Tarwin Lower
Flood Study

Report No. J155/R01

FINAL REPORT

January 2007

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Tarwin Lower
Flood Study

Report No. J155/R01
January 2007

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

15 Business Park Drive, Notting Hill Victoria Australia 3168
tel : 61 (03) 9558 9366 fax : 61 (03) 9558 9365
web : www.watech.com.au
ACN No. 093 377 283
ABN No. 60 093 377 283

DOCUMENT STATUS

Issue	Revision	Date	Issued To	Prepared By	Reviewed By	Approved By
Draft	D	28/08/06	Tarwin Properties WG CMA SGSC	ABC/SJD	SHM	ABC
Final		30/01/07	Tarwin Properties WG CMA SGSC	ABC/SJD	SHM	ABC

QFORM-AD-18 REV 5

It is the responsibility of the reader to verify the currency of revision of this report.

S:\J155_LOWERTARWIN\DOCS\REPORT\FINAL\J155R01_FINAL_2007_01_30.DOC

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

The township of Tarwin Lower sits on the floodplain of the Tarwin River near its confluence with Anderson Inlet. The town has been subject to flooding on a number of occasions resulting in inundation, road closures and other flood risks to the community.

The West Gippsland Catchment Management Authority (WGCMA) has recognized the need to investigate flood behaviour in the township with a view to identifying opportunities and constraints for mitigating flood problems. The first phase in this process is the investigation of existing flood behaviour in the town and surrounding floodplain areas.

The flood study has involved an analysis of the Tarwin River catchment rainfall-runoff hydrology, an assessment of flood behaviour in the town and surrounding floodplain areas, and an assessment of ocean storm surge related flooding. Design 100 year flood levels have been determined and the 100 year flood inundation extent identified.

This report outlines the investigations undertaken for the Lower Tarwin Flood Study, which provides definition of flooding behaviour in Tarwin Lower and the surrounding Floodplain. The study area locality is shown in Figure 2-1 including the whole Tarwin River catchment and the surveyed extent.

Water Technology was commissioned to undertake these investigations with AAMHatch and Redborough Mapping engaged to conduct the required photogrammetric, field and bathymetric survey. The investigations were carried out in accordance with instructions from the West Gippsland CMA and Tarwin Properties Investments Pty Ltd.

1.2 Purpose of this Report

The Lower Tarwin Flood Study project will provide reliable flood levels throughout the study area, and the basis for further detailed investigations for site specific development proposals in Tarwin Lower. The flood information produced by these investigations will also be readily used by West Gippsland CMA, the South Gippsland Shire as well as the Victoria State Emergency Service and the community to facilitate land use planning and emergency preparedness and response to flood situations.

1.3 Study Objectives

The aims of the investigations were as follows:

- Derive a RORB model for the whole of the Tarwin River catchment;
- Calculate expected design flow hydrographs on the Tarwin River at Tarwin Lower for the 100 year ARI event;
- Determine the 100 year ARI flood extent and depths;
- Provide flood level, inundation and extent maps;
- Provide advice on possible flood mitigation and/or flood risk reduction measures;

1.4 Structure of Report

This report details the investigations undertaken to achieve the above aims. The structure of this report is as follows:

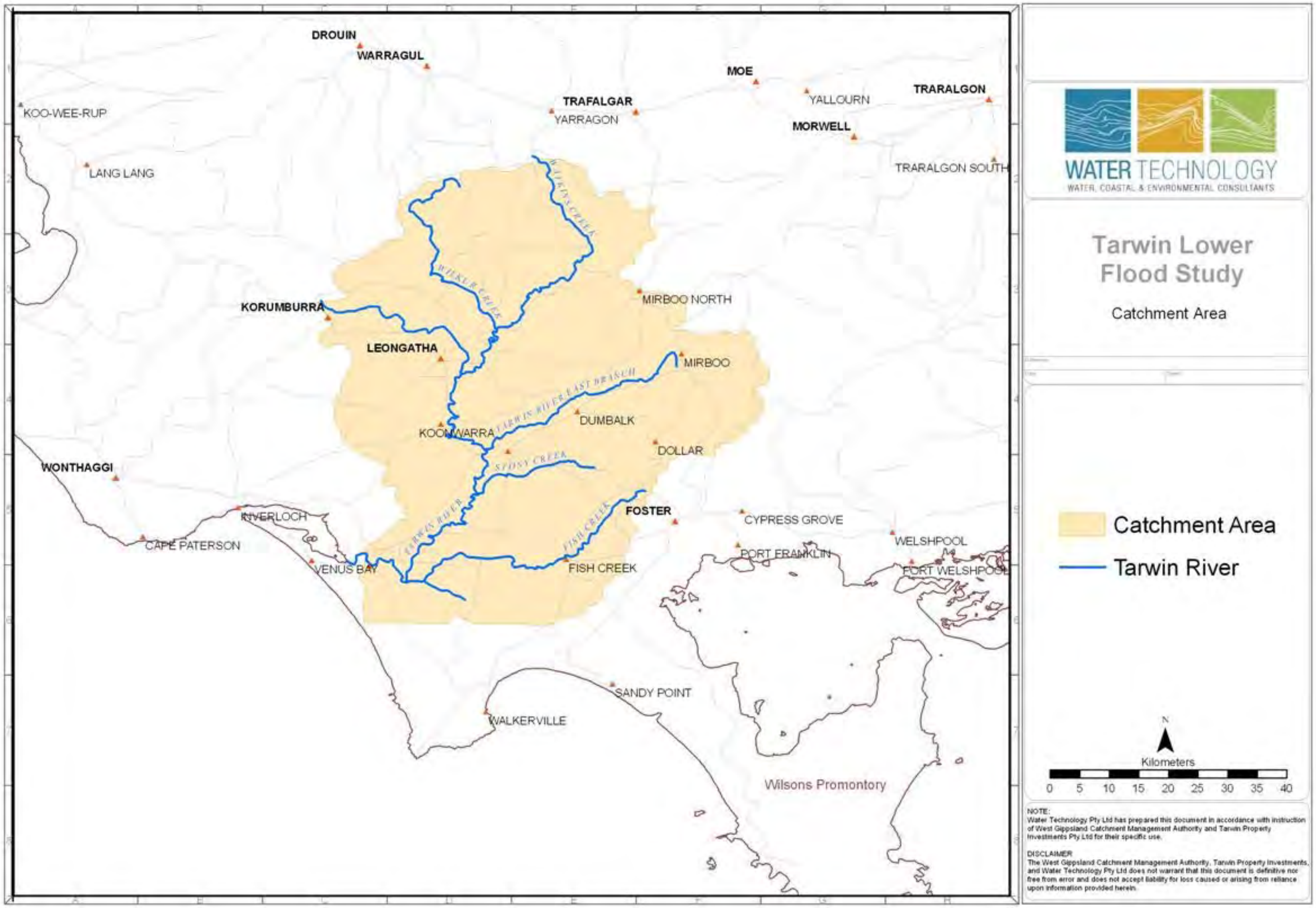
- Section 2 – describes key catchment features
- Section 3 – outlines the input data gathered for use in the study
- Section 4 – details the hydrologic analysis
- Section 5 – details the flood hydraulic analysis
- Section 6 – details the storm surge hydraulic analysis
- Section 7 – documents the adopted 100 year design flood levels and extents
- Section 8 – discusses flood mitigation opportunities

2 STUDY AREA

Tarwin River is in the South Gippsland Basin with a catchment area of approximately 1500 km^2 (see Figure 2-1). The Tarwin River flows south from the Strezlecki Ranges and discharges at the eastern end of Anderson Inlet, a shallow estuary connected to Bass Strait. Major tributaries include Tarwin River East and Fish Creek. The catchment is a rural area with small pockets of residential land use.

