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# Gayndah Flood Study Final Report Volume 1

R.B16183.005.RPT.00.doc

February 2008

# Gayndah Flood Study
# Final Report
# Volume 1

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# DOCUMENT CONTROL SHEET

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| | ***Document :*** | R.B16183.005.RPT.00.doc |
| | ***Project Manager :*** | Greg Rogencamp |
| | ***Client :*** | Gayndah Shire Council |
| | ***Client Contact:*** | Tony Gallwey |
| | ***Client Reference*** | SKN0625/06 |

| | |
|---|---|
| ***Title*** : | Gayndah Flood Study – Draft Final Report, Volume 1 |
| ***Author :*** | Joris Jörissen |
| ***Synopsis :*** | Report for the Gayndah Flood Study covering development and calibration of a numerical flood model of the Burnet River, assessment of flood risk in Gayndah Township (including flood mapping) and recommendations on town planning responses to flood risk. |

### REVISION/CHECKING HISTORY

| REVISION NUMBER | DATE OF ISSUE | CHECKED BY | | ISSUED BY | |
|---|---|---|---|---|---|
| 0 | 12/02/2008 | GJR | GJR | JGJ | |

### DISTRIBUTION

| DESTINATION | REVISION | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| Gayndah Shire Council | 11 | | | |
| Department of Emergency Services | 1 | | | |
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# FOREWORD

The Queensland Department of Emergency Services is administrating the Queensland studies under the Federal Department of Transport and Regional Services' "Natural Disaster Risk Management Studies Program." The aim of the program is to identify, analyse and evaluate the risks from natural disasters and to identify risk management measures to reduce the risk to life and property.

Flooding was identified as a major risk on the Burnett River floodplain and funding has been obtained through this program to develop a Floodplain Management Plan.

The publication "Floodplain Management in Australia – Best Practice Principles and Guidelines" (CSIRO, 2000) provides the framework for the development and implementation of a Floodplain Management Plan. The process outlined in CSIRO (2000) is described below.

**Floodplain Management Process**

| Stage | Description |
|---|---|
| 1. Flood Behaviour Definition | The nature and extent of the flood problem are determined. |
| 2. Floodplain Management Measures Investigation | Management measures for the floodplain are investigated in respect of both existing and proposed developments. These options are evaluated based on the impact on flood risk, while considering social, ecological and economic factors. |
| 3. Floodplain Management Plan | Following acceptance of Stage 2 recommendations, the preferred management options are documented in a plan. |
| 4. Implementation of the Plan | Involves formal adoption by Council of the floodplain risk management plan and a process of implementation for the selected flood, response and property modification options. |

BMT WBM was commissioned by Gayndah Shire Council to carry out Stages 1 and some aspects of Stage 2 of this process. This report documents the findings of these phases of the process. It defines the existing flooding problem and addresses development control measures that may be used to manage the flood risk in Gayndah.

# EXECUTIVE SUMMARY

**Introduction**

The Burnett River is located in south-east Queensland and its river system has a total catchment area of approximately 33,000 km$^2$. The catchment is bound to the north by the catchments of the Fitzroy River, to the northeast by the Kolan River, to the west and southwest by the Dawson River and the Condamine River, and to the south by the Brisbane River and the Mary River.

Gayndah Shire Council has identified that there is a risk to the community from flooding of the Burnett River. To quantify and evaluate the risk from flooding in Gayndah, Gayndah Shire Council has commissioned WBM to undertake a Flood Study. The Flood Study was in part funded under the Federal Department of Transport and Regional Services "Natural Disaster Risk Management Studies Program", which is administrated by The Queensland Department of Emergency Services. This report discusses the outcomes of the Flood Study.

**Objectives and Study Approach**

The purpose of the Gayndah Flood Study is to obtain a better understanding of the flood behaviour of the Burnett River and define the flood risk in Gayndah from flooding of the Burnett River. In addition, the study aims to form a basis for the development of Council's planning controls for developments within the study area.

BMT WBM's approach to the study involved a phased approach in which community involvement and consultation formed a central role throughout the course of the study. A schematic chart of the adopted study approach for the Gayndah Flood Study is presented in Figure 1-1.

**Flood Model Development and Calibration**

A numerical flood model of the Burnett River was developed for the purposes of defining the flood behaviour and assessing flood hazard and vulnerability of the study area. The flood model comprises of a hydrologic model and a hydraulic model.

The hydrologic model determines the runoff response of the Burnett River catchment to a particular rainfall event. The primary output from the hydrologic model are flow hydrographs at varying locations along the waterways. The hydraulic model simulates the movement of floodwaters through waterway reaches, storage areas and hydraulic structures for given hydrological input. The hydraulic model calculates flood levels and flow patterns and also models the complex effects of backwater, overtopping of embankments, waterway confluences, bridge constrictions and other hydraulic structure behaviour.

In conjunction with SunWater, a hydrologic model of the Burnett River catchment and associated tributaries was developed using the modelling software RORB. WBM then developed a hydraulic model of the Burnett River using the hydraulic modelling software TUFLOW. The hydraulic model is a dynamically linked one-dimensional / two-dimensional numerical model that covers approximately 70 km of the Burnett River from Claude Wharton Weir to the Paradise Dam. The layout of the TUFLOW hydraulic model is presented in Figure 4-3.

The validity of the hydrologic model was investigated by testing the performance of the hydrologic model against a range of historical flood events. The hydraulic model was calibrated to Gayndah's worst flood in recorded history, the February 1942 flood event. For the calibration of the hydraulic model, substantial information in relation to the February 1942 flood event was collected including recorded rainfall and streamflow data, flood marks and information on overlands flow patterns and inundation duration. Valuable information regarding the February 1942 event was obtained from interviews with residents of the Gayndah Shire (Resident Survey), including numerous flood marks throughout the township and descriptions of overlands flow patterns and inundation durations. The model calibration focussed on replication of peak flood levels and inundation patterns.

**Design Flood Assessment**

The calibrated flood models (hydrological and 2D/1D hydraulic) were then used to simulate a range of design flood events (i.e. 5%, 2%, 1%, 0.5% and 0.2% AEP flood events as well as the Probable Maximum Flood Event). Design flood events are hypothetical floods representing a specific likelihood of occurrence (for example 1% Annual Exceedance Probability flood). Design flood events are applicable to present date (i.e. 2007).

Flood behaviour was examined and flood maps were produced for each event showing levels, depths, velocities and velocity-depth products. Flood maps are presented in the Drawing Addendum (Volume 2 of the Report). Peak flood levels at key locations in the township are presented in Table 6-12.

Analysing the design flood events, the following is noted:

- During flood events, floodwaters from the Burnett River backfill into Oaky Creek and to a smaller extent into the numerous gullies along the banks of the Burnett River. This backfilling is the main mechanism of flooding in the township for relatively frequent flood events.
- The model results indicate that the flow path from the showgrounds towards Oaky Creek, as experienced during the 1942 flood event, does not occur for the flood events up to the 1% AEP event.
- From flood events with an AEP of 1% or greater, water levels in the reservoir of Claude Wharton Weir exceed 104.8mAHD and a flow path over the floodplain near Meson Street develops. As a result, not the entire river discharge flows over the weir of Claude Wharton Weir. The proportion of the river discharge that bypasses the weir increases with increasing flood magnitude.

**Climate Change**

The design flood events are applicable to present date and as such do not take into account potential future impacts of climate change. For Gayndah, climate change is likely to include increased extreme runoff of the Burnett River due to increases in extreme rainfall intensity in the Burnett River catchment.

Based on review of national and international publications on climate change impacts, it is advised that, for a planning horizon of 50 years (reference year 2057, a climate change allowance of 20% is applied to the present peak flow estimates (i.e. increase river peak flow discharges of design floods by 20%). It is recommended that for town planning purposes and development assessments in Gayndah, consideration is given to design flood events with a climate change allowance of 20%.

No modelling investigations were undertaken to assess potential impacts of climate change on the flood behaviour of the Burnett River. Nevertheless, an estimate of the 1% AEP event with climate change impact was made. For a planning horizon of 50 years (to 2057), the 0.5% AEP design flood event (without climate change allowance) is considered to be representative for the 1% AEP event with climate change allowance.

**Flood Hazard Assessment**

Flood Hazard is the term used to describe the potential risk to life and limb and potential damage to property resulting from flooding. The definition of flood hazard over the floodplains is important input to the development of a Flood Inundation Management Plan and town planning.

The following Flood Hazard categories were adopted for the Gayndah Flood Study:

- Low Hazard
- High hazard – Wading Unsafe
- High hazard – Depth
- Extreme hazard – Floodway (VxD > 1 $m^2/s$)
- Extreme hazard – Flow Velocity (V > 2 m/s)

Details on the definition of the adopted Flood Hazard categories are provided in Section 7.2. Using the Flood Hazard categorization above, Flood Hazard Maps for the design flood events considered were prepared. These Flood Hazard maps are presented in Drawing II-25 to Drawing II-30 In Volume 2.

**Development Control Planning**

It is recommended that GSC revises its Planning Scheme to incorporate improved floodplain risk management into the Scheme. For town planning in Gayndah, adoption of the Planning MATRIX Approach is recommended. The Planning MATRIX Approach distributes land-uses within the floodplain and controls development to minimise the flood risk to people and to property damages. Definition of Flood Hazard zones (areas of differing flood hazard levels based on the Defined Flood Events) forms a key component of the Planning MATRIX Approach.

The Defined Flood Event (DFE) represents the flood event adopted by local government for the management of development in a particular locality. For Gayndah, the recommended Defined Flood Event is the 1% EAP design flood event plus allowance for potential climate change impacts. For a planning horizon of 50 years (developments with a life cycle to 2057), the flood maps of the 0.5% EAP design flood event are considered to be representative of the 1% EAP flood event with climate change allowance.

Preliminary planning matrices developed for GSC are contained in Appendix F for each of the discrete land use categories. The Planning Matrices show the compatibility of various land uses for various flood hazard levels and specifies relevant control measures related to flooding. It is intended that the planning matrix be utilised by those Council officers assessing or advising on development applications. Instructions on the use of the GSC planning matrices are provided in Section 8.8

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# GLOSSARY

**Annual exceedance probability (AEP)** — The probability of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 $m^3/s$ has an AEP of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 $m^3/s$ (or larger) occurring in any one year.

**Australian Height Datum (AHD)** — National survey datum corresponding approximately to mean sea level.

**Average annual damage (AAD)** — Depending on its size (or severity), each flood will cause a different amount of flood damage. The annual average damage is the average damage 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 average annual damage provides a basis for comparing the effectiveness of different floodplain management measures (i.e. the reduction in the annual average damage).

**Average recurrence interval (ARI)** — The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20yr ARI design flood will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (see also annual exceedance probability).

**Catchment** — The catchment at a particular point is the area of land that drains to that point.

**DEM** — Digital Elevation Model - a three-dimensional model of the ground surface.

**Defined Flood Event** — The flood event adopted by a local government for the management of development in a particular locality. The DFE is generally not the full extent of the flood prone land.

**Design floor level** — The minimum (lowest) floor level specified for a building.

**Design flood** — A hypothetical flood representing a specific likelihood of occurrence (for example the 100 year or 1% probability flood).

**Development** — Existing or proposed works that may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.

**Discharge** — The rate of flow of water measured in terms of volume over time (i.e. the amount of water moving past a point). Discharge and flow are interchangeable.

**Effective warning time** — The available time that a community has from receiving a flood warning to when the flood reaches them.

**Flood** — Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.

**Flood awareness** — An appreciation of the likely threats and consequences of flooding and an understanding of any flood warning and evacuation procedures. Communities with a high degree of flood awareness respond to flood warnings promptly and efficiently, greatly reducing the potential for damage and loss of life and limb. Communities with a low degree of flood awareness may not fully appreciate the importance of flood warnings and flood preparedness and consequently suffer greater personal and economic losses.

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| **Flood damage** | The tangible and intangible costs of flooding. |
| **Flood behaviour** | The pattern / characteristics / nature of a flood. |
| **Flood frequency analysis** | An analysis of historical flood records to determine estimates of design flood flows. |
| **Flood fringe** | Land that may be affected by flooding but is not designated as floodway or flood storage. |
| **Flood hazard** | The potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies with circumstances across the full range of floods. |
| **Flood level** | The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum). Also referred to as "stage". |
| **Flood liable land** | See flood prone land. |
| **Floodplain** | Land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood (PMF) event. |
| **Floodplain management** | The co-ordinated management of activities that occur on the floodplain. |
| **Floodplain management measures** | A range of measures that are aimed at reducing the impact of flooding. This can involve reduction of flood damages, disruption and psychological trauma. |
| **Floodplain management plan** | A document outlining a range of measures aimed at reducing the flood risk. The plan is the principal means of managing the risks associated with the use of the floodplain. The plan usually contains both written and diagrammatic information describing how particular areas of the floodplain are to be used and managed to achieve defined objectives. |
| **Floodplain management scheme** | A floodplain management scheme comprises a combination of floodplain management measures. In general, one scheme is selected by the floodplain management committee and is incorporated into the plan. |
| **Flood planning levels (FPL)** | Flood planning levels selected for planning purposes are derived from a combination of flood levels and a freeboard. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of landuse and for different flood plans. As FPLs do not necessarily extend to the limits of flood prone land, floodplain risk management plans may apply to flood prone land beyond that defined by the FPLs. |
| **Flood prone land** | Land susceptible to inundation by the probable maximum flood (PMF) event. The flood prone definition should not be seen as necessarily precluding development. Floodplain Management Plans should encompass all flood prone land (i.e. the entire floodplain). |
| **Flood proofing** | Measures taken to improve or modify the design, construction and alteration of buildings to minimise or eliminate flood damages and threats to life and limb. |
| **Flood source** | The source of the floodwaters. |
| **Flood storages** | Floodplain areas that are important for the temporary storage of floodwaters during a flood. |

| | |
|---|---|
| **Floodway** | Those areas of the floodplain that carry significant volumes of floodwaters during a flood. |
| **Freeboard** | A factor of safety usually expressed as a height above flood level thus determing a flood planning level. Freeboard tends to compensate for factors such as wind/boart wave action, localised hydraulic effects and uncertainties in the design flood levels. |
| **Historical flood** | A flood that has actually occurred. |
| **Hydraulics** | The term given to the study of water flow in rivers, estuaries and coastal systems. |
| **Hydrograph** | A graph showing how a river or creek's discharge or water level changes with time. |
| **Hydrology** | The term given to the study of the rainfall-runoff process in catchments. |
| **Peak flood level, flow or velocity** | The maximum flood level, flow or velocity occurring during a flood event at a particular location. |
| **Probable maximum flood (PMF)** | An extreme flood deemed to be the maximum flood likely to occur. |
| **Probability** | A statistical measure of the likely frequency or occurrence of flooding. |
| **RORB** | Hydrological computer model software. |
| **Runoff** | The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek. |
| **Stage** | See flood level. |
| **Stage hydrograph** | A graph of water level over time. |
| **TUFLOW** | Fully two-dimensional and one dimensional unsteady flow hydraulic modelling software. |
| **Velocity** | The speed at which the floodwaters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section if a one-dimensional solution is used; and depth average if a two-dimensional solution is used. |
| **Water level** | See flood level. |

# 1 INTRODUCTION

## 1.1 Background

The Burnett River is located in south-east Queensland and its river system has a total catchment area of approximately 33,000 km$^2$. The catchment is bound to the north by the catchments of the Fitzroy River, to the northeast by the Kolan River, to the west and southwest by the Dawson River and the Condamine River, and to the south by the Brisbane River and the Mary River. Gayndah is situated on the banks of the Burnett River and is a central point in the Burnett region. Figure 2-1 shows the locality of Burnett River and the study area of the Gayndah Flood Study.

At Gayndah, the Burnett River is as a deep incised channel of approximately 20 m deep and 200 m to 250 m wide and most of the year, the river flows are low and water depths in the channel at gayndah are shallow. During flood events, the river swells sharply and the river channel becomes a fast-flowing watercourse.

The Burnett River caused flooding problems in the township of Gayndah at a number of occasions. Gayndah experienced its worst flood in recorded history in February 1942. In this event, floodwater broke over the Showground and became a wide stream towards Oaky Creek. Large areas of the township, both north and south of the river, were inundated or were enclosed by deep floodwaters. Damage to commerical and residential property was substantial.

Consideration of options to effectively manage the flood risk in Gayndah, and planning for future development, requires an understanding of the flood behaviour. To obtain a better understanding of the flood behaviour of the Burnett River and define the flood risk in Gayndah from flooding of the Burnett River, Gayndah Shire Council has commissioned WBM to undertake a Flood Study for Gaydah. The Flood Study was in part funded under the Federal Department of Transport and Regional Services "Natural Disaster Risk Management Studies Program", which is administrated by The Queensland Department of Emergency Services. This report discusses the outcomes of the Flood Study.

## 1.2 Study Objectives

The key objectives of the Gayndah Flood Study were as follows:

- To develop a state-of-the-art numerical flood model of the Burnett River within the study area that is capable of accurately replicating and predicting the flood behaviour of the Burnett River;
- To define the existing flood behaviour of the Burnett River in Gayndah;
- To develop a basis for the development of Council's planning controls for developments within the study area;
- To improve community awareness of risks associated with flooding in Gayndah.

## 1.3 Study Approach

The main stages of the Gayndah Flood study are presented in Figure 1-1 and a description of the stages is given below. It is worth noting that community consultation and involvement was a key element throughout all stages of the Flood Study.

Throughout the course of the study, community members had the opportunity to give input and feedback to the Study Team. In addition, three Community Open Sessions were held at key study phases. During the Community Open Sessions, the Project Team reported key progress of the Gayndah Flood Study to the community and provided individuals the opportunity to discuss their flood management issues on an individual basis.

Furthermore, a Resident Survey was conducted. The Resident Survey involved one-to-one interviews with residents of Gayndah in which information regarding historical flood events in Gayndah was collected and community's flooding concerns and issues were gauged.


**Figure 1-1 Study Approach – Gayndah Flood Study**

### 1.3.1 Gayndah Study Advisory Group

Gayndah Shire Council formed a Study Advisory Group (SAG) to oversee the Gayndah Flood Study and to ensure that issues important to the local community have been addressed. The SAG comprised:

- Local Councillors;
- Council officers;
- State Government representatives from DNRM and DES.

A series of discussion papers were presented and reviewed during the course of the study. These discussion papers represent the collective ideas of the consultant (BMT WBM), the SAG and the community.

In addition, regular meetings were held in Gayndah with the SAG at which the findings documented in the discussion papers were discussed and potential issues were identified at an early stage. The meetings were an important tool in ensuring that each member of the SAG understood the study methodology and provided opportunities for member of the SAG to manage the direction of study.

During the study, it was identified that the study would benefit from review by a town planning specialist. This resulted in review of the discussion papers by Insite Strategies, a town planning and development consultancy.

### 1.3.2 Data Collection

The development and calibration of the Burnett River Flood Model required the collection of various types of data, including:

- Topographical information
- Historical Flood data
- Site inspections
- Resident Survey
- Information on hydraulic structures

Topographical information was required for the development of a Digital Elevation Model (DEM), which is a three-dimensional model of the ground surface of the study area. Data for the DEM was obtained from existing photogrammetry, ground surveys (from Council's Sewerage Plans) and river cross-sections.

Information on hydraulic structures was obtained from relevant government bodies and organisations. Construction drawings of the bridge structures in the study area were made available from Department of Main Roads and required details on the dams and weirs were obtained from SunWater.

### 1.3.3 Assessment of Existing Inundation Behaviour

A flood model of Burnett River, its floodplains and associated tributaries was developed for the purposes of defining the flood behaviour and assessing flood hazard and vulnerability of the study area. Figure 2-1 shows the locality of Burnett River and the study area of the Gayndah Flood Study.

The flood model comprises of a hydrologic model and a hydraulic model.

The hydrologic model determines the runoff response of the Burnett River catchment to a particular rainfall event. The primary output from the hydrologic model are hydrographs for varying locations along the waterways describing the quantity, rate and timing of stream flow that results from rainfall events. These hydrographs then become a key input into the hydraulic model.

The hydraulic model simulates the movement of floodwaters through waterway reaches, storage areas and hydraulic structures. The hydraulic model calculates flood levels and flow patterns and also models the complex effects of backwater, overtopping of embankments, waterway confluences, bridge constrictions and other hydraulic structure behaviour.

In conjunction with SunWater, a hydrologic model of the Burnett River catchment and associated tributaries was developed using the modelling software RORB. WBM then developed a hydraulic model of approximately 70 km of the Burnett River using the software TUFLOW. The hydraulic model is a dynamically linked one-dimensional two-dimensional hydrodynamic numerical model.

To investigate the validity of the hydrologic model, the performance of the hydrologic model was tested against a range of historical flood events. The hydraulic model was calibrated to Gayndah's worst flood in recorded history, the February 1942 flood event. The model calibration/verification illustrated the flood model's ability to accurately reproduce historical flood patterns.

The calibrated flood model was then used to simulate a range of design flood events. Design flood events are hypothetical floods representing a specific likelihood of occurrence (expressed as a percentage). For this study, six design flood events were analysed, ranging from the 5% Annual Exceedance Probability (AEP) to the Probable Maximum Flood (PMF).

### 1.3.4 Interpretation of Inundation Behaviour for Development Control

On the basis of the results of the design flood analysis, a Flood Hazard Assessment was undertaken. Flood Hazard is the term used to describe the potential risk to life and limb and potential damage to property resulting from flooding. Determining the level of flood hazard is of considerable significance to the appropriateness of a site for various land uses.

Outcomes of the Flood Hazard Assessment were used to develop an approach to control development for Gayndah.

### 1.3.5 Reporting

Discussion papers detailing the methodology and findings at milestones throughout the course of the study were issued to each member of the SAG and presented at SAG meetings. The discussion papers were an important tool in ensuring that each member of the SAG understood the study methodology and gave members of the SAG the opportunity to manage the progress of the Flood Study.

This Draft Report of the Flood Study will be presented to the SAG and feedback is sought before issuing the Final Report.

# 2 STUDY AREA

## 2.1 Description of Study Area

The study area for the study comprises the township of Gayndah in the Gayndah Shire. Gayndah is located 360km northwest of Brisbane on the Burnett Highway (A3) and is situated on the banks of the Burnett River. The township is a central point in the Burnett region and has approximately 3000 inhabitants. The locality of Burnett River and the study area of the Gayndah Flood Study is shown in Figure 2-1.

Figure 2-2 presents an aerial photograph of the study area. From Figure 2-2 it can be seen that most of the buidlings (eg. houses and shops) in Gayndah are located on the south bank of the Burnett River and west of Oaky Creek. Around the township there are numerous large-scale citrus plantations. The remaining part of the study area is predominantly rural with low to medium density vegetation.

The Burnett River runs through Gayndah as a deep incised channel approximately 20 m deep and 200 m to 250 m wide. Near the township of Gayndah, the riverbed is heavily vegetated with gravel banks. Just upstream of township of Gayndah, there is Claude Wharton Weir, a dam in the Burnett River. The storage capacity of the Claude Wharton Weir is 12 800 ML at a FSL of 94.4 m AHD.

Photographs of key locations throughout the study area are included in Appendix B of this report.

## 2.2 Catchment Description

The Burnett River system has a total catchment area of approximately 33,000 km$^2$ and is shown in Figure 2-3. The catchment is bound to the north by the catchments of the Fitzroy River, to the northeast by the Kolan River, to the west and southwest by the Dawson River and the Condamine River, and to the south by the Brisbane River and the Mary River.

The major tributaries of the Burnett River are:

- Three Moon Creek and the Upper Burnett to the north;
- The Nogo River to the north-west;
- Auburn River to the south-west; Boyne and Stuart Rivers to the south; and
- Barker and Barambah Creeks to the south-east.

The mean annual rainfalls, based on 50 years of record, vary significantly throughout the catchment. The northern tributary catchments are the wettest area in which the mean catchment rainfalls vary from 1,000 mm in the Upper Burnett to 800 mm in Three Moon Creek. The drier middle and southern tributary catchments of Barker and Barambah Creeks and the Stuart and Boyne River recorded 750mm on average. The south-eastern tributary catchment of Auburn River recorded on average 700 mm. The driest area of the Burnett River catchment is the northwestern tributary catchment of the Nogo River, which recorded only 650 mm.

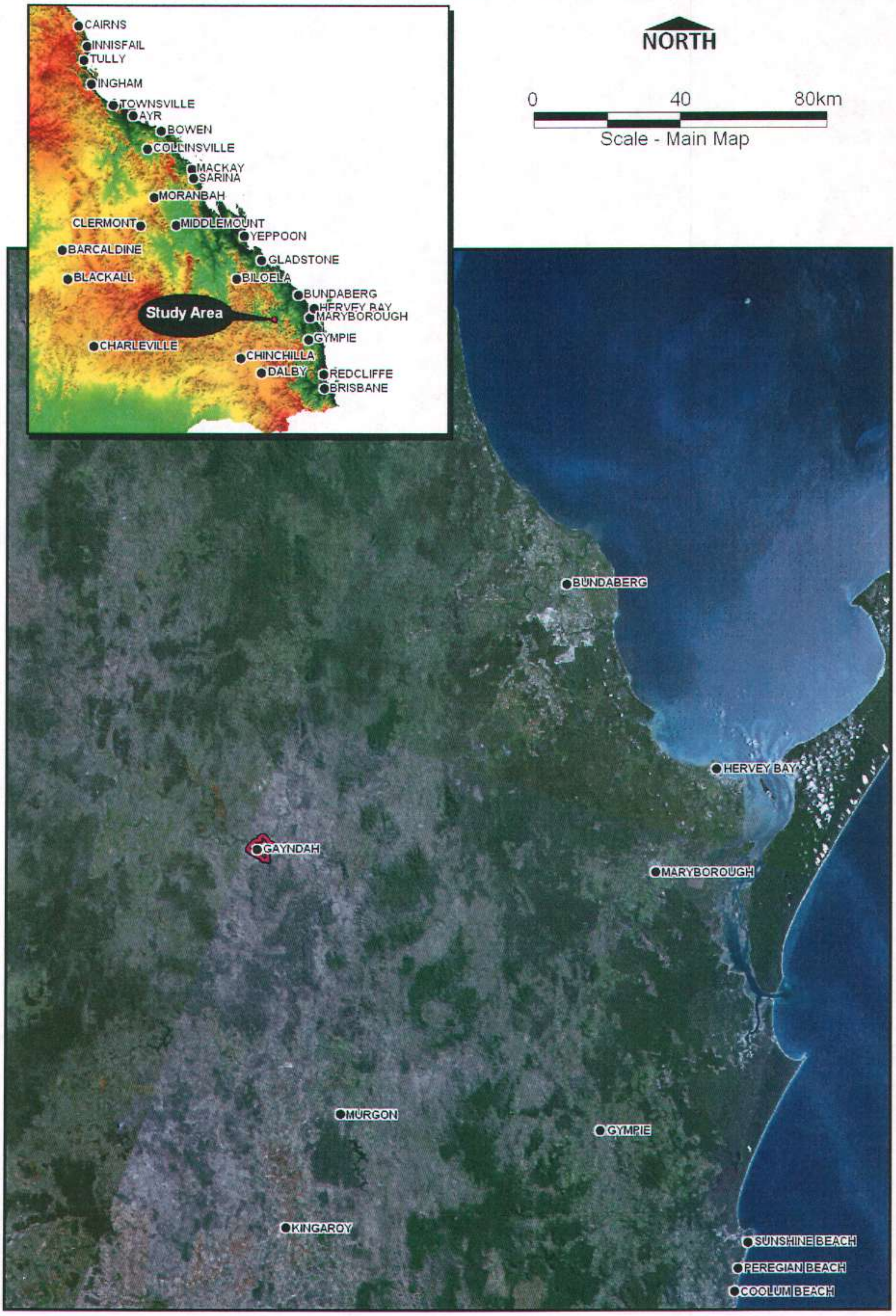
Land use in the Upper Burnett River catchment and its western tributary catchments are mainly associated with agricultural production. This ranges from cattle grazing in the drier western part of the catchment, to cultivation in the Upper Burnett, which increases in intensity further down to the Lower Burnett. The cultivation is largely associated with the supply of cattle fodder in the highland, while citrus, cotton, tomatoes, peanuts and sugarcane are grown in the areas of Middle Burnett, Lower Burnett and southern area tributary catchments. Minor land uses include power supply and mining industries in the upper catchments of the Barker/Barambah Creek system and the Stuart/Boyne River system.

Water storage development in the Burnet River catchment has been occurring gradually over the past 40 years, mainly for agriculture developments with small industrial demands for mining and power generation. Currently there are in excess of 30 existing storages with full supply capacities ranging from 30 ML (Monto Weir) to 300 000 ML (Paradise Dam).

The two main storages of interest in the modelled area are Paradise Dam and Claude Wharton Weir.

Paradise Dam is located at Adopted Middle Thread Distance (AMTD) 131.4 km on the Burnett River, approximately 40 km north-east of Gayndah. Its main purpose is to supply water for irrigation, although a portion of the available yield will be utilised to provide high priority water. The storage capacity of the dam is 300 000 ML at a Full Supply Level (FSL) of 67.6 m AHD.

Claude Wharton Weir is located at AMTD 202.4 km on the Burnett River, just upstream of the township of Gayndah. The storage capacity of the weir is 12 800 ML at a FSL of 94.4 m AHD.




**Locality Map of The Study Area** **Figure 2-1**

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**Aerial Photograph of The Study Area** **Figure 2-2**

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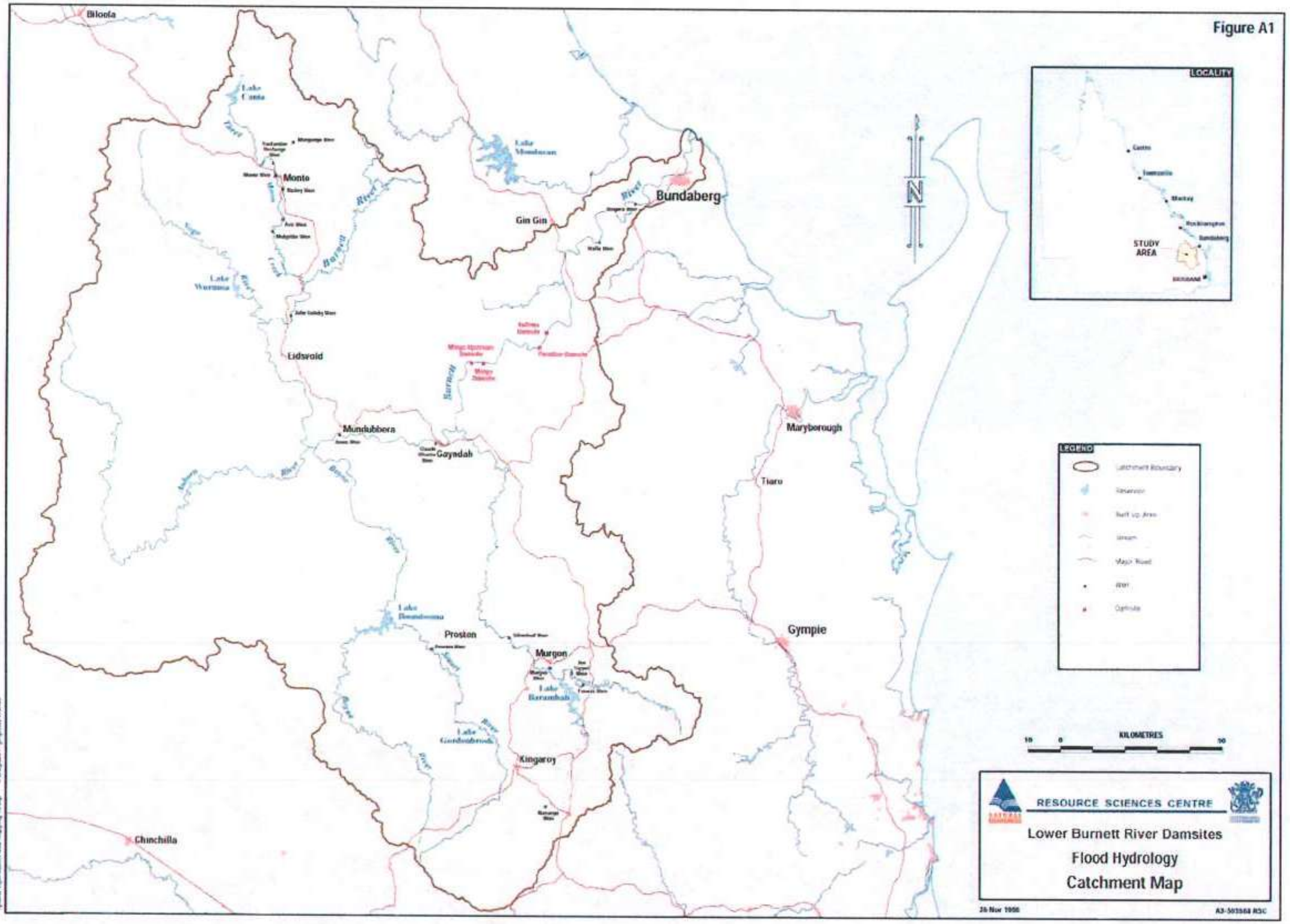



**Figure 2-3 Burnett River Catchment Map - From DNRM (1998)**

# 3 DATA COLLECTION

The development and calibration of the Burnett River Flood Model required the collection of various types of data. Data that was collected for this study included topographical data, information on historical flood events (recorded rainfall, flood levels and flows) and an existing hydrological model of the Burnett River Catchment.

