on Sewerage Contour Plans	Arthur Knee
Mosquito Depression (east Arm) Drain 36 Drainage Course Declaration Survey	LICS
Photography	
March 2000 non-flood colour aerial photography	AAM Survey via Council
Aerial photography of depression during 1958 flood	Council
Historical flood photos (taken at ground level)	Tatura Museum
Other Flood Information and Data	
Mosquito Depression RAFTS hydrologic model, Sinclair Knight Merz , 2002 (Computer Model)	Council
Mosquito Depression East Arm Quasi two dimensional (2D) MIKE11 Hydraulic Model (Sinclair Knight Merz, 2000)	Council
GIS layer of Tatura's underground drainage network including culvert dimensions and invert data.	Montgomery Watson Hazaar
Specific Reports	
Sinclair Knight Merz (2000) Mosquito Depression East Arm Catchment Modelling, Hydraulic Assessment Report For Golbourn Murray Water. November 2000.	Council
HydroTechnology (2000) Deakin Drainage Strategy, Report on Computer Modelling. May 1994.	Council
Murray Basin Consulting Group (1992) Deakin Main Drain Model Development. Report on Computer Modelling.	Council
MWH (2001) Tatura Township Stormwater Drainage Study	Council

2.2 Community Consultation Questionnaire

A mail out to all Tatura residents was carried out in January 2002. The mail out included a letter, a questionnaire and a map detailing the study area on two A4 sheets (Appendix A). Also included was a return, postage paid envelope, to encourage residents to fill in the questionnaire and return it to the council.

The resident survey was mailed out on the 9th of January 2002. Completed surveys were returned to council who compiled the responses and set up a database with all replies entered into the record in order of receipt. Of the 2200 letters mailed out, a total of 210 replies were received. A broad spectrum of the community responded to the questionnaire. Responses were received from long term residents who had been living in the town for up to 85 years, right down to those who were new to the area and had no knowledge of historical flooding.

Many historical and present day flooding problems were highlighted in the responses. A large number of these problems could be attributed to local drainage issues, however a good insight into flooding behaviour was gained through analysis of the responses.

The primary aim of the survey was to locate community members who had relevant flooding experience. Part of the questionnaire asked the resident to indicate if they had any information that could be shared with a member of the study team. Seventy-four residents indicated that there was an opportunity for an interview with the study team. Sixty-one respondents identified an opportunity for a one-on-one discussion with the study team in relation to flooding in the area. Table 2-1 gives a summary of the key outcomes from the resident survey.

Table 2-2 Resident Survey Summary Information

Total Number of Respondents	210
Longest Experience With Town Flooding	85 Years
Average History With Town Flooding	32 Years
Percentage of Respondents Aware of Flooding Problem in Tatura	68.1%
Percentage of Respondents Who's Properties Have Been Affected By Flooding	27.1 %
Percentage of Respondents Who Have Had Flood Waters Inside Buildings	14.3 %
Identified Flooding Years	1950, 1955, 1974 and 1993
Respondents Able to Show Flood Levels	58
Respondents Able to Detail Flooding in Other Areas	42
Respondents With Photographic Detail of Flooding in the Town	28
Respondents Available For Interview	74
Respondents Interested in Community Reference Group	61

2.3 Photogrammetry

QASCO photogrammetrists were appointed to collect photogrammetry for the study area. The photogrammetry was ground truthed and used to generate a Triangulated Irregular Network (TIN) model of the terrain within the study area. This formed the basis for the geometry of the hydraulic model.

3 HYDROLOGIC ANALYSIS

The objective of the hydrologic component of the study was to generate design hydrographs for a range of flood events (10, 20, 50, 100 and 500 ARI) at the Tatura township boundary. The lack of historical flow data for the Mosquito Depression East Arm required that the hydrologic analysis be based on design rainfall and hydrologic methods outlined in Australian Rainfall and Runoff (AR&R). Design hydrographs were produced at the study area boundaries to form the flow inputs to a TUFLOW hydraulic model used to simulate flood behaviour within the township.

3.1 Previous Modelling

Sinclair Knight Merz (2000) identified that the complexity of the upstream catchment dictates that the hydrologic analysis of the Mosquito Depression requires a two-step process.

1. **Generating Runoff Hydrographs** – Simulating rainfall and loss processes of the upper catchment using a rainfall runoff (RAFTS) model to determine the volume of runoff.

2. **Routing Runoff Hydrographs** – Simulating catchment storages and complex interlinking channels of the upstream catchment using a quasi two-dimensional hydraulic model (MIKE11) to determine the flood hydrographs at the town boundary.

As discussed above, a RAFTS model of the Mosquito depression has been developed and refined over the last decade for use in several hydrologic studies of the Mosquito Depression East catchment.

A schematic of the RAFTS model is shown in Figure 3-1 and a summary of the Subcatchment data as it appears in Sinclair Knight Merz (2000) is shown in Table 3-1.

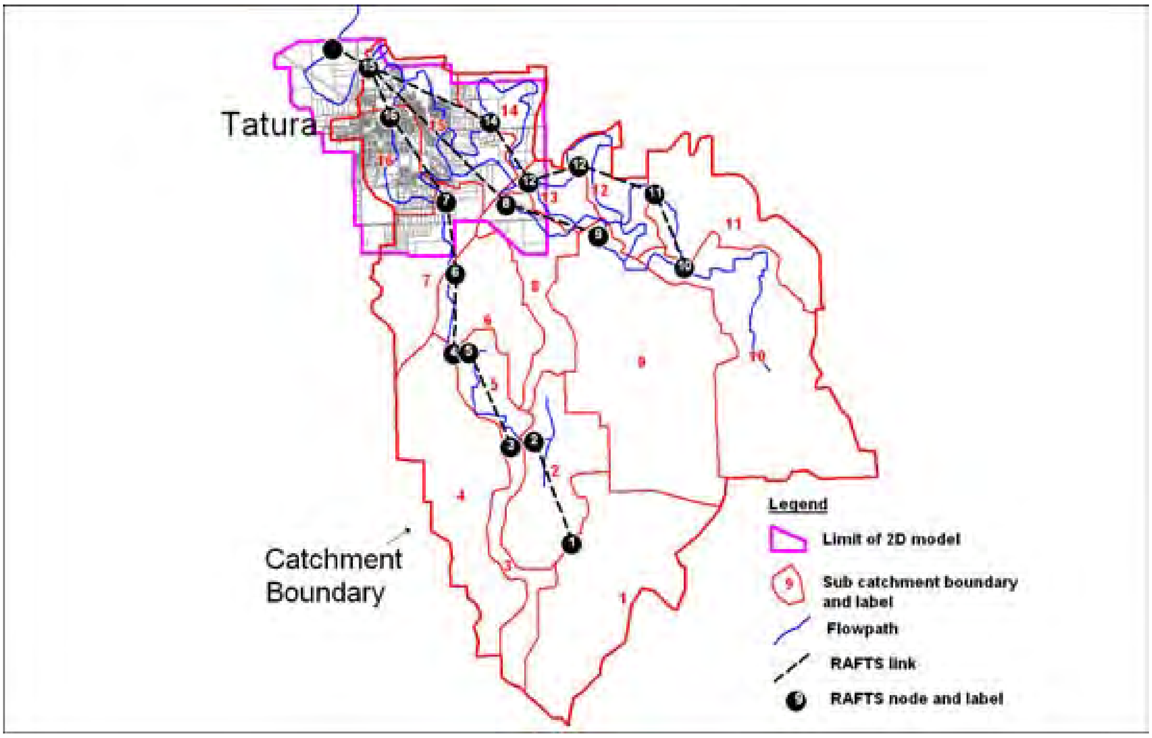

Figure 3-1 RAFTS Model Layout

Table 3-1 RAFTS Model Parameters

Sub-Catchment Area	Slope (%)	Grade (1 in n)	Area (ha)			Mannings (n)	
			Dryland	Irrigated	Total	Dryland	Irrigated
1	0.055	1820	129.9	579.7	709.6	0.09	0.075
2	0.055	1820	123.3	257.4	379.7	0.09	0.075
3	0.021	4830	43.9	128.4	172.3	0.09	0.075
4	0.057	1760	170.6	431.0	601.6	0.09	0.075
5	0.055	1820	63.5	81.6	145.1	0.09	0.075
6	0.114	880	63.8	231.3	295.0	0.09	0.075
7	0.051	1950	85.5	239.1	324.6	0.09	0.075
8	0.057	1770	98.6	158.3	256.8	0.09	0.075
9	0.043	2310	231.5	794.1	1025.6	0.09	0.075
10	0.050	2000	306.9	493.1	800.0	0.09	0.075
11	0.031	3230	82.3	318.3	400.6	0.09	0.075
12	0.007	15020	83.1	98.2	181.3	0.09	0.09
13	0.044	2250	43.4	74.8	118.2	0.09	0.09
14	0.016	6160	50.6	118.5	169.1	0.09	0.09
15	0.035	2900	184.4	176.2	360.6	0.09	0.075
16	0.012	8660	208.7	0.0	208.7	0.03	0.03
Total			**1970.3**	**4180.0**	**6148.8**		

Sinclair Knight Merz (2000) produced a quasi-2-dimensional MIKE 11 model of the Mosquito Depression East arm for the purpose of modelling proposed modifications in the Mosquito Depression floodway.

The model was built from a Digital Elevation Model and feature survey, incorporating the natural drainage channels, levee banks, agricultural storages, culverts and road crossings. The model extends down through the catchment to the town boundaries with little detail through the township itself. The model objective was the delivery of flood hydrographs to the township, but not precise flood levels through the town.

Model inflows were generated as rainfall excess hydrographs for the 16 subcatchments of the afore mentioned RAFTS model. Figure 3-2 shows the locations of culverts and weirs that have been included in the MIKE11 model.

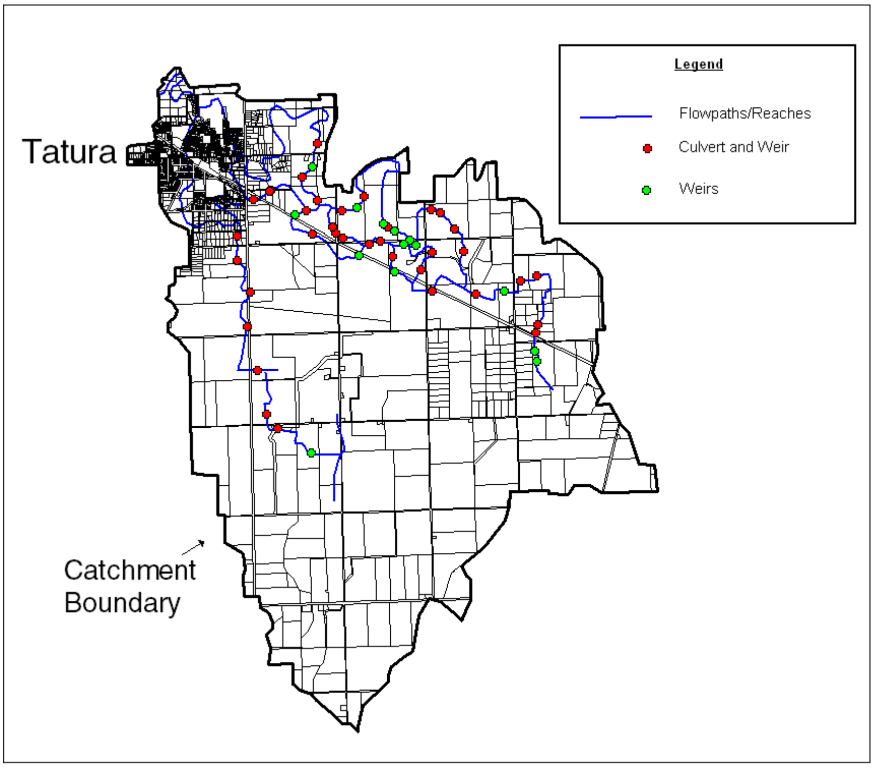

Figure 3-2 MIKE11 model layout showing modelled weirs and culverts

3.2 Current Modelling

Before adopting the two-step modelling approach presented in Section 3.1, WBM verified the methodology for a range of durations. The results of this verification, presented in Section 3.2.2, show that the approach is sound.

3.2.1 Design Rainfall Intensity and Losses

Design rainfall intensities described by Murray Basin Consulting Group (MBCG,1992) for the Mosquito Depression were determined from annual maxima series analysis of rainfall records in surrounding catchments. These values are presented in Table 3-2 alongside corresponding depths determined from AR&R.

Table 3-2 Design Rainfall

	24 Hour Duration Storm Rainfall Intensities for Different Recurrence Intervals (mm/hr)					
	2	**5**	**10**	**20**	**50**	**100**
Winter depths* (MBCG, 1992)	1.90*	2.66*	3.08*	3.63	4.29	4.88
AR&R	2.07	2.71	3.10	3.62	4.32	4.87

** Derived from annual maxima series analysis of rainfall records in surrounding catchments.*

The AR&R determined values were adopted in preference for a more conservative approach.

The study area lies within Zone 2 and is adjacent to Zone 1. The standard Zone 1 temporal pattern from AR&R was adopted consistent with previous studies (MBCG, 1992).

Winter loss models were adopted to provide the worst-case scenarios. These values are provided in Table 3-3.

Table 3-3 Rainfall Loss Parameters

Description	Initial Loss (mm)	Continuing Loss (mm/hr)
Winter dry land	11	0.8
Winter Irrigated land	9	0.8

3.2.2 Verification of Two-Step Modelling Approach

The two-step modelling approach described in Section 3.1 was verified using the 100-year ARI flood event with durations ranging from 1 hour through to 72 hours. The RAFTS model and then the MIKE11 model were run as described in the two-step process. Peak discharges were obtained from the RAFTS and MIKE11 models at the locations shown in Figure 3-3. The peak 100-year ARI discharges from both models are compared in Figure 3-4 and Figure 3-5, and a comparison between models of the peak flows at these locations resulting from 500, 100, 50, 20 and 10-year 36 hour duration storms are presented in Table 3-4.

The peak discharges indicated by the MIKE11 model are considerably lower than those indicated by the RAFTS model across the full range of durations tested. The difference in the predicted peak flow rates is a result of differences in the way the two models carry out flood routing.

The existing RAFTS model was set up to simulate routing by staggering hydrographs by a period of time estimated for a flood to arrive at the next downstream catchment outlet. In this manner, RAFTS only approximates routing and does not account for changes in the hydrograph shape that floodplain storage creates. This method is too simplistic to account for the attenuation of peak flows that floodplain storage and floodplain structures create when flood waters are held back behind embankments, levees and the like.