The study area comprises the township of Tarwin Lower and surrounding floodplain. The township of Tarwin Lower is situated on the southern side of the river, approximately 2km upstream from its confluence with Anderson Inlet. The town is surrounded by large areas of coastal floodplain, with extensive levee systems.

Anderson Inlet and Tarwin Lower are also subject to coastal inundation due to storm surges in Bass Strait. The extensive levee systems throughout the lower floodplain have been constructed over a long period designed to control nuisance flooding and storm surge inundation.



NOTE:
Water Technology Pty Ltd has prepared this document in accordance with instruction of West Gippsland Catchment Management Authority and Tarwin Property Investments Pty Ltd for their specific use.

DISCLAIMER
The West Gippsland Catchment Management Authority, Tarwin Property Investments, and Water Technology Pty Ltd does not warrant that this document is definitive nor free from error and does not accept liability for loss caused or arising from reliance upon information provided herein.

Figure 2-1: Tarwin River Catchment

3 AVAILABLE INFORMATION

This section outlines the different types of information utilised within the study including reference reports and documents as well as data, both previously available and collected specifically for this study.

3.1 Previous Studies

Previous hydrologic and/or hydraulic studies relevant to the present project and region include:

- Tarwin River (East Branch @ Dumbalk) Catchment Study (CRC of Catchment Hydrology 1996) – This study uses RORB to estimate the design floods of the Tarwin River at Dumbalk.

Information within the CRC study has been drawn on to assist in calibration and ground truthing for the current study.

3.2 Topographic and Cadastral Survey Data

3.2.1 Overview

Topographic and cadastral data have been collected from a number of sources including:

- Aerial Survey
- Field Survey
- Bathymetric Survey
- Existing local and state-wide data-sets

Topographic data has been gathered as part of the study from throughout the study area, Anderson Inlet and Tarwin River catchment. A listing of survey sources, along with the nominal accuracy of the data is provided below in Table 3-1.

Table 3-1: Available Topographic and Cadastral Data

Data	Estimated Nominal Accuracy	Source
10 m base contour data (from 1:25,000 state mapping)	Vertical +/- 5 m Horizontal +/- 10 m	Land Victoria
Cadastre	Vertical n/a Horizontal +/- 10 m	WGCMA
Field Survey (levee tops and other flood controls)	Vertical +/- 0.1 m Horizontal +/- .2 m	Redborough Mapping
Anderson Inlet Bathymetry	Vertical +/- 0.250 m Horizontal +/- 5 m	Redborough Mapping RAN Charts
Coastal bathymetry	Vertical +/- 0.50 m Horizontal +/- 5 m	RAN Charts
Digital Aerial Photography	Horizontal +/- 0.5 m	AAM Hatch

Note: As appropriate meta-data is not available for most data sources, reasonable estimates of survey accuracy have been made based on the capture techniques used and experience with previous, similar data sets.

3.2.2 Aerial Photogrammetry

Aerial photogrammetry of the main study area was undertaken by AAM Hatch. The aerial photography was flown on the 15th February 2005 covering the section of the study area extending from the Tarwin Lower Road south to Tarwin Meadows. The photogrammetry was supplied as a set of points and break-lines defining the surface topography. This low-level photogrammetry has a derived vertical accuracy of +/- 100mm to one standard deviation. The vertical accuracy of the photogrammetry is achieved through the use of surveyed control points. The photo-control points for this exercise were established and levelled by Reborough Mapping for use by AAM Hatch.

3.2.3 Field survey

Field survey was required to:

- Supplement the photogrammetry to define watercourse cross-sections below the water-line and other features obscured from the aerial photos such as bridge details.
- Supplement the photogrammetry to define levees and drainage channels that required finer surveying.
- Provide information in areas where no photogrammetry data was captured or available.

The field survey was conducted using traditional levelling techniques as well as high-accuracy RTK-GPS.

3.2.4 Coastal Bathymetry

Depth soundings for the areas in Andersons Inlet were completed by Redborough Mapping in November 2004.

Additional levels were also extracted from the Royal Australian Naval Charts. This data was converted from conventional latitude and longitude coordinates to AMG-55 and the vertical elevations were converted to AHD from chart datum to be consistent with the other study data.

3.2.5 Cadastre

Cadastral information was provided by the West Gippsland CMA for the study area. This information includes typical parameters such as Street Name, Number and property boundary. This information can be used to identify flood-prone properties.

3.2.6 Catchment DEM

A 250m grid of topography values was obtained from Geoscience Australia. This grid is based on 1:100,000 scale topography mapping of spot heights. In conjunction with this, 10m contours from Land Victoria were used in the downstream plains to generate the sub-catchment delineation for the Tarwin River hydrologic model.

3.2.7 Aerial Photography and Video

Aerial photos are an invaluable resource in flood studies. They can be used to interpret physical features and land-use on the ground and provide a context and background to flood model results and aid in presentation. Typically these photos are digitised and registered in a GIS system for analysis. Digital aerial photos were supplied by the CMA for the study area.

In August 2001, a moderate flood occurred in the Tarwin River. The West Gippsland CMA undertook an aerial survey of the event to document flooding throughout the catchment. Video was recorded and provided to the study team as a valuable indicative calibration data source. It is understood that the video was recorded at a time several hours after the peak of the flood.

3.3 Hydrologic and Hydraulic Data

3.3.1 Streamflow Data

Streamflow data is required for the hydrologic analysis and modelling. There are four stream gauging stations (past and present) located within the Tarwin River catchment, these are listed in Table 3-2 with the locations shown in Figure 3-1. However, only one of these gauges, at Meeniyan, was able to provide streamflow data that is suitable for the hydrologic analysis, whilst information at the other gauges was used to assist in the hydraulic model calibration and verification.

Table 3-2: Details of Streamflow Gauges

Station Number	Station name	Catchment Area (km2)	Period of record
227200	Tarwin River @ Meeniyan	1067	June 1955 to date
227226	Tarwin River East Branch @ Dumbalk North	127	April 1970 to date
227227	Wilkur Creek @ Leongatha	106	August 1970 to date
227228	Tarwin River East Branch @ Mirboo	43	January 1971 to December 1987

3.3.2 Rainfall data

Both temporal and spatial rainfall data were required for the hydrologic analysis. Pluviographic rainfall data indicates the rainfall temporal variation, and the daily rainfall data provides the spatial rainfall variation.

Pluviographic rainfall data

Table 3-3 shows the pluviographic stations employed by this study and Figure 3-3 displays their location. Additional pluviographic rainfall stations to those shown in Table 3-3 and Figure 3-3 are located within and adjacent to the Tarwin River catchment. These additional stations were not utilised by this study due to a lack of available data for the hydrologic model calibration events. Details of the hydrologic model calibration events are provided in Section 4.2.3.

Table 3-3: Details of pluviographic stations

Site Number	Name	Period of record

85227	East Tarwin (Mirboo Pastoral Company)	November 1971 to date
85240	Ellinbank Dairy Research Institute	August 1961 to December 2000
85106	Olsens Bridge (Morwell River Prison)	August 1977 to August 1991