Furthermore, detailed site inspections of the study area were undertaken by study team members and a survey of Gayndah Shire's residents was conducted to gather historical data. Key information collected for the Flood Study is discussed below.

## 3.1 Site Inspection

In November 2006, a detailed site inspection was undertaken by members of the study team to obtain a good appreciation of the study area and identify key features that may have a significant effect on the flood behaviour in the study area. The site inspection included riverbank and floodplain walkovers along selected sections of the Burnett River within Gayndah Shire.

Additional site inspections were undertaken in April 2007 and September 2007. Photographs of the study area, taken in November 2006, are included in Appendix B of this report.

## 3.2 Resident Survey

As part of the Gayndah Flood Study, members of the study team conducted a Resident Survey. The Resident Survey involved one-to-one interviews with residents of Gayndah in which information regarding historical flood events in Gayndah was collected.

For the Resident Survey 20 residents were interviewed. The interviews were designed to obtain information on historical flood event, in particular the 1942 event. A summary of the outcomes of the Resident Survey is included in Appendix A of this report.

Valuable information in relation to the February 1942 flood event was obtained, including:

- Numerous flood marks throughout the township of Gayndah;
- Information regarding time of inundation and inundation duration;
- Identification of flow paths;
- Estimates of peak velocities at key locations on the floodplain.

On the basis of the Resident Survey, a reconstruction of the February 1942 flood event was prepared and is also included in Appendix A.

Flood marks of the 1942 event that were identified during the resident survey are shown in Figure 3-1. A description of the identified flood marks in Gayndah and their levels are shown in Table 3-1. The flood marks were surveyed by Surveyors at Work in January 2007.

**Table 3-1 Flood Marks in Gaydah**

| Flood mark ID | Description of observation location | Surveyed level [mAHD] |
|---|---|---|
| FM1535 | 96 Capper Street, bottom floor boards | 104.21 |
| FM1582 | Toe of tree, opposite of 445 Little Woodmillar Road | 104.12 |
| FM1583 | Toe of pepperina tree in yard of 72 Queen Street | 105.65 |
| FM1590 | Toe of tree near shed, 83 West Burnett Terrace | 105.46 |
| FM1591 | 1st step from top of stairs of convent (St. Joseph School) | 105.26 |
| FM1585 | 35 Arthur Street, 2nd step front door stairs | 105.19 |
| FM1571 | 21 Bamboo Street, bottom floor boards | 103.44 |

## 3.3 Topographical Data

Several sources of topographic data were required for the development of the hydraulic model. The three primary topographic data sources are: Gayndah Shire Council sewerage plans, photogrammetry data and SunWater's Burnett River MIKE11 model cross sections. A description of the primary topographic data sources used for this study is presented below.

### 3.3.1 Gayndah Shire Council Sewerage Plans

Gayndah Shire Council Sewerage Plans were made available by Gayndah Shire Council. The sewerage plans contain surveyed ground levels (spot heights), 1-foot interval contours and surveyed floor levels. The data is based on a survey undertaken by J.F.H. Murray & Associates in 1964.

In total, 38 of 48 sheets were obtained from Gayndah Shire Council. The 38 sheets obtained cover a large proportion of the township of Gayndah. The 38 sheets were obtained in hardcopy and had a scale of 1:480 (1": 40'). The sheets were scanned and registered in a GIS. Surveyed ground levels (spot heights), 1-foot interval contours and floor levels were digitised. The elevations on sewerage plans are in feet above State Datum, which required conversion to metres above Australian Height Datum (m AHD).

The digitised spot heights and 1-foot interval contours were utilised to create a Digital Elevation Model (DEM) with a resolution of 2.5 m. The resulting DEM is shown in Figure 3-2.

To verify the elevations from the sewerage plans, ground levels on selected locations were re-surveyed in Jaunary 2007 (by Surveyors at Work). The levels are compared in Table 3-2.

From Table 3-2, it can be concluded that the levels from the sewerage plans approximate the surveyed ground levels with a relatively high level of accuracy. This provides confidence in the accuracy of the sewerage plans.

In addition to the ground elevations, the sewerage plans also contain an approximation of the flood extent of the February 1942 flood event.

Table 3-2 Verification of Accuracy of GSC Sewerage Plan Levels

| Description | Elevation from Sewerage plans [m AHD] | Elevation surveyed in Jan 2007 [m AHD] | Difference [m] |
|---|---|---|---|
| Floor level of the Burnett Hotel | 104.86 | 104.96 | +0.10 |
| Floor level of Council Chambers | 106.15 | 106.09 | -0.06 |
| Benchmark 37 (Meyer Street) | 105.01 | 105.03 | +0.02 |
| Benchmark 35 (Bamboo Street) | 100.74 | 100.76 | +0.02 |

### 3.3.2 Photogrammetry Data

Outside the township of Gayndah the topography has been defined by 1:20,000 scale photogrammetry data. The photogrammetry was obtained from SunWater. This data has a specified accuracy of ± 0.6 m in both vertical and horizontal direction.

The photogrammetry covers an area of approximately 100 km$^2$ including the entire domain of the two-dimensional part of the hydraulic model. The extent and ground elevations of the DEM derived from the photogrammetry is shown in Figure 3-3.

To analyse the accuracy of the photogrammetry data near Gayndah, the elevations from the photogrammetry have been compared with the sewerage plans. The area that was used to compare the elevations is shown in Figure 3-4.

A statistical comparison between the photogrammetry and GSC Sewerage Plans is shown in Figure 3-5. The mean deviation between the DEM from the photogrammetry and the DEM from GSC Sewerage Plan is 0.3 m, which means that the elevations from the sewerage plans are on average 0.3 m higher than the elevations from photogrammetry. The Root Mean Square (RMS) deviation of the height difference is 0.8 m (based on 45,728 samples).

Based on the comparison with the elevation from the sewerage plans, the photogrammetry is considered to have an acceptable accuracy for defining the topography outside of the township of Gayndah. Within the township of Gayndah, the elevations from the sewerage plans are used for the hydraulic modelling.

### 3.3.3 Burnett River MIKE11 Model Cross Sections

For the one-dimensional river network of the hydraulic model, cross sections from SunWater's Burnett River MIKE11 model were used. The river channel cross section data used in this MIKE11 model was produced in the 1960's by photogrammetry. The accuracy of this data is unknown, as the flying height of the contour data was not known.

For the Burnett River river section from immediately downstream of Gayndah to the Paradise Dam site, 49 river cross sections were obtained from the MIKE11 hydraulic model. The averaged spatial distance between the cross section is approximately 1.3 km.

To analyse the consistency of the MIKE11 cross sections with the DEM from the photogrammetry data, the four river channel cross-sections of the MIKE11 model closest to the study area were compared with cross section derived from the photogrammetry data. The four cross sections are compared in Figure 3-6 to Figure 3-9. It is noted that the precise location of the MIKE11 river cross sections was unknown, which introduces significant uncertainties in relation to comparison of the two data sources, especially in and around river bends where the riverbed tends to change substantially over a relatively short distance.

From Figure 3-6 to Figure 3-9, it can be concluded that the channel geometry (channel width and depth) is reasonably similar. The MIKE11 river channel cross sections tend to show slightly lower bed levels throughout the river channel.

## 3.4 Burnett River Catchment RORB Hydrological Model

In 1998 the Surface Water Assessment Group of the Department of Natural Resource and Mines (DNRM) developed a RORB runoff-routing model of the Burnett River catchment as part of the hydrologic investigation of the Lower Burnett River (DNRM, 1998).

The 1998 RORB runoff-routing model of the Burnett River catchment from DNRM was updated by SunWater in 2002 for their flood hydrology study of the Burnett River. This was undertaken as part of the design of the Paradise Dam water storage facility; (SunWater, 2002) and (SunWater, 2003).

This updated RORB model of the Burnett River catchment was obtained and used as a basis for the hydrological assessment for this study. The RORB model, including modifications made for this study, is discussed in Section 4.1 of this report.

## 3.5 Hydrometeorological Data

In 1998 the Surface Water Assessment Group of the Department of Natural Resource and Mines (DNRM) undertook a hydrologic investigation of the Lower Burnett River. For this study extensive hydrometeorological data was collected. The hydrometeorological data collected includes:

- Streamflow data from more than 50 gauging stations;
- Point rainfall data from numerous rainfall stations located in the Burnett River catchment; and
- Pluviograph data from 10 pluviograph stations.

A brief outline of the streamflow, rainfall and pluviograph data obtained by the 1998 study is given below. For further details, reference should be made to DNRM (1998).

### 3.5.1 Streamflow Data

In DNRM (1998), streamflow data at four stations, shown in Table 3-3, was obtained for the calibration of the RORB runoff-routing model of the Burnett River catchment.

**Table 3-3 Streamflow Gauging Stations Used for RORB Model Calibration**

| Station Number | Stream Name | AMTD (km) | Catchment Area (km$^2$) | Period of Combined Record |
|---|---|---|---|---|
| 136003 | Burnet River at Gayndah | 203.0 | 23,490 | 1954 – present |
| 136002 | Burnett River at Mount Lawless | 103.9 | 29,550 | 1910 – present |
| 136012 | Burnett River at Mingo Crossing | 154.5 | 30,500 | 1976 – 1988 |
| 136001 | Lower Burnet River at Walla | 98.7 | 32,445 | 1911 – present |

### 3.5.2 Rainfall Data

The 1998 study (DNRM, 1998) obtained rainfall data for the calibration storm events from a database of the DNR's Drought Research Group. The Drought Research Group's database consisted of a point rainfall data grid for the entire state, developed by interpolating between recorded data from the Bureau of Meteorology (BoM) rain gauges. Daily rainfall files for defined catchments and for particular locations in the system were compiled from the grid rainfall data by taking the mean of the daily rainfall at each grid point in the area of interest. The result was a file of the mean catchment or mean location rainfall for each day. Daily rainfall stations were utilised in this study to provide an indication of the depth of rainfall for historic storm events.

### 3.5.3 Pluviograph Data

The 1998 study (DNRM, 1998) obtained in excess of 10 pluviograph stations data from the BoM (Brisbane office), although some stations are located outside of the catchment area. Pluviograph data for events prior to 1990 were extracted from the database of the National Climatic Centre. Data for events after 1990 were supplemented by rainfall data collected from the BOM's Flood Warning Centre during the actual storm event.

## 3.6 Flood Gauge Records

For the calibration of the hydraulic model, flood gauge records of the February 1942 event were obtained and collated for this study. The flood gauge records at a number of locations along the Burnett River were obtained from a number of data sources including Bureau of Meteorology (http://www.bom.gov.au), the Department of Natural Resource and Mines (http://www.nrw.qld.gov.au), and various studies associated with the construction of the Paradise Dam; DNRM(1998), SunWater(2001) and SunWater(2002), SunWater(2003).

In addition, flood gauge data for Mount Lawless gauging station during the February 1942 event was obtained during the Resident Survey. The flood gauge data that was obtained during the Resident Survey was a copy of the original river gauge reading logbook of the Department of Irrigation & Water Supply for the period from 1938 to 1943. The river gauge reading logbook was made available by Mr. C. Greggery and his assistance in this matter is acknowledged.

Verification of the various water level measurements showed some deviations between the various data sources. For example, there is an uncertainty in the gauge zero datum of the flood gauge records of the Gayndah Gauging Station (Station number 136914). Databases from the Bureau of Meteology (owner of gauging station) report two gauge zero datums, namely 85.0 mAHD and 85.3 mAHD. Although it is confirmed that the datum at 85.3 mAHD was established during the most recent survey of the gauging board (2003), it is uncertain whether the flood gauge records are applicable to this datum. For this study, a gauge zero datum of 85.0 mAHD has been used.

The adopted peak flood levels and peak discharges from the river gauge records of the February 1942 event are shown in Table 3-4. The water level time series for the February 1942 event at Gayndah Gauging Station is shown in Figure 5-15. The recorded water level time series at Mt. Lawless Gauging Station is shown in Figure 5-16.

**Table 3-4 Obtained River Gauge Records for February 1942 Flood Event**

| Location | Station Number | Location AMTD [km] | Recorded peak level [m AHD] | Recorded peak discharge [m3/s] | Additional Types of Flood Records |
|---|---|---|---|---|---|
| Gayndah, near Claude Wharton Weir | 136003B | 203.0 | 105.91 | 15,225 | |
| Meson Street, Gayndah | 136914 | 200.1 | 104.66 | N/A | Water levels time series [from manual read Gauging boards] |
| Mount Lawless | 136002B | 183.9 | 92.97 | 17,055 | Hydrograph, Water levels time series [from manual read Gauging boards] |
| Mingo Crossing | 136012A | 154.5 | 69.42 | 16,380 | |
| Walla Weir | 136001 | 98.5 | N/A | 15,437 | Hydrograph |

## 3.7 Hydraulic Structures

Within the study area, a number of hydraulic structures that may have an impact on the flood behaviour of the Burnett River have been identified, namely three bridge structures and two dams.

The bridge three structures are:

- The Burnett Highway Bridge crossing the Burnett River in Gayndah;
- The Burnett Highway Bridge crossing Oaky Creek in Gayndah; and
- The Railway Bridge crossing the Burnett River at Mount Lawless.

The two dams are:

- Claude Wharton Weir in Gayndah; and
- Paradise Dam at Paradise

### 3.7.1 Bridge Structures

Both the Burnett River bridge crossing and the Oaky Creek bridge crossing have been replaced between February 1942 and present day. As this study considers both the situation during the February 1942 flood (calibration of hydraulic model) and the present situation (assessment of flood risk in Gayndah for present situation), it was required to obtain information on the bridge structures for both the situation in February 1942 and the present situation.

The Burnett River bridge structure that was present during the February 1942 flood was constructed in 1909 and was partially washed away during the February 1942 flood. Directly after the flood, the bridge was replaced by a temporary bridge structure that was there until 1990 when this temporary bridge structure was by the Les Baker Bridge. The Les Baker Bridge is the present bridge crossing over the Burnett River in Gayndah.

The bridge crossing over Oaky Creek in Gayndah that was present during the February 1942 event was constructed around 1934. In 1977, this bridge structure was replaced by the present bridge named the MacKenzie Bridge.

Details on the bridge structures of the Burnett Highway for both the situation in 1942 and 2007 were obtained from the Department of Main Roads. For the Les Baker Bridge, the MacKenzie Bridge and the bridge over Oaky Creek as present in 1942, construction drawings were obtained from the Department of Main Roads. These construction drawings were utilised to represent these hydraulic structures into the hydraulic model.

For the Burnett River bridge structure in 1942 no construction drawings could be made available. For representation of this bridge structure, historical photographs of the bridge and construction drawings of the temporary bridge structure were interpreted.

From a hydraulic viewpoint, the Burnett River Bridge crossing as present during the 1942 event was similar to the temporary bridge that was constructed in the months after the flood. The temporary bridge structure was a timber bridge structure with similar pier plan and deck level as the bridge structure that was present during the February 1942 event. Construction drawings of the temporary bridge structure over the Burnett River were obtained from the Department of Main Roads.

Details of the railway bridge structure at Mount Lawless were obtained during site inspections undertaken by members of the study team.

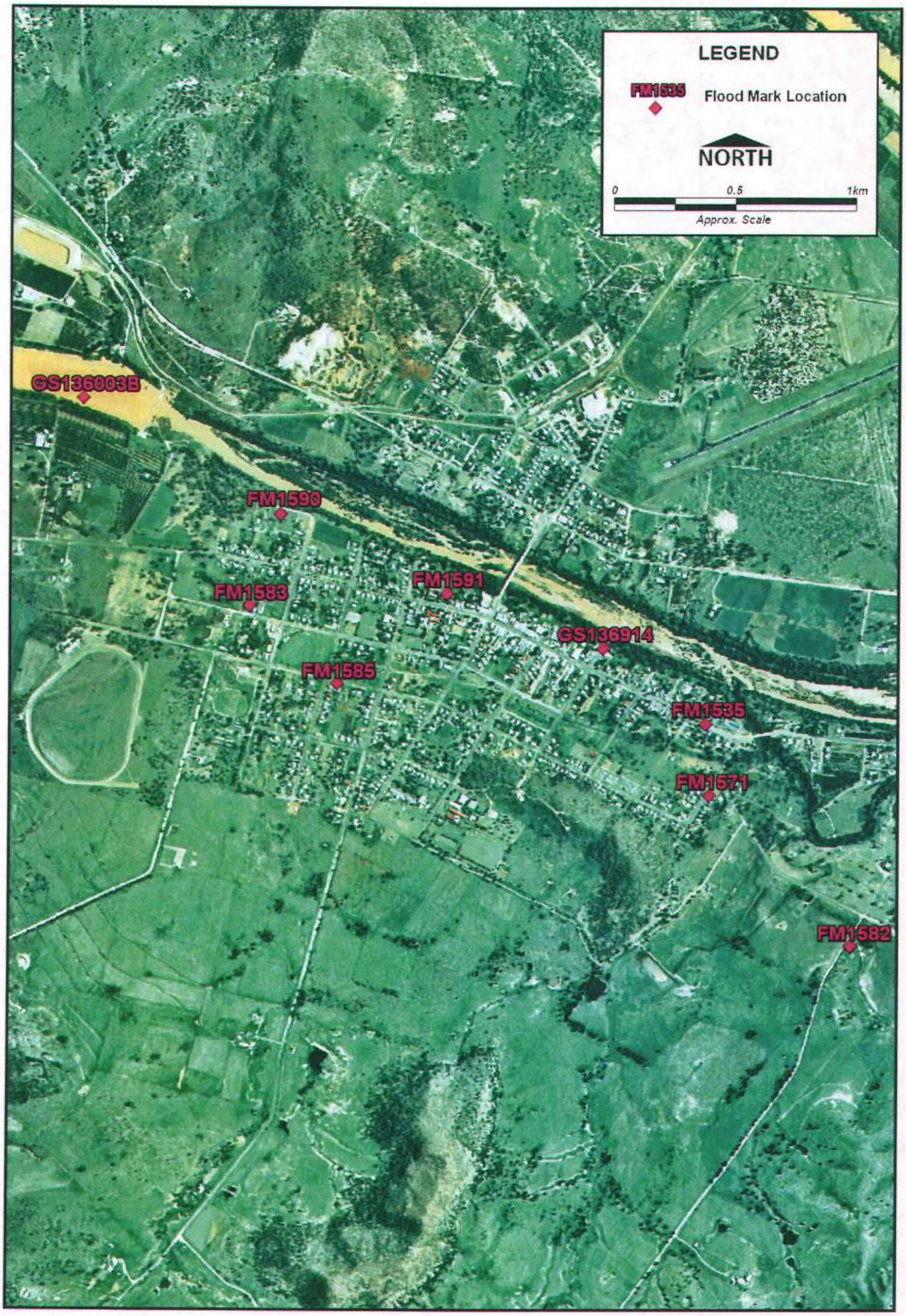
### 3.7.2 Dams

Two dam structures have been incorporated into the hydraulic model, namely the Claude Wharton Weir in Gayndah and the Paradise Dam near Paradise. Both dams were constructed in the last 20 years.

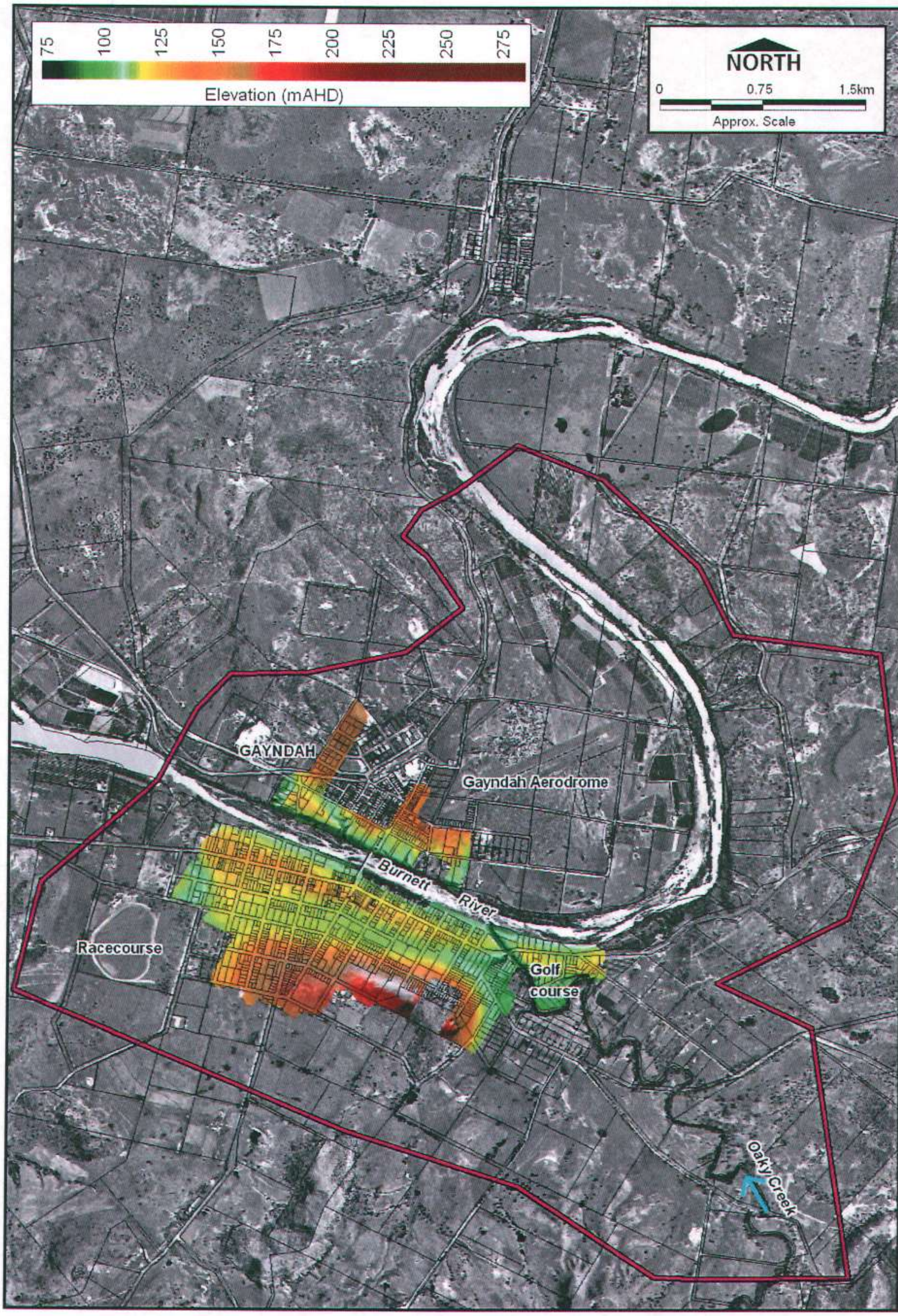
Paradise Dam is located at AMTD 131.4 km on the Burnett River, approximately 40 km north-east of Gayndah. Its main purpose is to supply water for irrigation, although a portion of the available yield will be utilised to provide high priority water. The storage capacity of the dam is 300 000 ML at a Full Supply Level (FSL) of 67.6 m AHD.

Claude Wharton Weir is located at AMTD 202.4 km on the Burnett River, just upstream of the township of Gayndah. The storage capacity of the weir is 12 800 ML at a FSL of 94.4 m AHD.

Details required for the implementation of both dams into the hydraulic model were obtained from SunWater, the owner/operator of the dams.



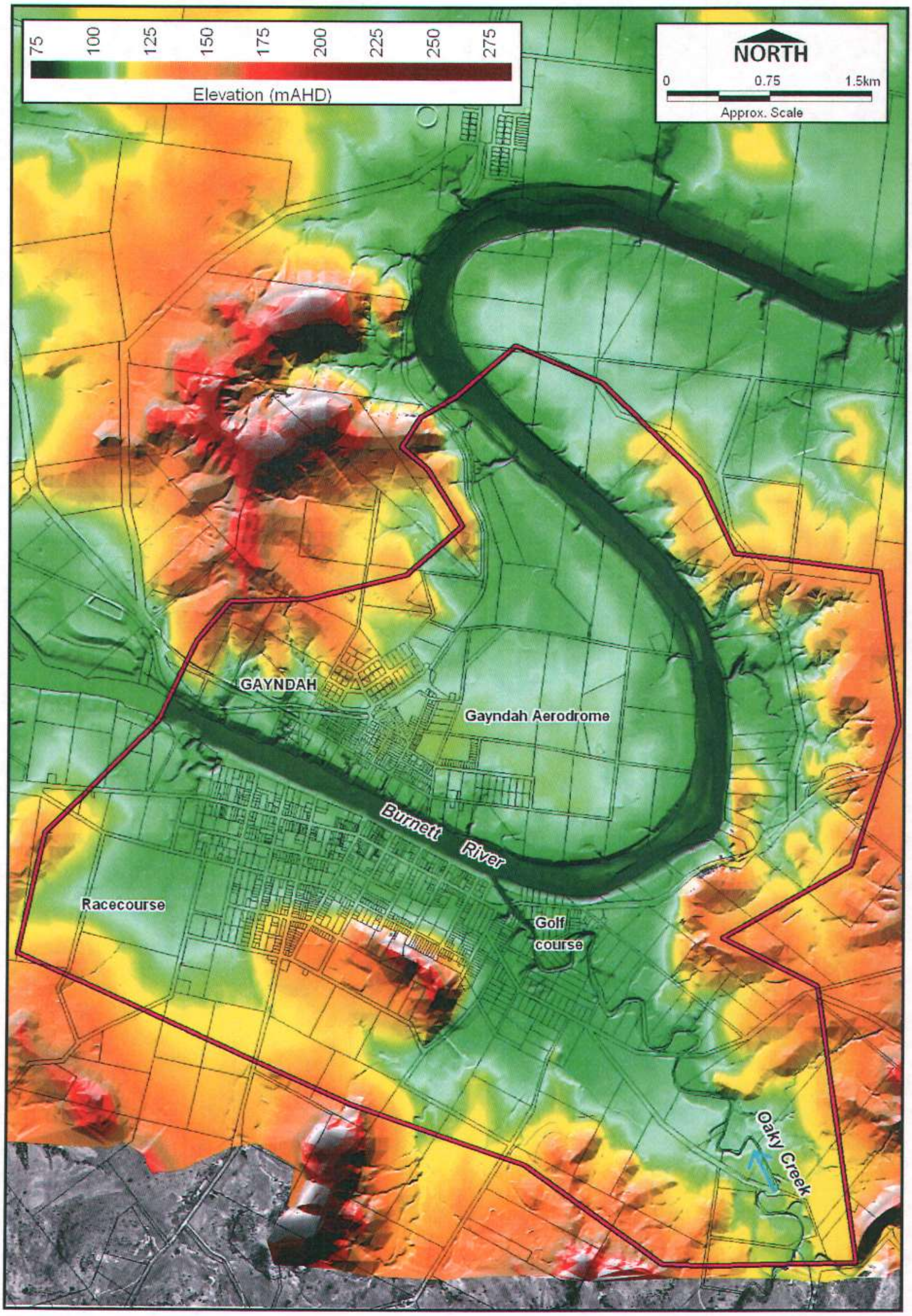

**Location Map of Flood Marks Identified** **Figure 3-1**



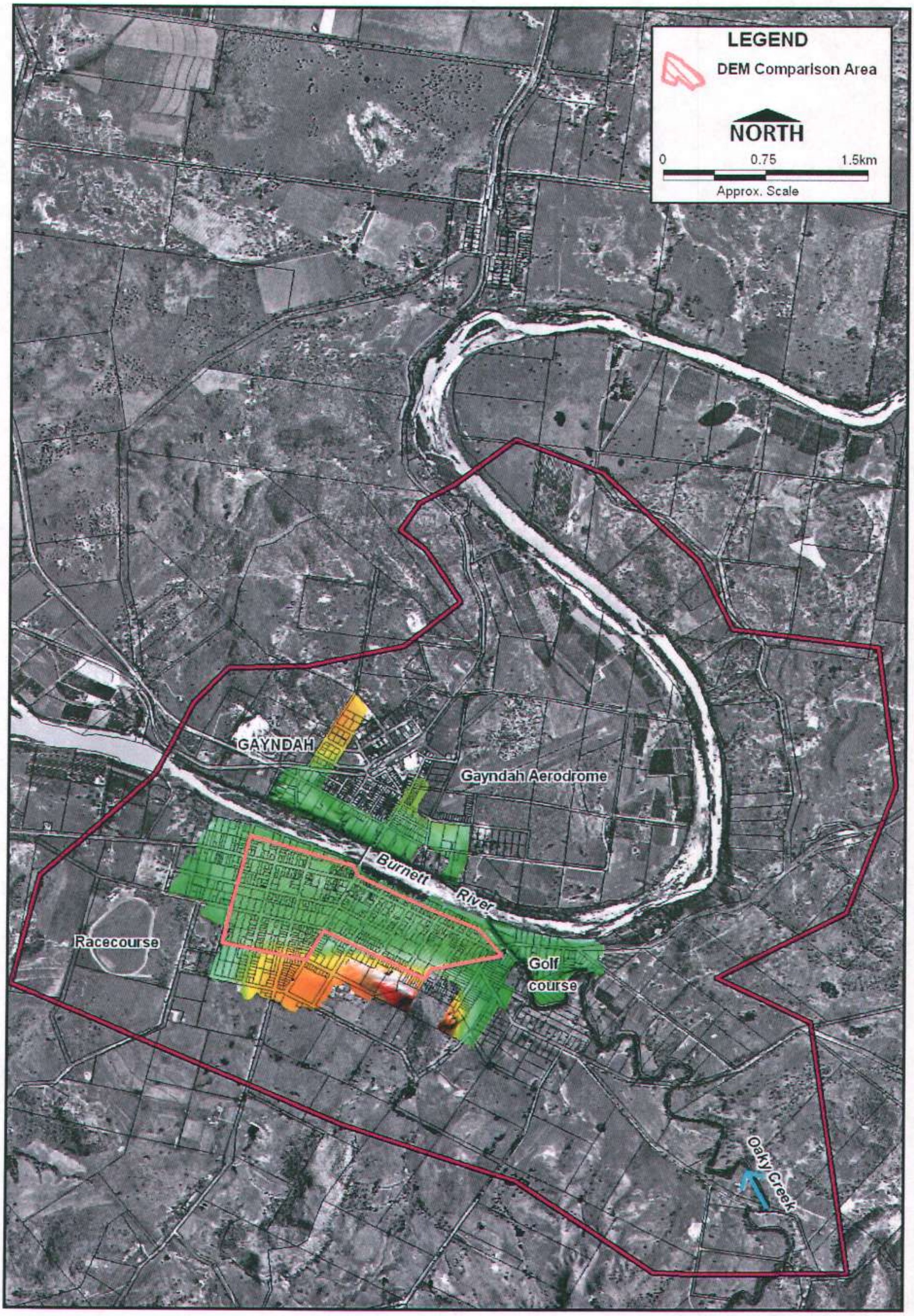

**DEM from Digitised Gayndah Shire Council Sewerage Plans**

**Figure 3-2**

I:\B16183_I_BRH Gayndah Flood Study GJR\DRG\FS_report\FLD_004_071119_DEM_sewerageplans.WOR