The MIKE11 model incorporates a far more sophisticated and rigorous basis for routing flows through floodplain storage and structures. MIKE11 accounts for the attenuation of these structures and storage thus reducing the peak flow arriving downstream.

The results of the MIKE11 model are considered to be more reliable on the basis of a superior scientific method of accounting for the effects of structures and storage within the floodplain on peak flows. Therefore, the two-step process is considered sound for this catchment.

3.2.3 Comparison of Flows in the Southern & Eastern Branches

The results of MIKE11 modelling show the pronounced effect floodplain storage has on hydrographs in the Southern and Eastern Branches. The critical duration 100-year hydrographs from MIKE11 were taken at the locations shown in Figure 3-3 and are presented in Figure 3-6.

The pronounced difference between hydrographs in the Southern and Eastern Branch can be attributed to the greater number of floodplain structures in the Eastern Branch. While the Southern and Eastern Branch catchments are of similar size, Figure 3-2 shows the differing number of floodplain structures. These structures increase the amount of floodplain storage within the Eastern Branch, which has the effect of dramatic attenuation of the peak flow reaching the town boundary and a delay in the arrival of the hydrograph peak by a number of days. Local residents of Tatura who experienced the 1955 flood event have verified this phenomenon.

3.2.4 Critical Duration

The two-step modelling approach described in Section 3.1 and Section 3.2.2 determined that the 36 hour duration 100-year ARI storm produced peak flows at the township boundary and was adopted as the critical duration for 500, 50, 20 and 10 year storm modelling.

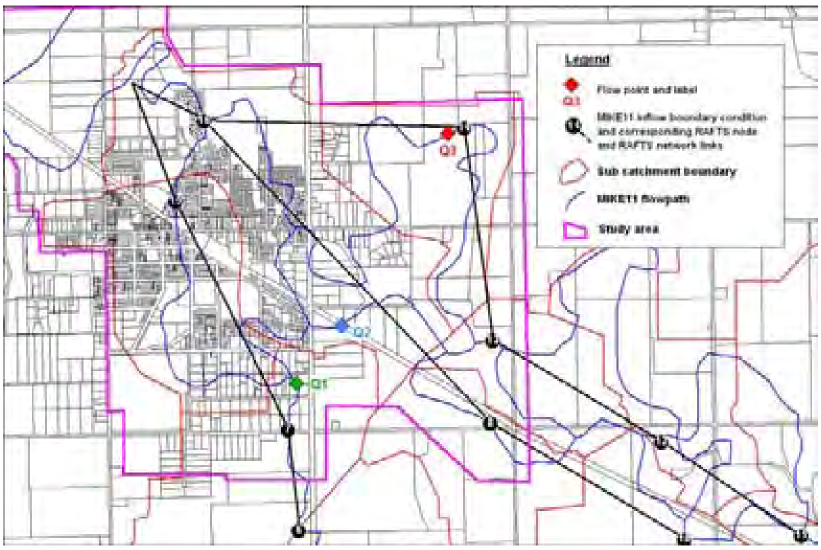

Figure 3-3 Flow comparison point locations

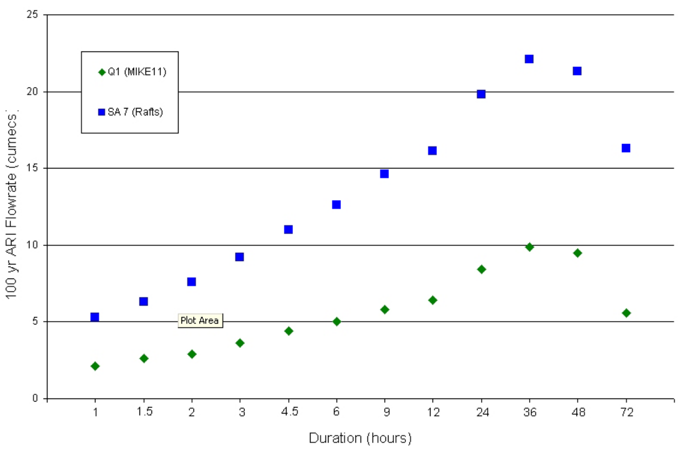

Figure 3-4 Peak discharges at output location Q1 (Southern Branch) for different duration 100yr storms

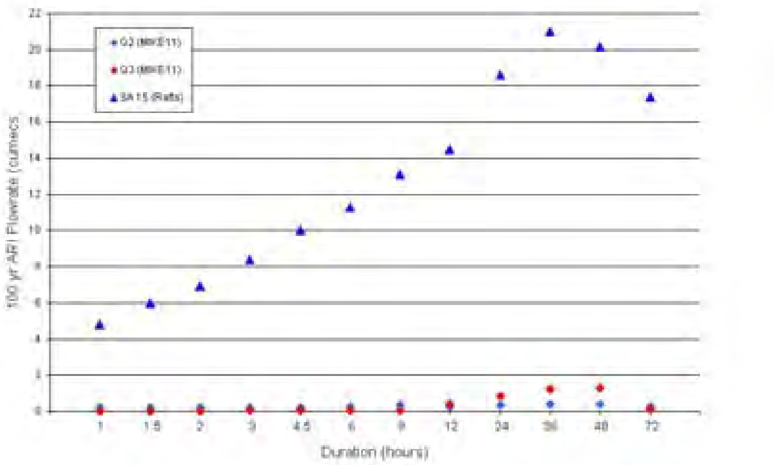

Figure 3-5 Peak discharges at output location Q2 and Q3 (Eastern Branch) for different duration 100yr storms.

Table 3-4 Comparison of RAFTS and MIKE11 Hydrologic Model Results

	RAFTS		MIKE11	
	Southern Branch	Eastern Branch	Southern Branch (Q1)*	Eastern Branch (Q2+Q3)**
500	33	32	12.4	3.0
100	22	21	7.3	1.9
50	18	17	5.6	0.6
20	14	13	4.1	0.5
10	10	9.4	3.0	0.4

* *Refers to flows at output location upstream of Q1 in Figure 3-3*

** *Refers to the sum of flows at locations upstream of Q2 and Q3 in Figure 3-3*

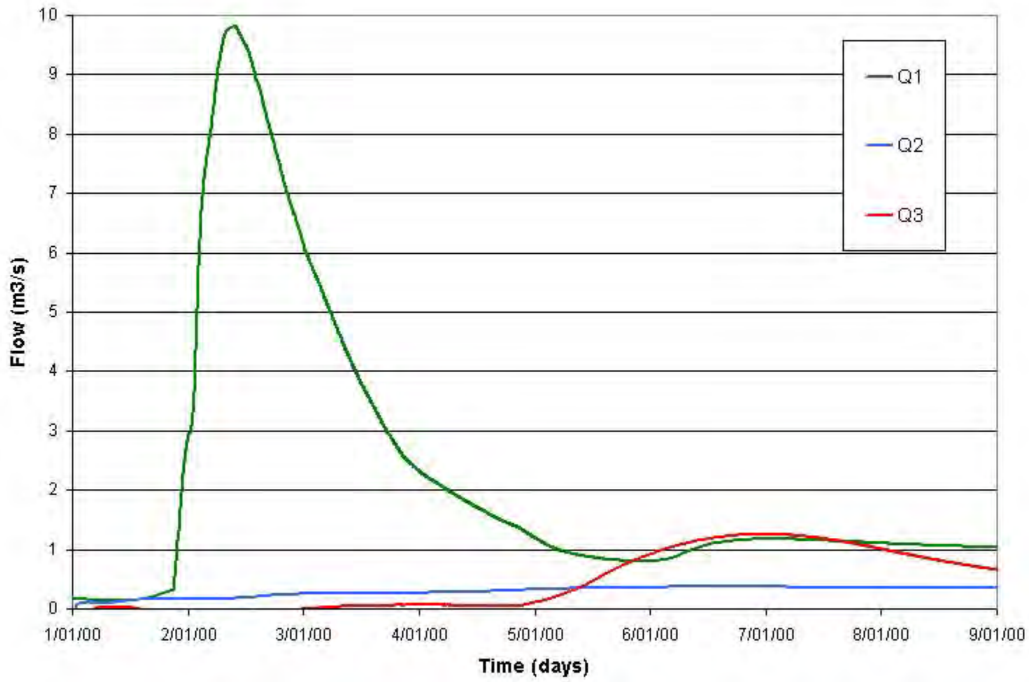

Figure 3-6 100-year ARI 36 hour Hydrographs

3.2.5 Sensitivity Analysis

Given the effect of structures in the floodplain on the arrival time and magnitude of the flows at the town boundary, a sensitivity analysis was carried out on the effect of the structures in the MIKE 11 model. The weir heights throughout the MIKE 11 model were lowered by a nominal height of 100 mm to reduce the amount of storage within the model and measure the change in attenuation to the peaks.

The 36 hour storm was rerun and the flows compared at points within the Tatura township boundary as shown in Figure 3-3. It should be noted that these flows are not at the boundary of the TUFLOW hydraulic model but at points inside the study area boundary where local sub-area inflows contribute. Figure 3-7 shows a comparison of hydrographs from the two models.

Lowering weir heights and storage within the catchment slightly reduced the peak flow in the southern branch, while slightly increasing the peak flow in the eastern branch. In addition, the flows in the eastern arm arrive at the town approximately 12 hours earlier. This shows the non-linearity of the catchments. Despite these effects, the difference in peak flows between models is smaller than the difference between 100 yr ARI peaks resulting from 24, 36 and 48 hour storms.

It is apparent from these results that the model is not highly sensitive to weir heights and the existing model can be adopted with confidence.

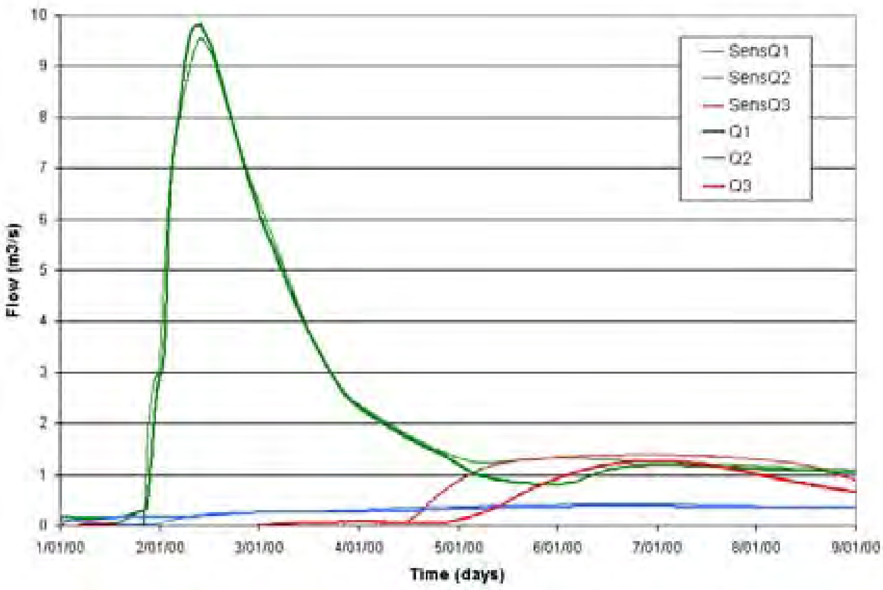

Figure 3-7 Sensitivity testing hydrograph comparisons

3.2.6 Probable Maximum Flood

An estimate of the Probable Maximum Precipitation (PMP) for the study area was derived using the approximate method for large catchments in Victoria developed by Nathan (1999). This method incorporates the use of an empirical equation involving factors of catchment area and the 50-year ARI 72 hour rainfall intensity. The relationship yields 719 mm total rainfall falling over the entire catchment during the 36 hour duration PMP.

On consultation with the TSC, a design hydrograph for the Probable Maximum Flood (PMF) was not developed because experience has shown a PMF of this magnitude will flood the entire study area, and beyond the extents of the hydraulic model. The results produced by the hydraulic model would not be accurate and therefore of no value. It was decided to adopt the 500-year ARI design hydrograph as the upper limit storm for assessing flooding impacts.

4 HYDRAULIC ANALYSIS

The hydraulic analysis involved developing a TUFLOW hydraulic model to simulate the behaviour of the Tatura Study Area for a range of flood events (10, 20, 50, 100 and 500 ARI). The key tasks for the hydraulic analysis were to:

- Select a suitable hydraulic modelling approach;
- Develop a hydraulic model that simulates the behaviour of overland flow paths and the underground drainage network and other features (eg pumps and flow constrictions) within the Tatura floodplain;
- Simulate the 10, 20, 50, 100 and 500 ARI design flood events and produce flood level, depth and velocity data; and
- Where possible, verify the performance of the hydraulic model by comparing the estimated flood levels to known flood marks.

4.1 Hydraulic Modelling Approach

The hydraulic modelling approach and software platform adopted to simulate flooding in Tatura consider the following important issues:

- Overland flows through the township follow multiple paths with interconnections controlled by a range of constructed and natural features. The distribution of overland flows varies throughout each event. Individual flow paths (and their relationship with others) are not always easily definable due to the flat topography within the township. In accordance with this it was necessary to develop a fully two dimensional (2D) hydraulic model of the study area.
- Within the township, the underground (trunk) stormwater drainage system can potentially convey a considerable portion of the flows during certain events. Therefore, it was important to incorporate the underground drainage system into the model.
- There are numerous culvert crossing and structures (including natural and man made levees) within the study area. The adopted hydraulic model was able to simulate a range of structures and controls.
- Flow paths and flood waters will enter and leave the study area at numerous locations, in accordance with the sinuosity and complexity of the drainage system surrounding the study area. Figure 1-2 shows the complexity of flowpaths within the study area (based on the Flood Data Transfer Project). Therefore, it was essential to simulate hydraulic characteristics beyond the immediate vicinity of the study area.
- Effective modelling of a range of floodplain management options can be most readily undertaken using a 2D modelling approach. 1D and quasi-2D models tend to be inflexible in their ability to comprehensively represent a complete range of structural management options with varying spatial configurations. The adopted 2D modelling approach was able to reliably simulate a range of management options and their impacts on flooding.
- Community input and ownership is critical to the development of an effective Floodplain Management Plan. An important part of this process involves conveying the results of complex hydraulic modelling assessments in a simple and non-technical manner (eg. through the use of

visual animations and plans). Flood model outputs from the 2D model were combined with GIS to provide the most effective means of conveying flood simulation results to the community.