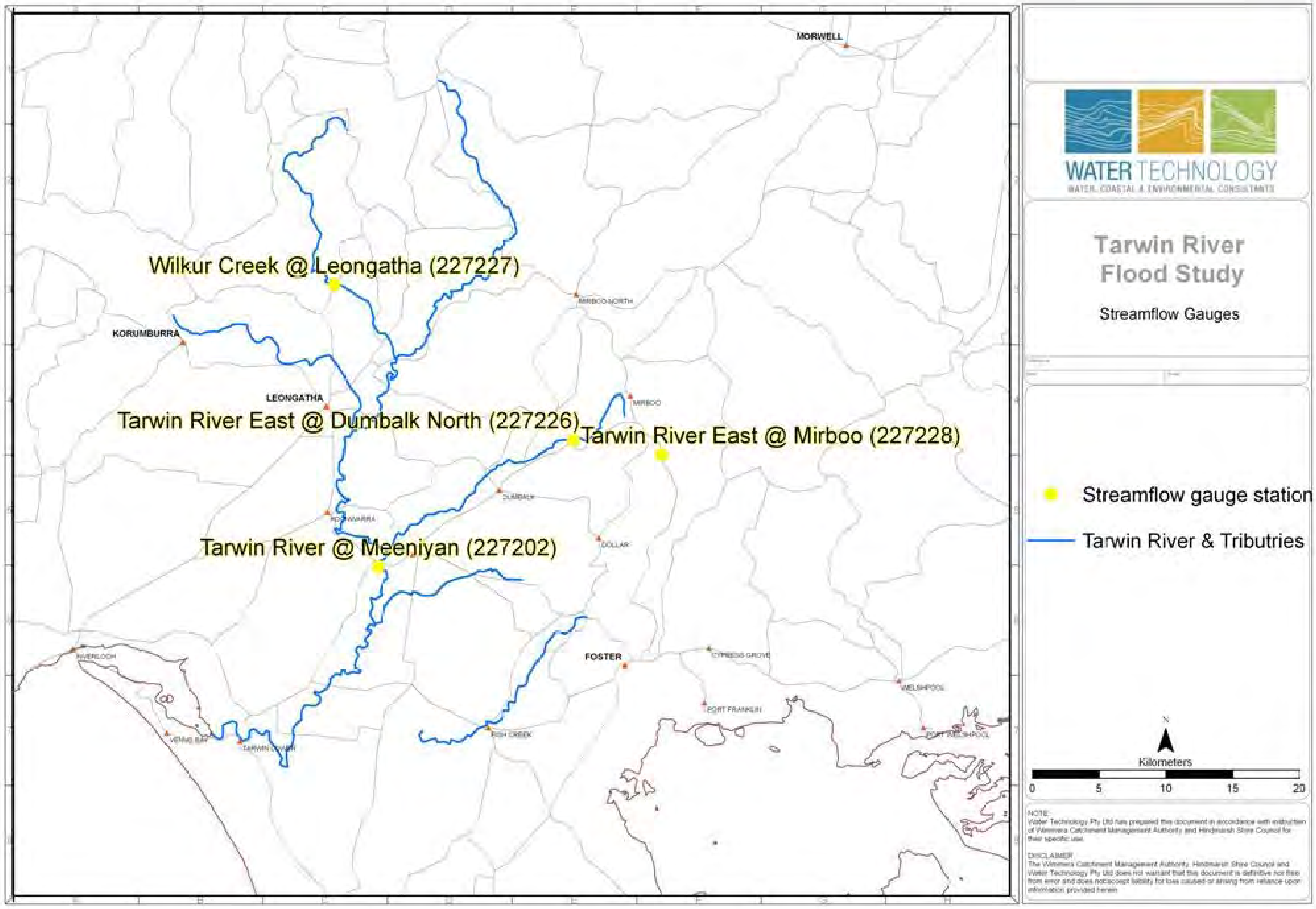


Figure 3-1: Stream Gauging Stations

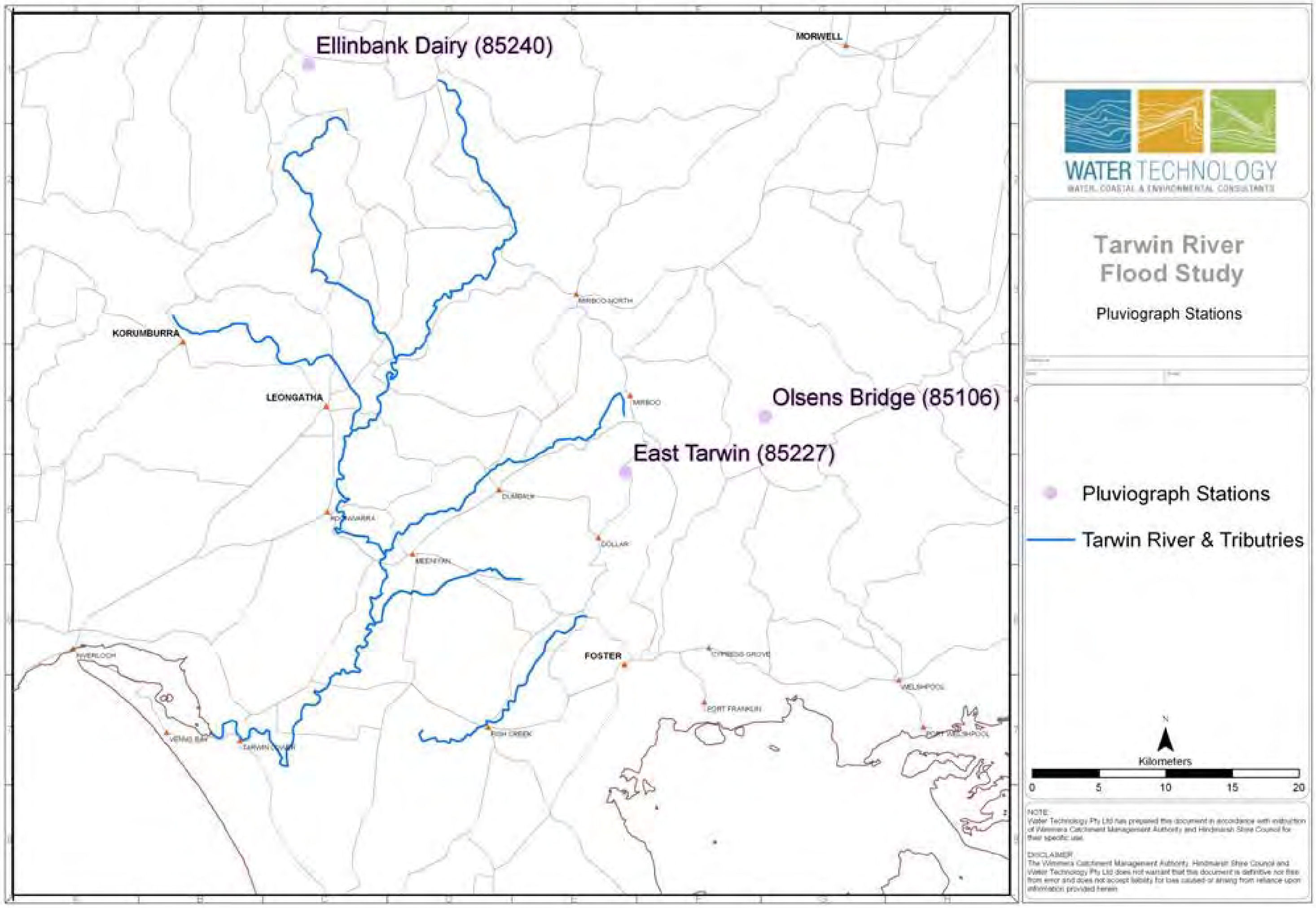


Figure 3-2: Pluviograph Stations

Daily rainfall data

Table 3-4 shows the daily rainfall stations and Figure 3-3 displays their location. Additional daily rainfall stations to those shown in Table 3-4 and Figure 3-3 are located within and adjacent to the Tarwin River catchment. These additional stations were not utilised by this study due to a lack of available data for the hydrologic model calibration events. Details of the hydrologic model calibration events are provided in Section 4.2.3.