**DEM from Photogrammetry** **Figure 3-3**

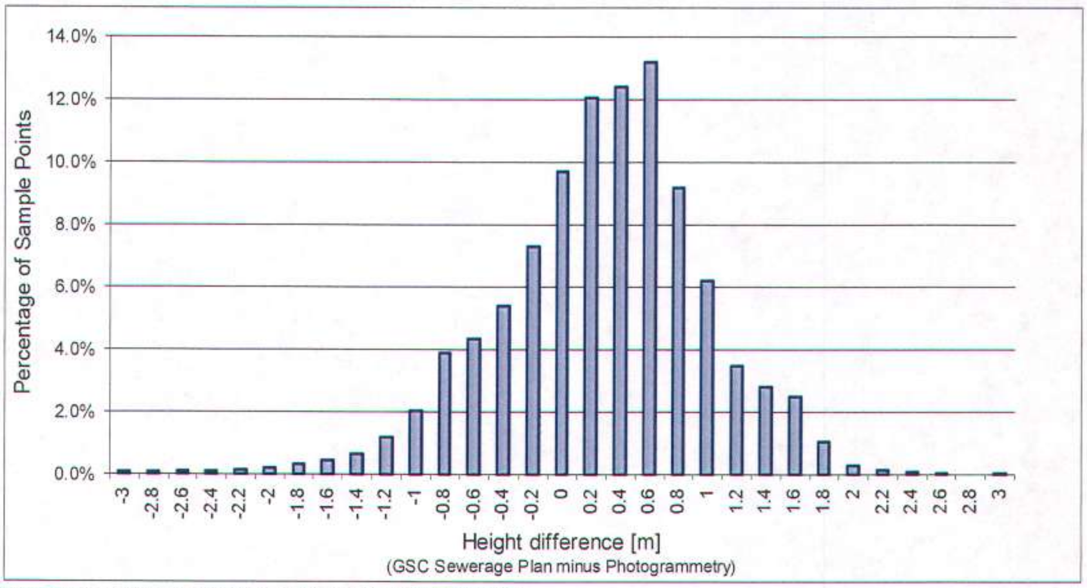



Area Used for Comparison of DEMs

Figure 3-4

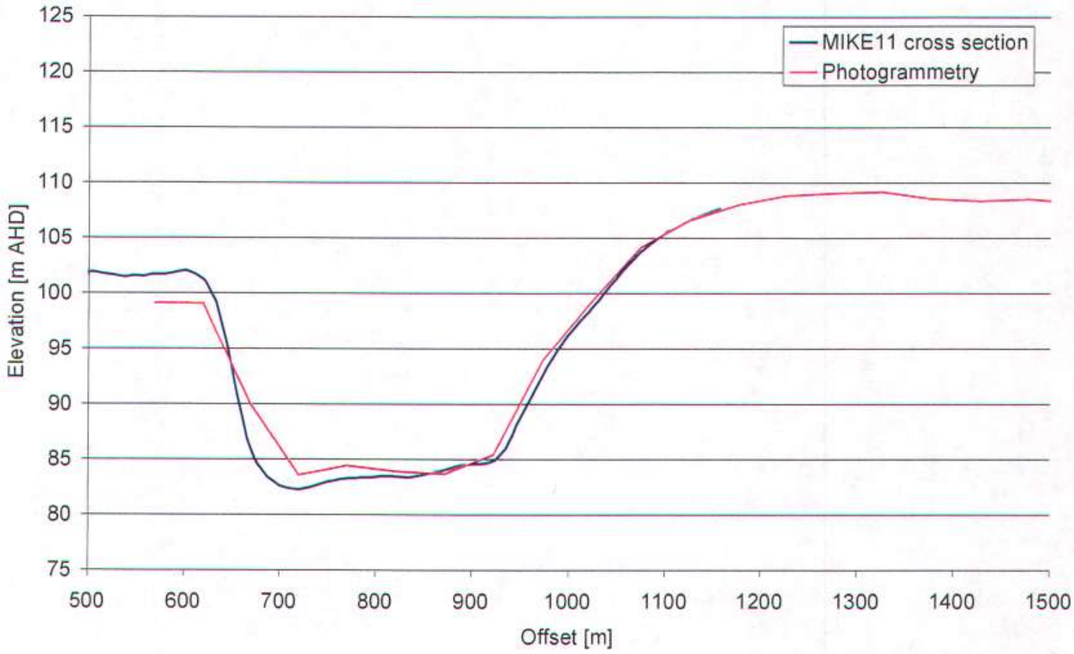
I:\B16183_I_BRH Gayndah Flood Study GJR\DRG\FS_report\FLD_006_071119_DEM_comparison_area.WOR

BMT WBM




K:\B16183.k.clb_Gayndah\reports\figures_calibration_report\analysis_DEMS.xls

**Figure 3-5 Elevation Difference Between Photogrammetry and GSC Sewerage Plans**




K:\B16183.k.clb_Gayndah\reports\figures_calibration_report\burnett_09000.xls

**Figure 3-6 Comparison Photogrammetry and MIKE11 Cross-Sections at Burnett R. 9000**

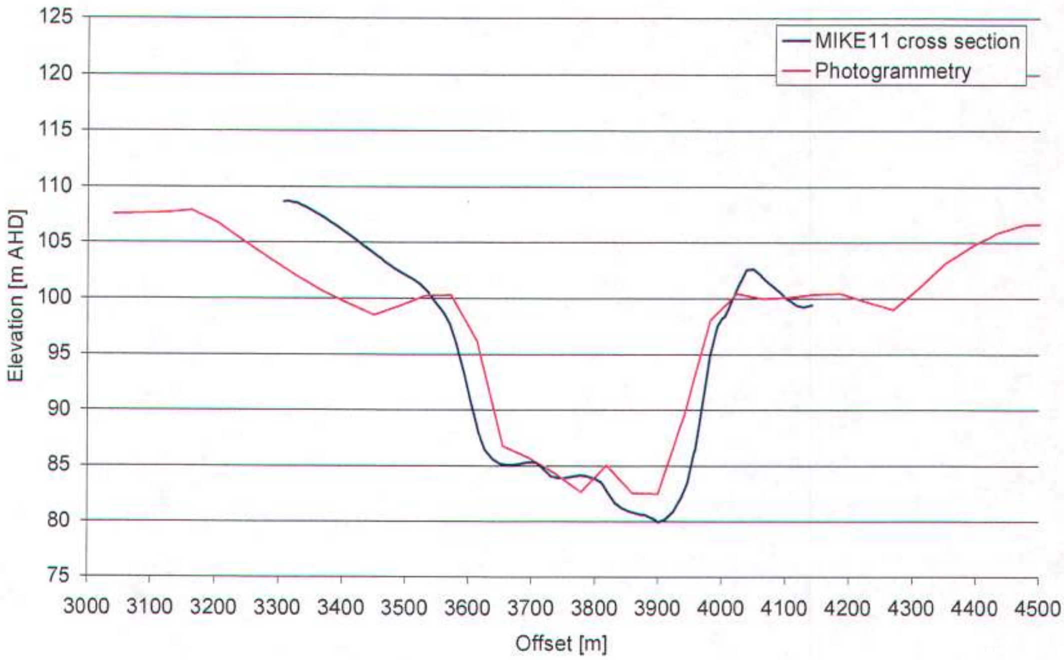



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**Figure 3-7 Comparison Photogrammetry and MIKE11 Cross-Sections at Burnett R. 10400**

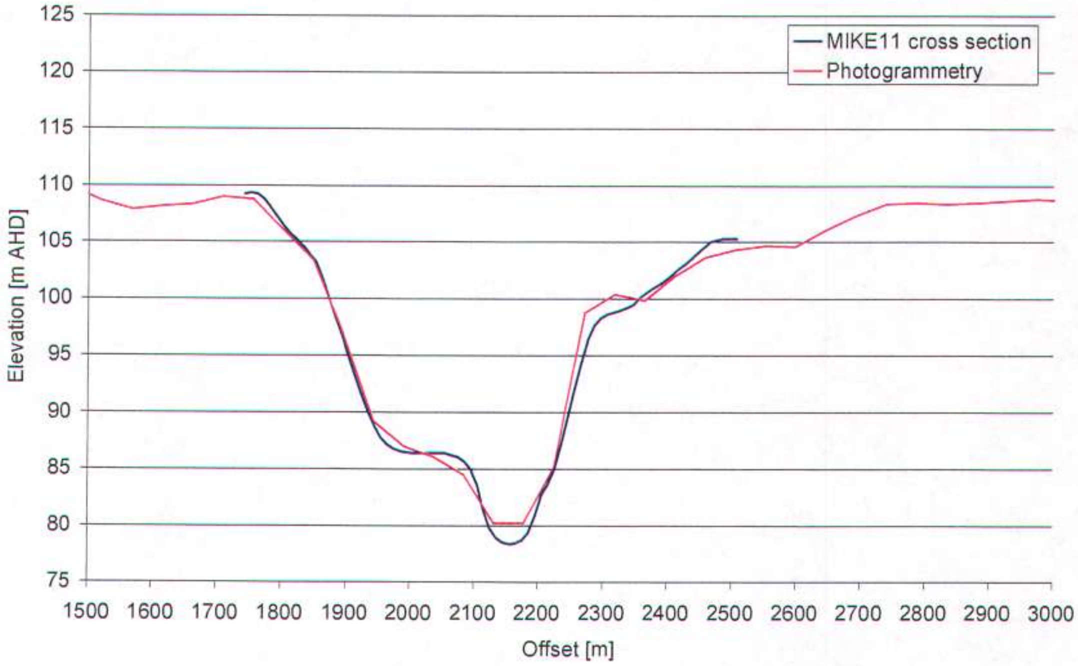


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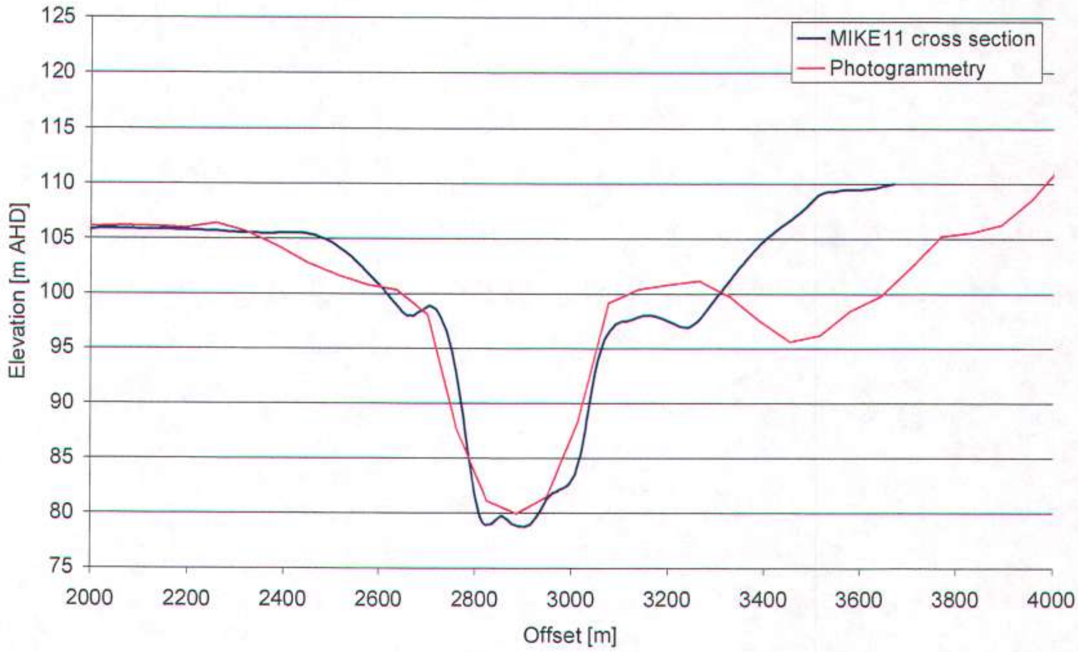
**Figure 3-8 Comparison Photogrammetry and MIKE11 Cross-Sections at Burnett R. 119400**




K:\B16183.k.clb_Gayndah\reports\figures_calibration_report\burnett_13600.xls

**Figure 3-9 Comparison Photogrammetry and MIKE11 Cross-Sections at Burnett R. 13600**

# 4 BURNETT RIVER FLOOD MODEL DEVELOPMENT

To define the flood behaviour in the study area and quantify the flood risk in Gayndah, a numerical flood model of the study area was developed. The flood model comprises of a hydrological model and a hydraulic model.

The hydrological model determines the runoff response of the Burnett River catchment to a particular rainfall event. The primary output from the hydrological model are hydrographs for varying locations along the waterways describing the quantity, rate and timing of stream flow that results from rainfall events. These hydrographs then become a key input into the hydraulic model.

The hydraulic model simulates the movement of floodwaters through waterway reaches (eg. river lengths), storage areas, and hydraulic structures. The hydraulic model calculates flood levels and flow patterns and also models the complex effects of backwater, overtopping of embankments, waterway confluences, bridge constrictions and other hydraulic structure behaviour.

In Section 4.1 the hydrological model is discussed, followed by a discussion on the hydraulic model in Section 4.2.

## 4.1 RORB Hydrological Model

To determine the runoff response of the Burnett River catchment to a particular rainfall event, the conceptual runoff-routing modelling RORB was used.

The primary outputs from a RORB model are hydrographs for varying locations along the waterways describing the quantity, rate and timing of stream flow that results from rainfall events. These hydrographs then become a key input into the hydraulic model.

In this section, a description of the RORB runoff-routing model used for the hydrological assessment is discussed.

### 4.1.1 RORB Modelling Methodology

The conceptual runoff-routing model RORB (Laurenson & Mein, 1997) was used to model the runoff response of the Burnett River catchment for design flood estimation at Gayndah. RORB is an interactive runoff and streamflow routing program that calculates catchment losses and streamflow hydrographs resulting from rainflow events.

The RORB model represents the catchment response by a network of conceptual storages. The net rainfall is routed through the network after appropriate losses are deducted. This results in a surface runoff hydrograph at points of interest within the catchment. Each storage has a non-linear storage-discharge relationship described by:

$$S = 3600 * k_c * k_{ri} * Q^m \qquad \text{(Equation 1)}$$

Where:

S = Storage in the reach ($m^3$).

Q = Discharge ($m^3/s$).

$k_c$ = Catchment storage parameter.

$k_{ri}$ = Relative delay time of storage "i" (dimensionless).

m = Degree of non-linearity of the catchment (dimensionless).

The two model parameters $k_c$ and m are typically evaluated from calibration of the model results against recorded streamflow using recorded rainfall and pluviograph data as model inputs. If no recorded streamflow data is available for the area of interest, $k_c$ may be estimated from regional relationships between $k_c$ and the catchment area.

For the Burnett River catchment RORB model used for this study, the model parameters $k_c$ and m were established from calibration of the model results against recorded streamflow using recorded rainfall and pluviograph data as model inputs.

### 4.1.2 RORB Model Layout

The RORB runoff-routing model of the Burnett River catchment was developed in 1998 by the Surface Water Assessment Group of DNRM as part of the hydrologic investigation of the Lower Burnett River. The RORB model covers the catchment of the Burnett River to Walla gauging station 136001 (AMTD 98.7 km), a total area of approximately 32,500 km$^2$ and consists of 155 sub-catchments.

The five major storages expected to influence the estimation of design flood hydrographs were included in the model. Details of these storages are given in Table 4.1 below. In order to reflect the condition of the Burnett River catchment at the time of each flood event, these major dam storages were progressively incorporated into the RORB model during the model calibration.

**Table 4-1 Major Storages Included in RORB Model**

| Storage Name | Stream Name | AMTD (km) | Full Supply Capacity (ML) |
|---|---|---|---|
| Cania Dam | Three Moon Ck | 110.1 | 89,000 |
| Wuruma Dam | Nogo River | 23.0 | 165,000 |
| Boondooma Dam | Boyne River | 86.7 | 212,000 |
| Bjelke Petersen Dam | Barker Creek | 1.3 | 125,000 |
| Paradise Dam | Burnett River | 131.2 | 300,000 |

The general RORB model layout and the 155 sub-catchments are shown in Figure 4-1.

For further details in relation to the RORB model reference should be made to DNRM(1998) and SunWater (2002).

### 4.1.3 2006 Modifications to RORB model

Modifications to the 2002 RORB runoff-routing model were required to make the RORB model more suitable for the purpose of this study. Some subcatchments required additional routing lengths and output locations and the expected backwater from Paradise Dam required an increased length of the drowned reach upstream. Details of modifications made to the 2002 Burnett River catchment RORB model are outlined below.

### Additional Routing Lengths

When schematising the subcatchment routing lengths, the 1998 hydrological study assumed a zero routing length for certain smaller subcatchments. This meant that rain falling on the subcatchment would be added directly to the flow in the river without accounting for the routing distance from the subcatchment centroid.

For the purposes of this study, extra detail was required for the subcatchments flowing into the Burnett River between Gayndah and Paradise Dam. For these subcatchments, a flow length between the subcatchment centroid and the Burnett River was estimated and this routing length incorporated into the RORB model. A summary of these additional routing lengths applied to these subcatchments is provided in Table 4-2.

**Table 4-2 Additional Routing Lengths Included in the RORB Model**

| Subcatchment Number | Additional Routing Length (km) |
|---|---|
| 107 | 3.7 |
| 104 | 6.2 |
| 143 | 5.5 |
| 144 | 6.2 |
| 145 | 10.0 |

### Drowned Reaches

The revision of the hydrological study undertaken by SunWater in 2002 assumed a drowned reach from Paradise Dam (AMTD 131.2km) to the centroid of Subcatchment 146, only 6.2km upstream. When at FSL, the ponded area of Paradise Dam in fact extends a considerable distance further upstream, to the junction of Subcatchments 142 and 143, a distance of 33.4km upstream. This additional drowned reach was incorporated into the RORB model for this study.

## 4.2 TUFLOW Hydraulic Model

The complicated nature of the floodplain flow patterns and importance of obtaining community confidence in the process required that state-of-the-art modelling techniques be adopted. Hence, TUFLOW, a fully 2D/1D dynamically linked hydraulic modelling system was used to model the Burnett River and, more specifically, the Gayndah town area.

The hydraulic model covers a length of approximately 70 km of the Burnett River, from just upstream of Claude Wharton Weir to Paradise Dam. Within the area of interest, the river and its floodplains are modelled by a high-resolution two-dimensional (2D) hydrodynamic model.

### 4.2.1 TUFLOW Hydrodynamic Modelling System

TUFLOW solves the full 2D shallow water equations based on the numerical solution scheme developed by Stelling (1984). This solution is based around the well-known ADI (alternating direction implicit) finite difference method. A square grid is used to define the discretisation of the computational domain.

Improvements to the Stelling 1984 scheme, including a robust wetting and drying algorithm and greater stability at oblique boundaries, and the ability to dynamically link a quasi-2D model were developed by Syme (1991). Further improvements including the insertion of 1D elements or quasi-2D models inside a 2D model and the modelling of constrictions on flow such as bridges and large culverts, and automatic switching into and out of upstream controlled weir flow have been developed subsequently.

TUFLOW models have been successfully checked against rigorous test cases [eg. Syme et al. (1998)], and calibrated and applied to a large range of real-world tidal and flooding applications. TUFLOW is a leading fully 2D hydrodynamic modelling system and has the ability to be dynamically linked to quasi-2D models and have quasi-2D models dynamically nested inside or through the fully 2D domain.

Hydraulic structure flows through large culverts and bridges are modelled in 2D and include the effects of bridge decks and submerged culvert flow. Flow over roads, levees, bunds, etc is modelled using the broad-crested weir formula when the flow is upstream controlled. For smaller hydraulic structures such as pipes or for weir flow over a bridge, 1D elements can be inserted at any points inside the 2D model area.

### 4.2.2 2D Model Extent

The floodplain area within the township of Gayndah has been represented using a two-dimensional (2D) hydrodynamic model. The 2D model domain covers 25.4 km$^2$ and includes the entire township of Gayndah and approximately 8 km of river channel of the Burnett River. The extent of the 2D model is shown in Figure 4-2.

The model is based on a 20m x 20m square grid, resulting in approximately 63,400 grid cells. With a typical channel width of 200 to 250m, the river channel is represented by approximately 10 to 12 grid cells. Oaky Creek has been incorporated into the 2D model using 3D breaklines. The model orientation is in line with the river channel alignment at Gayndah.

Each square grid element contains information on ground topography sampled from the DEM at 10 m spacing, surface resistance to flow (Manning's n value) and initial water level. Areas of different land-use type based on aerial photography and site inspections were identified for setting Manning's n values. For further details in relation to surface resistance reference should be made to Section 4.2.7 of this report.

### 4.2.3 1D/2D Model Interaction

While the Burnett River including floodplains within the study area is appropriately represented by the highly resolved two-dimensional model, the Burnett River downstream of the study area has been modelled with the 1D hydrodynamic model, ESTRY. The 1D hydrodynamic model is dynamically linked to the 2D model, allowing water to flow out of the 1D model into the 2D model and vice versa.

The following watercourses/river sections have been modelled using ESTRY:

- A short section of the Burnett River upstream of Claude Wharton Weir (representation of Claude Water Weir water supply facility);

- Approximately 61 km of the Burnett River downstream of Gayndah (from Ideraway to Paradise Dam, AMTD 192.2 to 131.2 km); and
- Most downstream section of Barambah Creek, up to approximately 15 km from the confluence with the Burnett River.

The extent of the 1D/2D model is shown in Figure 4-3.

### 4.2.4 Inflow Boundaries

The following inflow boundaries were obtained from the RORB hydrological model:

- Burnett River at Gayndah (upstream of Claude Wharton Weir; AMTD (km) 201.2);
- Barambah Creek (at confluence with Burnett River);
- Oaky Creek (at confluence with Burnett River);
- Inflows from four tributaries downstream of Barambah creek (at their respective inflow locations with the Burnett River);
- Rainfall runoff that runs as surface flow through the study area to the Burnett River, including rainfall on areas covered by the TUFLOW model.

The locations of the inflow boundaries are shown in Figure 4-3.

### 4.2.5 Downstream Boundary

At the downstream end of the 1D river model (at the Paradise Dam site), a water level versus flow boundary condition has been applied. The water level versus flow discharge relation for the situation before and after the construction of the dam was obtained from SunWater's Burnett River MIKE11 model.

The water level versus flow relation for both the situation before and after dam construction is shown in Figure 4-4.

### 4.2.6 Hydraulic Structures

Within the study area, there are a number of hydraulic structures that may affect the flood behaviour of the Burnett River. The structures were identified in Section 3.7. In this section the way in which these structures are represented into the hydraulic model is described.

#### Bridge Structures

Three bridge structures have been represented in the hydraulic model. There are two bridge structures that are located within the region that is represented by the 2D model domain (ie. Burnett River crossing and Oaky Creek crossing) and one bridge structure that is located within the region that is represented by the 1D model domain (railway bridge at Mount Lawless).

Bridge structures situated within the 2D model area (ie. Burnett River crossing and Oaky Creek crossing) are schematised using the following methodology.

To represent flow constriction caused by the bridge piers and the bridge deck including hand railings, the flow width of the grid cells at the bridge location were reduced in accordance with the loss of flow area at these locations. In addition, additional losses have been specified at the bridge location. These additional losses represent energy losses due to flow disturbance caused by bridge piers, the bridge deck and vena-contracta losses.

The loss factors for these energy losses have been derived using Waterway Design (Austroads, 1994). Waterway Design is a publication from the National Association of Road Transport and Traffic Authorities and is an industry standard guide to the hydraulic design of Bridges, Culverts and Floodways.

During the 1942 Flood Event, the Burnett River Crossing was completely submerged. In such a situation both bridge piers and the bridge deck cause a considerable flow disturbance. To represent the associated energy losses for this situation, the Additional Form Loss Coefficient for the Burnett River Crossing was derived by taking into account both the area occupied by piers and the bridge deck. It is noted that the hand railings of the old Burnett River Bridge were usually removed in preparation for a large flood as shown in Figure 4-5.

The adopted bridge loss factors for the situation in 1942 are summarised in Table 4-3.

**Table 4-3 Adopted Bridge Loss Coefficients For Situation in 1942**

| Bridge | Flow Constriction due to Piers& Bridge Deck ($A_{blocked}/A_{channel}$) | Additional Form Loss Coefficient |
|---|---|---|
| Burnett River Crossing | 10.0 % | 0.3 |
| Oaky Creek Crossing | 12.2 % | 0.5 |

Within the 1D model area, bridge structures were modelled using cross-sections to represent the open waterway area underneath the bridge deck and weirs to represent flow over the bridge deck.

Bridge loss factors for bridge structures within the 1D model are derived using Austroads (1994). For Mount Lawless Railway Bridge, a bridge loss coefficient of 0.3 is applied for flow regimes where the bridge remains unsubmerged and 1.56 for submerged flow regimes.

## Water Storage Facilities

Within the modelled area, there are two major water storage facilities, namely Claude Wharton Weir and Paradise Dam.

Claude Wharton Weir is located at AMTD 202.4 km on the Burnett River, just upstream of Gayndah. The storage capacity of the weir is 12 800 ML at a Full Supply Level (FSL) of 94.4 m AHD. The dam was constructed after February 1942.

For the design flood events, it is assumed that the storage reservoir at Claude Wharton Weir is completely full. The potential detention of floodwater for water levels beneath FSL is therefore discounted in the hydraulic model. The floodwater detention of the storage reservoir for water levels above FSL is represented in the hydraulic model by a storage area versus water level relation. The storage area versus water level relation for Claude Wharton Weir was obtained from SunWater.

The Paradise Dam, built in 2003, is located at AMTD 131.4 km on the Burnett River, approximately 70 km downstream of Gayndah. The storage capacity of the dam is 300 000 ML at a Full Supply Level (FSL) of 67.6 m AHD. The dam has a height in the order of 35 m.

In the model, the Paradise Dam water storage facility is located at the downstream boundary of the model. The weir of the storage facility is represented in the model by a rating curve (a water level versus flow boundary condition). The rating curve for the Paradise Dam was obtained from SunWater.

For the design flood events, it is assumed that the storage reservoir at the Paradise Dam is completely full. The potential detention of floodwater for water levels beneath FSL is therefore discounted in the hydraulic model. The floodwater detention of the storage reservoir for water levels above FSL is represented in the hydraulic model by a storage area versus water level relation. The storage area versus water level relation for the paradise Dam was obtained from SunWater.

### 4.2.7 Hydraulic Bed Roughness

Hydraulic bed roughness represents the conveyance capacity of the vegetative growth, bed and bank material, channel and floodplain sinuosity. Values of the roughness coefficient, Manning's n, have been based on industry standards and were optimised during the model calibration.

Observations during the site walk-overs and aerial photography have been utilised to define the hydraulic roughness throughout the model extents. A large proportion of the study area can be described as rural land with some vegetation and low-density developments. The riverbed tends to be more vegetated and has areas of medium density vegetation.

Within the study area, six different land use types have been identified. Table 4-4 shows the eight land use types and the Manning's n roughness coefficients used in the 2D hydraulic model.

**Table 4-4 Values of Manning's 'n' for Calibrated TUFLOW Model**

| Land use | Manning's 'n' |
|---|---|
| Riverbed of Burnett River | 0.050 |
| Riverbed of Oaky creek | 0.050 |
| Grassland, pasture | 0.040 |
| Parklands/sport fields | 0.043 |
| Heavily vegetated areas | 0.070 |
| Citrus plantations/nurseries | 0.060 |
| Urbanised Areas around Main Street | 0.500 |
| Roads/paved areas | 0.020 |

For the 1D model downstream of Gayndah, the bed roughness coefficients from the calibrated MIKE11 model were adopted. The adopted bed roughness coefficients for the river channel are a Manning's n value of 0.068 for the river section from Mingo Crossing to Paradise Dam, 0.043 from Mingo Crossing to Mount Lawless and 0.048 upstream of Mount Lawless.

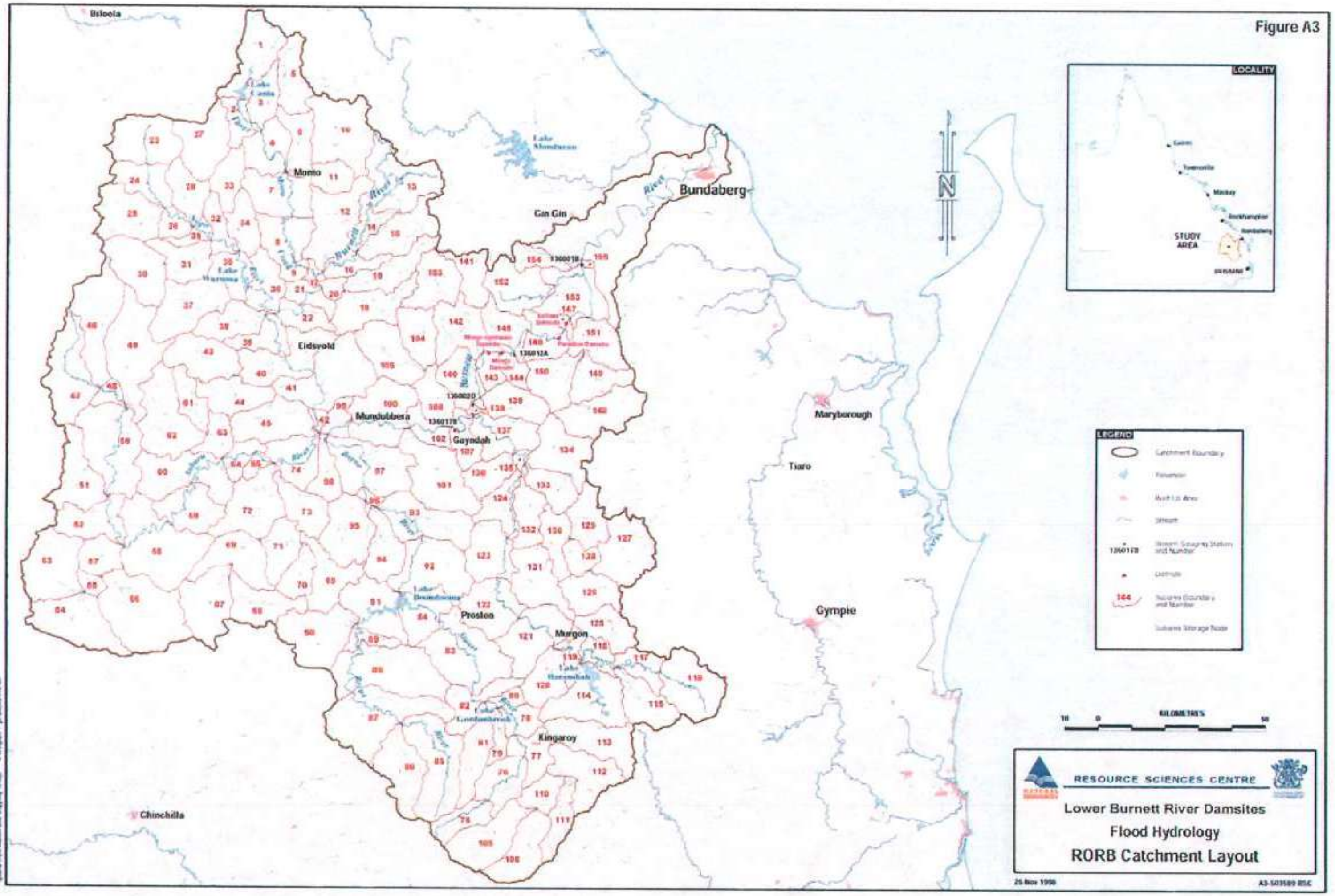
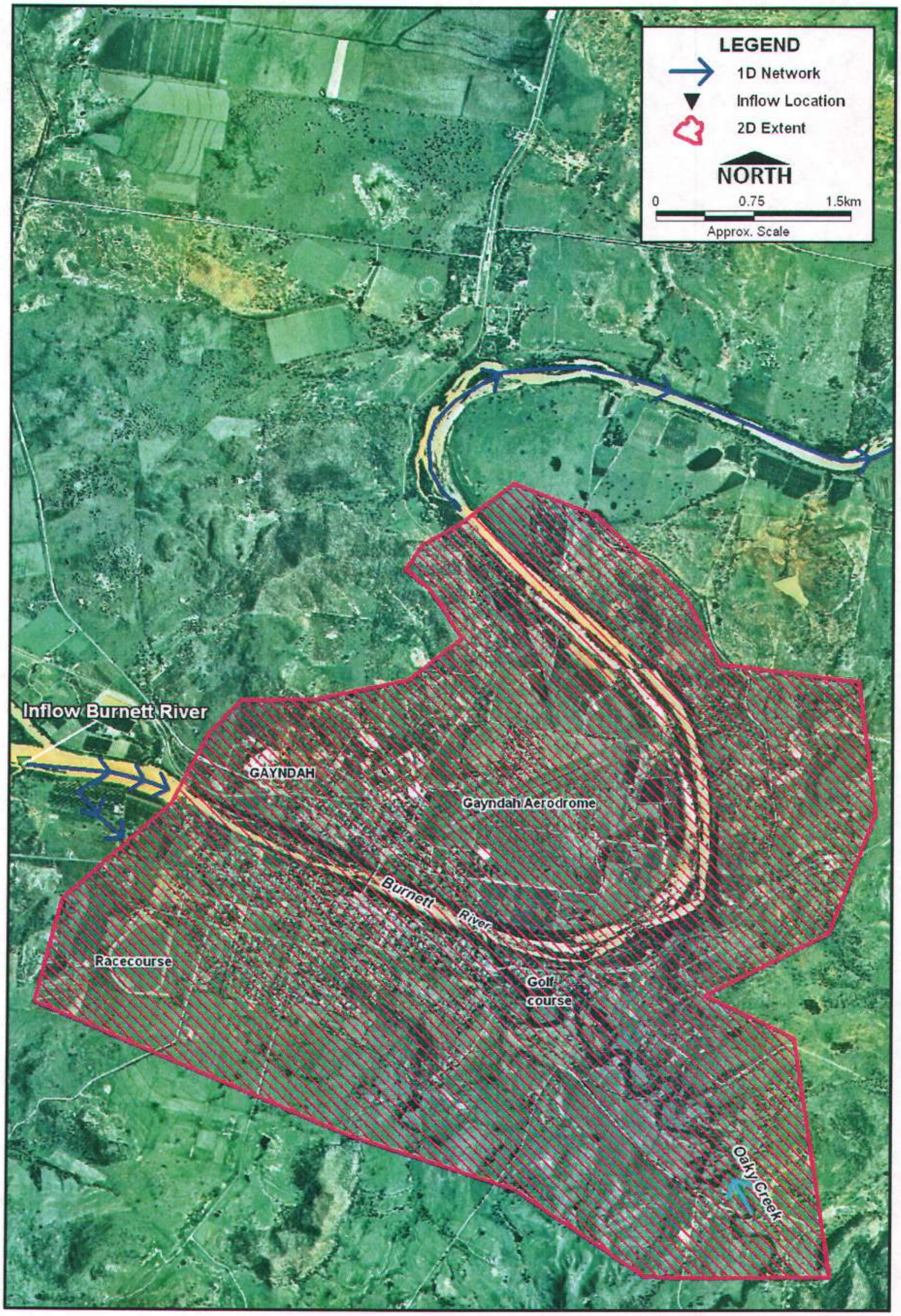



**Figure 4-1 RORB Model Catchment Layout (From DNRM, 1998)**




Extent of 2D Model Domain of TUFLOW Model

Figure 4-2

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**Extent of 1D/2D TUFLOW Model** **Figure 4-3**

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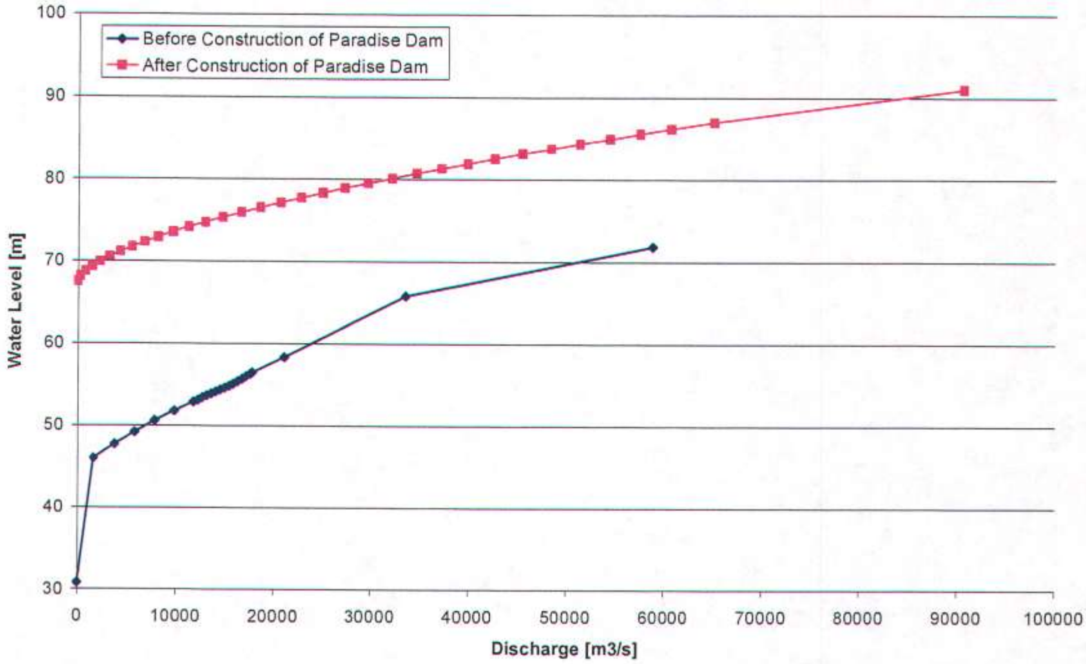


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**Figure 4-4 Water Level vs. Flow Relations for Paradise Dam (Downstream Boundary)**

**Figure 4-5 Old Burnett River Crossing with Removed Hand Railings During 1924 Flood Event (Courtesy: Gayndah Historical Museum)**

# 5 CALIBRATION OF FLOOD MODEL

## 5.1 Calibration of Hydrological Model

The model calibration of the RORB model made in 1998 by the Surface Water Assessment Group was retained for this study, since the model modifications outlined in Section 3.4 had a negligible effect on model results. A brief outline of the calibration is given below. For further details, reference should be made to DNRM (1998).