WBM's proprietary software, TUFLOW, satisfied the above criteria and was endorsed by the TSC for use in this study.

4.2 Hydraulic Model Development

4.2.1 Digital Elevation Model

A Digital Elevation Model (DEM) of the study area was generated from photogrammetry undertaken by QASCO. Points and break lines from the photogrammetry were used to establish a Triangulated Irregular Network (TIN), which formed a 3D shape of the area. For mapping purposes the TIN was sampled at the requisite resolution to create a regularly spaced grid of data points that form the DEM for use in the GIS and is shown in Figure 4-1. It is worth pointing out that the coloured shading of the DEM in Figure 4-1 is dramatised to illustrate the paths of the depression. For instance the elevation of the depression low points at the southern and eastern boundary of the DEM are 111.9 to 112.6 mAHD and at the downstream end of the model are approximately 110.15 mAHD. The flow path of the southern branch is approximately 6.8 km across the study area. A sinuous flow path for flows in the eastern arm is approximately 10.6 km long. Side slopes on the depression branches are very flat and range between 1(V):25(H) to 1(V):100(H).

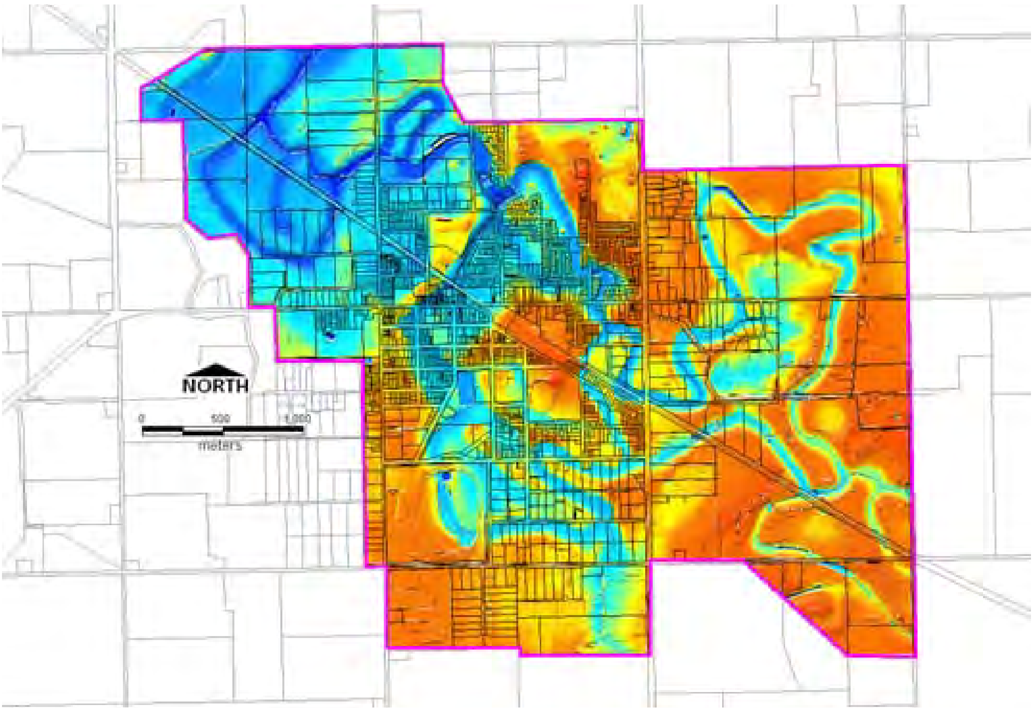

Figure 4-1 Study Area DEM

4.2.2 Model Resolution

One of the key considerations in establishing a 2D hydraulic model relates to the selection of an appropriate grid size. Grid size, or model resolution, must be balanced in consideration of the goals of the study and computation efficiency. Accordingly, the grid resolution must be selected to provide a suitable compromise of the following:

- The grid resolution must be fine enough to provide sufficient representation of the modelling domain to accurately simulate the physical characteristics the study area; and
- The grid resolution must result in a model with number of elements that will not result in unrealistically long run times.

Given the flat grade of the topography and poorly defined depression, as described in Section 4.2.1, a cell size of 10 metres was adopted for the entire Study Area. A 10m grid size, with appropriate 1D elements, provided suitable definition of land shape, key controls and waterways, while also keeping model run times to within realistic limits.

4.2.3 Model Layout

The extent and layout of the TUFLOW model including 1D elements is illustrated in Figure 4-2.

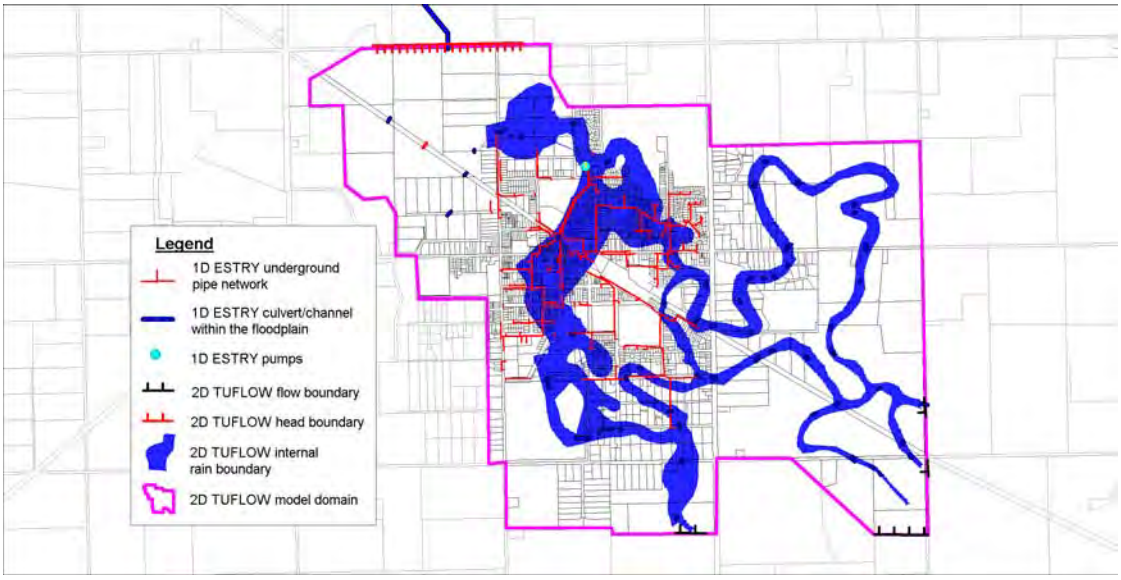

Figure 4-2 2D Hydraulic Model Layout

Roughness parameters for the model, presented in Table 4-1, were developed using a combination of data from the GSCC planning scheme, aerial photography and field inspections carried out by WBM. Manning's Roughness Coefficient (n) distribution for the model area is shown in Figure 4-3.

Table 4-1 TUFLOW Manning's 'n' Coefficients

Land use	Manning's n
Roads	0.025
Residential	0.2
Smaller Rural-Residential blocks	0.09
Crops	0.05
Commercial/Industrial	0.25
Railway corridor (potential obstructions)	0.07
Highly developed reserves and Parks	0.1
Orchards	0.12
Water body	0.02
Light density tree and grass reserve	0.035
Medium density tree and grass reserve	0.05
High density scrub and wetland	0.07
Pasture	0.05
Large rural-residential blocks	0.06

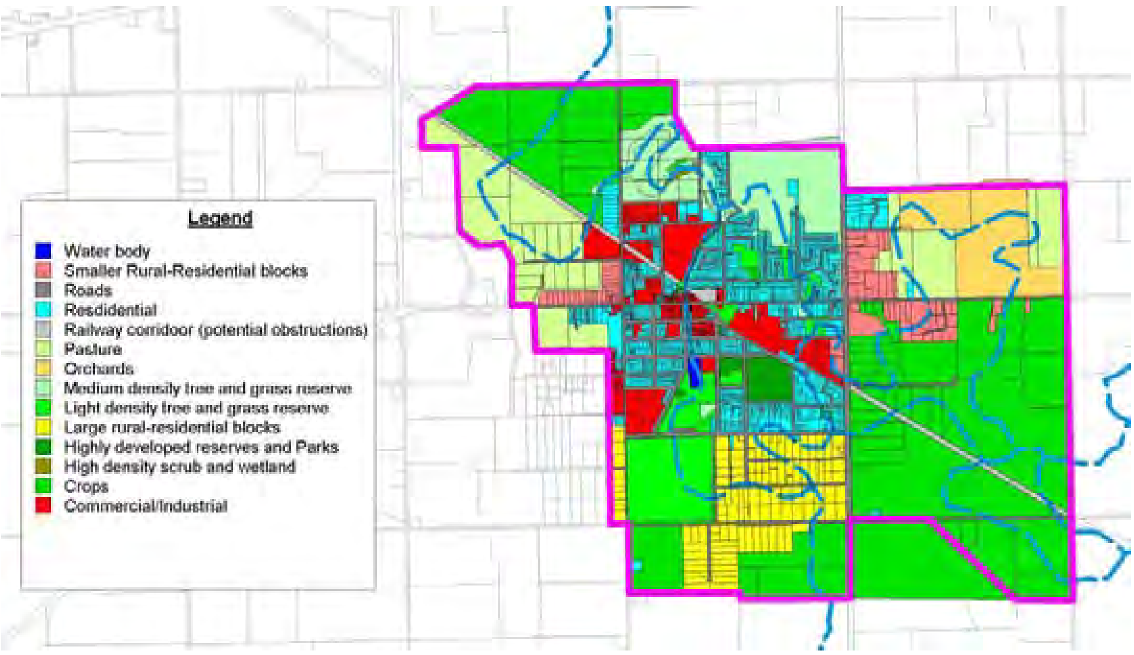

Figure 4-3Manning's 'n' Distribution

4.2.4 Model Boundary Conditions

External inflows to the Tatura model (run-off from catchments outside the 2D hydraulic model domain) occur as external flow boundary conditions.

Local inflows (run-off from subcatchments that lie within the 2D hydraulic model domain) were distributed directly over the Mosquito Depression East Arm as sub-area rainfall boundaries, as shown in Figure 4-2. This approach was adopted as the study was principally concerned with flooding from the Mosquito Depression East Arm rather than localised catchment flooding due to inadequate capacity within the minor drainage network. Peak flows from these catchments occur much earlier and are much smaller in magnitude than flows in the Mosquito Depression East Arm.

The internal and external flows for the model boundary conditions were provided as part of hydrological assessment, Section 3.

At the downstream boundary of the 2D model, the Mosquito Depression passes beneath Pyke Street via a 900 mm RCP. The Pike St culvert and a downstream length of 300 m of open channel has been modelled to ensure that the study area model is free from influence from the downstream boundary. The downstream boundary condition was adopted as a stage-discharge curve developed using cross-section geometry data from available feature survey (LICS, 2000). Sensitivity testing showed that peak water levels in the 2D study area were independent of the water level downstream of Pyke Street.

4.2.5 Structures

Culverts, underground drainage networks and pumps were modelled as 1D elements dynamically linked with the 2D domain. The linkage between the 1D and 2D domains allows free interchange of water between the underground drainage network and overland flow paths and accurately models interaction between the two systems.

Structural details, dimensions, locations and invert levels for aboveground culverts and pipe within the floodplain were obtained from Mosquito Depression (East Arm) Drain 36 Drainage Course Declaration Survey. Council representatives collected additional survey of several key structures.

The underground drainage network geometry, dimensions and invert levels within the commercial and residential areas of the township were obtained from a GIS layer provided by Montgomery Watson Hazar (2001).

The Margarete Street Pumping Station carries flows over an embankment into the Cussens Park Wetland. Five electric pumps remain on standby to commence pumping once stormwater enters the Margaret Street pump well. The combined capacity of the pumps is approximately 3.4 m^3/s and was modelled using the pump feature in TUFLOW.

Road and rail embankments, irrigation canals and farm dams form key hydraulic controls on the floodplain. These features are represented in the 2D hydraulic model by ‘z-lines’ (or break-lines). The levels on the z-lines are taken directly from the 3D string data contained in the photogrammetry survey. This modelling approach ensures the greatest level of accuracy in representing these features.

4.3 Design Event Modelling

The 10, 20, 50, 100 and 500-year ARI design storm events were modelled in TUFLOW. The 36 hour storm was identified as the critical storm duration during hydrologic analysis. The peak flood surfaces throughout the study area were mapped and are presented in Section 5. These events formed the basis for the assessment of the mitigation options, including the damages assessment.

As no data was available to calibrate the hydraulic model, a sensibility check was undertaken by comparing the flood extents with historical flooding patterns. Preliminary flood extents for each of the design runs were provided to the TSC who reviewed the extents in the context of their experience with historical flooding problems in the study area. Flooding behaviour predicted by the hydraulic model was verified by long term local resident, Arthur Knee, and modelling results were accepted by the TSC.

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5 MAPPING

This section provides a brief overview of the floodplain mapping process used in the investigation.

5.1 Inundation Mapping

TUFLOW produces a geo-referenced data set defining peak water levels throughout the model domain at the corners of its computational cells. The peak flood level from flood event was imported into GIS to generate digital models of the flood surfaces. Contours of the peak 100yr ARI flood height (relative to AHD) across the Study Area were extracted directly from the flood surface.

Peak flood depths for each ARI were calculated by subtracting the ground level from the flood surface. The GIS was used to carry out the calculation at a horizontal resolution identical to that of the DEM. The digital model of inundation depth was then contoured to map inundation depths over the model domain.

Based on discussions with the TSC, velocity and velocity depth mapping was not undertaken due to extremely slow flows through the study area.

The existing condition flood extents for the 36 hour 10, 20, 50, 100 and 500-year ARI design storm flood events are mapped in Figure 5-1.

A remote pocket of flooding is shown to occur in the vicinity of Hunter Street and between Unilever Foods and William Street. This backwater flooding is caused by elevated water levels at the railway underpass pushing water back up the minor drainage network.

The existing condition flood height, depth and depth of above floor flooding for the 36 hour 100-year and 10 year ARI events are mapped in Figure 5-2 and Figure 5-3.