Table 3-4: Details of daily rainfall stations

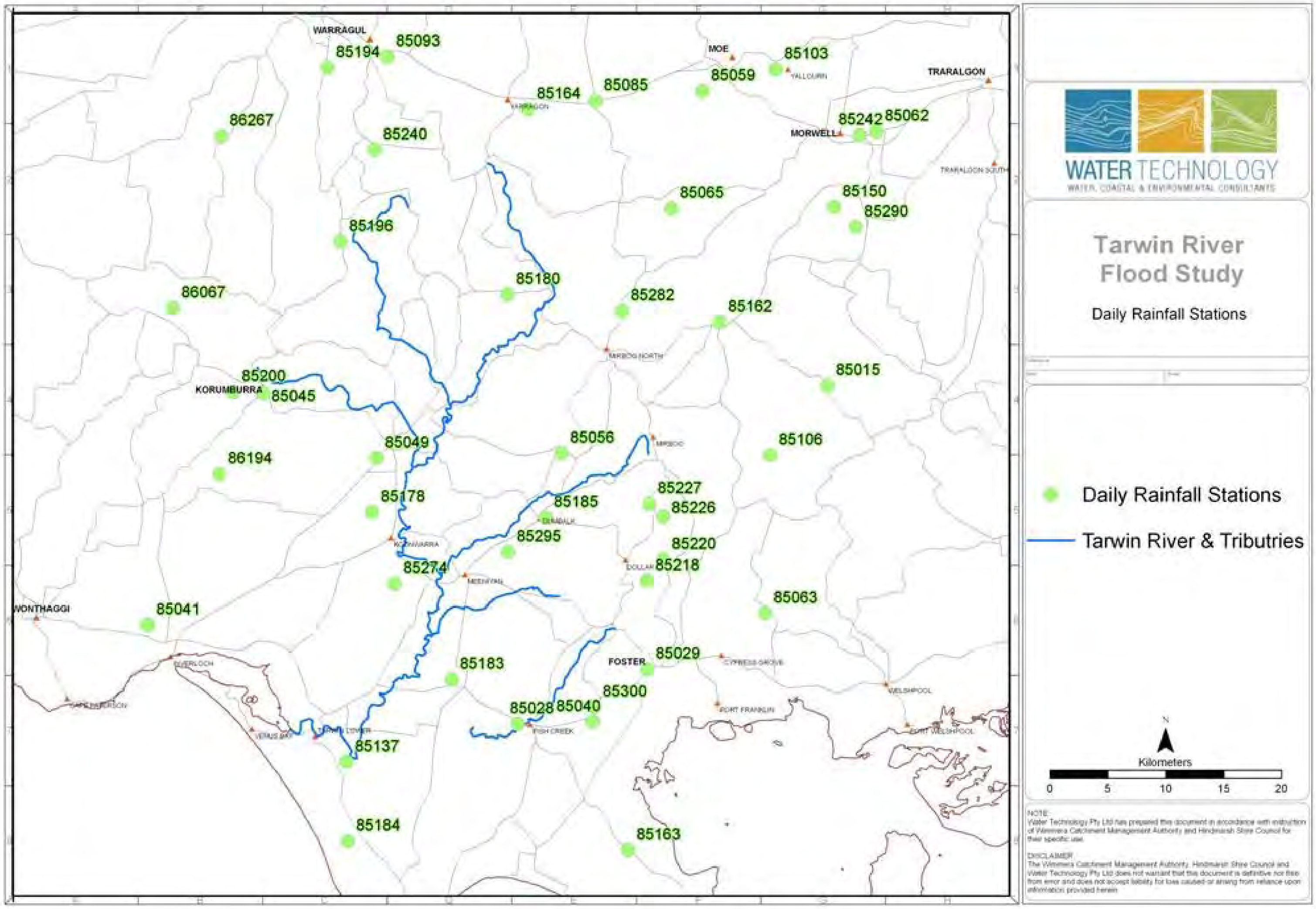
Site Number	Name	Period of record
85015	Budgeree East (Claremont)	1907 – 2001
85028	Fish Creek	1928 – present
85029	Foster (Post Office)	1884 – present
85040	Fish Creek (Hoddle Range)	1906 – present
85041	Inverloch	1884 – present
85045	Korumburra	1900 – present
85049	Leongatha Sth Gippsland Water	1896 – present
85056	Mardan South	1899 – 1978
85059	Moe Sth Gippsland Water	1897 – present
85062	Morwell (Mail Centre)	1887 – present
85063	Mount Best (Upper Toora)	1903 – present
85065	Narracan East (Lynnsmere)	1900 – 2001
85085	Trafalgar	1902 – present
85093	Warragul	1888 – present
85103	Yallourn SEC	1949 – 1994
85106	Olsens Bridge (Morwell River Prison)	1951 – 2003
85137	Tarwin Lower (Riverside)	1885 – present
85150	Hazelwood SEC	1963 – 1993
85162	Boolarra (Amy Court)	1967 – present
85163	Yanakie (Shallow Inlet)	1967 – present
85164	Yarragon (Lyn Park)	1968 – 2001
85178	Koonwarra (Leongatha South)	1969 – present
85180	Hallston	1969 – present
85183	Buffalo	1939 – present
85184	Tarwin Lower (Barana Plains)	1969 – 1988
85185	Dumbalk (Sly)	1969 – 1978
85194	Lardner	1970 – 2002
85196	Strezlecki (Allandee)	1970 – 1985
85200	Korumburra Sth Gippsland Water	1973 – present
85218	Altenhof (East Tarwin No. 1)	1971 – 1978

85220	East Tarwin No. 3	1971 – 1979
85226	East Tarwin (Kulbe)	1971 – 1980
85227	East Tarwin (Mirboo PastorL Company)	1971 – present
85240	Ellinbank Dairy Research Institue	1960 – 2000
85242	Morwell (Buckleys Hill)	1966 – 2001
85274	Meeniyan (Kasmar)	1981 – 2001
85282	Mirboo North Water Board	1899 – present
85290	Churchill	1989 – 1944
85295	Stony Creek	1993 – present
85300	Foster Hoddle	1955 – present
86067	Loch	1892 – 1981
86194	Outtrim	1882 – present
86267	Athlone McDonalds	1969 – 1987

3.3.3 Tide and Sea Level Data

In order to define boundary water level conditions at the mouth of the Tarwin River at Lower Tarwin, tide and sea level information has been gathered and/or derived. This consisted of:

- National tide tables, tidal constituents for a location representative of the ocean entrance to Anderson Inlet.
- Recorded sea levels at Inverloch, Tarwin River at Tarwin Lower, Venus Bay boat ramp and the entrance to Screw Creek from September 18th to October 20th 2004 – this data assists in the estimation of design sea levels to be used in conjunction with the design flood conditions.



NOTE:
Water Technology Pty Ltd has prepared this document in accordance with instruction of Wimmera Catchment Management Authority and Hindmarsh Shire Council for their specific use.

DISCLAIMER
The Wimmera Catchment Management Authority, Hindmarsh Shire Council and Water Technology Pty Ltd does not warrant that this document is definitive nor free from error and does not accept liability for loss caused or arising from reliance upon information provided herein.

Figure 3-3: Daily Rainfall Stations

4 HYDROLOGIC ANALYSIS

4.1 Overview

Downstream of Meeniyan there is significant floodplain storage within the Tarwin River Floodplain. Due to the size of these floodplain storages, design flood hydrograph shape and volume can play an important part in the overall impact of floods in the Tarwin Lower area. Subsequently, it was determined that the hydraulic analysis of this system requires full design hydrographs to be applied within the flood model. The purpose of the hydrologic analysis for this investigation was then to derive reliable design hydrograph estimates for the Tarwin River at Tarwin Lower.

The following two alternative design flood estimation approaches were employed:

- RORB model
- Scaled historical hydrograph

This section details the input data, methodology and outputs for the two design flood estimation approaches. The section concludes with a comparison and discussion of the design flood hydrographs yielded by the two approaches and the reasons underlying the selection of the adopted flood hydrograph.

4.2 RORB Model design flood estimation

4.2.1 Description of RORB Runoff Routing Model

The runoff-routing model RORB, developed by Laurenson and Mein (1992), is a general runoff and streamflow routing program that calculates flood hydrographs from rainfall and other channel inputs. The model subtracts losses from rainfall to determine surface runoff which is then routed through a network of storages to produce flood hydrographs at points of interest. It is an areally distributed, non-linear model that is applicable to both urban and rural catchments. The model can account for both temporal and spatial distribution of rainfall and losses.