The 1998 DNRM hydrologic study calibrated the runoff routing model against five historical flood hydrographs recorded at Walla gauging station. Hydrographs recorded at other gauging stations of Mount Lawless 136002 (AMTD 183.9 km), Gayndah 136003 (AMTD 203.0 km) and Mingo Crossing 136012 (AMTD 154.4 km) were also utilised, when available, for fine-tuning the initial and continuing loss rates.

The historical storm events used for calibration were selected to ensure consistent performance of the model for a wide range of the design flood estimates. Details of the storm events used for the model calibration are given in Table 5-1.

**Table 5-1 Details of Storm Events Used in Model Calibration**

| Storm Event | Start Date | Duration (hours) | RECORDED PEAK DISCHARGES ($m^3/s$) | |
|---|---|---|---|---|
| | | | Mt. Lawless | Walla Weir |
| February 1942 | 08-Feb-1942 | 136 | 17,055 | 15,437 |
| July 1954 | 09-Jul-1954 | 120 | 11,237 | 11,763 |
| January 1971 | 28-Jan-1971 | 360 | 9,400 | 9,253 |
| April 1974 | 25-Jan-1974 | 144 | 2,467 | 3,361 |
| April 1983 | 26-Apr-1983 | 216 | 3,517 | 4,127 |

The RORB model for the Burnett River catchment was set up to closely represent the catchment condition for each of the calibrated storm events.

Calibration of the runoff-routing model was based on the matching of peak discharges and flood volumes by means of adjusting model parameters $k_c$ and m. The adopted model parameters for the RORB model were the same for all events and were as follows:

$m = 0.85$

$k_C = 210$

Calibration results at Walla Gauging Station and Mt Lawless Gauging Station for the February 1942 event are given in Figure 5-1 and Figure 5-2. The calibration results for the other flood events considered are shown in Figure 5-3 to Figure 5-11.

Figure 5-2 shows that the magnitude of the recorded peak discharge at Mount Lawless is replicated with a high level of accuracy by the RORB model (within 1%). Further, Figure 5-2 shows that the rising limb of the modelled discharge at Mount Lawless is marginally advanced in comparison with the recorded values and the timing of the modelled peak discharge at Mount Lawless is predicted slightly earlier than recorded peak discharge.

Using the adopted model and loss parameters, agreements were achieved for all five flood events within 10% for the peak discharge and 2.5% for flood volume.

Analysing the performance of the adopted RORB model at the study area, it is concluded that the RORB model replicates the recorded hydrographs in the vicinity of Gayndah with an appropriate level of accuracy. The satisfactory model results for the flood events considered provide evidence that the RORB model is suitable for undertaking design simulations for this study.

## 5.2 Calibration of Hydraulic Model

### 5.2.1 Selection of Calibration Event

For calibration and validation of a hydraulic model, simulation of historical flood events is required. For this study, it was decided to consider one major flood event for calibration/verification of the hydraulic model. The flood event that was used to calibrate the model was the February 1942 flood event.

A main factor for selecting the February 1942 flood event for model calibration is that it is the largest flood event recorded on the Burnett River since settlement and caused major flooding throughout Gayndah. During this flood, a large number of properties on the floodplain of the Burnett River in Gayndah were inundated.

Another factor for selecting the February 1942 flood event is public perception. Typically the residents of Gayndah perceive the February 1942 flood event as the most destructive flood in living memory. Demonstrating the model's capability to replicate a major flood can be important in obtaining public confidence in the flood model.

Although the flood event occurred more than 60 years ago, extensive and detailed information regarding the flood event could be made available for model calibration. There was flow gauge data for four gauging stations on the Burnett River and six surveyed flood marks, indicating the maximum flood levels at various locations throughout the township of Gayndah (obtained from the Resident Survey). The surveyed flood marks cover a large part of the study area. In addition, the Resident Survey provided accurate information in relation to overland flow patterns and inundation durations in various parts of Gayndah. A summary of the reconstruction of the February 1942 event, based on the Resident Survey and obtained literature, is included in Appendix A.

### 5.2.2 Description of February 1942 Event

The February 1942 event was a major flood event with a peak discharge at Gayndah in excess of the 0.5 % Annual Exceedance Probability (AEP). The February 1942 event caused severe flooding throughout Gayndah with a large number of properties inundated.

For the model calibration to this event, the flow hydrographs as predicted by the RORB model were used as inflows after time correction (hydrographs from RORB model were adjusted to match the peak recorded peak flow at Mount Lawless Gauging Station).

The calibration of the hydraulic model to this event focussed on the reproduction of recorded peak flood levels in Gayndah and other locations along the Burnett River. Another aspect of the model

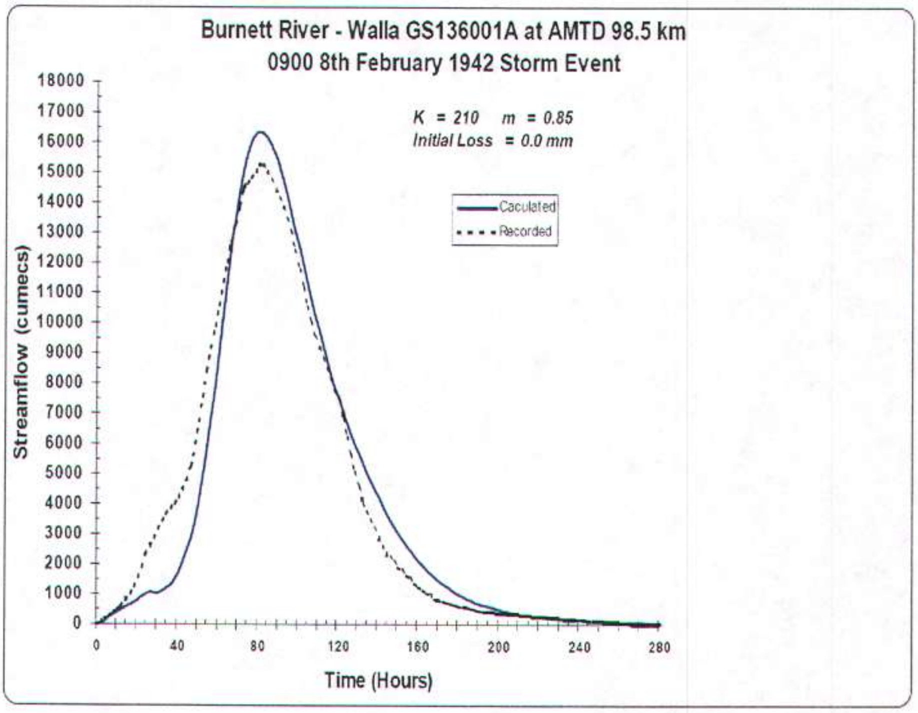



**Figure 5-1 Hydrographs Walla Gauging Station for February 1942 Flood Event**

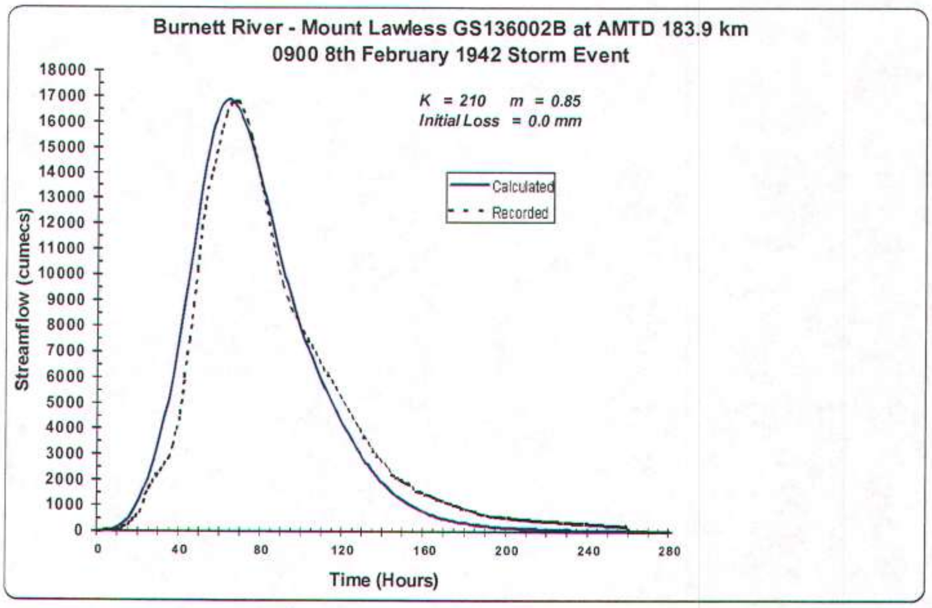



**Figure 5-2 Hydrographs at Mount Lawless Gauging Station for February 1942 Flood Event**

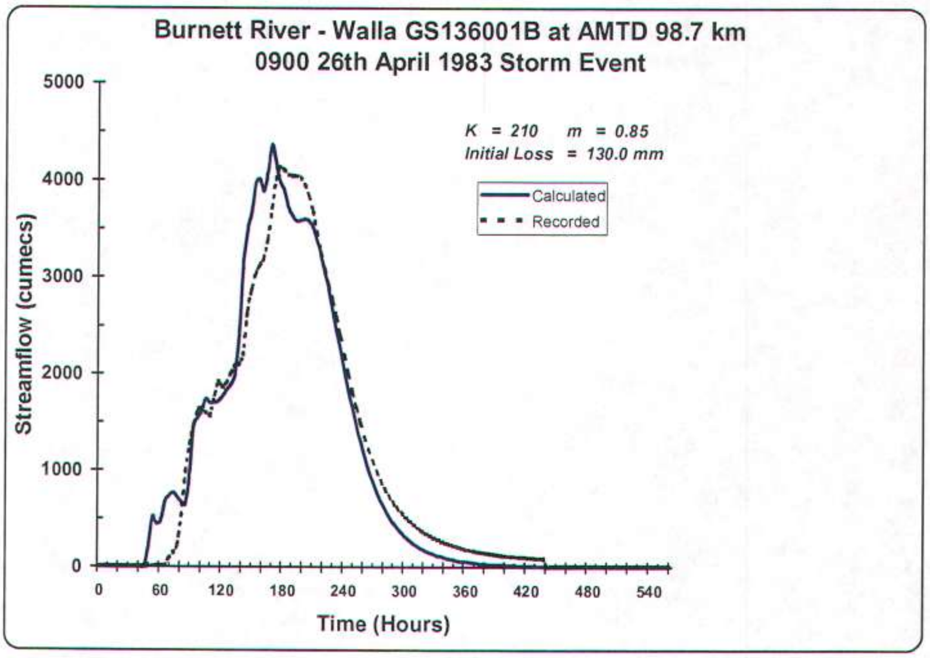



**Figure 5-3 Hydrographs at Walla Gauging Station for April 1983 Flood Event**

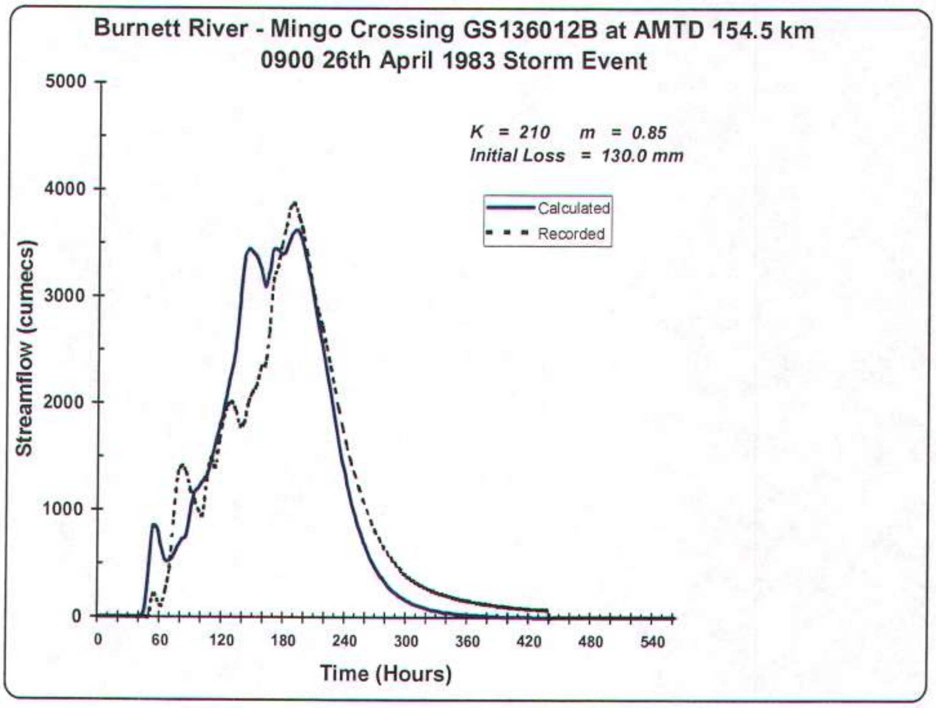



**Figure 5-4 Hydrographs at Mingo Crossing Gauging Station for April 1983 Flood Event**

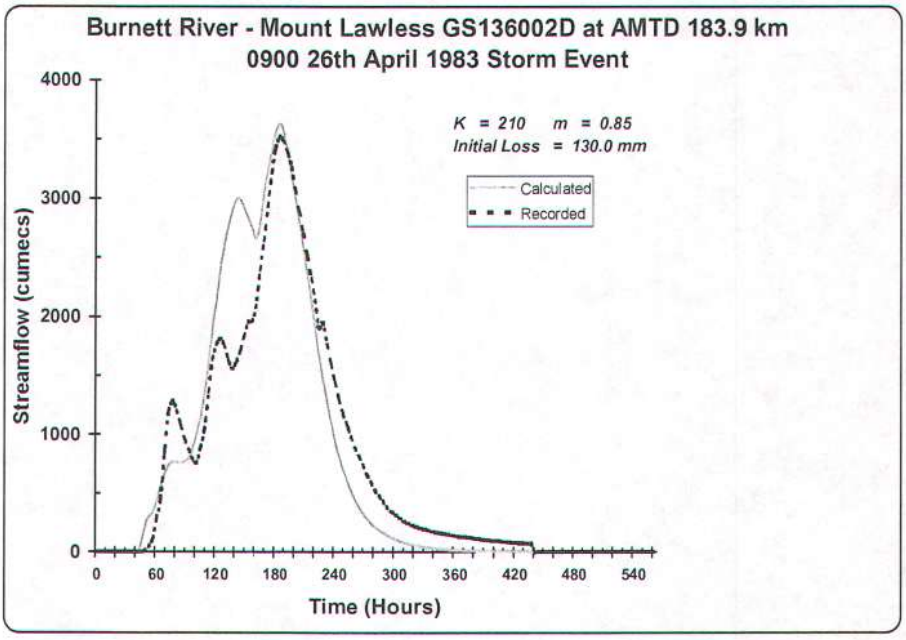



**Figure 5-5 Hydrographs at Mount Lawless Gauging Station for April 1983 Flood Event**

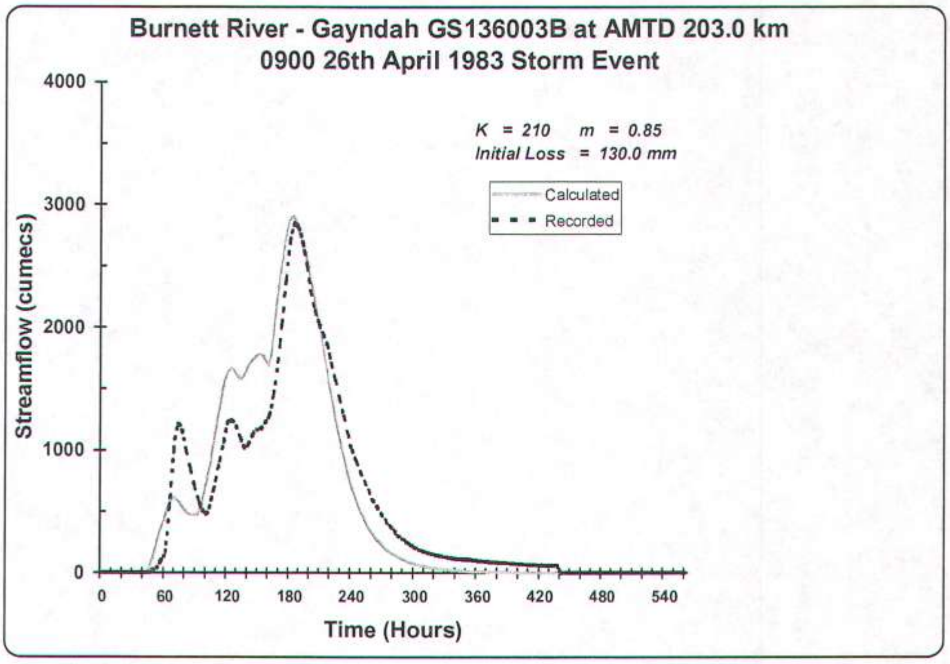



**Figure 5-6 Hydrographs at Gayndah Gauging Station for April 1983 Flood Event**

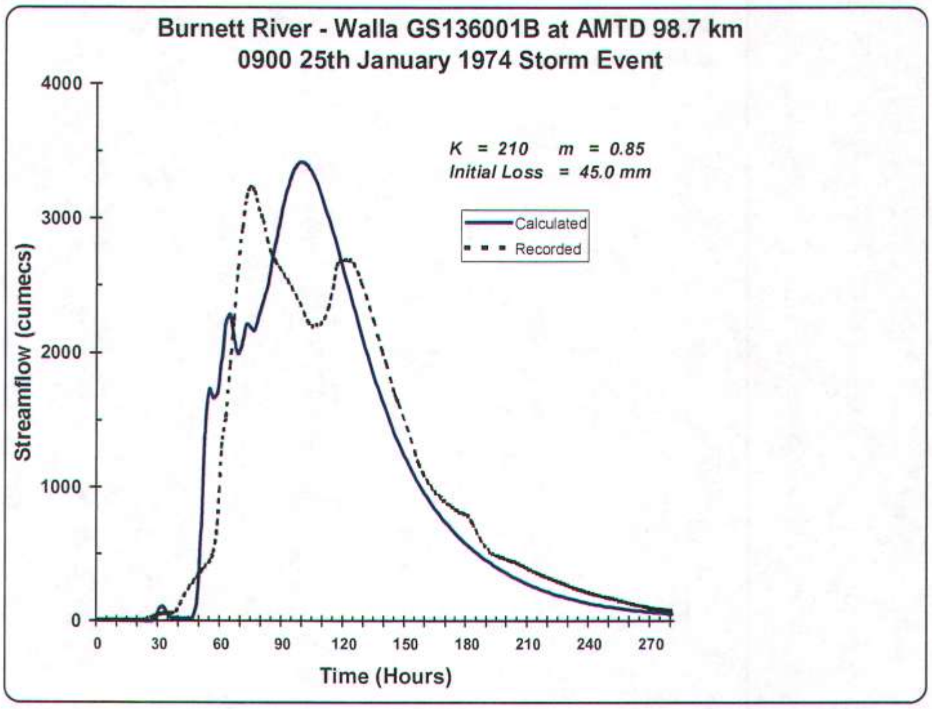



**Figure 5-7 Hydrographs at Walla Gauging Station for January 1974Flood Event**

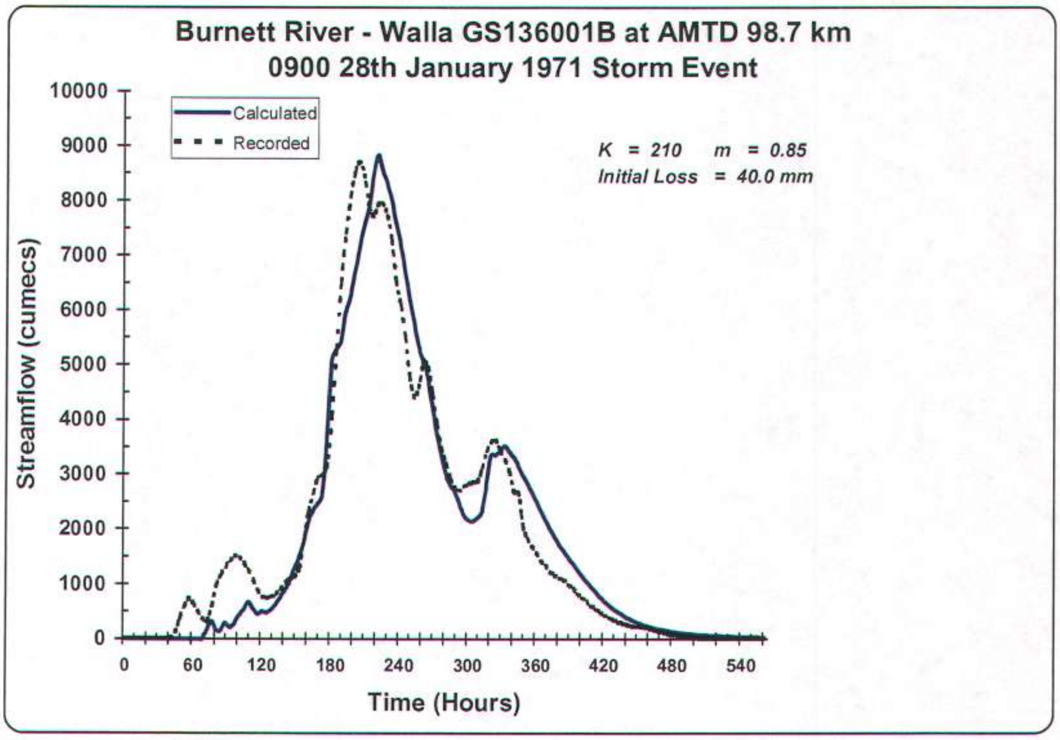



**Figure 5-8 Hydrographs at Walla Gauging Station for January 1971 Flood Event**

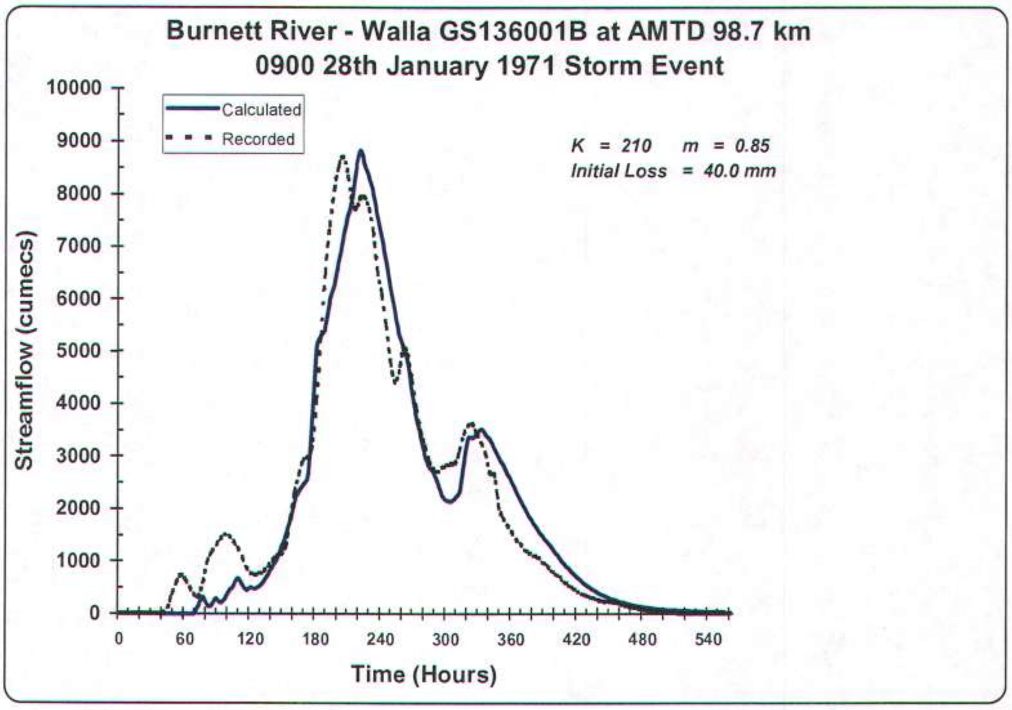



**Figure 5-9 Hydrographs at Walla Gauging Station for January 1971 Flood Event**

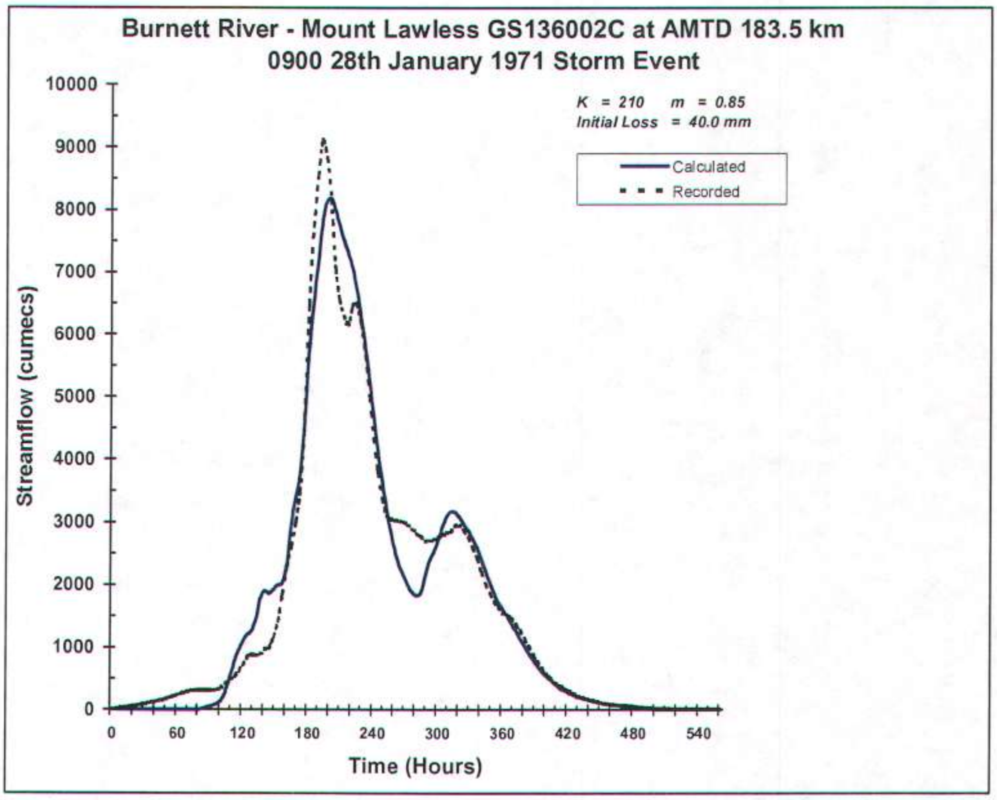



**Figure 5-10 Hydrographs at Mt. Lawless Gauging Station for January 1971 Flood Event**

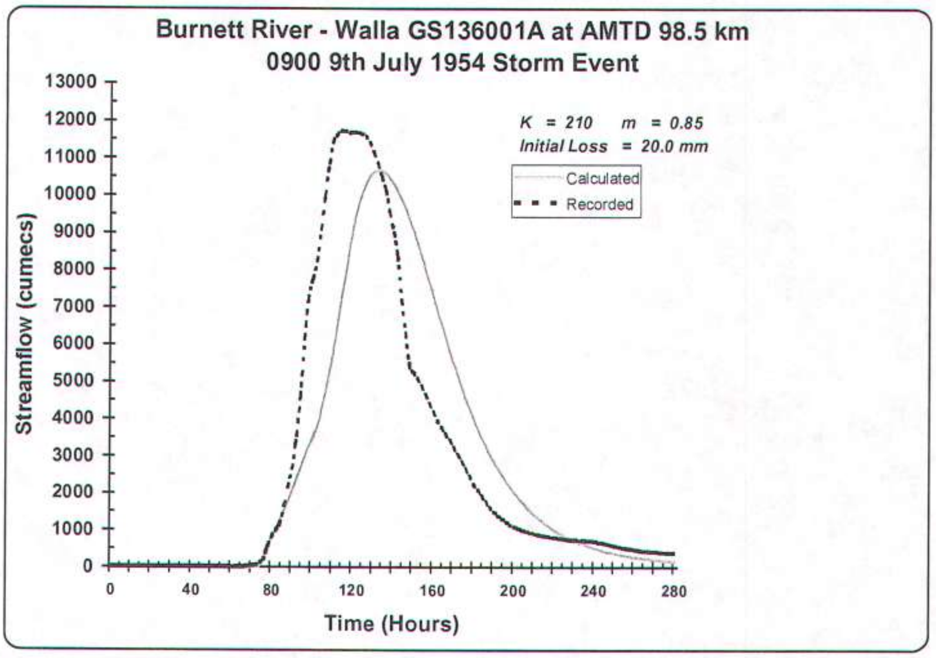
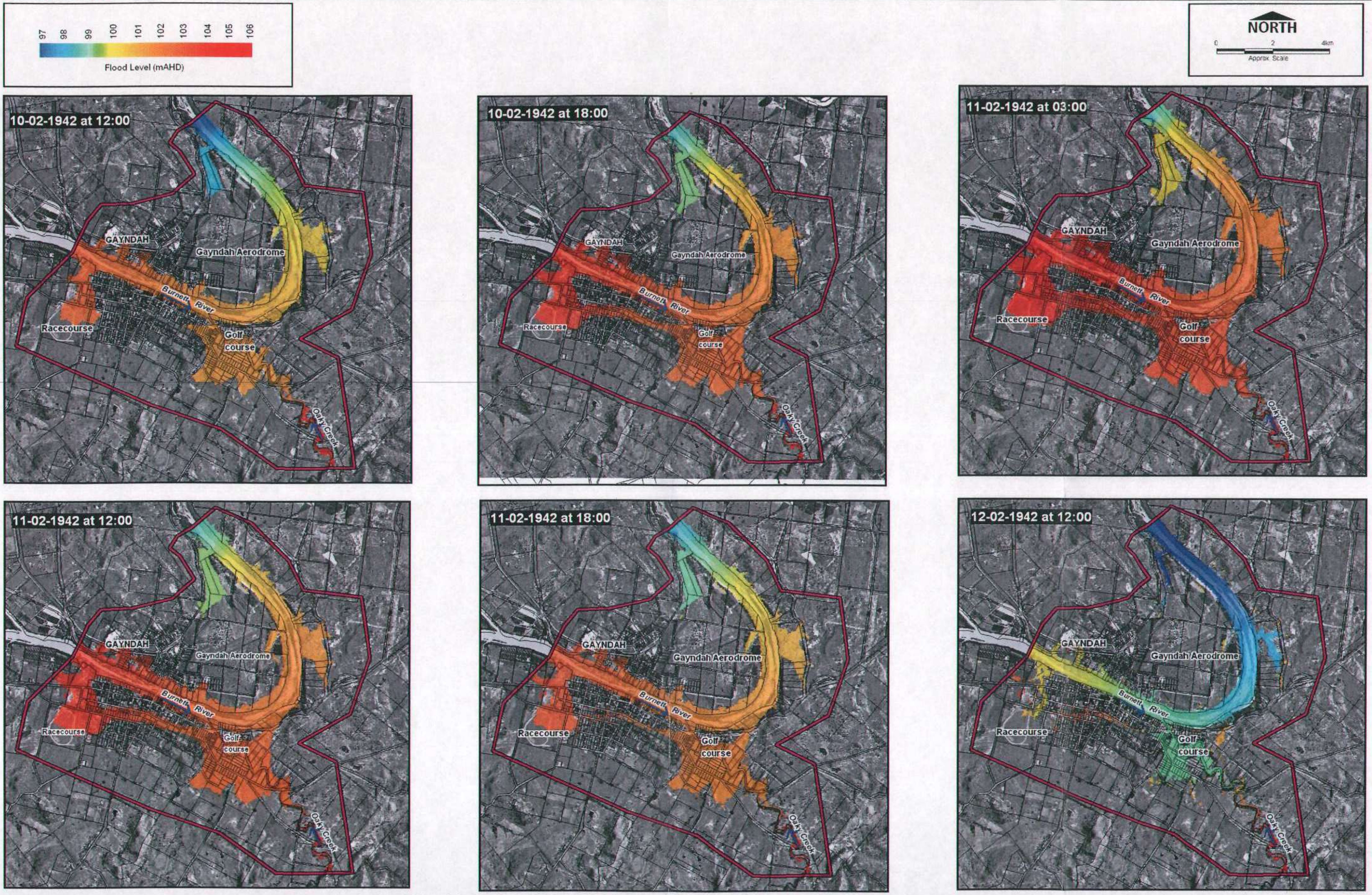