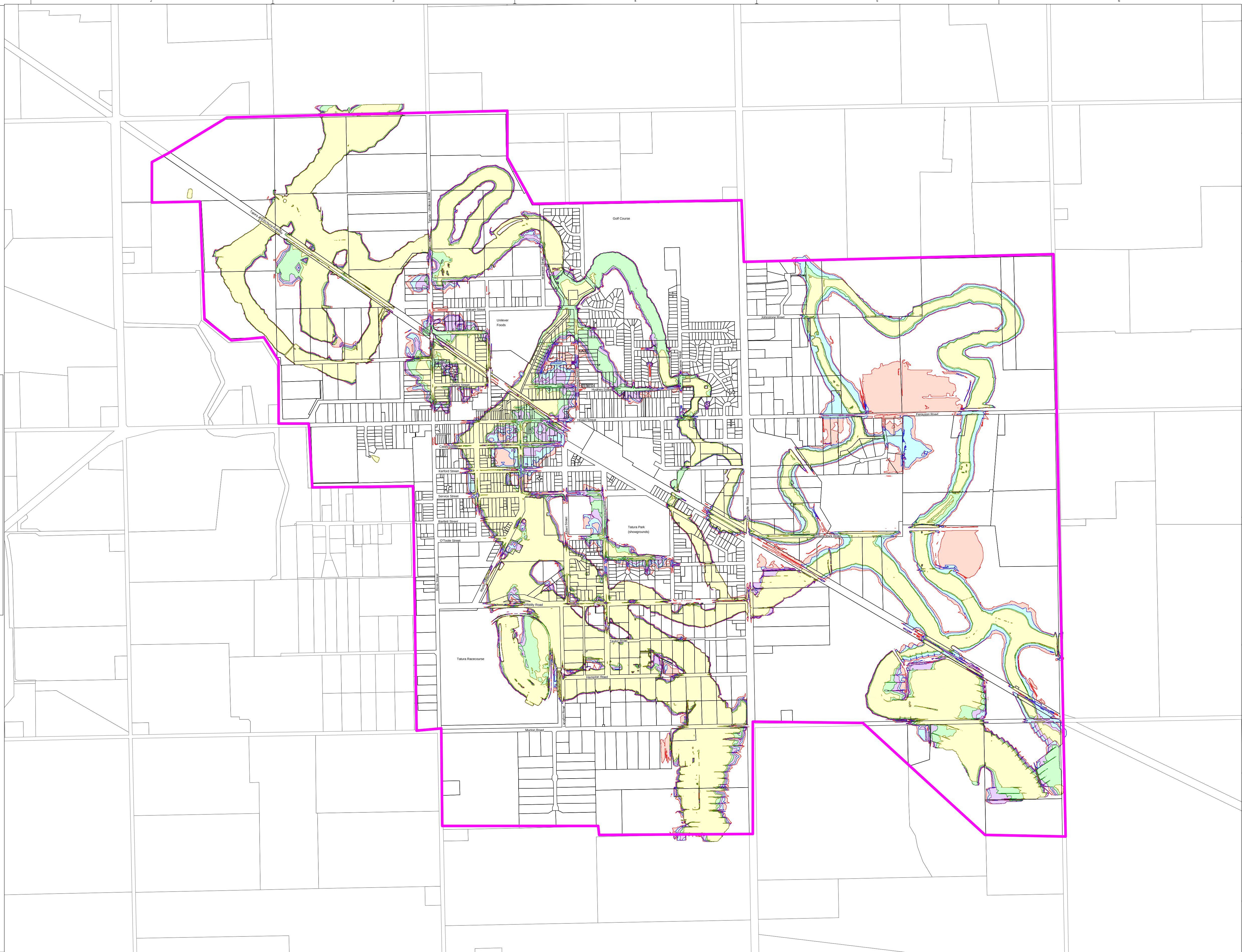
5.2 Planning Map

A flood planning map for Tatura, indicating the extent of Urban Floodway Zone (UFZ), Land Subject to Inundation (LSIO) and Floodway Overlays (FO) has been prepared in A1 format. The map integrates the 100-year ARI flood inundation mapping carried out under this study with the regional planning scheme. The basis of the planning map overlays were:

- LSIO is derived from the 100-year ARI flood extent as modelled in TUFLOW;
- FO and UFZ have been delineated according to depth of flow modelled for the 100-year ARI event; and
- Declared Flood Level isolines in approximately 0.1m increments, based on the modelled 100-year ARI peak flood level.

Preparation of the planning scheme was carried out under the Victoria Planning Provisions and in close consultation with Guy Tierney of the Broken Golbourn Catchment Management Authority.

The declaration of flood levels has been reproduced at an A3 scale and is presented in Appendix A.



NOTE
No two floods behave in exactly the same manner even though they may rise to the same height on the Ardmona-Merrigum Road gauge.
Information presented on this map represents a typical flood event. Please refer to "General Notes".

Legend

- 10-Year Flood Extent
- 20-Year Flood Extent
- 50-Year Flood Extent
- 100-Year Flood Extent
- 500-Year Flood Extent
- Study Area

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7. This map is a compilation of 500, 100, 50, 20 and 10 year ARI flood model results for existing catchment conditions.
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AUTHORISED BY		

Mosquito Depression at Tatura
Combined Flood Extent Map
Existing Flood Plain Conditions

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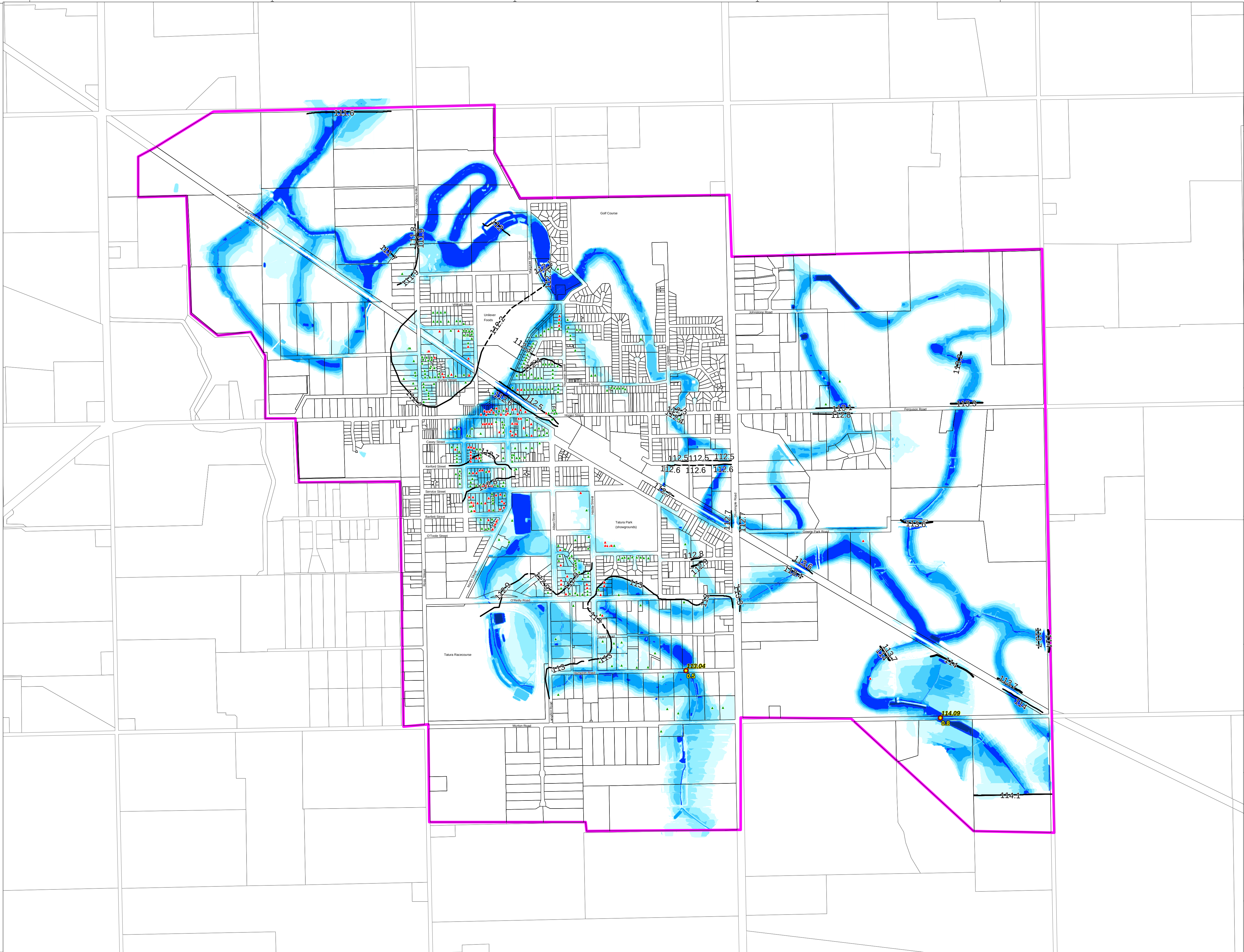
SHEET NUMBER 1 OF 1
DRG NO.
Figure 5-1



NOTE

No two floods behave in exactly the same manner even though they may rise to the same height on the Ardmona-Merrigum Road gauge. Information presented on this map represents a typical flood event. Please refer to "General Notes".

LEGEND

Flood Depth
- 0.00 to 0.25m
- 0.25 to 0.50m
- 0.50 to 0.75m
- 0.75 to 1.00m
- 1.00 to 2.00m
- greater than 2.00m

- Building Inundated above Floor
- Building Floor not Inundated
- 107.4 Flood Level Contour (m AHD)
- Study Area
- *Flood Level (mAHD)* *Flood Depth (m)*
- Proposed Gauge Location

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Australian Map Grid GDA 94, MGA Zone 55

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Mosquito Depression at Tatura
Existing Floodplain Conditions
100-Year ARI Flood Depth Map

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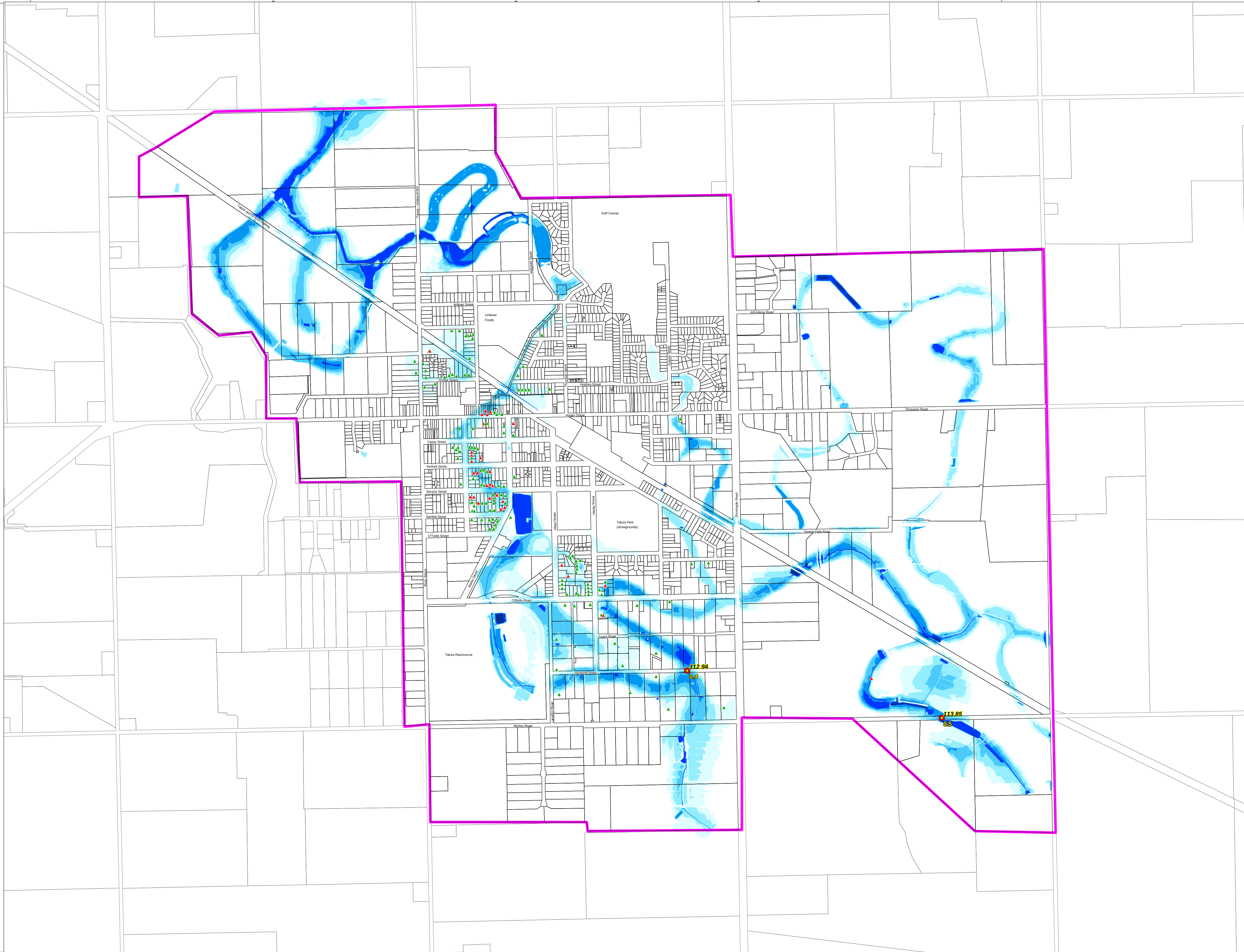
Figure 5-2



NOTE

No two floods behave in exactly the same manner even though they may rise to the same height on the Ardmona-Merrigum Road gauge.
Information presented on this map represents a typical flood event. Please refer to "General Notes".

LEGEND

Flood Depth

- 0.00 to 0.25m
- 0.25 to 0.50m
- 0.50 to 0.75m
- 0.75 to 1.00m
- 1.00 to 2.00m
- greater than 2.00m

- ▲ Building Inundated above Floor
- ▲ Building Floor not Inundated
- Study Area
- ◇ *Flood Level (mAHD)* *Flood Depth (m)*
- ● Proposed Gauge Location

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Mosquito Depression at Tatura
10-Year ARI Flood Depth Map
Existing Floodplain Conditions

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SHEET NUMBER 1 OF 1

DRG NO. *Figure 5-3*

6 FLOOD DAMAGE ASSESSMENT

Flood damage assessment is an important component of floodplain management as it enables an understanding of the magnitude of assets under threat from flooding. The ANUFLOOD flood damage assessment method was adopted for Tatura and is described in the following sections.