RORB has two principal parameters, k_c and *m*. The parameter *m* describes the degree of non-linearity of the catchment’s response to rainfall, while the parameter k_c describes the storage available with the catchment. The rainfall loss parameters relate to the conversion of rainfall into surface runoff. The RORB model can represent these losses either by the initial loss/continuing loss model, or by the initial loss/volumetric runoff coefficient model. The catchment is subdivided into sub-areas based on topographical features. This catchment sub-division allows for spatial variation of catchment characteristics and rainfall inputs.

4.2.2 RORB Model Structure

For the Tarwin River catchment, the RORB model sub-catchments were defined to coincide with watershed boundaries, stream junctions, and the location of gauging stations. The sub-catchments were defined using CatchmentSIM (Ryan 2003). CatchmentSIM automatically delineates watershed and sub-catchment boundaries, generalises geophysical parameters and provides in-depth analysis tools to examine and compare the hydrologic properties of sub-catchments. The DEM data was used to delineate the catchment area into sub-catchments for the RORB model. In total the Tarwin River catchment was sub-divided into 52 sub-catchments. Figure 4-1 shows the RORB model catchment sub-division.

Within RORB, provision is available to represent the various types of main watercourse characteristics e.g. natural reach, unlined but excavated and lined or piped. All the watercourses were classified as natural reaches for this study.

4.2.3 RORB Model Calibration

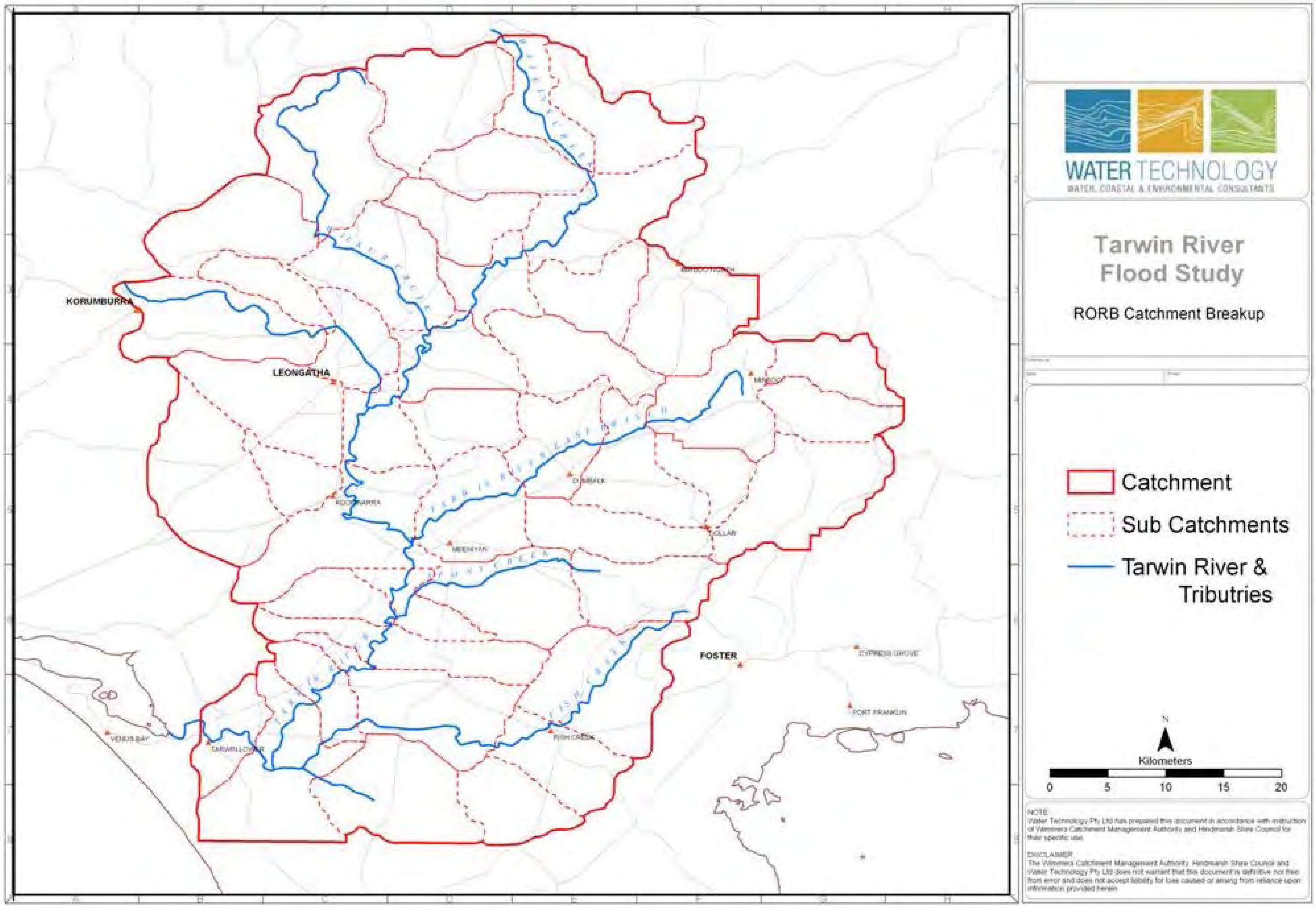
The RORB model calibration requires the comparison of the modelled flood hydrographs with observed flood hydrographs at streamflow gauge(s) throughout the catchment. For this study, design flood hydrographs were required for Tarwin River. Ideally the RORB model would be calibrated to the observed flood hydrographs at several gauges located within the Tarwin River catchment. As outlined in Section 3.3.1, there are four streamflow gauges located within the Tarwin River catchment.

Examination of the available streamflow data showed only the streamflow data for Tarwin River at Meeniyan was suitable for use in the RORB model calibration. As a result, the calibration of the RORB model parameters was undertaken to the observed streamflow data for Tarwin River at Meeniyan. This calibration approach results in the model parameters determined at a gauge located within the catchment being applied to the entire Tarwin River catchment above Tarwin Lower.

The selection of suitable flood events for model calibration was dependent on the availability of concurrent streamflow and pluviographic rainfall data. Three flood events, July 1977, September 1993 and August 2001 were selected for the RORB model calibration. The details of the selected calibration flood events for Tarwin River at Meeniyan are provided in Table 4-1. The rank of the peak flow in the available streamflow record indicates the relatively magnitude of the calibration events. As seen in Table 4-1, the selected calibration events are three of the four largest flood events to occur during the available streamflow record (1955 to date). The second largest flood event occurred in 1960 before the availability of concurrent pluviographic rainfall data and as such was not suitable for the RORB model calibration.

Table 4-1 RORB Model Calibration Events

Event	**Event Start & Finish Date**	**Tarwin River at Meeniyan (227202)**	
		Observed Peak flow (m^3/s)	**Rank of peak flow in record**
July 1977	26/7/1977 – 1/8/1977	278.0	1
22 September 1993	13/9/1993 – 25/9/1993	230.3	3
22 August 2001	16/8/2001 – 1/9/2001	229.5	4



NOTE:
Water Technology Pty Ltd has prepared this document in accordance with instruction of Wimmera Catchment Management Authority and Hindmarsh Shire Council for their specific use.

DISCLAIMER
The Wimmera Catchment Management Authority, Hindmarsh Shire Council and Water Technology Pty Ltd does not warrant that this document is definitive nor free from error and does not accept liability for loss caused or arising from reliance upon information provided herein.

Figure 4-1: RORB model structure – catchment subdivision

Subarea rainfalls

For each calibration event the rainfall depth was estimated for each sub-area to account for the spatial variation of rainfall across the catchment. The rainfall depth on each sub-area was estimated through storm event rainfall isohyets. The storm event rainfall isohyets were developed with the use of the pluviographic and daily rainfall stations as indicated in Table 3-3 and Table 3-4 respectively.