**Figure 5-11 Hydrographs at Walla Gauging Station for July 1954 Flood Event**




**Flood Levels at Key Moments During February 1942 Flood Event**

**Figure 5-12**

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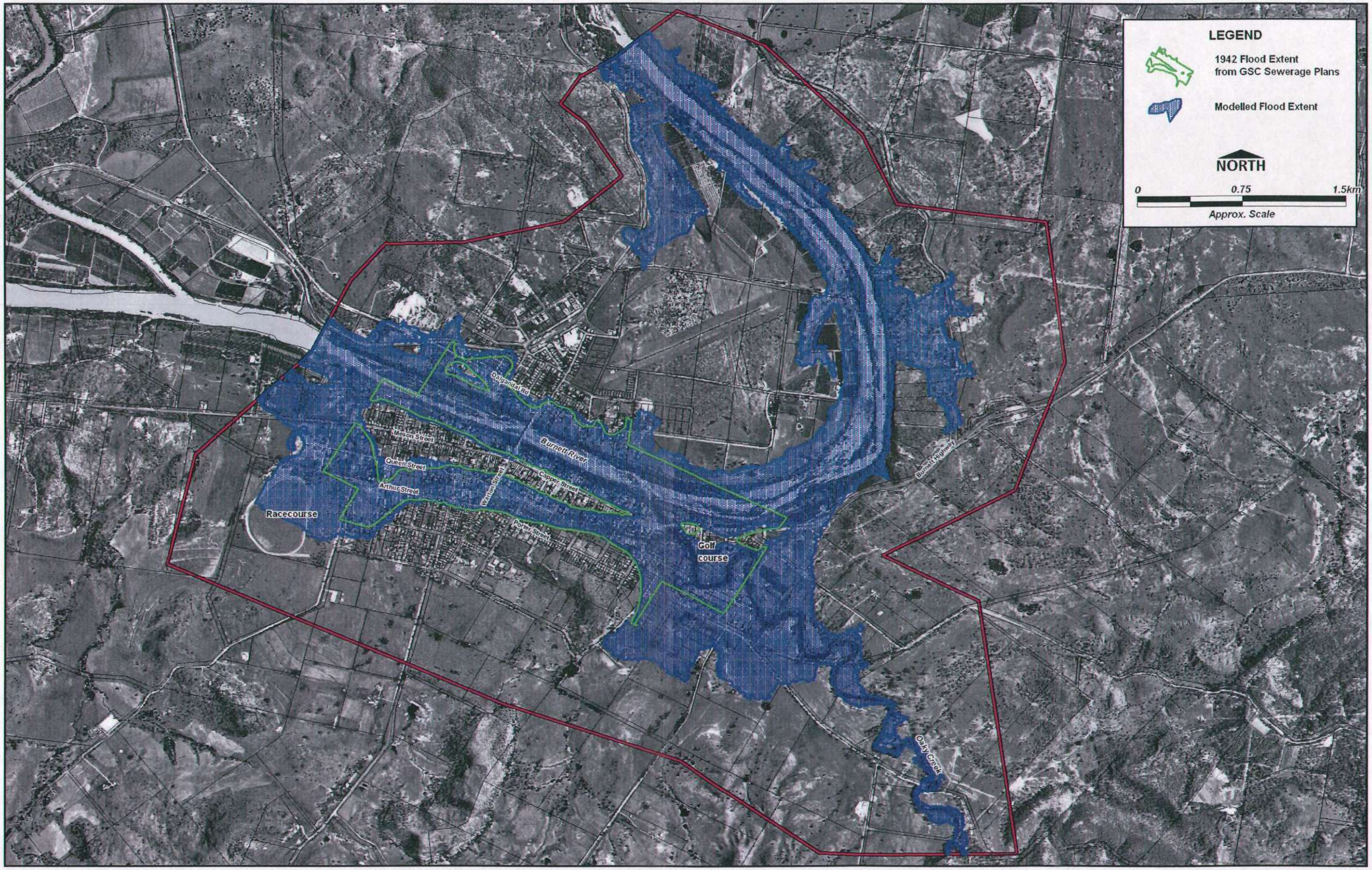


**Maximum Flood Extent During February 1942 Flood Event** **Figure 5-13**

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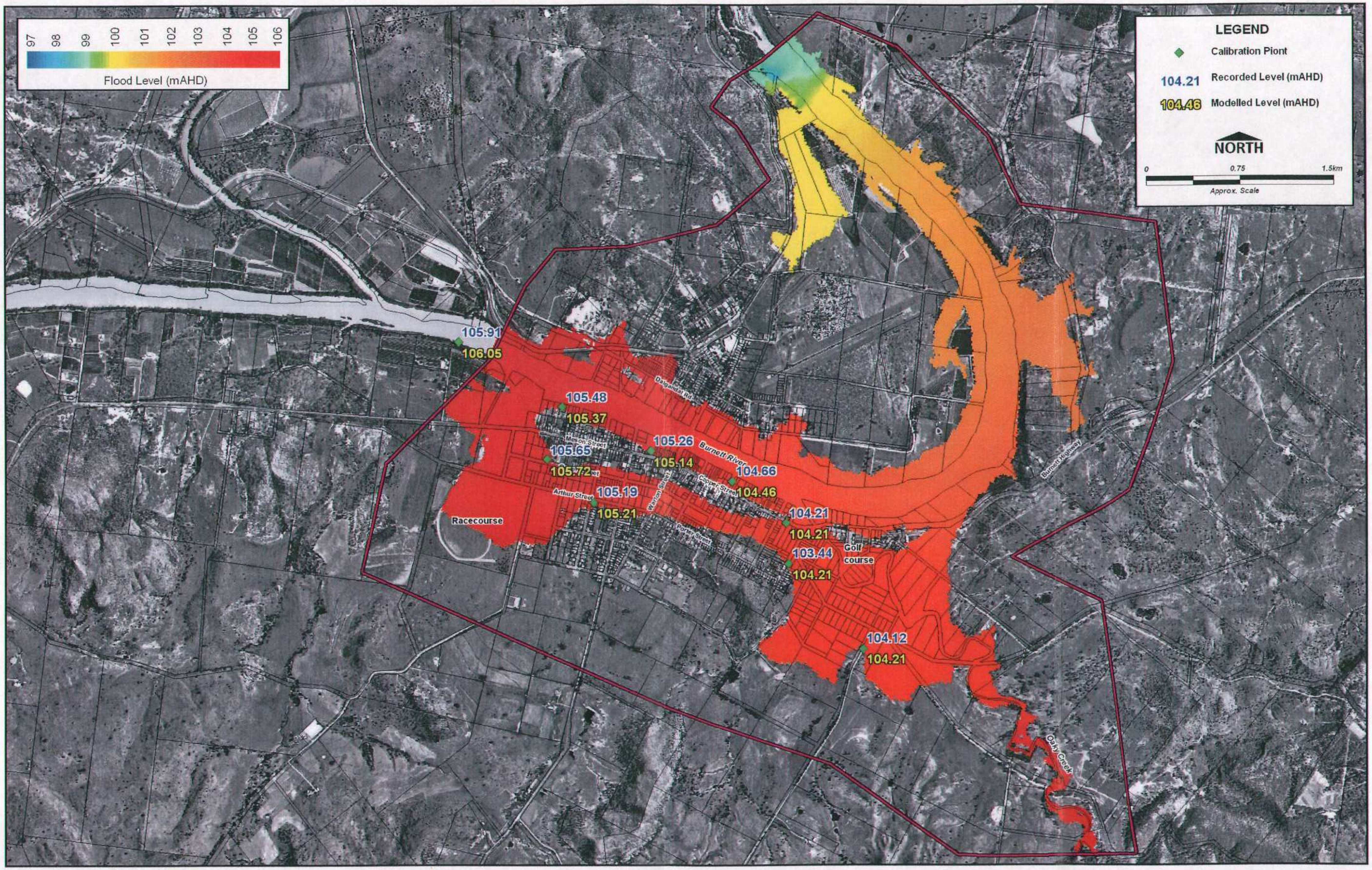
BMT WBM




Recorded and Modelled Peak Flood Levels at Various Locations in Gaydnah

Figure 5-14

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BMT WBM

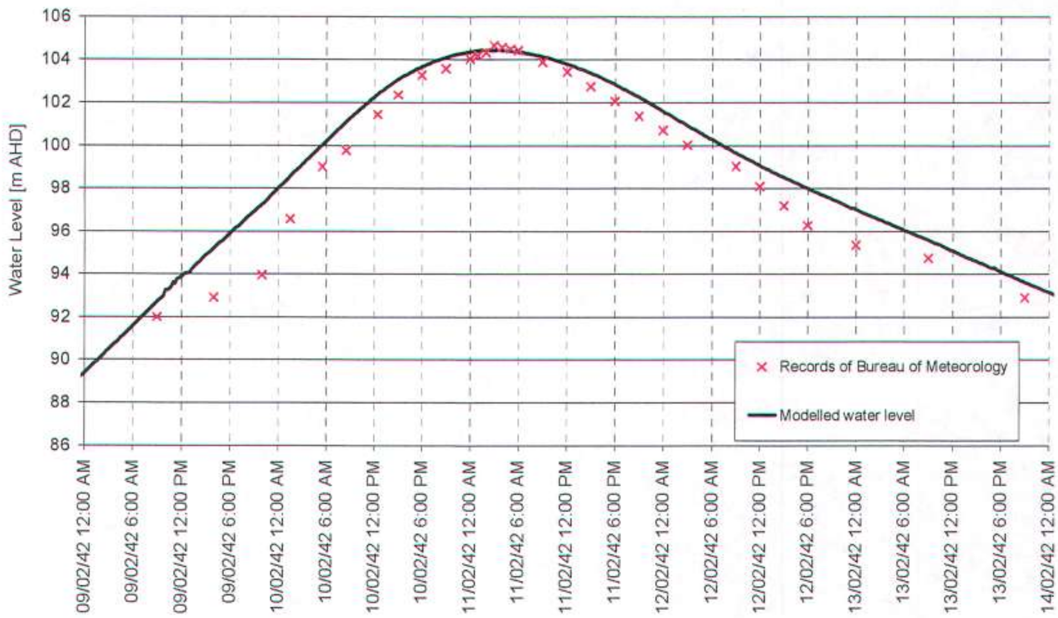


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**Figure 5-15 Measured and Modelled Water Levels at Gauging Station 136914 (Simon Street, Gayndah)**

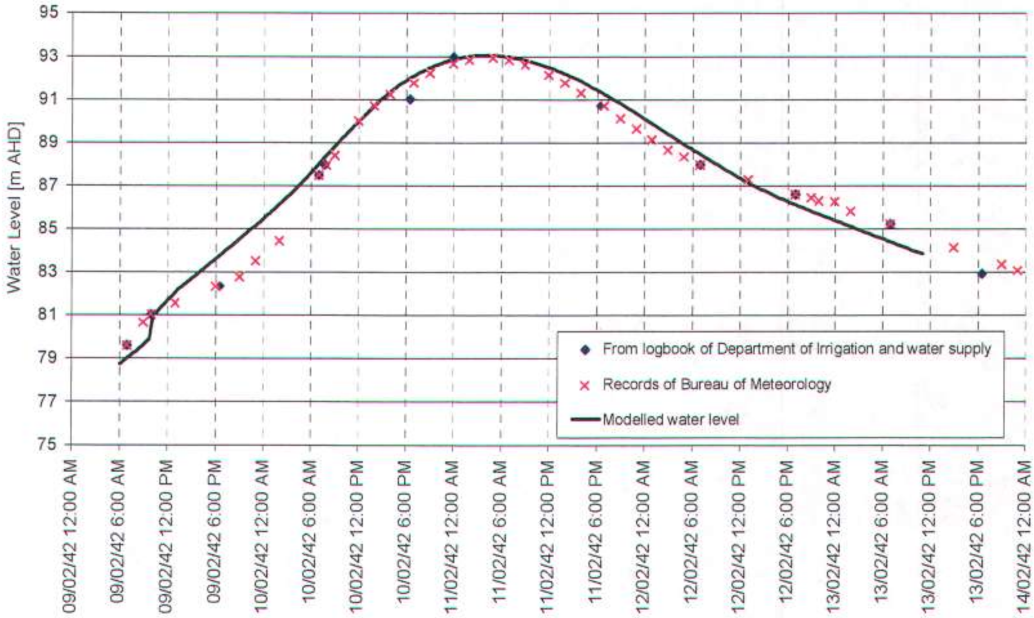


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**Figure 5-16 Measured and Modelled Water Levels at Gauging Station 136002B (Mt. Lawless)**

# 6 ASSESSMENT OF DESIGN FLOOD EVENTS

## 6.1 Introduction

This Section describes the assessment of the design flood events. Design flood events are hypothetical floods representing a specific likelihood of exceedance (expressed as a percentage).

For this study, six design flood events were analysed, ranging from the 5% Annual Exceedance Probability (AEP) to the Probable Maximum Flood (PMF). The design flood events considered for the flood study are summarised in Table 6-1.

**Table 6-1 Design Flood Events Considered**

| AEP | Comments |
|---|---|
| 5% (1:20) | A hypothetical flood or combination of floods with an annual exceedance probability of 5%. This represents a scenario likely to occur on average once every 20 years |
| 2% (1:50) | As for the 5% AEP flood but with a 2% probability or 50 year return period |
| 1% (1:100) | As for the 5% AEP flood but with a 1% probability or 100 year return period |
| 0.5% (1:200) | As for the 5% AEP flood but with a 0.5% probability or 200 year return period |
| 0.2% (1:500) | As for the 5% AEP flood but with a 0.2% probability or 500 year return period |
| PMF (< 0.005%) | A hypothetical flood or combination of floods, which represent an extreme scenario based on the probable maximum precipitation event (PMP). It is only used for special purposes where a high factor of safety is recommended. PMP rainfall estimates were derived using GTSMR 2003. |

The assessment oThe assessment of the design flood events comprised of a hydrological analysis and a Hydraulic modelling analysis. The hydrological analysis of the design flood event is discussed in Section 6.2 and the hydraulic assessment of the design flood event in Section 6.4.

## 6.2 Hydrological Analysis of the Design Flood Events

The hydrological assessment was undertaken to develop design flood hydrographs for the Burnett River and associated tributaries. The design flood hydrographs, which were used to provide inflows to the hydraulic model of the Burnett River, were derived using the calibrated Burnett River catchment RORB model.

Estimation of design flood hydrographs involved the application of the design event rainfall data as input to the calibrated Burnett River catchment RORB model. Verification of the design flood hydrographs resulting from the model was undertaken by comparing the peak flow magnitudes derived from the RORB model with peak flow estimates resulting from a statistical analysis of the recorded peak flows (Flood Frequency Analysis).

### 6.2.1 Estimation of Design Rainfall

Estimation of design flood hydrographs, using the design event approach, involved the application of the design event rainfall data as input to the calibrated Burnett River catchment RORB model. This approach assumes that the probability of the design flood event is the same as the associated design rainfall event from which it is estimated.

The rainfall depth for design rainfall events are dependent on the catchment area considered. For the development of the design flood hydrographs of this study, three catchments are considered, namely the Burnett River Catchment to Gayndah, Burnett River Catchment to Walla and the Residual catchment. The Residual Catchment is the catchment of the Burnett River between Gayndah and Walla, which includes Barambah Creek.

Rainfall estimates for Frequent to Rare Floods (design flood events up to 0.05% AEP were derived using the regional CRC-FORGE method described by Hargraves (2005) for durations of 15 minutes up to 120 hours.

Rainfall estimates for the Probable Maximum Precipitation event (PMP) were derived using GTSMR (2003), which provides guidelines to estimating PMPs for durations up to 120 hours in regions of Australia affected by tropical storms.

The methods used to derive the design rainfall estimates for these catchments are summarised below.

#### *6.2.1.1 Areal Reduction Factors*

An Areal Reduction Factor (ARF) is introduced to convert point rainfall estimates to areal estimates and to correct for the variation of rainfall intensity over a large catchment area.

The ARFs adopted for this study were derived using the CRC-FORGE methodology for the Burnett River catchment. The ARF for all duration events for each catchment is summarised in Table 6-2 below.

**Table 6-2 Design Areal Reduction Factors**

| Catchment | Duration 24h | Duration 36h | Duration 48h | Duration 72h | Duration 96h | Duration 120h |
|---|---|---|---|---|---|---|
| Burnett River to Gayndah | 0.727 | 0.805 | 0.840 | 0.862 | 0.876 | 0.727 |
| Burnett River to Walla | 0.708 | 0.791 | 0.828 | 0.851 | 0.866 | 0.708 |
| Residual | 0.780 | 0.845 | 0.874 | 0.892 | 0.904 | 0.780 |

#### *6.2.1.2 Rainfall Estimation for Frequent, Large and Rare Floods*

Design rainfall estimates for the 5% AEP up to the 0.05% AEP events for durations of 15 minutes to 120 hours were derived by CRC-FORGE methodology. CRC-FORGE is a method of regional rainfall frequency analysis that derives rainfall depth estimates of frequent, large and rare flood events. The method uses the concept of an expanding region focussed at the site of interest. For Queensland, Hargraves (2005) developed an application, which derives these rainfall estimates.

Table 6-3, Table 6-4 and Table 6-5 contain the CRC-FORGE design rainfall estimates for the events of interest in this study, namely the 5% AEP up to the 0.2% AEP for the storm durations of 24 hours to 120 hours for the Burnett River to Gayndah, Burnett River to Walla and Residual catchments respectively. Note that the appropriate ARFs have been applied to the values in the tables.

**Table 6-3 CRC-FORGE Design Rainfall – Burnett River to Gayndah Catchment**

| Duration (Hours) | Rainfall Depth (mm) | | | | |
|---|---|---|---|---|---|
| | 5% AEP (1:20) | 2% AEP (1:50) | 1% AEP (1:100) | 0.5% AEP (1:200) | 0.2% AEP (1:500) |
| 24 | 102 | 123 | 139 | 155 | 177 |
| 48 | 141 | 170 | 191 | 213 | 243 |
| 72 | 161 | 194 | 219 | 245 | 281 |
| 96 | 172 | 208 | 234 | 262 | 300 |
| 120 | 181 | 218 | 246 | 274 | 314 |

**Table 6-4 CRC-FORGE Design Rainfall – Burnett River to Walla Catchment**

| Duration (Hours) | Rainfall Depth (mm) | | | | |
|---|---|---|---|---|---|
| | 5% AEP (1:20) | 2% AEP (1:50) | 1% AEP (1:100) | 0.5% AEP (1:200) | 0.2% AEP (1:500) |
| 24 | 104 | 126 | 141 | 158 | 181 |
| 48 | 144 | 174 | 196 | 219 | 252 |
| 72 | 165 | 199 | 225 | 252 | 291 |
| 96 | 178 | 214 | 242 | 271 | 312 |
| 120 | 187 | 226 | 255 | 285 | 327 |

**Table 6-5 CRC-FORGE Design Rainfall – Residual Catchment**

| Duration (Hours) | Rainfall Depth (mm) | | | | |
|---|---|---|---|---|---|
| | 5% AEP (1:20) | 2% AEP (1:50) | 1% AEP (1:100) | 0.5% AEP (1:200) | 0.2% AEP (1:500) |
| 24 | 128 | 155 | 174 | 195 | 223 |
| 48 | 171 | 207 | 234 | 263 | 304 |
| 72 | 193 | 233 | 265 | 299 | 347 |
| 96 | 206 | 250 | 284 | 320 | 373 |
| 120 | 217 | 263 | 299 | 337 | 392 |

#### *6.2.1.3 Rainfall Estimation for Extreme Floods*

Probable Maximum Precipitation (PMP) estimates for the Burnett River to Gayndah and the Burnett River to Walla catchments were calculated based on GTSMR (2003). The PMP calculation sheets for both catchments are provided in Appendix D.

It was unnecessary to calculate a PMP estimate for the Residual catchment, since an event of considerably smaller magnitude on the Residual catchment combined with a PMP event on the Burnett River to Gayndah would result in a PMP event at Walla. Events on the Residual catchment were concurrent events that, combined with events on the Burnett River to Gayndah catchment, would result in AEP neutrality at Walla.

Note that for durations up to 6 hours, GSDM (2003) is applicable. However, given the large size of the catchments, the critical duration was estimated to be greater than 6 hours and PMP for durations less than 6 hours were not required.

According to GTSMR (2003), the AEP of the PMP Design Flood event was estimated to be approximately $2.3*10^{-3}$% (1:43,000) for the Burnett River to Gayndah and approximately $3.2*10^{-3}$%

(1:31,000) for the Burnett River to Walla. Table 6-6 provides the PMP estimates for both catchments for durations from 24 hours to 120 hours.

**Table 6-6 GTSMR PMP Rainfall**

| Duration (Hours) | PMP Estimates (mm) | |
|---|---|---|
| | Burnett River to Gayndah | Burnett River to Walla |
| 24 | 541 | 491 |
| 36 | 653 | 599 |
| 48 | 757 | 699 |
| 72 | 941 | 877 |
| 96 | 1,061 | 984 |
| 120 | 1,097 | 1,015 |

### *6.2.1.4 Adopted Design Rainfalls*

Plots of the Adopted Design Rainfall are presented in Figure 6-1, Figure 6-2 and Figure 6-3. Note that no estimates were made between the 0.05% AEP (1:2,000 AEP) and PMP events.

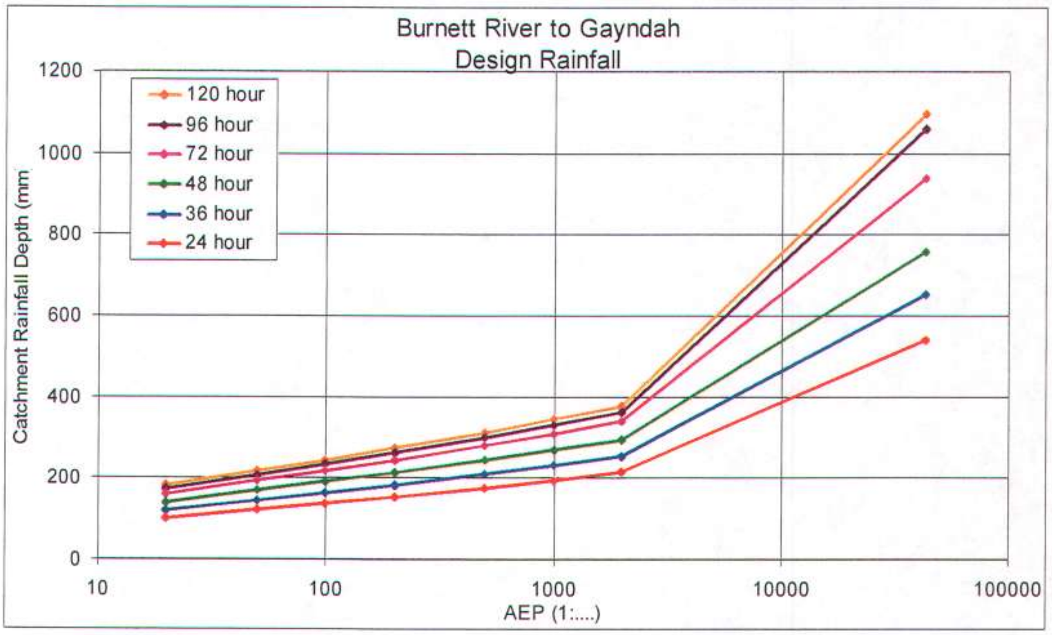



**Figure 6-1 Adopted Design Rainfall – Burnett River to Gayndah Catchment**

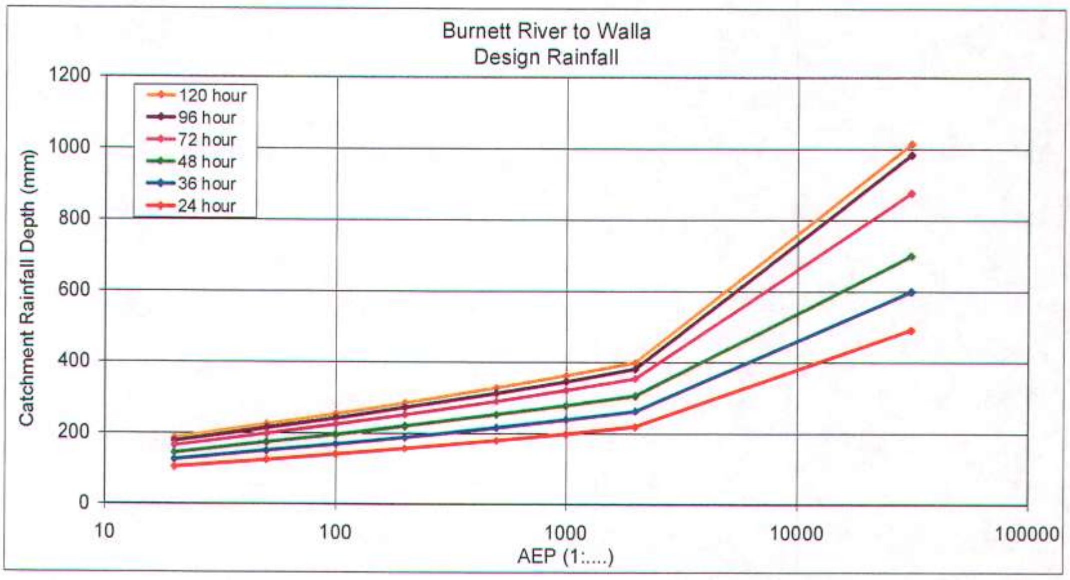



**Figure 6-2 Adopted Design Rainfall – Burnett River to Walla Catchment**

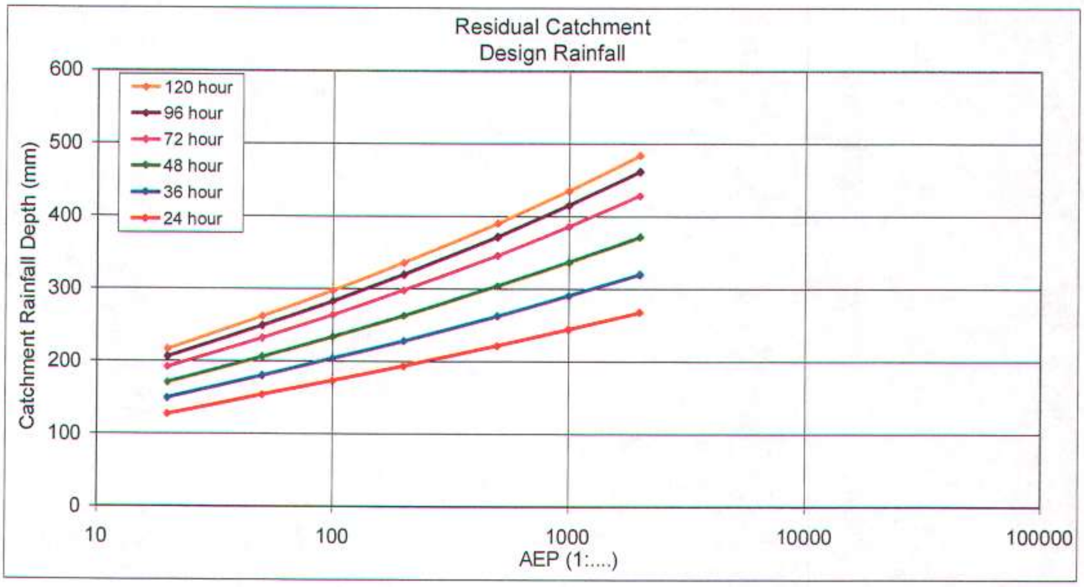



**Figure 6-3 Adopted Design Rainfall – Residual Catchment**

### *6.2.1.5 Temporal Patterns*

Design temporal patterns are used to distribute design rainfall estimates over time and can have significant impact on the estimation of the design floods.

The GTSMR (2003) specifies temporal patterns to be used for specified catchment areas. Hence, for the Burnett River to Gayndah, Burnett River to Walla and the Residual catchment, the appropriate temporal pattern for the corresponding catchment area was used.

The temporal patterns used for all flood events considered are tabulated in Appendix E.

#### *6.2.1.6 Adopted Design Model Parameters*

As discussed in Section 5.1, the adopted model parameters for m (catchment degree of non-linearity and $k_c$ (catchment storage parameter) are 0.85 and 210 respectively.

Parameters for the design loss rates were kept consistent with previous hydrological studies of the Burnett River; (DNRM, 1998), (SunWater, 2002) and (SunWater, 2003). The design rainfall loss rates applied are:

- Initial loss = 0 mm.
- Continuing loss = 1.5 mm/h for events with AEP's of 0.1% or less
- Continuing loss = 1.75 mm/h for events with AEP's greater than 0.1%

For further details, reference should be made to (DNRM, 1998), (SunWater, 2002) and (SunWater, 2003).

### 6.2.2 Design Flood Hydrographs

On the basis of design rainfalls, design flood hydrographs were derived using the Burnett River catchment RORB model.

In estimating design floods from design rainfalls, it is the usual practice to assume that the design rainfall of a given AEP will result in a design flood of the same AEP. This assumes that a number of inputs to the process, e.g. losses, model parameters, temporal patterns, etc. are themselves AEP neutral.

#### *6.2.2.1 Design Flood Hydrographs at Gayndah*

The adopted rainfall depths and temporal patterns for the catchment of the Burnett River to Gayndah were routed through the RORB model to determine peak discharges for the various storm durations and AEPs.

The peak design flows in the Burnett River at Gayndah over the range of durations are given in Table 6-7. The critical durations (shaded in Table 6-7) were found to be the 36 hour duration storm for the 5% AEP, 2% AEP and PMP events, and the 48 hour duration storm for the 1% AEP, 0.5% AEP and 0.2% AEP events.

**Table 6-7 Peak Flows ($m^3/s$) – Burnett River at Gayndah**

| AEP | Duration (hours) | | | | | |
|---|---|---|---|---|---|---|
| | 24 | 36 | 48 | 72 | 96 | 120 |
| 5% (1:20) | 6,840 | 6,960 | 6,760 | 5,510 | 4,540 | 4,650 |
| 2% (1:50) | 9,510 | 9,890 | 9,810 | 8,170 | 6,980 | 6,990 |
| 1% (1:100) | 11,510 | 12,130 | 12,180 | 10,250 | 8,930 | 8,880 |
| 0.5% (1:200) | 13,630 | 14,490 | 14,670 | 12,520 | 11,010 | 10,920 |
| 0.2% (1:500) | 16,780 | 17,900 | 18,240 | 15,770 | 13,990 | 13,940 |
| < 0.005% (PMP) | 73,160 | 82,080 | 81,990 | 77,940 | 76,610 | 76,140 |

### *6.2.2.2 Concurrent Floods on the Residual Catchment*

Once the critical storm durations at Gayndah had been determined, it was necessary to determine the concurrent flooding event on the Residual catchment that would maintain AEP neutrality over the Burnett River between Gayndah and Walla, as outlined in Section 7.3 of Australian Rainfall and Runoff (AR&R, 2001).