6.1 Methodology

The basic procedure for calculating the monetary flood damages is provided below.

- Identify the areas inundated and the depth of inundation for the range of design flood events (10, 20, 50, 100 and 500-year ARI design storm events) modelled using the TUFLOW hydraulic model.
- Calculate the depth of flooding within each property for each ARI event using the surveyed floor levels of properties that are flood-affected.
- Prepare stage-damage relationships for residential and commercial properties. These relationships will account for such factors as the relative degree of flood preparedness of the community.
- Produce total flood damages for the range of flood events for both residential and commercial/industrial properties.
- Sum damages for all properties for each ARI event and present the results in a probability-damage graph.
- Assume indirect damages are 30% of direct damages as recommended in the RAM (Rapid Appraisal Method) report (NRE, 2000).
- Determine the average annual damages (AAD).

Damages to public infrastructure have not been included in this analysis.

6.1.1 Stage-damage Curves

ANUFLOOD residential stage-damage curves were used for this flood damage assessment. These curves were sourced from NRE (2000). The non-residential stage-damage curves, also ANUFLOOD curves, were sourced from a journal paper by Smith (1994) “Flood Damage Estimation – A review of urban stage-damage curves and loss functions”. The curves have all been indexed to 2004 units using appropriate CPI factors sourced from Bureau of Statistics.

ANUFLOOD has 15 non-residential stage-damage curves. For each building size (small, medium and large), there are 5 curves representing 5 value classes. Because the existing building floor level information did not include data on the type, size or condition of each of the buildings considered, the size and condition of each residential buildings was assumed to be medium and average respectively.

The RAM report suggests that the ANUFLOOD curves underestimate flood damages. To address this issue, increases of 60% have been applied to both the residential and non-residential curves, as recommended in the RAM.

Ratios to convert Potential damages to Actual damages were used as per the recommendations from the RAM. That is, for a community who have not experienced flooding in the last five years with approximately 13 hours warning time, a factor (ratio) of 0.8 is used to reduce the potential damages to actual damages.

6.1.2 Outside Buildings

Damages to equipment outside the building are not included in the standard stage-damage curves used. Such damages may include damage to fences, driveways, lower level laundries and outdoor equipment. To account for this, an estimate of "ground equipment damages" was made as a function of ground level inundation. That is, assume a sliding scale from $0 to $1000 with $1000 being the maximum. The full $1000 damage is experienced once the flood level has reached the floor level of the building. The sliding scale works on the difference between the ground level and the floor level (eg a ground level of 1m, floor level of 2m, flood level of 1.5m receives ground equipment damages of $500).

Ground damages for inundated properties without floor level information have been assumed equal to the average ground damages cost for properties where floor level surveys have occurred.

6.1.3 Indirect Damages

Indirect damages refer to the costs incurred to a community during a flood and include emergency response and disruptions to employment, commerce, tourism, transport and communication. The RAM report suggests that these costs are approximately 30% of direct damages.

6.1.4 Damages Calculations

The peak depth of flooding was determined at each property for the 10, 20, 50, 100 and 500-year ARI events and the associated cost extracted from the stage-damage relationships. Total damages for each flood event were determined by summing the predicted damages for each individual dwelling. The AAD was then calculated.

The AAD is the average damage in dollars per year that would occur in a designated area from flooding over a very long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events). Estimation of the AAD provides a basis for comparing the effectiveness of different floodplain management measures (i.e. the reduction in the AAD). The AAD is the area under the probability-damage graph. Ideally the probable maximum flood damages is included in the AAD analysis, and it is also necessary to assume a flood ARI in which no damages occur. As no flood larger than the 500-year ARI event was modelled, the probability-damages graph was extrapolated, and it was assumed that no damages would occur in the 2 year ARI event.

6.2 Flooded Properties

Depth of above floor flooding was required for the flood damages assessment, and also to provide an initial indication of the benefit of a mitigation option before proceeding to the economic analysis. Above floor flooding occurs when the height of floodwaters exceeds the height of the floor in habitable rooms within the property. Flooding of garages and carports does not constitute above floor flooding. The depth of above floor flooding was calculated by subtracting the floor level at each property from the flood height at that property for each design event. The number of properties inundated above floor level in each event is shown in Table 6-1.

Table 6-1 Number of Flooded Properties

ARI (years)	Number of Properties	
	Flooded Above Ground Level	Flooded Above Floor Level
500	483	201
100	399	132
50	312	92
20	220	46
10	163	32

6.3 Flood Damages

The total existing conditions damages for each design flood event are presented Table 6-2 and illustrated in Figure 6-1. The existing conditions AAD , also presented Table 6-2, is $239,000.

Table 6-2 Existing Case Damages Summary

Event		Existing Case			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
500+	0.2%	$4,104,000	$1,231,000	$5,336,000	$34,500
100	1%	$2,524,000	$757,000	$3,281,000	$26,000
50	2%	$1,437,500	$431,000	$1,868,500	$41,000
20	5%	$663,000	$199,000	$862,000	$34,500
10	10%	$397,000	$119,000	$516,000	$103,000
2	50%	$0	$0	$0	-
Average Annual Damage					**$ 239,000**

Note – PMF damages are usually adopted as the upper extent of damages. In this case 500-year ARI event was adopted.

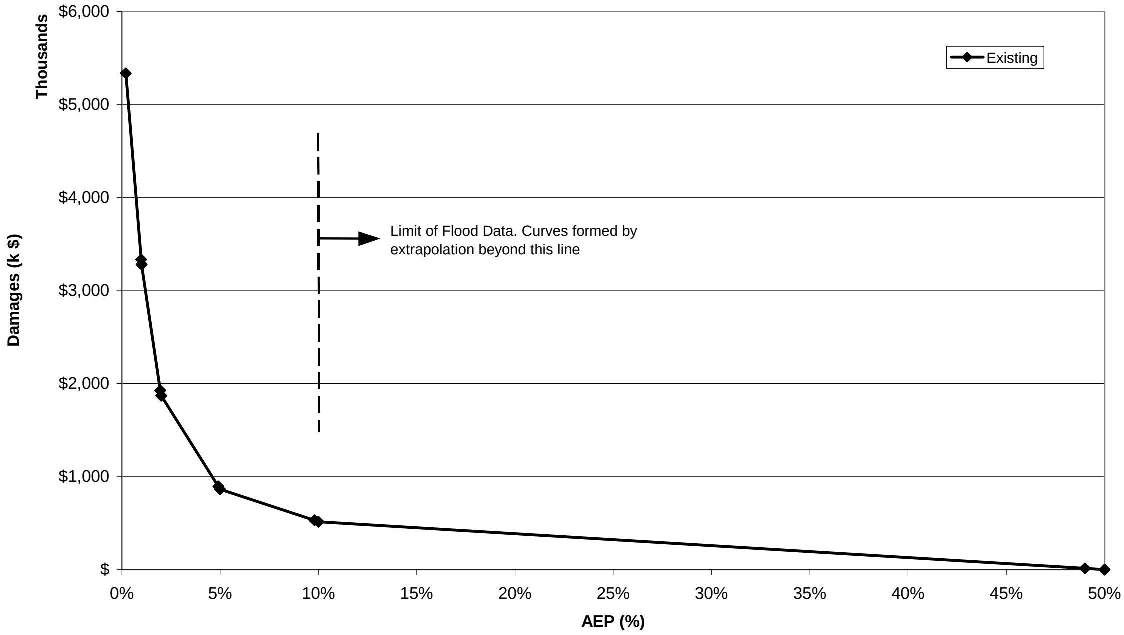


Figure 6-1 Existing Condition Probability Damages Curve

7 FLOOD MITIGATION SCHEME DEVELOPMENT

This section outlines the selection of several mitigation options to combine in the development of a Preferred Mitigation Scheme to help alleviate existing flooding.

The assessment followed four key stages:

- Identification of focus areas in which to alleviate flooding;
- Identification of mitigation options preferred by the community;
- Screening of mitigation options for feasibility; and
- Selection of mitigation options for detailed impact assessment.

7.1 Focus Areas

Through the modelling of the existing flooding conditions at Tatura and consultation with the TSC a number of key areas of concern were determined.

The worst affected area of Tatura, and the area with the best opportunity to relieve flooding, lies upstream of the Tatura and Toolamba railway along the Southern Branch of the Mosquito Depression East Arm. A large number of flood affected properties and businesses fall within the area, and given their close proximity to one another, flood mitigation works are likely to prove cost effective.

The Eastern Branch is affected less severely by flooding than the Southern Branch. The number of flood-affected properties along the Eastern Branch is much smaller and due to their sparse distribution, there is less opportunity for flood relief.

7.2 Mitigation Option Identification And Option Screening

A host of possible flood mitigation options were considered as part of the first pass identification. The community of Tatura was involved via a mail out survey, which sought to identify effective flood mitigation options that were preferred by the community.

A list of mitigation options suggested by the community is compiled in Table B-1 of Appendix B. These suggestions typically fall into 5 categories;

- Bypassing of flows from the Southern Arm around flood prone properties;
- Providing floodplain storage for flood waters;
- Increasing hydraulic capacity of the existing drainage pathways by enlarging waterways and drains;
- Implementing land use controls within the floodplain; and
- Managing flows during floods.

Potential flood mitigation options were compiled and presented to the community. These works are presented in Figure B-1. Flood mitigation options were then screened for feasibility and effectiveness. The following sections describe the practicalities of community suggested mitigation options which formed the basis of the screening process.

7.2.1 Flow Diversions

Diverting flows around and away from the flood prone areas of town has been identified as an opportunity to reduce the severity of flooding within Tatura.

Diverting floodwaters from the Southern Branch into the Eastern Branch via pipes or floodplain modifications was ruled out as a mitigation option because it simply transfers flooding to the neighbouring catchment.

7.2.2 Floodplain Storage

The provision of flood storage within the catchment to attenuate peak flood flows has been identified as an option to alleviated flooding through the town.

The attenuation effect of flood storage on peak flows at the Tatura township is discussed in Section 3.2.5. This method of flood mitigation can be effective but is dependent on the volume of flood storage that can be provided. The opportunity to do this in the Southern Branch catchment is limited due to the risk of adversely affecting the upstream land uses and properties.

This method of flood mitigation is made further complex by the non linear nature of the catchments. During sensitivity testing of the hydrologic models, lowering levees by 0.1 m actually reduced the peak flow in the southern branch at the town boundary. This indicates that an extremely large area within the upstream catchment must be designated to floodwater storage to have an effect on flow rates at the township. The provision of such storage is not practical and this option was not investigated.

7.2.3 Increased Hydraulic Capacity of Floodways and Drainage Infrastructure

Numerous suggestions were made by the community to provide increased flow capacity to structures and floodways within the floodplain and the designation of additional floodways.

Existing development and space constraints within the township rule-out the designation of additional floodways and the provision of additional underground drainage capacity. Purchasing land or laying pipes underneath existing buildings is expensive and in many cases only small gains would be made in improving underground conveyance.

The best opportunity for removing flooding is to improve the capacity of above ground structures that act as flood level controls. The identification and location of these structures is described in Section 7.3

7.2.4 Land Use Controls

Planning constraints are already in place to restrict development within the floodplain and prevent modifications of terrain within existing floodways.

7.2.5 Flood Response Procedures

Flood response procedures can reduce the losses associated with flooding.

Management of floodwaters with penstocks at Lake Bartlett and cutting through roads has not been investigated as part of this study. The capacities of the penstocks are far less than flows expected in extreme events investigated in this study.

Sandbagging can be employed to prevent backwater flooding in the vicinity of Hunter Street and between Unilever Foods and William Street. Sand bags must be employed at drain outlets North and South of the railway embankment after local runoff has escaped via the drainage network and before the peak of the flood passes through the town.

A flood warning and dissemination system to residents would help reduce flood damages at Tatura. The system would require co-operation of residents who are informed and understand what to do in the event of a flood warning being issued. Preparations can be made to arrange supplies of sandbags for the construction of temporary levees. Residents can move valuable items above anticipated flood levels, as well as obtain food and other vital supplies.

7.3 Preferred Flood Mitigation Options

The preferred flood mitigation options aim to improve the capacity of key structures within the floodplain, allowing for floodwaters to pass more efficiently through the study area, thereby reducing flood levels throughout the town (minimum afflux). The effect of several structures on flood levels can be seen in the longitudinal profile presented in Figure 7-1.

Several flood mitigation options were identified as having the most potential benefit to flood levels. The decision on which options were to be considered was undertaken in consultation with the TSC. These options were screened using hand calculations to evaluate their effectiveness on reducing flood levels.

Mitigation options that are expensive to construct and proved to have little effect on flood levels were disregarded. The flood mitigation options that proved cost effective in the option screening are summarised in Table 7-1 and are presented in Figure 7-2. These options form the basis of the preferred Flood Mitigation Scheme that was the subject of a detailed assessment, and is described in Section 8.

Subsequent modelling explored the possibility of sandbagging the outlets of culverts that drain the areas in the vicinity of Hunter Street and between Unilever Foods and William Street. This proved effective in reducing backwater flooding without having an adverse effect on flood levels at the railway embankment. This is considered a flood response measure rather than a structural mitigation measure and was not included in the mitigation scheme.