The temporal distribution of rainfall was determined by assigning the rainfall pattern from the available pluviographic stations listed in Table 3-3.

Baseflow separation

Examination of the streamflow data at Meeniyan shows a reasonable baseflow component with the recessing limbs of the selected calibration events extending over 1 to 2 days. As such, it was considered necessary to remove the baseflow component from the observed hydrograph prior to use in the RORB calibration.

4.2.4 RORB model parameter calibration

There are two model parameters (k_c & m) requiring calibration. The calibration approach adopted by this study was as follows:

- Set m = 0.8. This value is an acceptable value for the degree of non-linearity of catchment response (ARR99)
- For each calibration event the initial loss was determined to result in a reasonable match between the modelled and observed rising limb of the flood hydrograph. The continuing loss rate was determined to match the modelled and observed runoff volume at the Meeniyan gauge.
- For each calibration event k_c values were trialled to achieve reasonable re-production of the peak flow and general hydrograph shape for Tarwin River at Meeniyan.

The initial loss continuing loss rainfall loss model was adopted with for this study.

The RORB parameter k_c was varied to provide a reasonable match between the observed peak flow and modelled peak flow at the Meeniyan gauge. In varying k_c consideration was given to matching the observed and modelled hydrograph shape. A summary of calibration results are provided in Table 4-2. The recorded peak flows in Table 4-2 vary from the recorded peak flows in Table 4-1 due to the removal of the baseflow component.

Table 4-2 RORB model calibration parameters

Event	**k_c value**	**Tarwin River at Meeniyan**			
		Rainfall loss parameters		**Peak flow (m^3/s)**	
		IL (mm)	**CL (mm/h)**	**Recorded***	**Modelled**
July 1977	46	30	0.26	254	279
September 1993	46	44	0.37	199	201
August 2001	46	30	0.22	184	193

** Recorded peak flow following the removal of the baseflow component.*

Figure 4-2 to Figure 4-4 displays the modelled and recorded flood hydrographs for the calibration events at the Meeniyan gauge. The recorded hydrographs shown in Figure 4-2 to Figure 4-4 are following the baseflow removal.

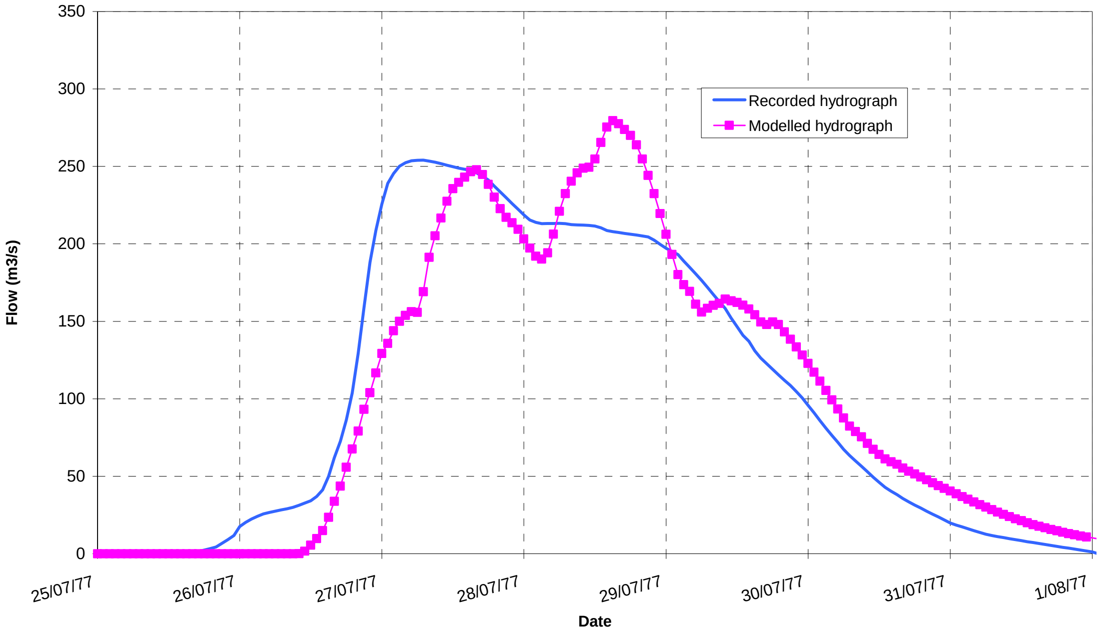


Figure 4-2: RORB calibration – Tarwin River at Meeniyan: July 1977 event (k_c = 46, IL = 30 mm, CL = 0.26 mm/h)

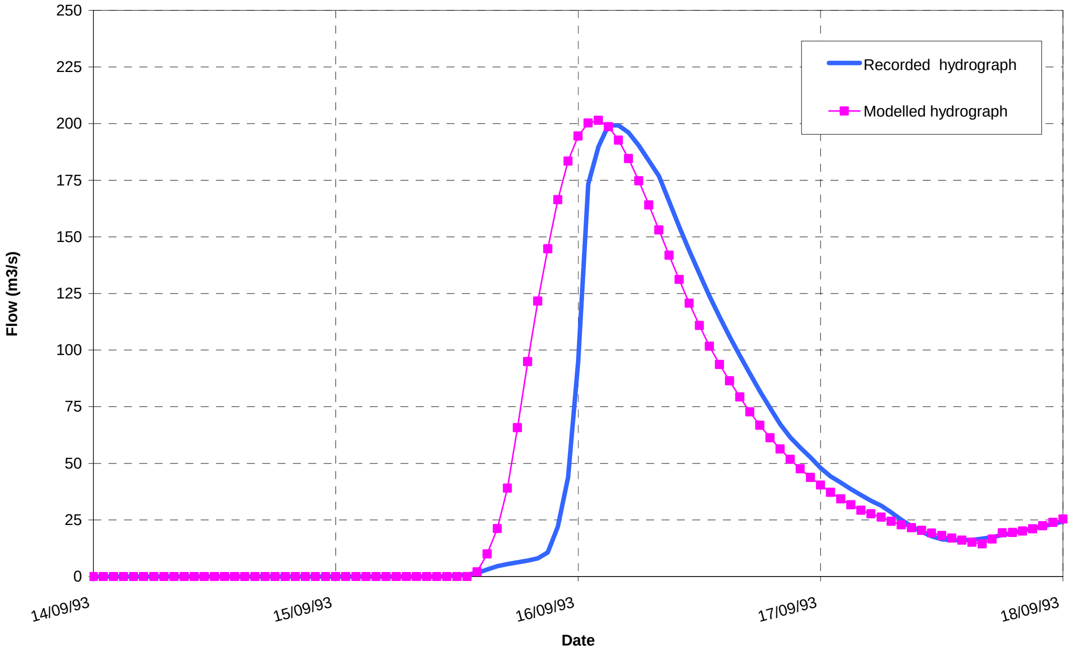


Figure 4-3: RORB calibration – Tarwin River at Meeniyan: September 1993 event (k_c = 46, IL = 44 mm, CL = 0.37 mm/h)