To achieve this, it was necessary to estimate the design flows for the Burnett River to Walla catchment, and then to determine the concurrent event on the Residual catchment, which, when combined with the critical duration event on the Burnett River to Gayndah catchment, would result in a similar peak flow at Walla.

To determine the design flows for the Burnett River at Walla, the adopted rainfall depths and temporal patterns for the catchment of the Burnett River to Walla were routed through the RORB model with Paradise Dam removed. For the determination of the design flows the critical storm duration of each AEP as determined previously for the Burnett River at Gayndah were used.

The resulting peak design flows at Walla are given in Table 6-8.

**Table 6-8 Peak Design Flows - Burnett River at Walla**

| AEP | Duration (hours) | Rainfall Depth (mm) | Peak Flow ($m^3/s$) |
|---|---|---|---|
| 5% (1:20) | 36 | 124 | 8,210 |
| 2% (1:50) | 36 | 150 | 11,630 |
| 1% (1:100) | 48 | 196 | 15,150 |
| 0.5% (1:200) | 48 | 219 | 18,160 |
| 0.2% (1:500) | 48 | 252 | 22,640 |
| <0.005% (PMP) | 36 | 599 | 83,980 |

### *6.2.2.3 Estimation of Design Flows for Residual Catchment*

The design flows for the Residential catchment follow from the design flows for the Burnett River to Gayndah and for the Burnett River to Walla. To determine the design flows for the Residual catchment, for each AEP, the critical duration event over the Burnett River to Gayndah was combined with a range of AEP events on the Residual catchment of the same duration. The resultant peak flows at Walla were then compared to the peak flows calculated at Walla for a single event over the Burnett River to Walla catchment. As stated earlier, Paradise Dam was removed from the Burnett River to Walla model.

This method is best illustrated by use of an example. The critical duration for a 5% AEP event on the Burnett River to Gayndah is 36 hours and resulted in a peak discharge of 6,960 $m^3/s$. The resulting peak discharge for a 36-hour duration 5% AEP event on the Burnett River to Walla is 8,210 $m^3/s$.

To maintain the peak flow at Walla for this AEP, several concurrent design events of varying AEP on the Residual catchment were trailed. In this case, it was found that a 10% AEP event on the Residual catchment resulted in a peak discharge of 8,260 $m^3/s$, acceptably close to the peak discharge of the 5% AEP event at Walla, thus maintaining AEP neutrality. In general, it was found that the AEP of the Residual catchment required to maintain AEP neutrality was less than the AEP of the design events at Gayndah and Walla. The results for all AEPs are summarised in Table 6-9.

**Table 6-9 Estimation of Trailed Concurrent Events in Residual Catchment**

| Catchment | Peak Flow at Walla ($m^3/s$) |
|---|---|
| **5% AEP Design Flood Event (1:20) - Critical Duration - 36 hours** | |
| Burnett River to Walla | 8,210 |
| Burnett River to Gayndah (6,960 $m^3/s$) | |
| • Combined with 5% AEP in Residual | 8,770 |
| • **Combined with 10% AEP in Residual** | **8,260** |
| • Combined with 20% AEP in Residual | 7,880 |
| **2% AEP Design Flood Event (1:50) - Critical Duration - 36 hours** | |
| Burnett River to Walla | 11,630 |
| Burnett River to Gayndah (9,890 $m^3/s$) | |
| • Combined with 2% AEP in Residual | 12,470 |
| • **Combined with 5% AEP in Residual** | **11,660** |
| • Combined with 10% AEP in Residual | 11,140 |
| **1% AEP Design Flood Event (1:100) - Critical Duration - 48 hours** | |
| Burnett River to Walla | 15,150 |
| Burnett River to Gayndah (12,180 $m^3/s$) | |
| • **Combined with 1% AEP in Residual** | **15,650** |
| • Combined with 2% AEP in Residual | 14,960 |
| • Combined with 5% AEP in Residual | 14,050 |
| **0.5% AEP Design Flood Event (1:200) - Critical Duration - 48 hours** | |
| Burnett River to Walla | 18,160 |
| Burnett River to Gayndah (14,670 $m^3/s$) | |
| • Combined with 0.5% AEP in Residual | 18,890 |
| • **Combined with 1% AEP in Residual** | **18,110** |
| • Combined with 2% AEP in Residual | 17,420 |
| **0.2% AEP Design Flood Event (1:500) - Critical Duration - 48 hours** | |
| Burnett River to Walla | 22,640 |
| Burnett River to Gayndah (18,240 $m^3/s$) | |
| • Combined with 0.2% AEP in Residual | 23,470 |
| • **Combined with 0.5% AEP in Residual** | **22,350** |
| • Combined with 1% AEP in Residual | 21,560 |
| **PMP Event - Critical Duration - 36 hours** | |
| Burnett River to Walla | 83,980 |
| Burnett River to Gayndah (82,080 $m^3/s$) | |
| • Combined with 0.2% AEP in Residual | 85,240 |
| • **Combined with 0.5% AEP in Residual** | **84,150** |
| • Combined with 1% AEP in Residual | 83,360 |

Table 6-11 Peak Inflow Discharges of Design Flood Events

| Design Flood Event | Peak Discharge at Inflow Location [m³/s] | | | |
|---|---|---|---|---|
| | Burnett River at Claude Wharton Weir | Barambah Creek | Surface runoff across Study Area (2D model) | Oaky Creek |
| 5% AEP (1:20) | 6,960 | 1,983 | 63.0 | 82.4 |
| 2% AEP (1:50) | 9,890 | 2,638 | 80.8 | 105.7 |
| 1% AEP (1:100) | 12,180 | 4,054 | 82.5 | 108.0 |
| 0.5% AEP (1:200) | 14,670 | 4,054 | 94.8 | 124.1 |
| 0.2% AEP (1:500) | 18,240 | 4,874 | 111.6 | 146.2 |
| PMF | 82,080 | 4,874 | 428.2 | 560.6 |

## 6.4 Hydraulic Assessment of Design Flood Events

The calibrated TUFLOW hydraulic model described in Discussion Paper 1 was modified to reflect changes in the catchment experienced between 1942 and present date. This involved the representation of two water storage facilities (Claude Wharton Weir and Paradise Dam) and two replaced bridges, namely the Les Baker Bridge (crossing of Burnett Highway with the Burnett River) and the McKenzie Bridge (crossing of Burnett Highway with Oakey Creek). For details on the representation of these hydraulic structures, reference should be made to Section 4.2.6.

The TUFLOW hydraulic model was then used to simulate the 5%, 2%, 1%, 0.5% and 0.2% AEP design flood events as well as the PMF (Probable Maximum Flood). Animations of these design flood events are included on the CD ROM in Appendix C. The animations show the propagation of the flooding throughout Gayndah Township and are in AVI format, which can be viewed with standard video viewing software such as WINDOWS Media Player.

The model results of the design flood events were used to prepare a set of flood maps, which are included in Volume 2 of this report. The flood maps of all design flood events considered are also provided to Council as digital GIS data.

Drawing II- 1 to Drawing II- 6 in Volume 2 present the peak flood levels of the design flood events considered as well as the PMF. Peak flood depths, flow velocities and the peak velocity-depth products are shown in Drawing II- 7 to Drawing II- 24. A long section of the peak flood levels along the Burnett River between Claude Wharton Weir and Paradise Dam is shown in Figure 6-7. Peak flood levels at key locations are summarised in Table 6-12.

Assessing the peak flood levels of the design flood events, it is noted that the bridge deck of the Les Baker Bridge will be inundated for flood events with an AEP of just larger than 1% (bridge deck is at

104.0 mAHD), while the MacKenzie Bridge (bridge deck at 101.5 mAHD) is inundated from flood events with an AEP between 2% (1:50) and 1% (1:100). The flow velocities on the bridge deck of Les Baker Bridge are expected to be high when overtopping occurs. This is in contrast to the flow velocities at the MacKenzie Bridge, where flow velocities on the bridge deck are expected to be fairly low.

**Table 6-12 Peak Flood Levels at key locations in Gayndah**

| | Peak Flood Level [m AHD] | | | | | |
|---|---|---|---|---|---|---|
| **Location** | **5% AEP** | **2% AEP** | **1% AEP** | **0.5% AEP** | **0.2% AEP** | **PMF** |
| Sauer Gully | 99.8 | 102.2 | 104.0 | 105.5 | 107.3 | 119.3 |
| Les Baker Bridge | 99.1 | 101.5 | 103.2 | 104.7 | 106.6 | 118.9 |
| Golf Course | 98.5 | 100.8 | 102.5 | 104.0 | 105.9 | 118.4 |

## 6.5 Climate Change

State Planning Policy 1/03 demands that the potential impacts of climate change are addressed as part of a flood study. For Gayndah, the potential impacts of climate change are most likely to be related to increased runoff of the Burnett River due to increases in extreme rainfall intensity in the Burnett River catchment.

Although, to date there have been no conclusive studies that quantify the impact of climate change due to the greenhouse effect on either the frequency or intensity of major (flood) rainfall events in the Burnett River Catchment, it is important to consider the potential adverse consequences of climate change on flooding for town planning purposes.

In order to enable a quantified assessment of potential climate change impacts on flood risk in Gayndah, national and international publications were reviewed. A summary of this review is provided below.

### 6.5.1 Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) is a scientific intergovernmental body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP). The IPCC was established to provide the decision-makers and others interested in climate change with an objective source of information about climate change.

Its latest report "Climate Change 2007 - Impacts, Adaptation and Vulnerability" was launched on 6 April 2007 in Paris. This report (IPCC, 2007) includes projections for annual temperature rises (global warning). For Australia, within 400 km of the coast, IPCC predicts an increase in annual average temperature of +0.3 to 2.7 °C by 2050 (Refer to Chapter 11 of Working Group II Report "Impacts, Adaptation and Vulnerability"). The ranges of projected annual average temperature are based on results from forty SRES emission scenarios.

The potential implications of the projected increase in annual average temperature on extreme rainfall events were interpreted using guidance of New Zealand Climate Change Office; "Preparing for Climate Change - A guide for local government in New Zealand" (NZCCO, 2004). For a 100 year ARI flood event with a 48 hour storm duration, (NZCCO, 2004) recommends an extreme rainfall increase of 5.5 % per degree Celsius of warming. With an increase in annual average temperature of +0.3 to 2.7 °C, this would result in a 100 year ARI rainfall depth increase by +2 to +15% or 4 to 28 mm.

Although these extreme rainfall depth increases have not been explicitly investigated through a modelling analysis, interpretation of modelling results for the design flood events indicate that this may correspond with an increase in peak flow discharge at Gayndah by up to around 20%.

### 6.5.2 Australian Greenhouse Office

On behalf of the Australian Greenhouse Office (Department of Environment and Heritage), CSIRO investigated potential impacts of climate change. The results are documented in (CSIRO, 2006).

The CSIRO study considered two climate change scenarios; the Low Global Warming scenario, which assumes the lowest SRES emission scenario and lowest climate sensitivity and the High Global Warming scenario, which assumes the highest SRES emission scenario and highest climate sensitivity. The report analysed 10 different regions in Australia.

For South-eastern Queensland, (CSIRO, 2006) reports an increase of extreme daily rainfall intensity by 2040 of +0% to +30% (for the Low Global Warming scenario and the High Global Warming scenario respectively). It is noted that the predicted impacts on extreme daily rainfall intensity are based on one single model and apply to a 1 in 20 year flood event.

### 6.5.3 Planning Policy Statement 25: Development and Flood Risk

Planning Policy Statements (PPS) set out the Government's national policies on different aspects of land use planning in England. Planning Policy Statement 25 deals with flood risk management of land use planning.

In making an assessment of the impacts of climate change on flooding from rivers, PPS 25 recommends consideration of an increased peak river flow of +20% for a planning period from 2025 to 2085. For an appropriate response to the uncertainty about climate change impacts on extreme rainfall intensity, PPS 25 recommends an increase of +10% for a planning period from 2025 to 2055 and +20% for 2055 to 2085.

### 6.5.4 Recommended Consideration of Climate Change Impacts

For Gayndah, the climate change impacts are most likely to be related to increased runoff of the Burnett River. Preliminary modelling has identified that flood conditions in Gayndah are sensitive to changes in the peak river discharge. Therefore flood conditions in Gayndah are likely to be sensitive to potential adverse impacts of climate change. This means that a site currently located in a low risk area could over its life cycle be lying within a higher risk area (eg. high hazard zone).

To ensure that planning decisions in Gayndah are sustainable for the future, it is strongly recommended that potential impacts of climate change are considered when making decisions in relation to town planning or proposed developments.

Based on the review of national and international publications on climate change impacts, an 20% increased peak flow discharge may provide an appropriate response to the uncertainty about climate change impacts for a planning horizon of 50 years (reference year 2057).

It is recommended that for town planning purposes and development assessments in Gayndah, consideration is given to flood events with a climate change allowance of 20% (ie. the peak flows of the design flood events should be increased by 20 % to allow for climate change impacts).

Although no specific modelling investigations were undertaken in this study to assess the flood conditions with climate change impacts, nevertheless an estimate for the 1% AEP event inclusive of climate change impacts was made. Applying a peak flow allowance of 20% to the 1% AEP design flood event inflow hydrograph of the Burnett River at Gayndah, results in a peak inflow discharge that is similar to the peak flow of the 0.5% AEP design flood event ($Q_{1\%\ AEP}$ plus 20%= 14,616 $m^3/s \approx$ 14,670 $m^3/s = Q_{0.5\%\ AEP}$). As such, the flood maps of the 0.5% AEP design flood event may be used to assess flood conditions of the 1% AEP flood event with climate change impacts.

## 6.6 Conclusions of Design Flood Assessment

Calibrated hydrological and hydraulic numerical models have been utilised to investigate the flood behaviour of the Burnett River at Gayndah. The flood models were used to simulate the 5%, 2%, 1%, 0.5% and 0.2% AEP design flood events as well as the PMF event (Probable Maximum Flood).

Flood maps of design flood events are presented in Drawing II-1 to Drawing II-24 in Volume 2 and animations of the design flood events are included on the CD ROM in Appendix C.

In relation to the flood model results for the design flood events, the following is noted:

- The 1% AEP design flood event for the Burnett River at Gayndah is expected to have a peak flow discharge of approximately 12,180 $m^3/s$, caused by an average rainfall depth of around 196mm in 48 hours. The peak discharge of the 1% AEP design flood event is likely to be experienced around 2.5 days into the flood event.
- During flood events, floodwaters from the Burnett River backfill into Oaky Creek and to a smaller extent into the numerous gullies along the banks of the Burnett River. This backfilling is the main mechanism of flooding in the township for relatively frequent flood events. For the 5% AEP flood event (AEP of 1:20), substantial flooding occurs around the golf course due to backfilling of Oaky Creek, including parts along Nanango Street, Short Street and Alfred Street;
- Peak flood levels around Sauer Gully are 104.0mAHD for the 1% AEP flood event (AEP of 1:100), with the 5% AEP flood level (AEP of 1:20) at 99.8mAHD and the 0.5% AEP flood level (AEP of 1:200) at 105.5mAHD;
- Peak flood levels at the Les Baker Bridge are 103.2mAHD for the 1% AEP flood event (AEP of 1:100), with the 5% AEP flood level (AEP of 1:20) at 99.1mAHD and the 0.5% AEP flood level (AEP of 1:200) at 104.7mAHD;

- Peak flood levels around the golf course are 102.5mAHD for the 1% AEP flood event (AEP of 1:100), with the 5% AEP flood level (AEP of 1:20) at 98.5mAHD and the 0.5% AEP flood level (AEP of 1:200) at 104.0mAHD;
- The model results indicate that the flow path from the showgrounds towards Oaky Creek, as experienced during the 1942 flood event, does not occur for the flood events up to the 1% AEP design flood event. For the 1% AEP design flood event, the area around Queen Street and Warton Street remains dry. However it is highly uncertain if this area remains dry during flood event with an annual exceedance probability of 1% when possible impacts of climate change are taken into account;
- From flood events with an AEP of 1% or greater, water levels in the reservoir of Claude Wharton Weir exceed 104.8mAHD and a flow path over the floodplain near Meson Street develops. As a result, not the entire river discharge flows over the weir of Claude Wharton Weir. The proportion of the river discharge that bypasses the weir increases with increasing flood magnitude. For the 1% AEP event, the peak discharge of the flow that is routed over the floodplain into the town area is 14 $m^3/s$ (or 0.1 % of peak discharge), 578 $m^3/s$ (or 3.9 % of peak discharge) for the 0.5% AEP event and 1,777 $m^3/s$ (or 9.7% of peak discharge) for the 0.2% AEP event;
- The flood conditions in Gayndah are likely to be sensitive to potential adverse impacts of climate change. To ensure that flood risk management policies are sustainable for the future, it is recommended to consider the potential impacts of climate change on the flood behaviour in Gayndah when making decisions in relation to town planning or proposed developments;
- For Gayndah, an appropriate response to the uncertainty about climate change impacts for a planning horizon of 50 years (to 2057) would be consideration of a peak flow discharge allowance of 20%. With a peak flow discharge allowance of 20%, the peak flow discharge of the Burnett River at Gayndah for the 1% AEP flood event inclusive of climate change impacts to 2057 is similar to the peak flow discharge for the 0.5% AEP design flood event (without climate change). The flood maps for the 0.5% AEP design flood event may therefore be used to assess flood conditions of the 1% AEP flood event with climate change impacts to 2057.

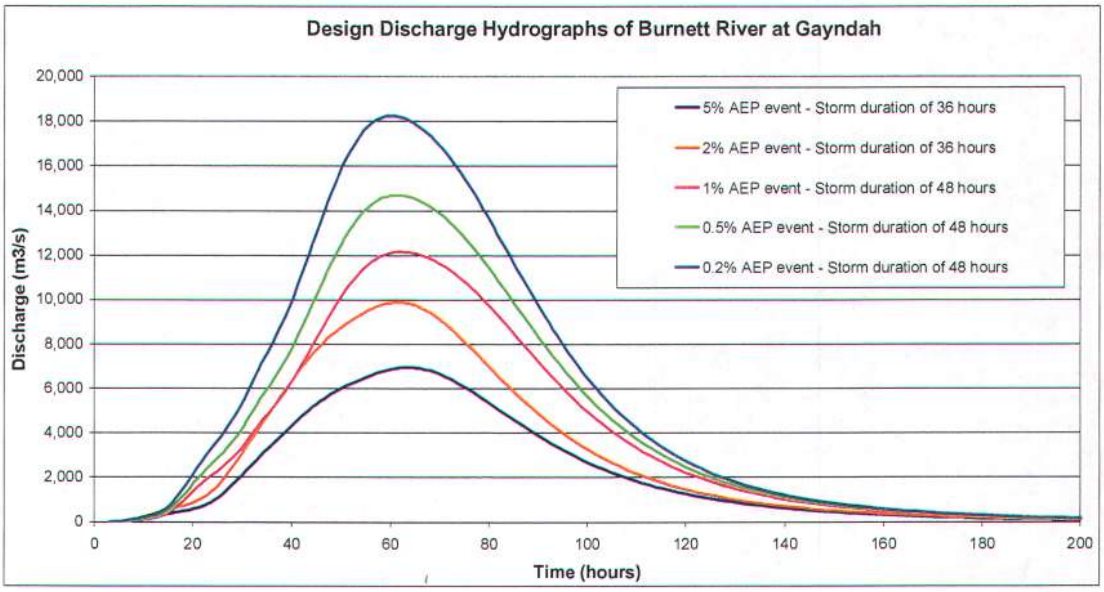



**Figure 6-5 Design Inflow Hydrographs for Burnett River to Gayndah**

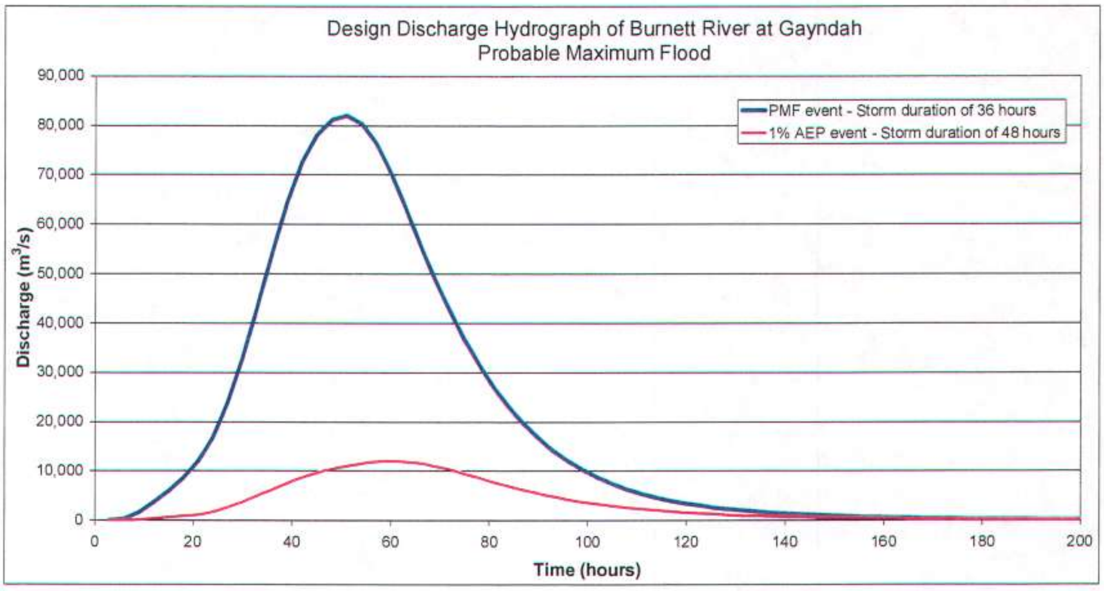



**Figure 6-6 Design Inflow Hydrographs for Burnett River to Gayndah - PMF**

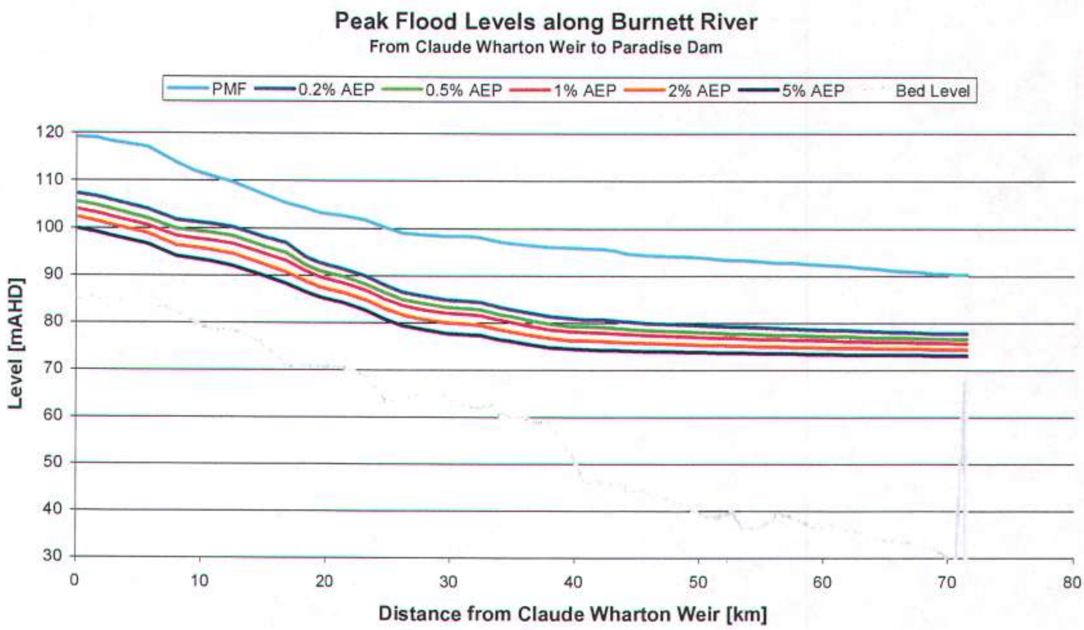



**Figure 6-7 Peak Flood Levels along Burnett River**

# 7 FLOOD HAZARD ASSESSMENT

## 7.1 Introduction

Flood Hazard is the term used to describe the potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies both in time and place across a floodplain. Floodwaters are deep and fast flowing in some areas, whilst at other locations they are shallow and slow moving. It is important to determine and understand the variation of degree of hazard and flood behaviour across the floodplain over a wide range of possible floods.

The definition of flood hazard over the floodplains is important input to the development of a Flood Inundation Management Plan and town planning. This section discusses the different approaches available for defining flood hazard.

## 7.2 Flood Hazard Categorisation

A review of the methodology in CSIRO (2000), DLWC (2001) and previous floodplain management plans for the categorisation of flood hazard is undertaken and a methodology is recommended for the Burnett River floodplain at Gayndah.

### 7.2.1 CSIRO (2000)

It is necessary to divide the floodplain into flood hazard categories that reflect the flood behaviour across the floodplain. Guidance is provided in "Floodplain Management in Australia – Best Practice Principles and Guidelines by CSIRO, (CSIRO, 2000). (CSIRO, 2000) refers to the degree of flood hazard as being a function of:

- The size (magnitude) of flooding;
- Depth and velocity (speed of flowing water);
- Rate of floodwater rise;
- Duration of flooding;
- Evacuation problems;
- Effective flood access;
- Size of population at risk;
- Land use;
- Flood awareness/readiness; AND
- Effective flood warning time.

CSIRO (2000) suggests four degrees of hazard: low, medium, high and extreme. The categorisation of the floodplain is largely qualitative using the above factors. For example, medium hazard is where adults could wade safely, but children and elderly may have difficulty, evacuation is possible by a sedan, there is ample time for flood warning and evacuation and evacuation routes remain trafficable for at least twice as long for the required evacuation time.

A key factor in the ease of evacuation from an area is the water depth and the velocity along the evacuation route, i.e., the stability of pedestrians wading through flood waters or vehicles driving along flooded roads. CSIRO (2000) notes that there are estimation procedures available for stability estimation, but considers that further research is required across a broader range of conditions and so does not recommend a procedure for hazard categorisation on this basis.

### 7.2.2 DLWC (2001)

DLWC (2001) identifies similar contributing factors to flood hazard as identified in CSIRO (2000). However, in recognition of the need to incorporate floodplain risk management into statutory planning instruments, DLWC (2001) recommends that land-use categorisation in flood prone areas be based on two categories, 'hydraulic' and 'hazard'. Hydraulic categories "*reflect the impact of development activity on flood behaviour*", and hazard categories reflect "*the impact of flooding on development and people.*" Three hydraulic categories are identified – fringe flooding, flood storage and floodway – and two hazard categories – high and low resulting in the following categories:

1 Low Hazard – Flood Fringe;

2 Low Hazard – Flood Storage;

3 Low Hazard – Floodway;

4 High Hazard – Flood Fringe;

5 High Hazard – Flood Storage; and

6 High Hazard – Floodway.

A definition of the hydraulic and hazard categories is given in Table 7-1.

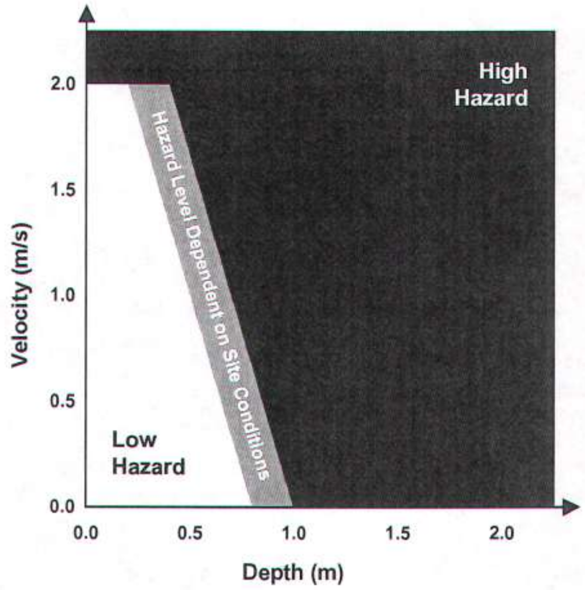
**Table 7-1 Definition of Hydraulic and Hazard Categories**

| Category | Definition |
|---|---|
| **Hydraulic** | |
| *Flood Fringe* | The remaining area of flood prone land after floodway and flood storage have been defined. Development in this area would not have any significant effect on the pattern of flood flow and/or flood levels. |
| *Flood Storage* | Those parts of the floodplain that are important for the temporary storage of floodwater during the passage of a flood. A substantial reduction of the capacity of the flood storage would increase nearby flood levels, re-distribute flows and increase flows downstream. |
| *Floodway* | Those areas where a significant volume of water flows during floods and are often associated with natural channels. If they are even only partially blocked, there will be a significant increase in flood levels and possibly a re-distribution of flows resulting in impacts elsewhere. |
| **Hazard** | |
| *Low* | People and possessions could be evacuated by trucks and/or wading. The risk to life is considered to be low. |
| *High* | Evacuation by trucks would be difficult, able-bodied adults would have difficulty wading to safety, possible danger to personal safety and structural damage buildings is possible. |

DLWC (2001) recommends that the definition of hazard initially be undertaken using relationships between depth (D) and velocity (V) of floodwater, i.e., using hydraulic principles, and then the categorisation should be refined using the other contributing factors to hazard noted in Section 7.2.1.

The consideration of depth and velocity is based on curves presented in the manual and shown in Figure 7-1 and Figure 7-2. In basic terms, the first of these curves shows high hazard for:

- Depths greater than 1m;
- Velocities greater than 2 m/s; and
- D + 0.3 x V > 1.0 (where D=Depth, V=Velocity).




**Provisional Hazard Categories**

**Figure 7-1 Hazard Categories from DLWC (2001)**

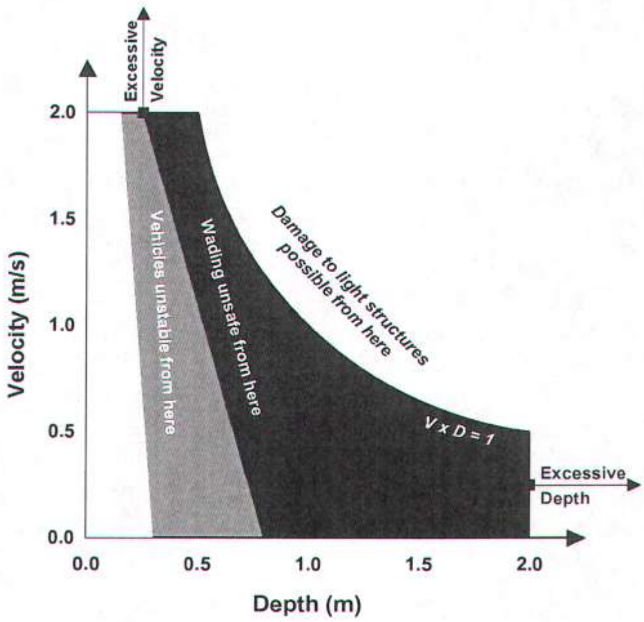



**Figure 7-2 Velocity and Depth Relationships from DLWC (2001)**

### 7.2.3 Recommended Flood Hazard Categorisation

In considering the application of these issues to the specific flood characteristics of the Burnett River floodplain at Gayndah, it is noted that:

- Duration of flooding is long (in the order of days) across the floodplain;
- Warning times are reasonably long;

- Rates of floodwater rise are relatively high; and
- Flood awareness is generally reasonably high and does not vary significantly across the floodplain.

The above four parameters are not significantly variable to warrant specific treatment and are therefore not used to define variations in the flood hazard. The flood hazard is therefore defined on the remaining, varying characteristics of:

- The size of the flood;
- Depth and velocity of floodwaters; and
- Evacuation and access.

On this basis it recommended that the hazard categories as indicated in Table 7-2 be adopted for Gayndah and that they be defined in accordance with the criteria in Figure 7-3, which combines Figure 7-1 and Figure 7-2. The recommended hazard categorisation, as shown in Figure 7-3, has been used in other flood studies in Queensland [eg. (WBM, 2003) and (WBM, 2005)].