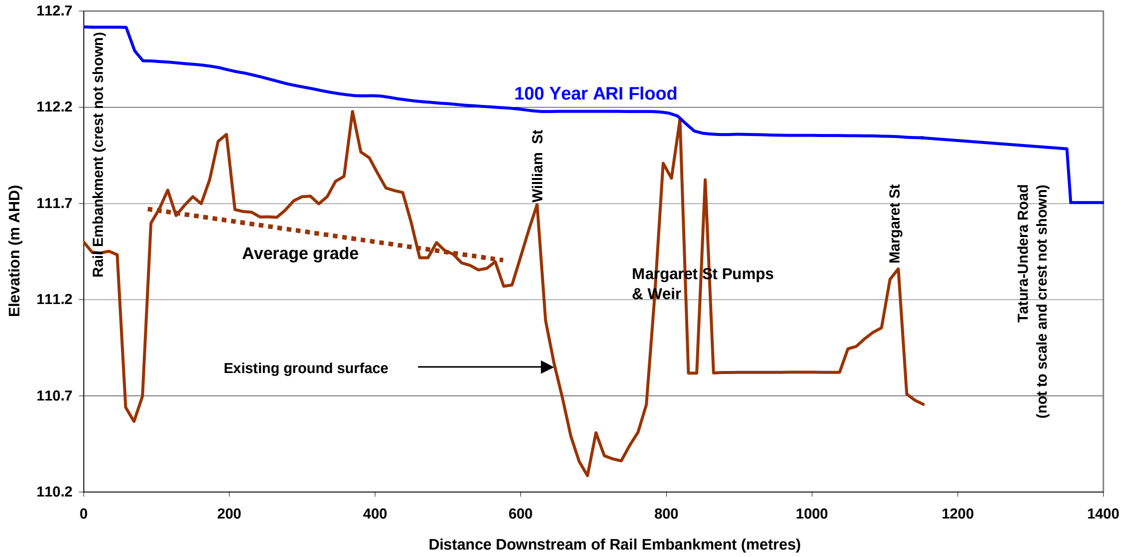
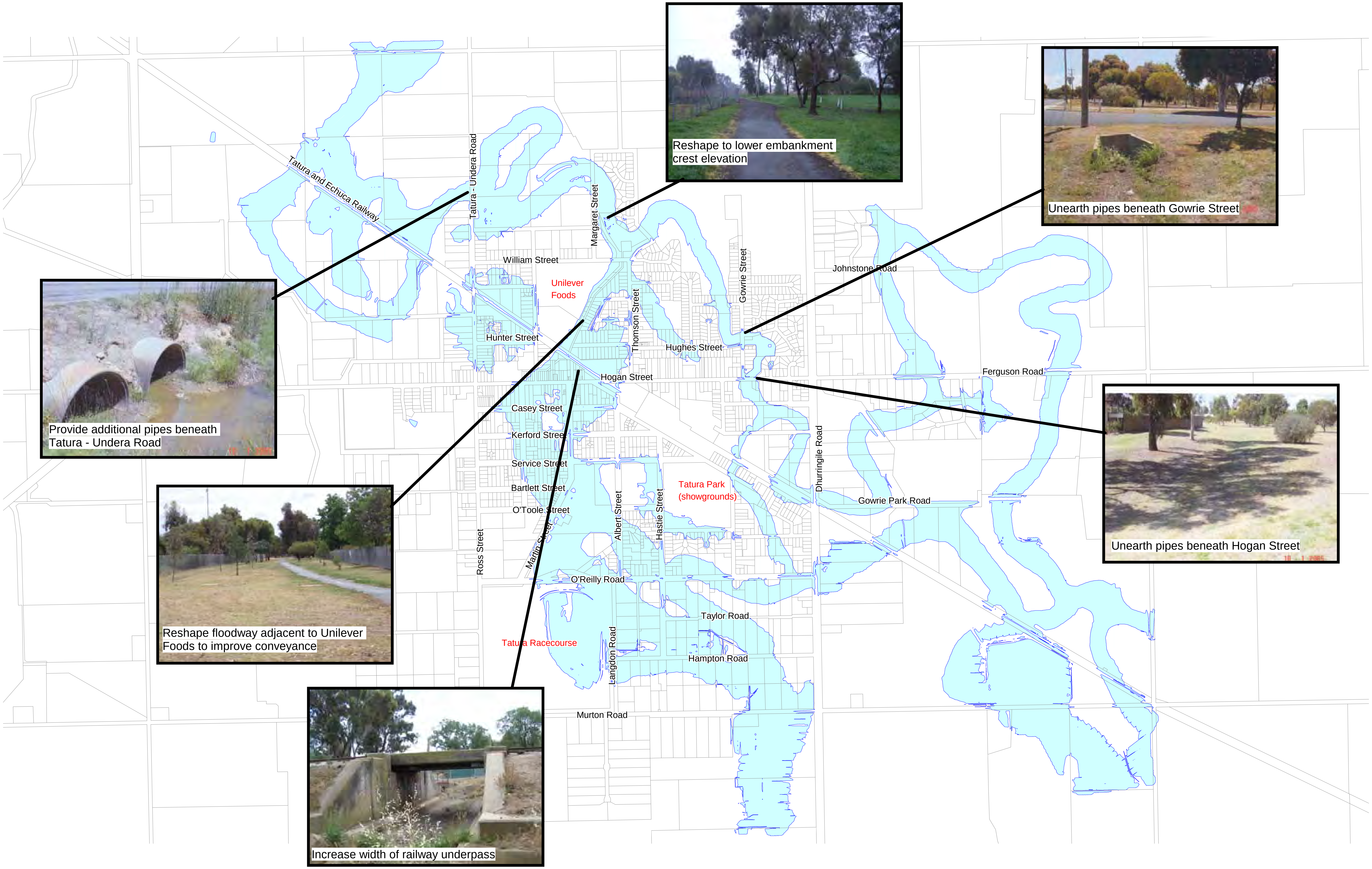


Figure 7-1 100-year longitudinal profile of peak flood levels at hydraulic controls through Tatura

Table 7-1 Mitigation Option Element Screening

Details	Outcomes	Recommended for Detailed Assessment
Duplication of existing pipes at Tatura Undera Road	Reduced flood levels upstream	√
Lowered elevation of terrain immediately East of Margaret Street Pumps.	Reduced flood levels upstream	√
Unearth Pipe culverts beneath Gowrie Street	Reduced flood levels upstream	√
Unearth Pipe culverts beneath Hogan Street	Reduced flood levels upstream	√
Regrade floodway adjacent to Unilever Foods	Reduced hydraulic grade line within reserve	√
Increase the capacity of the Rail Drain/Underpass	Reduced flood levels upstream	√



Preferred Mitigation Scheme Elements **Figure 7-1**

8 FLOOD MITIGATION SCHEME ASSESSMENT

Hydraulic impacts associated with the preferred Mitigation Scheme and design standard were quantified using the hydraulic model. Impacts to hydraulic characteristics will be clearly represented using flood maps showing net increases and reductions in water level, flood flow distribution, velocity, changes in flood affected properties and flood hazard.

8.1 Flood Impact Assessment

8.1.1 Hydrology

The existing hydrology, as described in Section 3, was used in hydraulic modelling of the preferred scheme.

8.1.2 Hydraulic Modelling

The existing case hydraulic model, as described in Section 4, was modified to incorporate the augmented drainage features of the preferred scheme. Model parameters and boundary conditions were not changed nor were the model boundary conditions. The preferred Mitigation Scheme model incorporated modifications as follows:

- **Railway Underpass:** Augmentation of existing Railway Drain/Underpass. The existing underpass was widened from 3.17 m to 7.0 m

- **Unilever Floodway:** The existing topography of the Unilever Floodway was modified to carry flows more efficiently. In combination with Railway Drain/Underpass works, this will further reduce flood levels.

- **Hogan Street Culverts:** Additional four 1.2 m diameter RCPS beneath Hogan Street that were not included in the existing case modelling, included in the model.

- **Gowrie Street Culverts:** Additional four 1.2 m diameter RCPS beneath Gowrie Street that were not included in the existing case modelling, included in the model.

- **Margaret Street Pump Weir:** The existing embankment to the south of Cussens Park Wetlands and East of the Margaret Street Pump station controls flood levels upstream into the Unilever Floodway. The elevation of the embankment was lowered by reshaping.

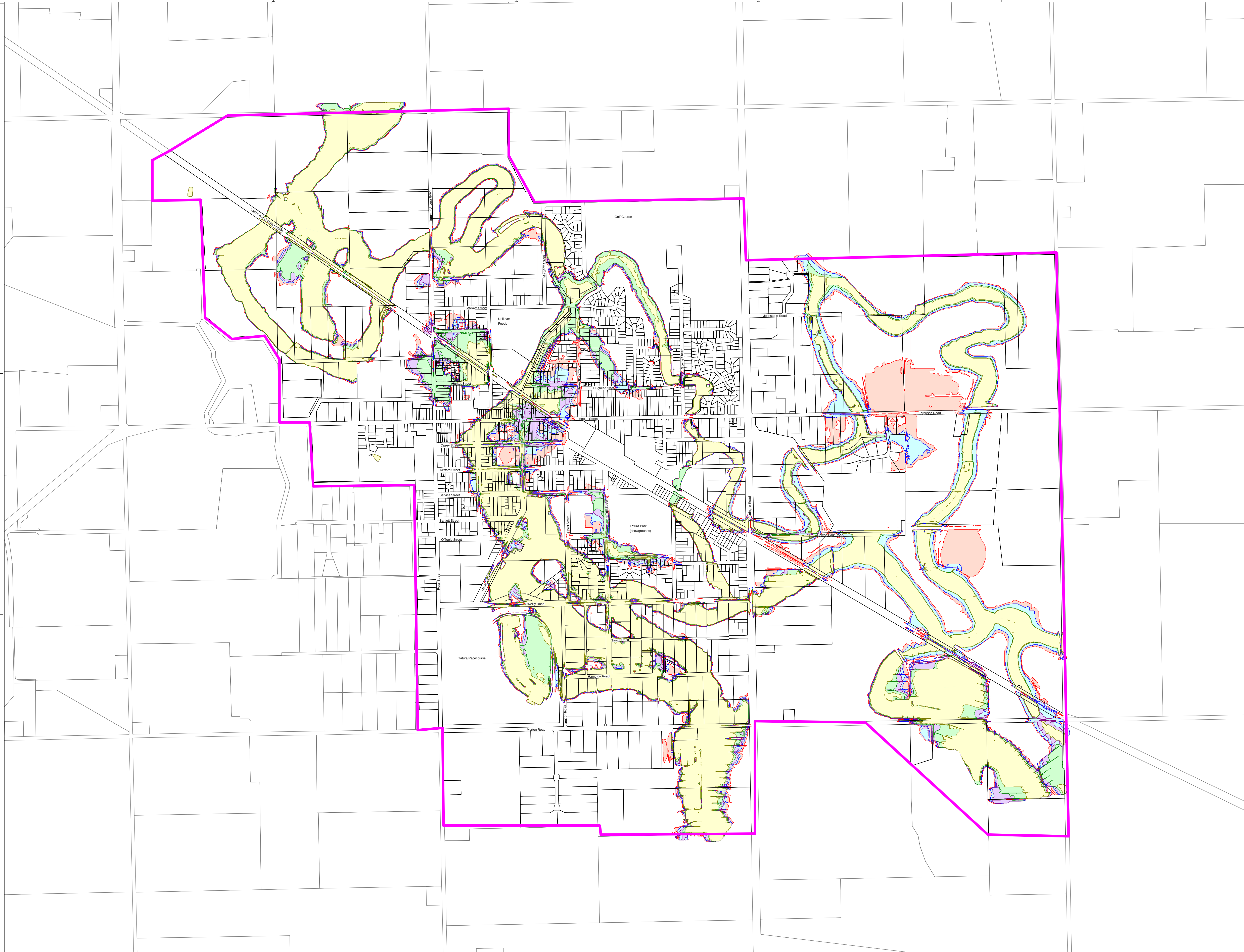
- **Tatura Undera Road Culverts:** The existing capacity of the culverts beneath Tatura Undera Road (two 1.2 m diameter RCPs and one 0.5 m diameter RCP) was increased by including four additional 1.5 m diameter RCPs.

The 10, 20, 50, 100 and 500-year ARI design floods were assessed using the same 36 hour duration events used for the existing case.

8.1.3 Flood Mapping

A peak flood height DEM for flooding under the Mitigation Scheme was developed for each flood event. The flood extents for the 10, 20, 50, 100 and 500-year ARI design storm flood events are mapped in Figure 8-1.

The change in peak flood height for the 100-year ARI event was calculated by subtracting the existing case peak flood heights from the preferred scheme peak flood heights at each TUFLOW grid. The change in peak flood height was then colour contoured and mapped. The change in flood levels across the Study Area are shown in Figure 8-2.



NOTE
No two floods behave in exactly the same manner even though they may rise to the same height on the Ardmona-Merrigum Road gauge.
Information presented on this map represents a typical flood event. Please refer to "General Notes".

Legend

- 10-Year Flood Extent
- 20-Year Flood Extent
- 50-Year Flood Extent
- 100-Year Flood Extent
- 500-Year Flood Extent
- Study Area

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6. This map has been prepared using the best available data and computer modelling and mapping techniques. The accuracy of this map however, is not absolute and reflects only the accuracy of the data and techniques used.
7. This map is a compilation of 500, 100, 50, 20 and 10 year ARI flood model results for proposed mitigation scheme.
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GREATER SHEPPARTON

PREPARED BY	P. Gillam	29/10/04
CHECKED	M. Turnley	29/10/04
AUTHORISED BY		

Mosquito Depression at Tatura
Combined Flood Extent Map
Preferred Mitigation Scheme Conditions

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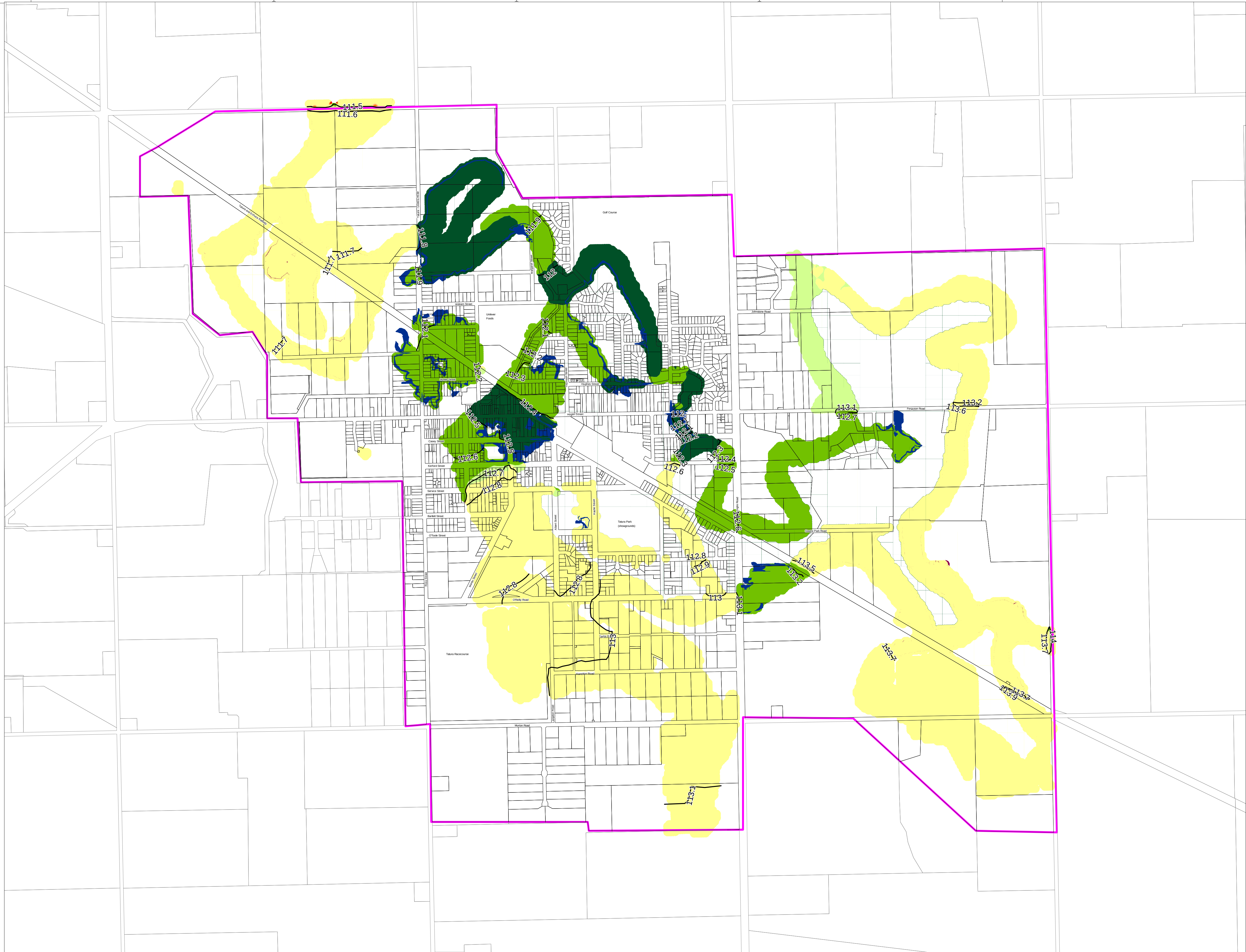
SHEET NUMBER 1 OF 1
DRG NO.
Figure 8-1