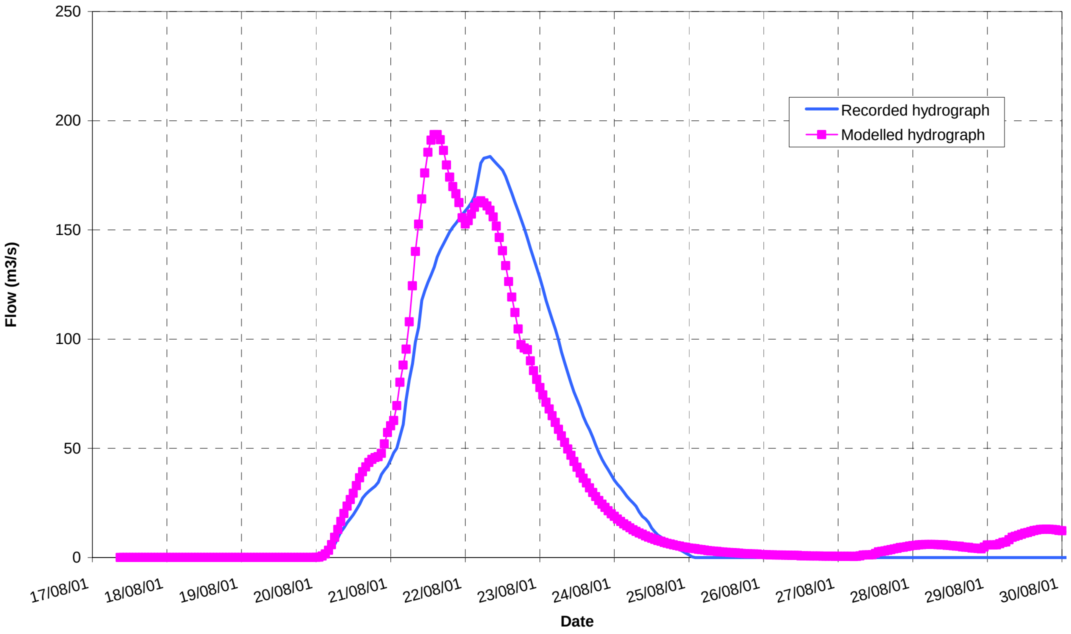


Figure 4-4: RORB calibration – Tarwin River at Meeniyan: August 2001 event (k_c = 46, IL = 30 mm, CL = 0.22 mm/h)

The fits of the modelled and observed flood hydrographs were considered reasonable. Some differences in the timing of the peak flow were found. These differences were considered to be due to the assumed representation of the spatial and temporal variation of rainfall across the catchment. Attempts were made to improve the timing of the modelled peak flows by varying the assignment of observed temporal pattern from the pluviographic rainfall data to the RORB model sub-areas. During the calibration, the modelled flood hydrographs, both peak flow and shape, were found to be sensitive to the assignment of the observed pluviographic rainfall data.

A k_c value of 46 was found to result in a reasonable fit of the peak flow and hydrograph shape for the calibration events. Various regional k_c estimation equations have been developed. The regional prediction equations are based on the catchment area. Table 4-3 displays a comparison of this study's adopted k_c values and regional k_c estimates.

Table 4-3 Comparison of adopted k_c and regional k_c estimates

Source	k_c value
Adopted Study k_c	46
Australian Rainfall and Runoff (1999) Victoria. Mean annual rainfall > 800 mm Leongatha Mean Annual Rainfall 967 mm Catchment area to Tarwin Lower 1547 km^2 $k_c = 2.57 A^{0.45}$	70

The adopted k_c value was considerably lower than the values provided by the regional equation. The regional prediction equation was developed using data from 18 catchments in Victoria. The standard error associated with the regional prediction equation is +32% and -

24%. This study's k_c value lies below the lower standard error limit of 53. This comparison of k_c values reflects the uncertainty in the determination of appropriate k_c values. Nevertheless, the good comparison of the RORB model results with observed flows at Meeniyan provides sufficient confidence in the model performance and the parameters adopted for its use in design flood estimation.

Section 4.2.5 provides a verification of the RORB model parameters for use in design flood estimation.

4.2.5 RORB model verification for design flood estimation

The RORB model parameters determined in Section 4.2.3 were assessed for their suitability in design flood estimation. The RORB model parameters were combined with the design rainfall information from Australian Rainfall and Runoff (ARR 1999) to produce design peak flows for the Tarwin River at Meeniyan. These modelled peak flows were compared to the results of a frequency analysis of observed peak flows.

Annual series flood frequency analysis

Annual flood frequency analysis was undertaken for Tarwin River at Meeniyan. For the annual flood series a Log Pearson 3 (LP3) distribution was fitted by the method of moments (ARR 1999). The annual peak flow series was assembled from data retrieved for the period 1955 to date. Prior to 1972, only mean daily flows were available at Meeniyan. These mean daily flows were adjusted to estimate peak instantaneous flow for the period 1955 to 1971. Figure 4-5 shows the flood frequency analysis for the Tarwin River at Meeniyan. It indicates a 100 year peak flow at Meeniyan of 341 m^3/s.

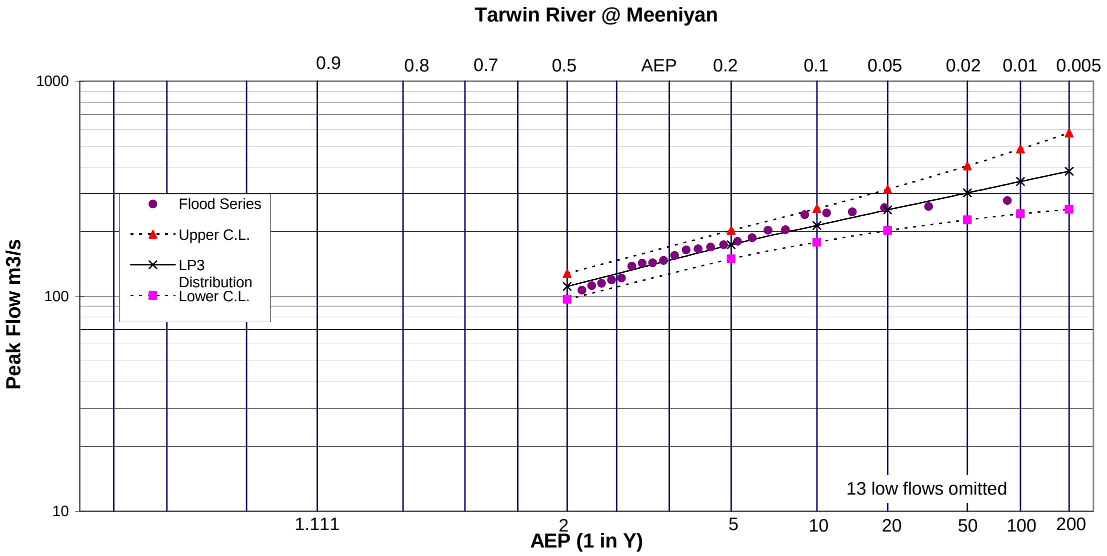


Figure 4-5 Flood frequency analysis - Tarwin River at Meeniyan – Peak Flow (annual series)

Rainfall depths

For the model verification, rainfall depths for the 20 and 50 year ARI were determined by the Intensity Frequency Duration (IFD) procedures outlined in Chapter 2 of ARR99. The IFD estimates were made for the centroid of the Tarwin River catchment. The IFD parameters are provided in Table 4-4.

Table 4-4 Tarwin River catchment (Meeniyan) IFD parameters

IFD Parameter	Value
1 hour duration 2 year ARI	16.0
12 hour duration 2 year ARI	3.4
72 hour duration 2 year ARI	0.875
1 hour duration 50 year ARI	33.0
12 hour duration 50 year ARI	5.8
72 hour duration 50 year ARI	1.6
Regional skew G	0.55
Geographic factor F2	4.33
Geographic factor F50	14.65

Rainfall temporal patterns

The temporal pattern adopted can also have a major affect on the magnitude of the design flood estimate. The temporal patterns used in the verification process were obtained from ARR99.

The ARR99 temporal patterns are intended for use with design rainfalls up to an ARI of 500 years. They represent intense bursts within longer storms and embody the average variability of a region and duration. The patterns are presented in Volume 2 of ARR99.

Baseflow component

As outlined in Section 4.2.3, the Tarwin River catchment has a baseflow component of approximately 25m^3/s. This baseflow was removed during the modelling analysis, and needs to be included back into the derived design flow data. Accordingly, a baseflow component was added to the design flood hydrograph produced by RORB.