**Table 7-2 Flood Hazard Categories for Gayndah Township**

| Hazard category | Description |
|---|---|
| Low hazard | Adults can wade, evacuation by sedan-type vehicles possible in early stage of flooding |
| High hazard – Wading Unsafe | Wading not possible, risk of drowning, large trucks able to evacuate |
| High hazard - Depth | Wading not possible, risk of drowning, evacuation with trucks not possible, structural damage limited |
| Extreme hazard – Floodway (VxD > 1 $m^2/s$) | Wading not possible, damage to structures possible, high probability of death |
| Extreme hazard – Flow Velocity (V > 2 m/s) | Wading not possible, damage to structures likely, high probability of death |

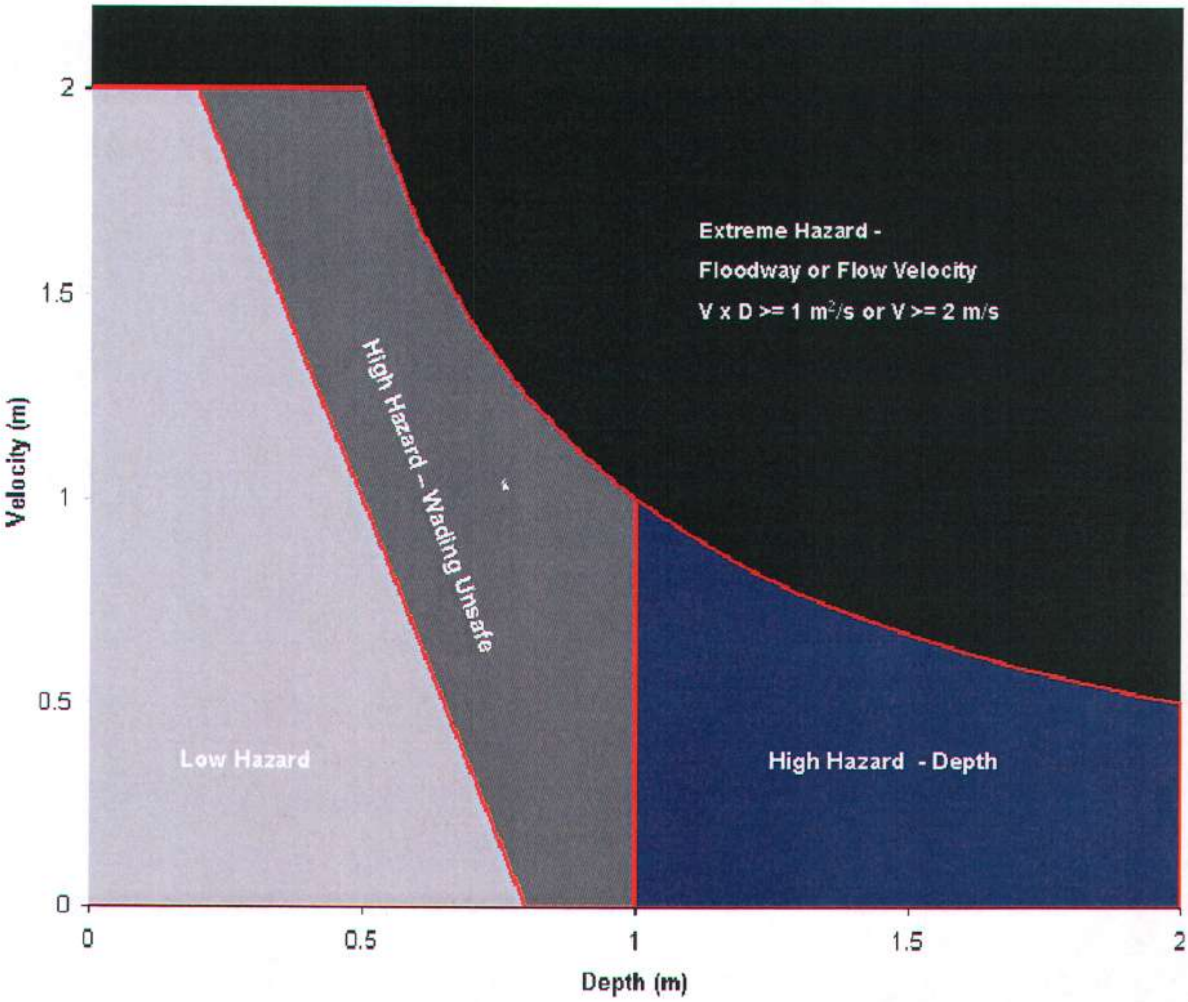



**Figure 7-3 Definition of Recommended Flood Hazard Categories**

## 7.3 Flood Hazard Maps

Using the Flood Hazard categorisation described in the previous section. Flood hazards have been determined for the study area. The resulting Flood Hazard maps, indicating the degree of flood hazard across the floodplain for the design flood events considered, are presented in Drawing II-25 to Drawing II-30.

## 7.4 Flood Risk Profile - Gayndah Township

In addition to flood hazard, another important consideration for floodplain management is assessment of the flood risk profile of the locality under consideration.

The flood risk profile of a locality is best analysed through assessment of the flood damages for the entire range of possible flood events (each AEP event up to the PMF) and investigation of the annual flood damage probability spectrum (ie. the distribution of the total annual flood damage over the range of flood events). For the assessment of flood damage for each AEP event, methodologies based on stage-damage relationships may be used. An example of these methodologies is the

ANUFLOOD methodology, which is described in "Guidance on the assessment of Tangible Flood Damages" (DNRM, 2002).

In this study, a qualitative assessment of the flood risk profile of Gayndah Township was made. Analysing the design flood event, one can conclude that there is a sharp change in flood conditions in the township between the 1% AEP design flood event and the 0.5 % AEP design flood event with a significant larger area inundated and substantial higher flood levels. As a result, one may expect that there is a large rise of flood damage between the 1% AEP design flood event and the 0.5 % AEP design flood event.

Figure 7-4 presents a conceptual Flood Damage Curve for the Gayndah Township. A conceptual Flood Damage Curve for a typical floodplain is also shown in Figure 7-4. The conceptual flood damage curve for Gayndah shows a sharp increase in flood damages between the 1% AEP design flood event and 0.5% AEP design flood event, corresponding with the sharp change in flood conditions. It is noted that the curves are conceptual curves and are for illustrative purposes only.

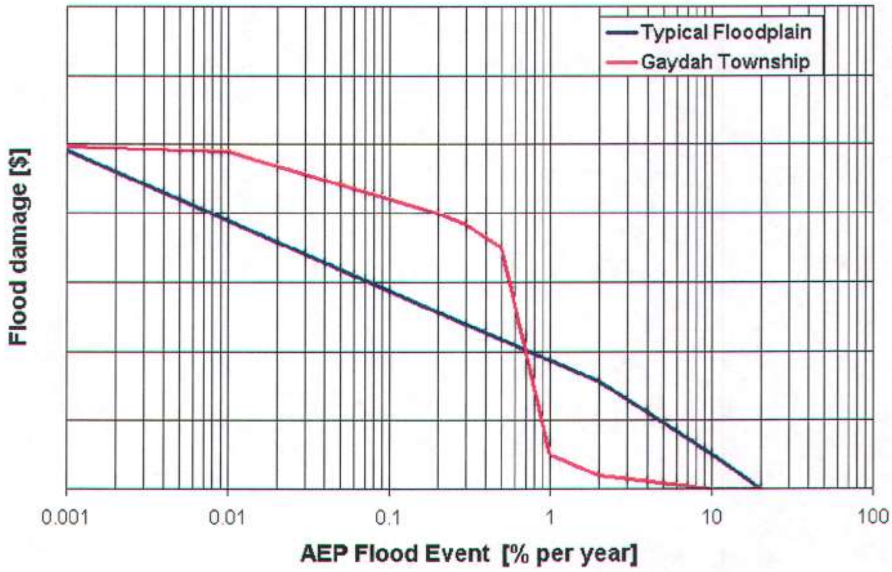



**Figure 7-4 Conceptual Flood Damage Curve – Gayndah**

Based on Flood Damage Curves (such as shown in Figure 7-4), Cumulative Annual Damage Curves can be derived, which are representations of the flood risk profile of the localities. A conceptual Cumulative Annual Damage Curve for Gayndah and for a typical floodplain is shown Figure 7-5.

From Figure 7-5, it can be seen that for typical floodplains the Cumulative Damage curve has a convex shape with a sharp rise for high probabilities. The curve for Gayndah however is expected to have a concave shape. This has important implications for the management of the flood risk and is of importance when deciding on the Flood Event used for management of development on the floodplain.

This is understood by consideration of the residual flood risk for both situations. In Figure 7-5, the residual risk for Gayndah and a typical floodplain is shown for the adopted flood event as the flood event with an annual probability of exceedance of 1% (1% AEP design flood event). From Figure 7-5, it is noted that the residual risk for the curve of Gayndah is significantly larger than the residual risk for average floodplains. In other words, in order for the township of Gayndah to maintain a similar proportion of residual risk as other floodplains, the flood event adopted for management of development on the floodplain needs to have a smaller probability of exceedance than typically would be used.

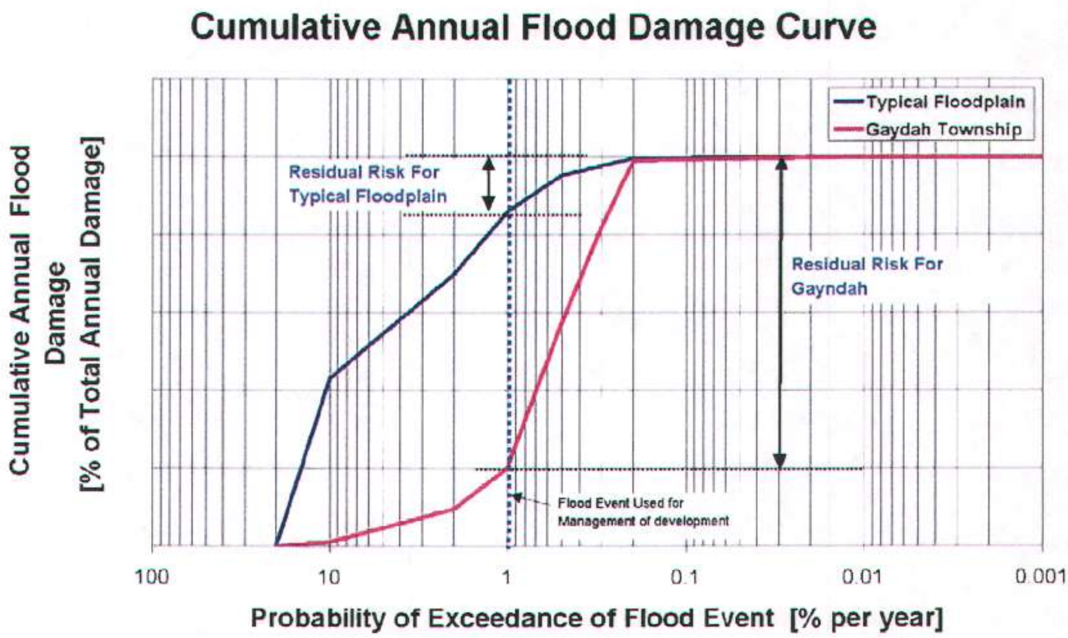



**Figure 7-5 Comparison of Residual Risk at Gayndah**

# 8 FLOODING AND DEVELOPMENT CONTROL PLANNING

## 8.1 Background

In recent years, floodplain management has placed increasing emphasis on non-structural solutions. In particular, the use of town planning controls, which relate to a number of different non-structural floodplain management measures including floor level controls, flood warning and evacuation, building design, voluntary house purchase, distribution of appropriate land-uses etc.

Traditional floodplain planning has relied almost entirely on the definition of a single flood standard, which has usually been based on the 100 year ARI flood event. Overall, this approach has worked satisfactorily. However, it is now viewed as simplistic and inappropriate in certain situations. In particular, it has failed to comprehensively consider the varying land uses and flood risks on the floodplain.

The Traditional Approach to floodplain planning results in restricted development on a merit basis below the Flood Standard and most development above the flood standard. This also reinforced the community belief that there is no flood hazard above the flood standard. Problems of the Traditional approach were identified by Bewsher (Bewsher and Grech, 1997) and include:

- Creation of a 'hard edge' to development at the Flood Planning Level (FPL);
- Distribution of development within the floodplain in a manner which does not recognise the risks to life or the economic costs of flood damage;
- Unnecessary restriction of some land uses from occurring below the FPL, while allowing other inappropriate land uses to occur immediately above the FPL;
- Polarisation of the floodplain into perceived 'flood prone' and 'flood free' areas;
- Lack of recognition of the significant flood hazard that may exist above the FPL (and as a result, there are very few measures in place to manage the consequences of flooding above the FPL); and
- Creation of a political climate where the redefinition of the FPL (due to the availability of more accurate flood behaviour data, or for other reason) is fiercely opposed by some parts of the community, due to concern about significant impacts on land values ie. land which was previously perceived to be 'flood free' will now be made 'flood prone' (despite the likelihood that such impacts may only be short term).

With the release of the State Planning Policy Guidelines for Mitigating the Adverse Impacts of Flood, Bushfire and Landslide (DLGP/DES, 2003), new approaches have emerged. These approaches provide a transitional level of control based on flood hazard and the sensitivity of the possible range of land-uses to the flood risk. Careful matching of land use to flood hazard maximises the benefit of using the floodplain and minimises the risk of flooding.

An approach that promotes the definition of varying flood hazard across the floodplain and defines appropriate land-uses with the hazard zones and when required, provides adequate development controls for the relevant land-use and hazard is outlined in DLWC (2001). Figure 8-1 illustrates the general approach to planning promoted in DLWC (2001).

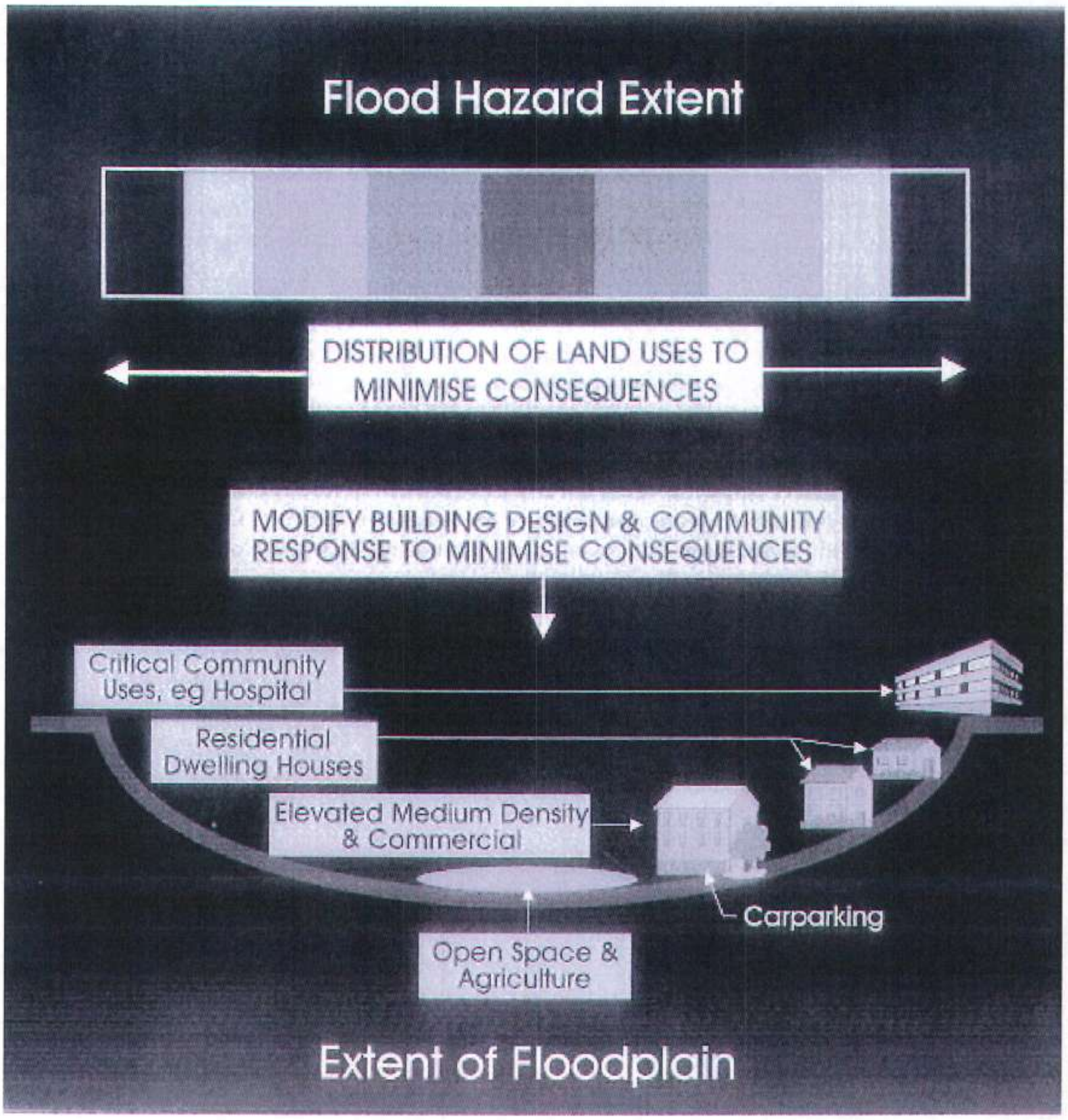



**Figure 8-1 Flood Hazard Extent – NSW Floodplain Management Manual)**

## 8.2 Current Approach in Gayndah Shire

Currently, Gayndah Shire Council has no formal Planning Approach to floodplain management and appropriateness of development applications are being assessed by consideration of the flood extent and peak flood levels of the 1942 flood, as shown on GSC's sewerage plans. As the Flood Planning Level (FPL) for all land uses the flood level of the 1942 flood plus 300 mm freeboard is used. No formal consideration is given to other floods than the 1942 event or the associated flood hazards.

It is recommended that GSC revises its Planning Scheme to incorporate improved floodplain risk management into the Scheme.

## 8.3 Proposed Approach - Planning MATRIX

For town planning in Gayndah, a planning approach known as the Planning MATRIX Approach is recommended. The Planning MATRIX Approach was initially developed for the Blacktown Floodplain Management Study in NSW by Bewsher Consulting, and recommended to various councils in Queensland (Cardwell Inundation Study, Herbert River Floodplain Management Study and Laidley Creek Floodplain Management Study).

The approach distributes land-uses within the floodplain and controls development to minimise the flood damages as illustrated in Figure 8-1. Using this approach, a matrix of development controls, based on the flood hazard and land use, can be developed which is illustrated and explained in Figure 8-2 (From Bewsher and Grech, 1997). A number of plans showing flood hazard, land-use and flood level information accompanies the MATRIX, the total of which constitutes a planning scheme for floodplain development control.

Steps involved in developing a Planning MATRIX in accordance with Queensland State Planning Policy follow:

- Determination of the Defined Flood Event
- Categorising the Floodplain - divide the floodplain into areas of differing levels of flood hazard.
- Prioritising Land Uses - review all land-uses used by council and divide into discreet categories of land uses with similar levels of sensitivity to the flood hazard. The categories are then listed under each hazard band in the planning matrix in priority of land use.
- List Planning Controls (Building and Community Response) - assign different planning controls to modify building form and the ability of the community to respond in times of flooding, depending on type of land use and location. A number of these controls will be non-structural controls.

The Planning MATRIX approach can be adopted by Council as a methodology to assess applications for development on the floodplain by implementing the planning MATRIX approach into the GSC Planning Scheme. A decision is required from GSC (possibly via the SAG) as to whether the Planning Matrix should be adopted in principle and which hazard categories should be incorporated. As part of this implementation, future planning schemes should account for land-use, flood hazard and recommend appropriate control measures.

## 8.4 Defined Flood Event (DFE)

The Defined Flood Event (DFE) represents the flood event adopted by local government for the management of development in a particular locality. An important aspect when deciding on which flood event to adopt for the management of development should be consideration of flood risk profile of that particular locality.

For Gayndah, the recommended Defined Flood Event is the 1% EAP flood event plus allowance for potential climate change impacts over the planning period (ie. the life cycle of the development under consideration).

For developments with a design life cycle of 50 years, an appropriate allowance for the climate change impacts on the Burnett River at Gayndah is considered to be a peak flow discharge increase of 20 % (See also Section 6.5).

Using the recommended climate change allowance of 20%, the river flow discharge of the Burnett River for 1% EAP design flood event with climate change allowance is closely approximated by the river flow discharge of 0.5% EAP design flood event (without climate change allowance). Therefore, the flood maps of the 0.5% EAP design flood event are considered to be representative of the 1% EAP flood event with climate change impacts to 2057.

The recommended Defined Flood Event for the Gayndah Township is the 0.5% EAP design flood event (reference year: 2007). Peak flood levels of the 0.5% EAP design flood event are presented in Drawing II- 31 and the flood hazard map in Drawing II- 32.

## 8.5 Definition of Flood Hazard

Determining the level of flood hazard is of considerable significance to the appropriateness of a site for various land uses. Careful matching of land use to flood hazard maximises the benefits of using the floodplain and minimises the flood risk.

The hazard categories that have been adopted for the Gayndah Flood Study are described in Section 7.2. The flood hazard maps for the study area are presented in Drawing II- 25 to Drawing II- 30. When applying the Planning MATRIX Approach, the Flood Hazard Map for the Defined Flood Event is to be used. The flood hazard map for the Defined Flood Event is presented in Drawing II- 32.

In addition to the flood hazard categories as defined in Section 7.2, the Planning MATRIX Approach used an additional flood hazard category, namely "Flood Prone Land – No Hazard". This flood hazard category is defined as land that is inundated by the PMF event but not inundated by the DFE.

For assessment of development applications within the Gayndah Township, Council officers assessing or advising on development applications can determine the flood hazard category of the site by visual inspection of hardcopy plans or by interrogation of a GIS layer of the relevant flood hazard map.

## 8.6 Land Use Categorisation

All land uses used by Gayndah Shire Council are to be reviewed and each land use is to be classed into discreet categories of land uses with similar levels of compatibility to flood hazard. The categories are then listed under each hazard band in the planning matrix in priority of land use. For the definition of the land use categories, Table A2.1 of the State Planning Policy 1/03 Guideline (DLGP/DES, 2003) may be used.

It is recommended that for each Land-Use Category a Flood Planning Matrix is developed. When development applications are being processed, Council staff will source the appropriate matrix to specify any control measures related to flooding.

## 8.7 Development of GSC Flood Planning Matrices

Preliminary planning matrices developed for GSC are contained in Appendix F for each of the discrete land use categories. The Planning Matrices in Appendix F show the compatibility of various land uses for various flood hazard levels and specifies relevant control measures related to flooding.

For determination of the flood hazard level of a site, the Flood Hazard Map for the Defined Flood Event (DFE) is to be used.

## 8.8 Use of Gayndah Shire Council Planning Matrix

It is intended that the planning matrix be utilised by those Council officers assessing or advising on development applications. The procedure used by officers follows these steps:

- Determine the proposed land use of the site under consideration;
- Identify the flood hazard category applicable to the site under consideration again by either visual inspection of hardcopy plans or by interrogation of a GIS layer; and
- Use the matrices presented in Appendix F to determine the controls relating to the site based on land use and flood hazard category.

There is the potential for a significant advantage in being able to access the land-use and flood hazard category from a GIS database as both items are able to be provided with one on-screen query. The data has been developed with this in mind.

An example of the application of the matrix approach to determining a floor level for a habitable building in a High Hazard area is presented below in Table 8-1.

| DEVELOPMENT WITHIN A RESIDENTIAL AREA | | | | | |
|---|---|---|---|---|---|
| | | FLOOD HAZARD CATEGORY FOR DEFINED FLOOD EVENT | | | |
| CONTROLS | DEVELOPMENT TYPE | Flood prone land - No Hazard | Low Hazard | High Hazard | Extreme Hazard |
| Fill Level | New Development | No Minimum | No Minimum | No Minimum | |
| | Emergency Services | PMF Flood Level | PMF Flood Level | | |
| Floor Level | Habitable Buidling | No Minimum | DFE Flood Level + 0.3m | DFE Flood Level + 0.3m | |
| | Emergency Services | PMF Flood Level | PMF Flood Level | | |

**Table 8-1 Example Use of Matrix for Habitable Building in High Hazard Area**

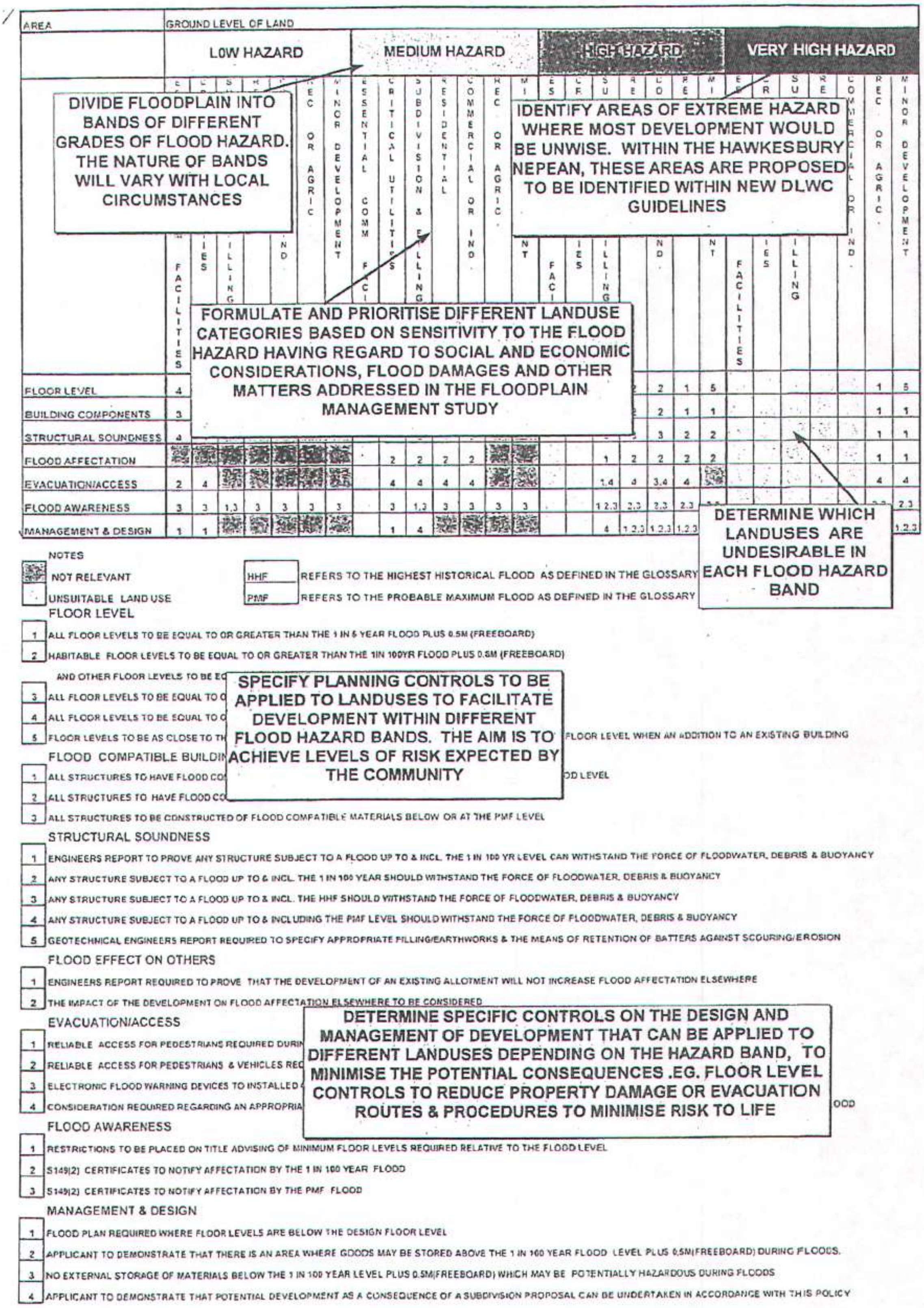



**Figure 8-2 Planning Matrix Approach (From Bewsher and Grech, 1997)**

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# APPENDIX A: SUMMARY OF RESIDENT SURVEY

In November 2006, members of the Study team conducted a Resident Survey amongst residents of Gayndah Shire. The Resident Survey had the following objectives:

- Collection of local flooding information regarding the February 1942 flood event (in terms of flood levels, overland flow patterns and flow velocities);
- Development of a better understanding of the community's flooding concerns and issues;
- Assessment of flooding awareness of residents.

For the Resident Survey, 20 residents were interviewed. The selection of the interviewed residents was predominantly based on their potential knowledge/experience regarding the February 1942 flood event. Seven of the 20 residents interviewed had experienced the February 1942 flood event themselves.

In the selection of residents also representativeness of the Gayndah community was taken into consideration. The 20 residents interviewed are considered to provide a fair representation of the Gayndah community.

**Community Awareness / Flooding Issues**

The Resident Survey indicates the flooding awareness in Gayndah is reasonably high and most residents are aware of potential risks of flooding from living on a floodplain.

However, some residents have an opinion that at the moment Gayndah Shire Council's planning policies in relation to flooding are inappropriate and revision of these policies is required.

**Information on February 1942 Flood Event**

It appeared that knowledge of the February 1942 flood is relative well spread throughout Gayndah's community; 13 interviewees were able to provide information in relation to the February 1942 event. Invaluable information in relation to the flood behaviour of the February 1942 flood event was obtained during the Resident Survey.

Information that was obtained included:

- Several new flood marks throughout Gayndah;
- Information on flow paths and flow velocities;
- Information on inundation duration; and
- Historical changes to topography and land usage that have been experienced in Gayndah

The flood marks obtained from the Resident Survey were surveyed and used for the calibration of the hydraulic model. The locations of the flood marks used for the calibration are shown in Figure 3-1.

On the basis of local knowledge obtained from the Resident Survey and additional information from literature a reconstruction of the February 1942 flood event was prepared. A summary of this reconstruction is presented below.

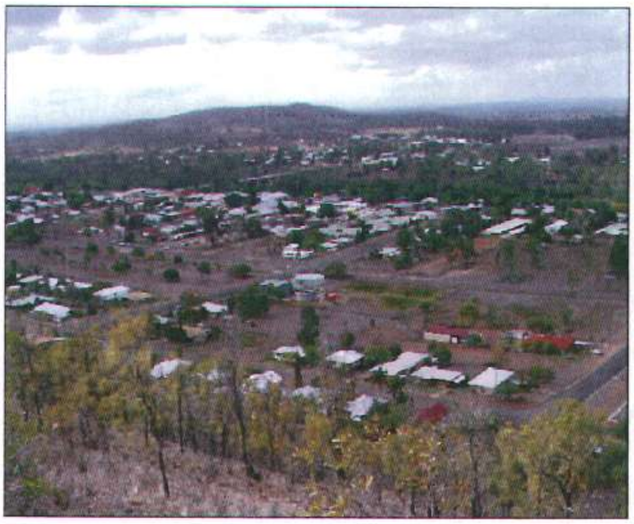
**Summary Reconstruction of February 1942 Flood Event**

The Burnett River was already swollen after heavy rainfall events prior to the flood. On February 10th, floodwater broke over the Showground (Fisher Avenue/Spencer Street) and became a wide stream towards Oaky creek, already flooded with backwash from the Burnett River. Floodwater was flowing over the floodplain south of Capper Street, from Sauer Gully to Oaky Creek for approximately a day.

In the night from the 10th to the 11th of February, people were evacuated from the area around Capper Street by rowing boat. For several hours around the peak of the flood, the currents on the floodplain around Queen Street were too strong for boat crossings between Capper Street and Hospital Hill.

At the peak of the flood, large parts of Gayndah, both on the north and the south bank, were inundated. However, the highest part of the main street and the convent and nearby buildings was kept dry, but surrounded by water. The maximum flood depth on the floodplain around Queen Street was up to several meters.

# APPENDIX B: PHOTOGRAPHS OF STUDY AREA



*Township of Gayndah From Anchor's Lookout*

*Typical Built-up Area within Township of Gayndah*

*Typical Sight of Rural Parts of the Study Area*

## Photographs of Selected Locations - November 2006

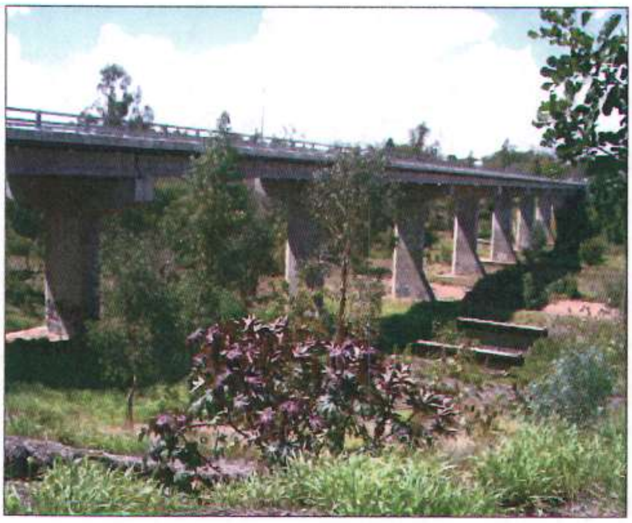
*River Channel of Burnett River at Gayndah*

*River Channel of Oaky Creek near Confluence with Burnett River*

*River Channel of Barambah Creek near Crossing with Burnett Highway*

## Photographs of Selected Locations - November 2006

*Claude Wharton Weir*
*From Upstream, North Bank of Burnett River*



*Les Baker Bridge*
*From Downstream, South Bank of Burnett River*


*Mount Lawless Gauging Station and*
*Mount Lawless Railway Bridge*
*From Upstream, North Bank of Burnett River*

## Photographs of Selected Locations - November 2006

# APPENDIX C: CD-ROM WITH FLOOD MODEL ANIMATIONS

# APPENDIX D: GTSMR CALCULATION SHEETS – PMP EVENT

# WORKSHEET 2: Generalised Tropical Storm Method Revised (GTSMR)

| LOCATION INFORMATION | | | | |
|---|---|---|---|---|
| Catchment Name: Burnett River to Gayndah<br>GTSMR zone(s): COASTAL | | | State: QLD | |
| **CATCHMENT FACTORS** | | | | |
| **Topographical Adjustment Factor** | | | **TAF** = 1.0384 (1.0 – 2.0) | |
| **Decay Amplitude Factor** | | | **DAF** = 0.982 (0.7 – 1.0) | |
| **Annual Moisture Adjustment Factor**<br>Extreme Precipitable Water ($EPW_{catchment}$) = 86.6985 | | | $MAF_a$ = $EPW_{catchment}$/120.00<br>$\mathbf{MAF_a}$ = 0.7225 (0.4 – 1.1) | |
| **Winter Moisture Adjustment Factor** (where applicable)<br>Winter EPW ($EPW_{catchment\_winter}$) = n/a | | | $MAF_w$ = $EPW_{catchment\_winter}$/82.30<br>$\mathbf{MAF_w}$ = n/a (0.4 – 1.1) | |
| **PMP VALUES (mm) - Annual** | | | | |
| Duration (hours) | Initial Depth ($\mathbf{D_a}$) | PMP Estimate $=\mathbf{D_a x TAF x DAF x MAF_a}$ | Preliminary PMP Estimate (nearest 10mm) | Final PMP Estimate (from envelope) |
| 1 | Where applicable, calculate GSDM (Bureau of Meteorology, 2003) depths | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 12 | (no preliminary estimates available) | | | |
| 24 | 734.5 | 541 | 540 | 540 |
| 36 | 886.5 | 653 | 650 | 650 |
| 48 | 1027.3 | 757 | 760 | 760 |
| 72 | 1277.7 | 941 | 940 | 940 |
| 96 | 1440.6 | 1061 | 1060 | 1060 |
| 120 | 1489.1 | 1097 | 1100 | 1100 |
| **PMP VALUES (mm) – Winter** (where applicable) | | | | |
| Duration (hours) | Initial Depth ($\mathbf{D_w}$) | PMP Estimate $=\mathbf{D_w x TAF x DAF x MAF_w}$ | Preliminary PMP Estimate (nearest 10mm) | Final PMP Estimate (from envelope) |
| 1 | Where applicable, calculate GSDM (Bureau of Meteorology, 2003) depths | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 12 | (no preliminary estimates available) | | | |
| 24 | | | | |
| 36 | | | | |
| 48 | | | | |
| 72 | | | | |
| 96 | | | | |

Prepared by ................................ Date ....../....../...... Checked by ................................ Date ....../....../......