LEGEND

Change in Flood Level

- Now Wet
- -0.03 to 0.03m
- -0.05 to -0.03m (reduced flooding)
- -0.15 to -0.05m (reduced flooding)
- -0.35 to -0.15m (reduced flooding)
- Now Dry

Note: A negative value denotes a reduction in flood levels

107.4 Proposed Flood Level Contour (m AHD)

Study Area

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6. This map has been prepared using the best available data and computer modelling and mapping techniques. The accuracy of this map however, is not absolute and reflects only the accuracy of the data and techniques used.
7. This map shows changes to 100-year ARI flood levels only. The flood extent shown is indicative. Please refer to Figure 8-3 for the changes to the 100-year flood extent.
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Australian Map Grid GDA 94, MGA Zone 55

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AUTHORISED BY		CONSULTANT REFERENCE	

Mosquito Depression at Tatura

100-Year ARI Flood Mitigation Works Impacts

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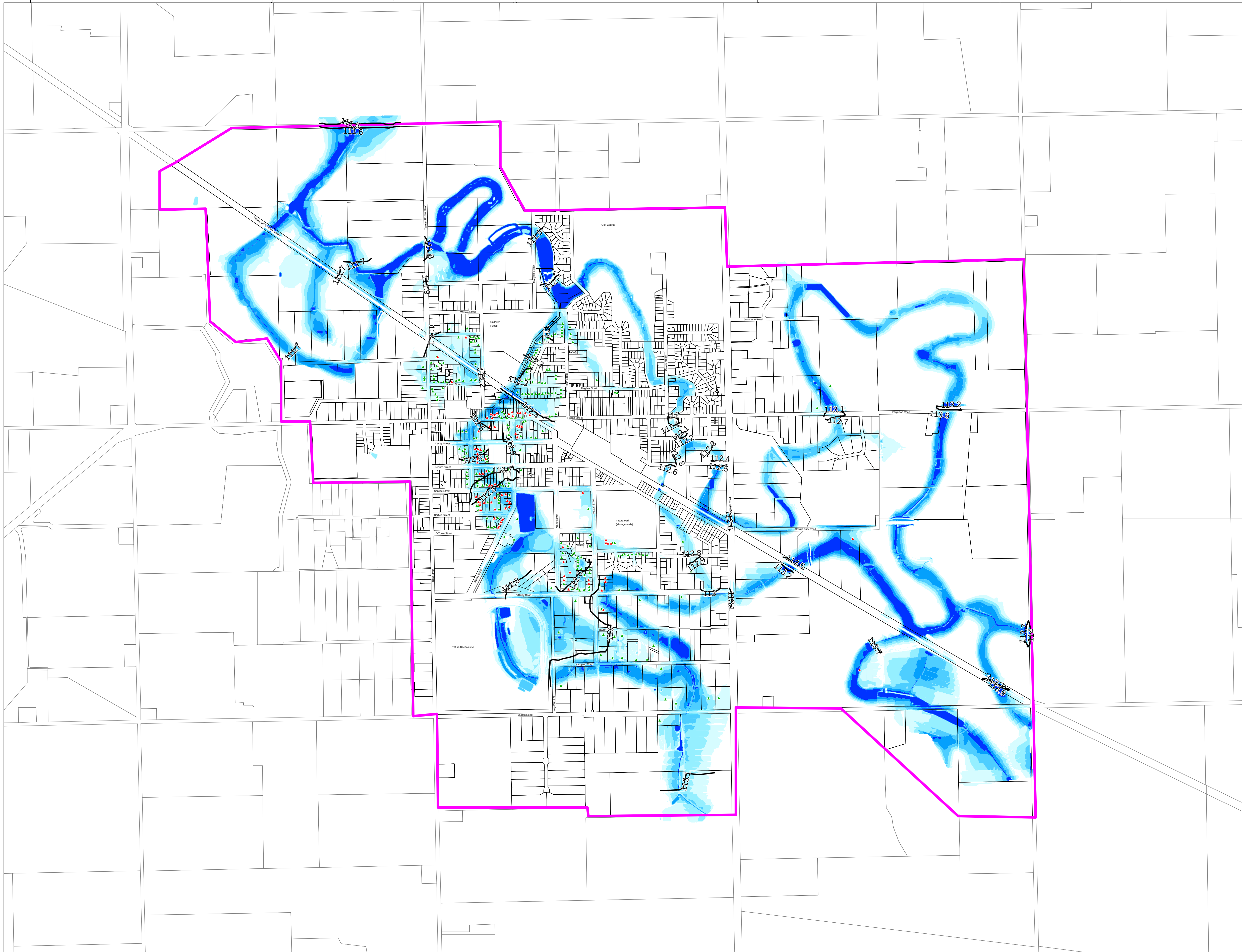
Figure 8-2



NOTE

No two floods behave in exactly the same manner even though they may rise to the same height on the Ardmona-Merrigum Road gauge. Information presented on this map represents a typical flood event. Please refer to "General Notes".

LEGEND

Flood Depth

- 0.00 to 0.25m
- 0.25 to 0.50m
- 0.50 to 0.75m
- 0.75 to 1.00m
- 1.00 to 2.00m
- Building Inundated above Floor
- Building Floor not Inundated
- 107.4 Proposed Flood Level Contour (m AHD)
- Study Area

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6. This map has been prepared using the best available data and computer modelling and mapping techniques. The accuracy of this map however, is not absolute and reflects only the accuracy of the data and techniques used.
7. This map shows 100 year ARI flood model results for existing catchment conditions.
8. WBM Oceanics Australia does not warrant that this map is definitive nor free of error and does not accept liability for any loss caused or arising from reliance upon information provided herein.

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Australian Map Grid GDA 94, MGA Zone 55

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Mosquito Depression at Tatura Proposed Mitigation Scheme 100-Year ARI Flood Depth Map

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CORRESPONDENCE NUMBER: R.M6058.003.00.doc

SHEET NUMBER: 1 OF 1

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Figure 8.3

8.2 Mitigation Scheme Flood Damage Assessment

In general, the benefits of the construction of flood management measures are as follows:

- Increased flood immunity of properties protected by the measure;
- Decreased cost of flood damage to properties protected by the measure;
- Decreased potential for loss of life during floods within the area protected by the measure; and
- Decreased emotional, social and psychological trauma experienced by residents during and after flooding.

The Mitigation Scheme will not significantly benefit public infrastructure such as roads and so public infrastructure was not included in flood damage assessments. It is also important to note that flood management measures may have the effect of increasing flood levels in other areas, thereby resulting in increased flood damages to properties elsewhere.

Of the factors listed above, the change in flood damages is the only one that can be easily quantified in monetary terms. In Section 6, the flood damages for the existing conditions were calculated. The flood damages have been calculated for the Mitigation Scheme. The reductions (or increases) in these damages quantify the monetary benefit of each measure.

The overall financial viability of a scheme is initially assessed by calculating the monetary benefit-cost ratio (BCR).

The procedure for calculating benefit-cost ratios is outlined below:

1. Calculate the **average annual benefit** associated with the preferred scheme (i.e. the reduction in annual average damages) using the method described in Section 6.3,

2. Convert the **average annual benefit** to a **total benefit** by multiplying by the **present worth factor**;

3. Calculate the **total cost** of the preferred scheme.

4. Calculate the monetary **benefit-cost ratio**:

$$Benefit - Cost\ Ratio = \frac{Total\ Benefit}{Total\ Cost}$$

These ratios are used to evaluate the economic potential for the preferred scheme to be undertaken. A monetary benefit-cost ratio of 1.0 indicates that the monetary benefits are equal to the monetary costs. A ratio greater than 1.0 indicates that the benefits are greater than the costs while a ratio less than 1.0 indicates that the costs are greater than the benefits.

In floodplain management, a BCR substantially less than 1.0 may still be considered viable because the economic analysis does not include the intangible benefits of a measure such as emotional and social effects to a community.

In order to calculate the BCR, the annual financial benefits (the change in average annual damages) of a measure needs to be converted to a total benefit over a period of time. This is due to the difficulty in comparing a "lump sum" cost with an "annual" benefit.

A financial project life of 30 years was chosen for this study. **This does not imply that the projected structural life of the scheme is only 30 years.** In fact, some measures should be effective in reducing the frequency of flooding for centuries to come.

It is **not** correct to simply multiply a long term average annual benefit by the financial project life of 30 years to derive a total worth of the benefits. To do so would ignore the important point that the benefits from this scheme (ie. reduced flood damages) will occur over time and in the future.

For example, a benefit of $2.3 million to be gained in 10 years time is not worth $2.3 million now but only $1.2 million now. This is because $1.2 million could be invested now and appreciate at say 7 % p.a. over and above inflation for 10 years. This would then be equivalent to $2.3 million in 10 years time. This is called the **Present Value** of the benefit. It is a universally accepted economic theory and used in all major project economic analyses. The adopted rate of 6 % is called the discount rate and is within the 6 to 8 % typically considered for assessing public works.

8.2.1 Mitigation Scheme Flooded Properties

Peak flood height surfaces were used to calculate the number of properties flooded, which was then used in the flood damages assessment for the Mitigation Scheme. The mitigation case 36 hour 100-year ARI flood height, depth and depth of above floor flooding are mapped in Figure 8-3. A comparison in the number of flood affected properties under existing conditions and the preferred scheme is presented in Table 8-1.

Table 8-1 Reduction in Flooded Properties Under the Preferred Scheme

ARI (years)	No. Flooded Grounds		Reduction	No. Flooded Floors		Reduction
	Existing	Scheme		Existing	Scheme	
500	483	418	*65*	201	140	*61*
100	399	318	*81*	132	98	*34*
50	312	248	*64*	92	66	*26*
20	220	187	*33*	46	36	*10*
10	163	132	*31*	31	27	*4*

The Mitigation Scheme provides a good level of flood relief within the township.

8.2.2 Mitigation Scheme Flood Damages

The reductions (or increases) in flood damages have been calculated to quantify the monetary benefit of the proposed Mitigation Scheme. Total damages for each design flood event are presented in Table 8-2 and illustrated in Figure 8-4. The AAD under the preferred Mitigation Scheme presented in Table 8-2, is $179,000.

Table 8-2 Mitigation Case Damages Summary

Event		Mitigation Case			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
500+	0.2%	$2,593,000	$778, 000	$3,371,000	$21,000
100	1%	$1,455, 000	$436,500	$1,891,500	$15,000
50	2%	$ 850, 000	$255,000	$1,105,000	$26,000
20	5%	$ 494,500	$148,000	$643,000	$27,000
10	10%	$ 345, 000	$103, 000	$448,000	$89,500
2	50%	$ 0	$ 0	$ 0	-
Average Annual Damage					**$ 179,000**

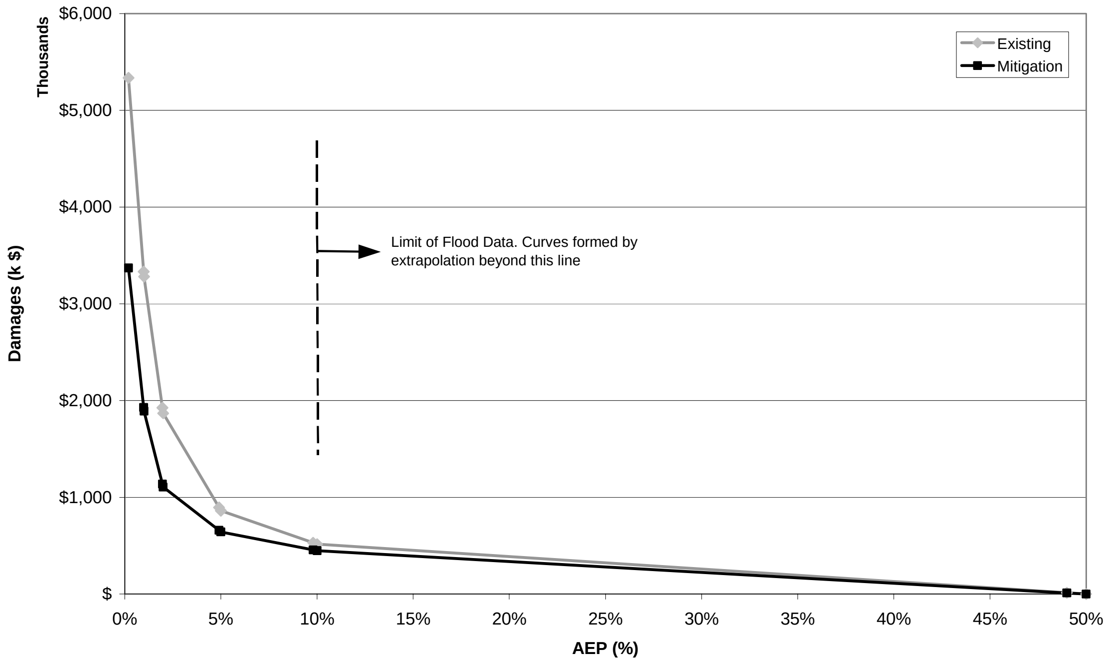

Figure 8-4 Mitigation Case Probability Damages Curve

8.2.3 Mitigation Scheme Capital Costs

The cost to construct the Mitigation Scheme was estimated by Greater Shepparton Engineering Design Unit. A summary of costs for each mitigation option is presented in Table 8-3.

Table 8-3 Mitigation Scheme Capital Costs

Item	Capital Cost
Railway Underpass	
Victrack fees for review of design	$2,000
Supply and lay box culverts for drainage underpass upgrade	$100,000
Alternative 7m precast deck slab	$21,000
Contingencies (40%)	$49,200
Alterations to Services	$2,000
Engineering design (5%)	$8,710
Total	**$182,910**
Duplication of pipes at Undera-Tatura Rd	
Supply of four 12.2 m lengths of 1500mm RCPs	$19,520
Lay RCPs	$19,520
Supply of concrete end walls	$9,300
Traffic management	$3,000
Contingencies (40%)	$15,712
Alterations to Services	$2,000
Total	**$73,880**
Unearth Pipes at Hogan St	
Excavate and clean out pipes	$300
Contingencies (40%)	$120
Total	**$420**
Unearthed Pipes at Gowrie St	
Excavate and clean out pipes	$300
Contingencies (40%)	$120
Total	**$420**
Reshape Floodway at Unilever Floods	
Reshape Floodway at Unilever Floods	$21,600
Contingencies (40%)	$8,640
Total	**$30,240**
Margret Street Pumps Embankment	
Lower existing embankment at Margaret Street by approximately 150 mm	$13,500
Contingencies (40%)	$5,400
Total	**$18,900**
TOTAL	**$ 307,000**

8.2.4 Mitigation Scheme Financial Benefit

The benefit cost analysis for the proposed Mitigation Scheme is summarised in Table 8-4. A discount rate of 6% for a design life of 30 years was used on advice from Greater Shepparton City Council. It is expected that the Mitigation Scheme will provide benefit to the community for more than 30 years.

Table 8-4 Mitigation Scheme Benefit Cost Ratio Summary

	Existing	Mitigation Scheme
Damages (PA)	$ 239,000	$179,000
Benefit (PA)		$60,000
Benefit (NPV)		$827,000
Scheme Capital Cost		$307,000
Benefit Cost Ratio		**2.7**

9 FLOOD WARNING SYSTEM

There is currently no flood warning system operating for Tatura. Knowledge of flooding behaviour in Tatura and warning of impending floods would assist the community of Tatura in reducing the flood impacts. It is unlikely that the Bureau of Meteorology will implement a flood warning system in this catchment. However components of a flood warning system were considered.

9.1 Peak Flood Height Gauges for Tatura

Consideration was given to installation of peak flood height gauges in the locations shown in Figure 5-2. It was considered by the TSC that these would provide limited flood warning benefit because of the lack of a flood warning system within this catchment. They would provide two locations at which peak flood heights could be obtained after a flood, however flood level information throughout the town could be gathered from water levels and flood markers recorded by residents during future floods.

9.2 Flood Forecast Correlation

This study was originally expected to include the development of a flood forecasting database to clearly show the linkages and correlations between rainfall depth and flood extent. There are no existing rainfall gauges within the upstream catchment and the expense of installing a telemetry rainfall gauge limits their applicability to this study.

9.3 Rainfall Telemetry Stations

It was proposed by the TSC that telemetry rainfall gauges in neighbouring catchments could be utilised to provide warnings of significant rainfall events. The installation of telemetry gauges within the catchment could also be considered. However this system would require good understanding of the significance of catchment rainfall events to flooding in Tatura and that this knowledge be part of Council’s emergency response plan.

10 FLOODPLAIN MANAGEMENT PLAN COMMUNITY CONSULTATION

The preferred Floodplain Mitigation Scheme was presented to the TSC and Community via a public meeting and information session on 21 June, 2005.

The information session presented the results of the mitigation option screening process, and detailed hydraulic and economic analysis of the results of the preferred Mitigation Scheme.

Concerns were raised by a property holder on Pyke Street, that flood mitigation works would adversely affect flooding on his property. Modelling indicates that there will be an increase in peak 100-year ARI flood levels in the area of approximately 5 mm. Upgrading culverts beneath Pike Road as per Tatura-Under Road will reduce this afflux. The cost involved will reduce the cost benefit ratio from 2.7 to 2.2. These additional culverts were not included in Mitigation Scheme modelling. Therefore flood extents, depth and heights presented in this report do not include the benefits of these additional pipes.

A resident raised a concern about blockages to drainage infrastructure worsening flood levels, particularly in the vicinity of the railway bypass. Blockage analysis was not carried out as part of this study, however the proposed Mitigation Scheme will increase the hydraulic capacity of the railway underpass through widening the opening, the underpass will be less prone to blockage. In the case of blockage at the railway embankment, it is anticipated that the Mitigation Scheme will still relieve existing flooding.

A resident raised a concern that the Mitigation Scheme will alter the hydrologic response of the Mosquito Arm Depression East by increasing the capacity of the floodway structures. Where this can be a problem in some catchments, flood modelling shows that there may be a minor increase in flood levels at the downstream extent of the study area. This is predicted to be 5 mm in a 100-year ARI event. The Mitigation Scheme will therefore have minor effects on the study area. On a catchment scale, the hydrology of the existing catchment has been significantly altered by anthropogenic practices in the upper catchment, and the effects of the Mitigation Scheme are anticipated to be small in comparison.

A concern was raised about Council's management of penstocks at Lake Bartlett during rain events. This question was outside the scope of the study and the concern was referred to Council's representative.

There were no other concerns raised at the meeting and a number of positive comments were made in relation to the cost effectiveness of the proposed Mitigation Scheme.

11 FLOOD RESPONSE PLANS

Advice regarding key aspects of a Flood Response Plan will be provided to Council to assist in the preparation of the Plan as part of its Municipal Emergency Management Plan. Flood animations generated from the hydraulic model, along with flood maps and GIS layers have been provided to Council to assist in flood response plans implementing :

- Road closures;
- Resident evacuation;
- Examination of key elements of the flood mitigation works;
- Sanding bagging and emergency response to supplement protection; and
- Flood monitoring and data collection.

Particular flood response measures that should be included in the Flood Response Plans include:

- the unearthing of culverts at Hogan Street and Gowrie Street; and
- the sandbagging of culvert outlets that drain the areas in the vicinity of Hunter Street and between Unilever Foods and William Street. Sand bags must be employed at drain outlets North and South of the railway embankment after local runoff has escaped via the drainage network and before the peak of the flood passes through the town.

12 CONCLUSIONS AND RECOMMENDATIONS

The following recommendations to Council, in order of highest to lowest priority, have been made as a result of this study. The recommended actions are to:

- Implement the preferred Flood Mitigation Scheme starting at Tatura-Undera Road and working upstream.
- Update Council planning schemes and maps to reflect the results from the study;
- Adopt and declare flood planning levels based on the 100-year ARI flood level plus freeboard where appropriate;
- Update Council flood response plans to include the results from the study; and
- Prepare and disseminate flood information to the residents of Tatura.

13 REFERENCES

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Murray Basin Consulting Group (1992) *Deakin Main Drain Model Development*. Report on Computer Modelling.

Montgomery Watson Hazar (2001) Tatura Township Stormwater Drainage Study

Nathan (1999), *A Quick Method for Estimating Probable Maximum Precipitation in the Tropical and South East Region of Australia*, Dr R Nathan.

NRE (2000), *Rapid Appraisal Method (RAM) for Floodplain Management*, Department of Natural Resources and Environment, State of Victoria, May 2000.

Sinclair Knight Merz (2000) Mosquito Depression East Arm Catchment Modelling, Hydraulic Assessment Report For Golbourn Murray Water. November 2000.

APPENDIX A: TATURA MOSQUITO DEPRESSION DECLARATION OF FLOOD LEVELS

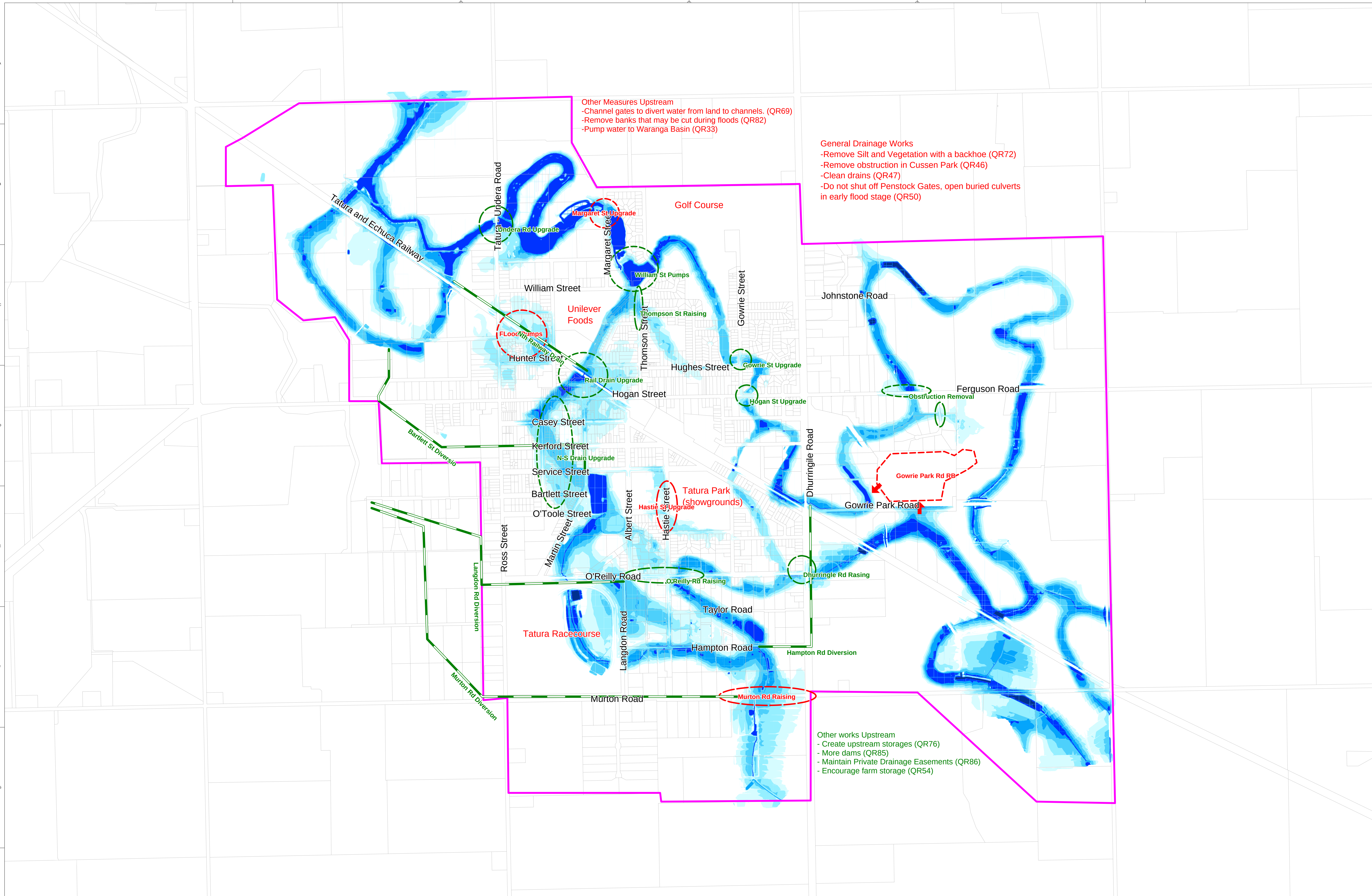
APPENDIX B: PREFERRED MITIGATION OPTIONS IDENTIFIED DURING COMMUNITY CONSULTATION

A list of preferred mitigation options suggested by the community was compiled via a mail out survey to the residents of Tatura is compiled in Table B-1. These options are depicted in Figure B-1.

Table B-1 Preliminary Mitigation Options

Suggested Flood Mitigation works	
Bypass Flows - 6	Divert peak flows of the southern depression (Hampton Rd) into the eastern arm (near the intersection of Brown St and Dhurringile Rd). (i.e. before flood peak from the eastern catchment). Relocate Waranga Basin pumps to move water from storage areas through a channel to Waranga Basin or Goulburn river. Intersect stream bed near Murton Rd and direct to existing drain west of the town. Intercept stream beds west of town and direct north into the Cussen Park depression. Construct bypass drains south of township to take all southern water west to Mosquito - possibly use Pogue Rd. Divert flood water west to mosquito, south, upstream of township. Use bypass drains and floodways to divert flood water around town perimeter.
Increased Storage - 8	Retain Cussen Park as a wetland for flood storage. Create local farm flood storages.
Enlarge Waterways and Drains - 9	Remove weirs and structures in Cussen Park. Build a large surface drain along the north side of the railway line to drain into Cussen Park. Enlarge the 150mm pipe line from Lake Bartlett to Ross St. Upgrade the barrel drain capacity and larger underground pipes, particularly in the older parts of the town. Relocate main drain outlet after leaving the centre of the town under the railway line. Install pipeline from Lake Bartlett North down Francis St north-south. Improve sale yards catchment drainage via O'Toole St, Bartlett St, Service St and Kerford St Pipe. Remove Murton Rd drain which diverts water into Hampton Rd instead of under Murchison Rd to floodway channel and Mosquito Depression. Install flood pumps to disperse piping along railway reserve to the North West.
Land Use - 10	Maintain and clear private easements (no fill allowed). Make sure these are 'escape routes' for flood waters. Remove farm banks and control the flood water.
Other	Open buried culverts in the early stages of flooding. Clean out drains (e.g. McKay St)

	Plan water release (i.e. from sewerage ponds) in flood time and have somewhere west of town for water. Channel gates that can be used to divert water from land to channels. Do not shut off Penstock Gates.



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BY		

GREATER SHEPPARTON

Tatura Floodplain Management Plan
Flood Mitigation Option Assessment

Questionnaire Response and Other Mitigation Options

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Figure B - 1

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