## WORKSHEET 2: Generalised Tropical Storm Method Revised (GTSMR)

| LOCATION INFORMATION | |
|---|---|
| Catchment Name: Burnett River to Walla | State: QLD |
| GTSMR zone(s): COASTAL | |

| CATCHMENT FACTORS | |
|---|---|
| **Topographical Adjustment Factor** | **TAF** = 1.0362 (1.0 – 2.0) |
| **Decay Amplitude Factor** | **DAF** = 0.9849 (0.7 – 1.0) |
| **Annual Moisture Adjustment Factor** | $MAF_a$ = $EPW_{catchment}$/120.00 |
| Extreme Precipitable Water ($EPW_{catchment}$) = 87.0297 | $\mathbf{MAF_a}$ = 0.7252 (0.4 – 1.1) |
| **Winter Moisture Adjustment Factor** (where applicable) | $MAF_w$ = $EPW_{catchment\_winter}$/82.30 |
| Winter EPW ($EPW_{catchment\_winter}$) = n/a | $\mathbf{MAF_w}$ = n/a (0.4 – 1.1) |

**PMP VALUES (mm) - Annual**

| Duration (hours) | Initial Depth ($D_a$) | PMP Estimate $=D_a x TAF x DAF x MAF_a$ | Preliminary PMP Estimate (nearest 10mm) | Final PMP Estimate (from envelope) |
|---|---|---|---|---|
| 1 | Where applicable, calculate GSDM (Bureau of Meteorology, 2003) depths | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 12 | (no preliminary estimates available) | | | |
| 24 | 663.5 | 491 | 490 | 490 |
| 36 | 809.2 | 599 | 600 | 600 |
| 48 | 944.5 | 699 | 700 | 700 |
| 72 | 1184.9 | 877 | 880 | 880 |
| 96 | 1329.6 | 984 | 980 | 980 |
| 120 | 1371.0 | 1015 | 1010 | 1010 |

**PMP VALUES (mm) – Winter** (where applicable)

| Duration (hours) | Initial Depth ($D_w$) | PMP Estimate $=D_w x TAF x DAF x MAF_w$ | Preliminary PMP Estimate (nearest 10mm) | Final PMP Estimate (from envelope) |
|---|---|---|---|---|
| 1 | Where applicable, calculate GSDM (Bureau of Meteorology, 2003) depths | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 12 | (no preliminary estimates available) | | | |
| 24 | | | | |
| 36 | | | | |
| 48 | | | | |
| 72 | | | | |
| 96 | | | | |

Prepared by ................................ Date ....../....../...... Checked by .............................. Date ....../....../......

# APPENDIX E: TEMPORAL PATTERNS OF DESIGN RAINFALL EVENTS

Table E-1: Design Temporal Patterns for Burnett River to Gayndah (Catchment Area 23 320km$^2$)

GTSMR method 2003 – temporal pattern for 20 000km$^2$ catchment

| Time (hours) | Duration 24h | Duration 36h | Duration 48h | Duration 72h | Duration 96h | Duration 120h |
|---|---|---|---|---|---|---|
| 3 | 7.15 | 6.62 | 4.76 | 2.29 | 0.90 | 0.23 |
| 6 | 9.01 | 10.28 | 4.32 | 3.94 | 1.15 | 2.81 |
| 9 | 15.44 | 7.95 | 4.79 | 8.36 | 4.10 | 2.97 |
| 12 | 22.20 | 2.31 | 9.22 | 10.10 | 2.18 | 0.86 |
| 15 | 12.72 | 6.06 | 15.39 | 7.39 | 5.60 | 2.42 |
| 18 | 11.26 | 5.38 | 6.01 | 5.39 | 6.35 | 2.59 |
| 21 | 17.06 | 12.44 | 2.68 | 3.41 | 8.52 | 4.60 |
| 24 | 5.15 | 17.86 | 1.83 | 4.24 | 5.86 | 1.70 |
| 27 | | 13.60 | 7.22 | 7.05 | 3.18 | 3.16 |
| 30 | | 9.53 | 8.32 | 4.84 | 2.60 | 7.38 |
| 33 | | 4.31 | 3.94 | 5.93 | 3.69 | 8.36 |
| 36 | | 3.65 | 10.93 | 2.87 | 2.10 | 2.19 |
| 39 | | | 7.71 | 2.45 | 3.89 | 1.58 |
| 42 | | | 5.96 | 1.59 | 6.94 | 1.00 |
| 45 | | | 3.91 | 2.06 | 5.09 | 6.39 |
| 48 | | | 3.02 | 1.86 | 2.78 | 3.56 |
| 51 | | | | 6.50 | 1.65 | 5.50 |
| 54 | | | | 3.76 | 1.44 | 4.93 |
| 57 | | | | 4.75 | 4.58 | 3.37 |
| 60 | | | | 2.88 | 3.29 | 1.84 |
| 63 | | | | 2.43 | 3.52 | 4.09 |
| 66 | | | | 1.16 | 1.73 | 3.78 |
| 69 | | | | 1.48 | 2.98 | 0.69 |
| 72 | | | | 3.25 | 1.83 | 1.10 |
| 75 | | | | | 0.85 | 0.33 |
| 78 | | | | | 1.26 | 1.47 |
| 81 | | | | | 3.08 | 0.81 |
| 84 | | | | | 1.39 | 5.89 |
| 87 | | | | | 1.16 | 1.18 |
| 90 | | | | | 1.75 | 1.43 |
| 93 | | | | | 2.65 | 1.75 |
| 96 | | | | | 1.92 | 0.75 |
| 99 | | | | | | 1.87 |
| 102 | | | | | | 1.22 |
| 105 | | | | | | 2.14 |
| 108 | | | | | | 0.41 |
| 111 | | | | | | 0.62 |
| 114 | | | | | | 0.56 |
| 117 | | | | | | 0.12 |
| 120 | | | | | | 2.35 |

Table E-2: Design Temporal Patterns for Burnett River to Walla
(Catchment Area 31 100km$^2$)
GTSMR method 2003 – temporal pattern for 40 000km$^2$ catchment

| Time (hours) | Duration 24h | Duration 36h | Duration 48h | Duration 72h | Duration 96h | Duration 120h |
|---|---|---|---|---|---|---|
| 3 | 4.86 | 13.16 | 6.52 | 1.40 | 0.90 | 0.47 |
| 6 | 11.50 | 12.08 | 11.57 | 5.27 | 1.53 | 1.88 |
| 9 | 12.53 | 4.39 | 8.73 | 8.21 | 2.04 | 2.33 |
| 12 | 22.98 | 5.36 | 9.66 | 9.18 | 1.33 | 0.87 |
| 15 | 8.66 | 2.39 | 16.04 | 2.71 | 2.59 | 4.43 |
| 18 | 17.38 | 8.46 | 3.93 | 3.64 | 6.01 | 3.83 |
| 21 | 15.99 | 5.88 | 2.05 | 3.87 | 7.21 | 4.99 |
| 24 | 6.09 | 17.36 | 4.48 | 4.76 | 6.57 | 1.55 |
| 27 | | 10.95 | 7.61 | 6.74 | 5.15 | 2.01 |
| 30 | | 9.99 | 2.94 | 12.02 | 4.25 | 5.84 |
| 33 | | 6.74 | 1.54 | 6.27 | 5.45 | 9.01 |
| 36 | | 3.25 | 8.26 | 0.84 | 1.89 | 7.71 |
| 39 | | | 5.10 | 1.52 | 3.86 | 4.06 |
| 42 | | | 5.62 | 1.84 | 9.20 | 1.37 |
| 45 | | | 2.58 | 1.14 | 3.67 | 1.62 |
| 48 | | | 3.37 | 2.25 | 3.15 | 3.12 |
| 51 | | | | 4.08 | 1.57 | 6.48 |
| 54 | | | | 4.41 | 1.82 | 3.61 |
| 57 | | | | 3.33 | 2.07 | 1.51 |
| 60 | | | | 7.38 | 3.04 | 1.14 |
| 63 | | | | 2.10 | 3.35 | 2.46 |
| 66 | | | | 2.93 | 2.41 | 3.43 |
| 69 | | | | 1.67 | 2.81 | 1.82 |
| 72 | | | | 2.45 | 0.67 | 1.09 |
| 75 | | | | | 1.83 | 0.99 |
| 78 | | | | | 2.17 | 2.90 |
| 81 | | | | | 3.31 | 2.25 |
| 84 | | | | | 1.88 | 5.39 |
| 87 | | | | | 1.83 | 0.94 |
| 90 | | | | | 2.25 | 0.67 |
| 93 | | | | | 2.46 | 1.24 |
| 96 | | | | | 1.72 | 0.74 |
| 99 | | | | | | 2.70 |
| 102 | | | | | | 2.09 |
| 105 | | | | | | 1.17 |
| 108 | | | | | | 0.56 |
| 111 | | | | | | 0.37 |
| 114 | | | | | | 0.31 |
| 117 | | | | | | 0.23 |
| 120 | | | | | | 0.81 |

Table E-3: Design Temporal Patterns for Residual Catchment
(Catchment Area 8 780km$^2$)
GTSMR method 2003 – temporal pattern for 10 000km$^2$ catchment

| Time (hours) | Duration 24h | Duration 36h | Duration 48h | Duration 72h | Duration 96h | Duration 120h |
|---|---|---|---|---|---|---|
| 3 | 6.96 | 7.18 | 2.25 | 1.44 | 1.99 | 1.38 |
| 6 | 11.00 | 5.12 | 5.18 | 4.62 | 4.00 | 1.54 |
| 9 | 17.20 | 4.53 | 5.94 | 6.76 | 3.51 | 2.77 |
| 12 | 22.93 | 3.17 | 8.07 | 7.02 | 1.66 | 1.44 |
| 15 | 12.39 | 5.79 | 14.77 | 5.54 | 5.16 | 1.66 |
| 18 | 4.99 | 5.36 | 2.62 | 7.75 | 4.29 | 2.53 |
| 21 | 15.82 | 7.77 | 3.88 | 3.44 | 5.92 | 4.10 |
| 24 | 8.72 | 17.48 | 7.44 | 4.13 | 6.79 | 2.67 |
| 27 | | 11.87 | 5.52 | 1.45 | 3.72 | 4.51 |
| 30 | | 9.28 | 3.26 | 6.33 | 2.78 | 5.85 |
| 33 | | 12.40 | 3.58 | 5.05 | 1.42 | 3.01 |
| 36 | | 10.05 | 10.38 | 9.93 | 3.21 | 2.45 |
| 39 | | | 8.71 | 3.99 | 6.20 | 1.30 |
| 42 | | | 9.39 | 2.93 | 7.93 | 3.76 |
| 45 | | | 6.39 | 2.21 | 5.74 | 3.35 |
| 48 | | | 2.64 | 2.66 | 4.68 | 2.03 |
| 51 | | | | 2.86 | 0.85 | 9.42 |
| 54 | | | | 1.66 | 1.05 | 7.35 |
| 57 | | | | 4.31 | 2.77 | 2.24 |
| 60 | | | | 4.79 | 3.20 | 0.96 |
| 63 | | | | 2.75 | 1.21 | 6.33 |
| 66 | | | | 2.11 | 3.96 | 3.24 |
| 69 | | | | 3.90 | 2.22 | 1.01 |
| 72 | | | | 2.38 | 1.39 | 0.66 |
| 75 | | | | | 0.75 | 0.50 |
| 78 | | | | | 2.04 | 0.83 |
| 81 | | | | | 2.72 | 1.20 |
| 84 | | | | | 0.96 | 5.54 |
| 87 | | | | | 1.13 | 1.91 |
| 90 | | | | | 2.31 | 1.03 |
| 93 | | | | | 2.91 | 0.77 |
| 96 | | | | | 1.53 | 0.74 |
| 99 | | | | | | 4.99 |
| 102 | | | | | | 1.74 |
| 105 | | | | | | 3.60 |
| 108 | | | | | | 0.37 |
| 111 | | | | | | 0.20 |
| 114 | | | | | | 0.14 |
| 117 | | | | | | 0.27 |
| 120 | | | | | | 0.59 |

# APPENDIX F: FLOOD PLANNING MATRICES

# FLOOD PLANNING MATRIX

**TABLE 1: RESIDENTIAL, COMMERCIAL AND INDUSTRIAL DEVELOPMENT WITHIN AN URBAN AREA**

| Controls | Development / Building Type | Flood prone - No Hazard[1] | Flood Hazard Category[4] Low Hazard | High Hazard - Wading Unsafe or High Hazard - Depth | Extreme Hazard - Floodway or Extreme Hazard - Flow Velocity |
|---|---|---|---|---|---|
| Land Use Suitability & Fill Level | Existing Lot - including infill subdivision | NCF | SF1 | SF1 | LUI |
| | (this line not used) | | | | |
| | Subdivision - en globo | NCF | SF2 | SF2 | LUI |
| | Emergency Services Site (Hospitals, etc.) | NCF | SF3a | LUI | LUI |
| | Other Community Service Building (School, etc.) | NCF | SF3b | LUI | LUI |
| Floor Level | New Habitable Building | NCF | FL2c | FL2c | LUI |
| | New Commercial or Industrial Building | NCF | FL2a | FL2a | LUI |
| | New Emergency Service Building (Hospitals, etc.) | FL3a | FL3a | LUI | LUI |
| | New Other Community Service Building (School, etc.) | FL3b | FL3b | LUI | LUI |
| | New Ancillary Building (eg shed, carport) | NCF | FL1 | FL1 | LUI |
| | Building Extension | NCF | FL4a | FL4b | LUI |
| | (this line not used) | | | | |
| Building Components | | NCF | BC1 | BC1 | LUI |
| Structural Soundness | Ancillary Building (eg. shed, carport) | NCF | SS1 | SS1 | LUI |
| | Other Building | NCF | SS1 | SS2 | LUI |
| Flood Effect | Existing Lot - including infill subdivision | NCF | FE2 | FE2 | LUI |
| | Subdivision - en globo | NCF | FE2 | FE2 | LUI |
| | New Ancillary Building (eg shed, carport) | NCF | FE2 | FE2 | LUI |
| | Building Extension | NCF | FE1 | FE2 | LUI |
| | Other Developments (road raising, etc) | NCF | FE2 | FE2 | FE3 |
| Evacuation & Access | Existing Lot - including infill subdivision | NCF | EA1 | EA3 | LUI |
| | Subdivision - en globo | NCF | EA3 | EA3 | LUI |
| | Emergency Service Site (Hospitals, etc.) | NCF | EA4a | LUI | LUI |
| | Other Community Service Site (Schools, etc.) | NCF | EA4b | LUI | LUI |
| Flood Awareness, etc | | NCF | FA2 | FA2 | FA2 |

Note 1: This category is defined as land that is inundated by the PMF but not inundated by the DFE

Note 2: Small-scale development implies development on rural land that is small relative to the width of the floodplain and is not part of a planned large-scale development.

Note 3: Weatherproof Area Definition - Enclosed areas excluding garages / carports / open verandahs

Note 4: For applicable Flood Hazard Category, reference should be to Flood Hazard Map for the DFE

## Control Measures

| | |
|---|---|
| NCF | No Controls for flooding applicable |
| LUI | Land Use Incompatible with flood hazard - Development only to be considered in special circumstances, site and development specific controls to be defined by Council |
| | **LAND USE SUITABILITY & MINIMUM FILL LEVEL** |
| SF1 | Consider for development subject to the controls below. No minimum fill level required. |
| SF2 | Consider for development subject to the controls below. For residential and commercial areas, the minimum fill level to be greater than or equal to the DFE flood level. For industrial areas, the minimum fill level to be greater than or equal to the 10 year flood level. |
| SF3a | Consider for development subject to the controls below. Minimum fill level greater than or equal to the PMF flood level. |
| SF3b | Consider for development subject to the controls below.<br>Council to give consideration on the benefits of using the development during and after a flood emergency.<br>If the site is to be used for a flood emergency, the minimum fill level should preferably be greater than or equal to the PMF flood level. |
| | **MINIMUM FLOOR LEVEL** |
| FL1 | No minimum floor level required (Council to advise developer of flood risk and potential damage to building & contents. Flood levels available on request) |
| FL2a | All floor levels to be greater than or equal to the DFE flood level |
| FL2b | For permissible uses other than residential, it is preferable to have all floor levels greater than or equal to the DFE flood level subject to industry standards and individual site assessment. |
| FL2c | All habitable floor levels to be greater than or equal to the DFE flood level plus 0.3m |
| FL3a | All floor levels to be greater than or equal to the PMF flood level. |
| FL3b | If practical, some or all floor levels to be greater than or equal to the PMF flood level, so that these buildings will be available for accommodation / storage during and after a flood emergency. Minimum floor level to be greater than or equal to the DFE flood level |
| FL4a | Habitable, commercial or industrial floor levels to be as close to the *minimum floor level* above as practical and not less than the floor level of the existing building being extended if the existing floor level is less than or equal to the minimum floor level. If the extended weatherproof area[3] exceeds 50% of the existing weatherproof area, the extension is treated as a new building. The extended weatherproof area is measured as the cumulative area of any previous extensions plus the proposed extension. If building is idenitified as being suitable for voluntary house raising scheme, Council to discuss potential house raising with owner. |
| FL4b | As for FL4a with the maximum percentage increase in extended weatherproof area[3] to be:<br>(a) 50% if the extension's floor level is less than one (1) metre below the DFE flood level;<br>(b) 25% if the extension's floor level is greater than two (2) metres below the DFE flood level; or<br>(c) pro-rata between 50% and 25% for floor levels from one (1) metre to two (2) metres below the DFE flood level. |
| | **BUILDING COMPONENTS** |
| BC1 | Buildings to have flood compatible material below the higher of (a) the minimum floor level or (b) the DFE flood level plus 0.3m. |
| | **STRUCTURAL SOUNDNESS** |
| SS1 | No structural soundness requirements for the force of floodwater, debris & buoyancy. Must still comply with BCA requirements. |
| SS2 | Engineers report to prove that structures subject to a flood up to the DFE can withstand the force of floodwater, debris & buoyancy. |
| | **FLOOD EFFECT** |
| FE1 | No action required |
| FE2 | The flood impact of the development to be considered by Council, with Council having the right to request an engineer's report (see FE3 below) |
| FE3 | Engineers report required to prove that the development will not result in adverse flood impact elsewhere |
| | **EVACUATION/ACCESS** |
| EA1 | Council to provide information on flood evacuation strategy |
| EA2 | Not used |
| EA3 | Site specific Flood Evacuation Strategy be developed consistent with Council / SES overall Flood Evacuation Strategy. |
| EA4a | Emergency service site - should have good access up to the PMF and preferably not cut-off from the main residential area(s).<br>Council to evaluate suitablility of site in this respect. |
| EA4b | If site to be used during and after a flood emergency (see FL3b above), should have good access up to the PMF<br>and preferably not cut-off from the main residential area(s). |
| | **FLOOD AWARENESS** |
| FA1 | Not used |
| FA2 | Not used |

**Figure F-1 Planning Matrix - Residential, Commercial, Industrial Land Use**

# FLOOD PLANNING MATRIX

| TABLE 2: DEVELOPMENT IN RURAL AREAS | | | | | |
|---|---|---|---|---|---|
| | | Flood Hazard Category[4] | | | |
| **Controls** | **Development / Building Type** | **Flood prone - No Hazard[1]** | **Low Hazard** | **High Hazard - Wading Unsafe or High Hazard - Depth** | **Extreme Hazard - Floodway or Extreme Hazard - Flow Velocity** |
| **Land Use Suitability & Fill Level** | Habitable Building | NCF | SF1 | SF1 | LUI |
| | Ancillary Building (eg. shed) | NCF | SF1 | SF1 | SF1 |
| | Other Developments (eg. levees, roads, dams, etc) | NCF | SF1 | SF1 | SF1 |
| | Emergency Services Site (Hospitals, etc.) | NCF | SF3a | LUI | LUI |
| | Other Community Service Building (School, etc.) | NCF | SF3b | SF3b | LUI |
| **Floor Level** | New Habitable Building | NCF | FL2c | FL2c | LUI |
| | (this line not used) | | | | |
| | New Emergency Service Building (Hospitals, etc.) | FL3a | FL3a | LUI | LUI |
| | New Other Community Service Building (School, etc.) | FL3b | FL3b | LUI | LUI |
| | New Ancillary Building (eg shed, carport) | NCF | FL1 | FL1 | FL1 |
| | Building Extension | NCF | FL4a | FL4b | LUI |
| | New Rural Industry | NCF | FL2b | FL2b | LUI |
| **Building Components** | | NCF | BC1 | BC1 | BC1 |
| **Structural Soundness** | Small-scale[2] Development (eg. shed, small dam) | NCF | SS1 | SS1 | SS2 |
| | Large-scale Development (eg. levee, raised road) | NCF | SS1 | SS2 | SS2 |
| **Flood Effect** | Small-scale[2] Development (eg. shed, small dam) | NCF | FE1 | FE2 | FE2 |
| | Large-scale Development (eg. levee, raised road) | NCF | FE2 | FE3 | FE3 |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| **Evacuation & Access** | Habitable Building | NCF | EA1 | EA3 | LUI |
| | (this line not used) | | | | |
| | Emergency Service Site (Hospitals, etc.) | NCF | EA4a | LUI | LUI |
| | Other Community Service Site (Schools, etc.) | NCF | EA4b | LUI | LUI |
| **Flood Awareness, etc** | | NCF | FA2 | FA2 | FA2 |

Note 1: This category is defined as land that is inundated by the PMF but not inundated by the DFE

Note 2: Small-scale development implies development on rural land that is small relative to the width of the floodplain and is not part of a planned large-scale development.

Note 3: Weatherproof Area Definition - Enclosed areas excluding garages / carports / open verandahs

Note 4: For applicable Flood Hazard Category, reference should be to Flood Hazard Map for the DFE

**Control Measures**

| | |
|---|---|
| NCF | No Controls for flooding applicable |
| LUI | Land Use Incompatible with flood hazard - Development only to be considered in special circumstances, site and development specific controls to be defined by Council |
| | **LAND USE SUITABILITY & MINIMUM FILL LEVEL** |
| SF1 | Consider for development subject to the controls below. No minimum fill level required. |
| SF2 | Consider for development subject to the controls below. For residential and commercial areas, the minimum fill level to be greater than or equal to the DFE flood level. For industrial areas, the minimum fill level to be greater than or equal to the 10 year flood level. |
| SF3a | Consider for development subject to the controls below. Minimum fill level greater than or equal to the PMF flood level. |
| SF3b | Consider for development subject to the controls below.<br>Council to give consideration on the benefits of using the development during and after a flood emergency.<br>If the site is to be used for a flood emergency, the minimum fill level should preferably be greater than or equal to the PMF flood level. |
| | **MINIMUM FLOOR LEVEL** |
| FL1 | No minimum floor level required (Council to advise developer of flood risk and potential damage to building & contents. Flood levels available on request) |
| FL2a | All floor levels to be greater than or equal to the DFE flood level |
| FL2b | For permissible uses other than residential, it is preferable to have all floor levels greater than or equal to the DFE flood level subject to industry standards and individual site assessment. |
| FL2c | All habitable floor levels to be greater than or equal to the DFE flood level plus 0.3m |
| FL3a | All floor levels to be greater than or equal to the PMF flood level. |
| FL3b | If practical, some or all floor levels to be greater than or equal to the PMF flood level, so that these buildings will be available for accommodation / storage during and after a flood emergency. Minimum floor level to be greater than or equal to the DFE flood level |
| FL4a | Habitable, commercial or industrial floor levels to be as close to the *minimum floor level* above as practical and not less than the floor level of the existing building being extended if the existing floor level is less than or equal to the minimum floor level. If the extended weatherproof area[3] exceeds 50% of the existing weatherproof area, the extension is treated as a new building. The extended weatherproof area is measured as the cumulative area of any previous extensions plus the proposed extension. If building is idenitified as being suitable for voluntary house raising scheme, Council to discuss potential house raising with owner. |
| FL4b | As for FL4a with the maximum percentage increase in extended weatherproof area[3] to be:<br>(a) 50% if the extension's floor level is less than one (1) metre below the DFE flood level;<br>(b) 25% if the extension's floor level is greater than two (2) metres below the DFE flood level; or<br>(c) pro-rata between 50% and 25% for floor levels from one (1) metre to two (2) metres below the DFE flood level. |
| | **BUILDING COMPONENTS** |
| BC1 | Buildings to have flood compatible material below the higher of (a) the minimum floor level or (b) the DFE flood level plus 0.3m. |
| | **STRUCTURAL SOUNDNESS** |
| SS1 | No structural soundness requirements for the force of floodwater, debris & buoyancy. Must still comply with BCA requirements. |
| SS2 | Engineers report to prove that structures subject to a flood up to the DFE can withstand the force of floodwater, debris & buoyancy. |
| | **FLOOD EFFECT** |
| FE1 | No action required |
| FE2 | The flood impact of the development to be considered by Council, with Council having the right to request an engineer's report (see FE3 below) |
| FE3 | Engineers report required to prove that the development will not result in adverse flood impact elsewhere |
| | **EVACUATION/ACCESS** |
| EA1 | Council to provide information on flood evacuation strategy |
| EA2 | Not used |
| EA3 | Site specific Flood Evacuation Strategy be developed consistent with Council / SES overall Flood Evacuation Strategy. |
| EA4a | Emergency service site - should have good access up to the PMF and preferably not cut-off from the main residential area(s).<br>Council to evaluate suitablility of site in this respect. |
| EA4b | If site to be used during and after a flood emergency (see FL3b above), should have good access up to the PMF and preferably not cut-off from the main residential area(s). |
| | **FLOOD AWARENESS** |
| FA1 | Not used |
| FA2 | Not used |

**Figure F-2 Planning Matrix - Rural Land Uses**

# FLOOD PLANNING MATRIX

| TABLE 3: OTHER | | | | | |
|---|---|---|---|---|---|
| | | Flood Hazard Category[4] | | | |
| Controls | Development / Building Type | Flood prone land - No Hazard[1] | Low Hazard | High Hazard - Wading Unsafe or High Hazard - Depth | Extreme Hazard - Floodway or Extreme Hazard - Flow Velocity |
| Land Use Suitability & Fill Level | Non-Habitable Building (shed, toilets, shelter, etc) | NCF | SF1 | SF1 | SF1 |
| | (this line not used) | | | | |
| | Other Developments (eg. levees, roads, dams, etc) | NCF | SF1 | SF1 | SF1 |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| Floor Level | Small-scale[2] Development (eg. shed, small dam) | NCF | NCF | NCF | NCF |
| | Large-scale Development (eg. levee, raised road) | NCF | NCF | NCF | NCF |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| Building Components | | NCF | BC1 | BC1 | BC1 |
| Structural Soundness | Small-scale[2] Development (eg. shed, small dam) | NCF | SS1 | SS1 | SS2 |
| | Large-scale Development (eg. levee, raised road) | NCF | SS1 | SS2 | SS2 |
| Flood Effect | Small-scale Development (eg. shed, small dam) | NCF | FE1 | FE2 | FE2 |
| | Large-scale Development (eg. levee, raised road) | NCF | FE2 | FE3 | FE3 |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| Evacuation & Access | Not Applicable | | | | |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| | (this line not used) | | | | |
| Flood Awareness, etc | Not Applicable | | | | |

Note 1: This category is defined as land that is inundated by the PMF but not inundated by the DFE

Note 2: Small-scale development implies development on rural land that is small relative to the width of the floodplain and is not part of a planned large-scale development.

Note 3: Weatherproof Area Definition - Enclosed areas excluding garages / carports / open verandahs

Note 4: For applicable Flood Hazard Category, reference should be to Flood Hazard Map for the DFE

## Control Measures

| | |
|---|---|
| NCF | No Controls for flooding applicable |
| LUI | Land Use Incompatible with flood hazard - Development only to be considered in special circumstances, site and development specific controls to be defined by Council |
| | **LAND USE SUITABILITY & MINIMUM FILL LEVEL** |
| SF1 | Consider for development subject to the controls below. No minimum fill level required. |
| SF2 | Consider for development subject to the controls below. For residential and commercial areas, the minimum fill level to be greater than or equal to the DFE flood level. For industrial areas, the minimum fill level to be greater than or equal to the 10 year flood level. |
| SF3a | Consider for development subject to the controls below. Minimum fill level greater than or equal to the PMF flood level. |
| SF3b | Consider for development subject to the controls below.<br>Council to give consideration on the benefits of using the development during and after a flood emergency.<br>If the site is to be used for a flood emergency, the minimum fill level should preferably be greater than or equal to the PMF flood level. |
| | **MINIMUM FLOOR LEVEL** |
| FL1 | No minimum floor level required (Council to advise developer of flood risk and potential damage to building & contents. Flood levels available on request) |
| FL2a | All floor levels to be greater than or equal to the DFE flood level. |
| FL2b | For permissible uses other than residential, it is preferable to have all floor levels greater than or equal to the DFE flood level subject to industry standards and individual site assessment. |
| FL2c | All habitable floor levels to be greater than or equal to the DFE flood level plus 0.3m |
| FL3a | All floor levels to be greater than or equal to the PMF flood level. |
| FL3b | If practical, some or all floor levels to be greater than or equal to the PMF flood level, so that these buildings will be available for accommodation / storage during and after a flood emergency. |
| FL4a | Habitable, commercial or industrial floor levels to be as close to the *minimum floor level* above as practical and not less than the floor level of the existing building being extended if the existing floor level is less than or equal to the minimum floor level. If the extended weatherproof area[3] exceeds 50% of the existing weatherproof area, the extension is treated as a new building. The extended weatherproof area is measured as the cumulative area of any previous extensions plus the proposed extension. If building is idenitified as being suitable for voluntary house raising scheme, Council to discuss potential house raising with owner. |
| FL4b | As for FL4a with the maximum percentage increase in extended weatherproof area[3] to be:<br>(a) 50% if the extension's floor level is less than one (1) metre below the DFE flood level;<br>(b) 25% if the extension's floor level is greater than two (2) metres below the DFE flood level; or<br>(c) pro-rata between 50% and 25% for floor levels from one (1) metre to two (2) metres below the DFE flood level. |
| | **BUILDING COMPONENTS** |
| BC1 | Buildings to have flood compatible material below the higher of (a) the minimum floor level or (b) the DFE flood level plus 0.3m. |
| | **STRUCTURAL SOUNDNESS** |
| SS1 | No structural soundness requirements for the force of floodwater, debris & buoyancy. Must still comply with BCA requirements. |
| SS2 | Engineers report to prove that structures subject to a flood up to the DFE can withstand the force of floodwater, debris & buoyancy. |
| | **FLOOD EFFECT** |
| FE1 | No action required |
| FE2 | The flood impact of the development to be considered by Council, with Council having the right to request an engineer's report (see FE3 below) |
| FE3 | Engineers report required to prove that the development will not result in adverse flood impact elsewhere |
| | **EVACUATION/ACCESS** |
| EA1 | Council to provide information on flood evacuation strategy |
| EA2 | Not used |
| EA3 | Site specific Flood Evacuation Strategy be developed consistent with Council / SES overall Flood Evacuation Strategy. |
| EA4a | Emergency service site - should have good access up to the PMF and preferably not cut-off from the main residential area(s).<br>Council to evaluate suitablility of site in this respect. |
| EA4b | If site to be used during and after a flood emergency (see FL3b above), should have good access up to the PMF and preferably not cut-off from the main residential area(s). |
| | **FLOOD AWARENESS** |
| FA1 | Not used |
| FA2 | Not used |

Figure F-3 Planning Matrix - Other Land Uses