Design parameters verification

The design information contained in ARR99 was combined with the calibrated design parameters to derive design peak flows. These modelled design peak flows were compared with the results of the flood frequency analysis for the 100 year ARI event. The critical storm duration for Tarwin River at Meeniyan was 36 hours for the 100 year ARI event.

The rainfall loss parameters were adjusted until similar peak flows from the RORB model and FFA were obtained for the 100 year ARI event. The rainfall loss parameter values, initial loss 30 mm and a continuing loss of 3.0 mm/hr, resulted in a 100 year peak flow of 354m^3/s, which was considered to provide good agreement between the RORB model and FFA peak flows for the 100 year ARI event. These rainfall loss parameters were adopted for use in design flood hydrograph estimation. The verification plot for the Tarwin River at Meeniyan is shown in Figure 4-6.

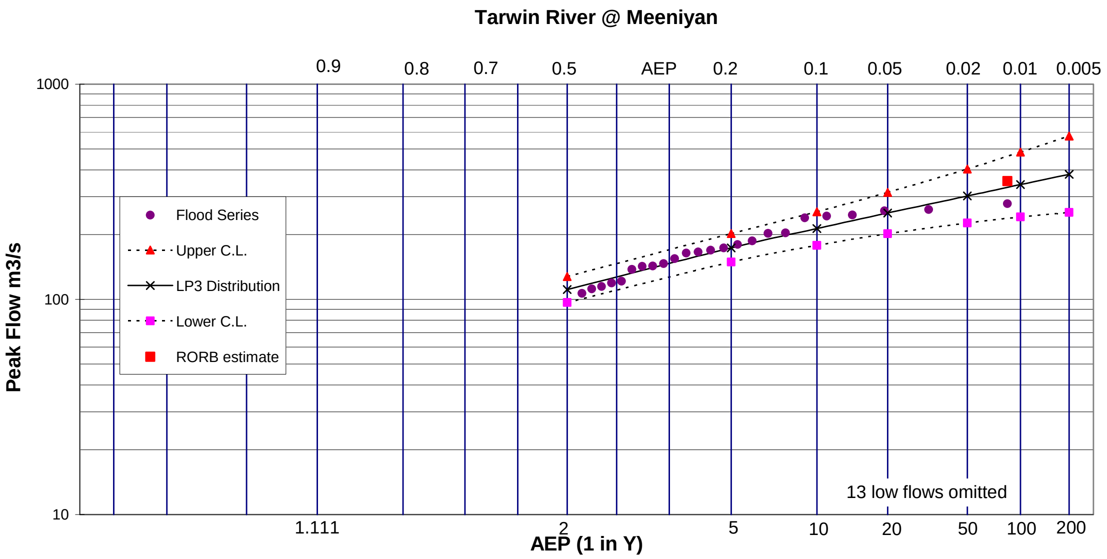


Figure 4-6 Verification of design parameters for Tarwin River at Meeniyan

4.2.6 RORB model design flood estimation

The design flood estimation inputs include:

- Design Rainfalls (ie. depth, temporal and spatial patterns)
- Design Rainfall Losses
- Routing Parameters

Details of the selection of appropriate design inputs are contained in Section 4.2.5

A design flood hydrograph was determined for the 100 year ARI event over a range of storm durations. This range of storm durations was required to ensure the critical storm durations were determined throughout the study area. Peak storm duration was found to be 36 hours, with a peak flow of 574m^3/s at Tarwin Lower. Figure 4-7 below shows the 100 year flood hydrograph at Meeniyan and Tarwin Lower.

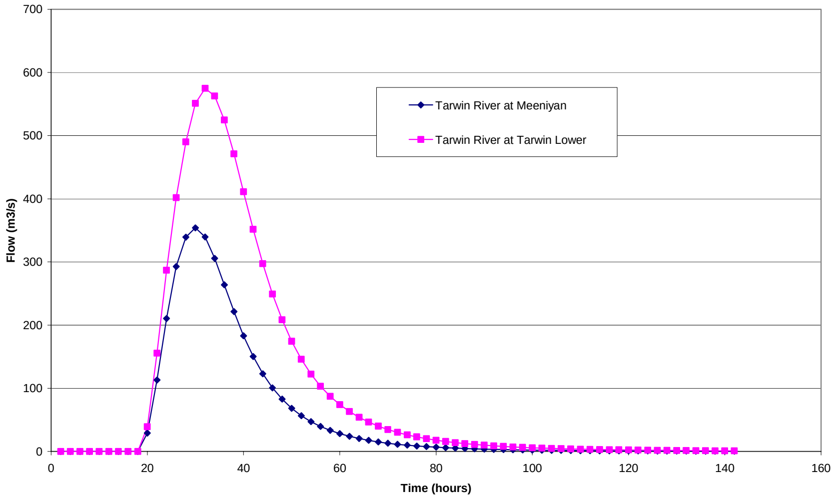


Figure 4-7 RORB 100 Year Design Hydrograph – Tarwin River at Meeniyan and Tarwin Lower

4.3 Flood Volume

In addition to annual peak flow flood frequency analysis, annual peak 5 day volume (5DV) frequency analysis was also undertaken as an additional check on the design events generated. For the annual peak 5DV series, a LP3 distribution was fitted by the method of moments (ARR, 1999). Figure 4-8 shows the peak 5DV flood frequency analysis for the Tarwin River at Meeniyan.

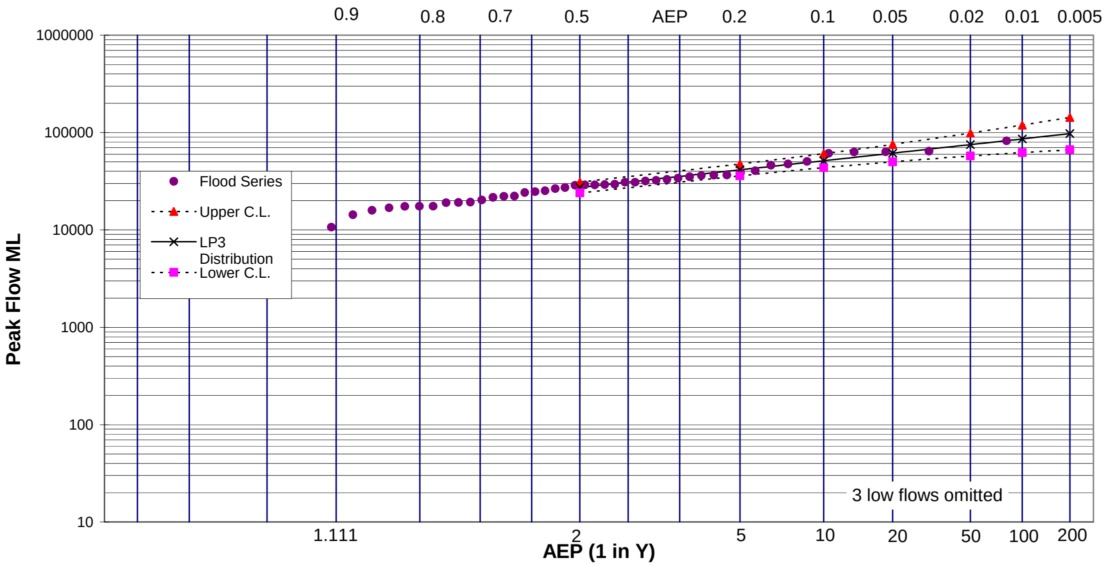


Figure 4-8 Flood frequency analysis - Tarwin River at Meeniyan – Peak 5DV (annual series)

Assessing the peak 5DV of the design hydrograph revealed a significant disparity between the design event, calibration events and frequency analysis flood volumes. The frequency analysis of the 5 day volumes yields a 100 year 5 day volume of 86200 ML. The 100 year design flood hydrograph from the RORB model, as outlined in Section 4.2.6, has 5 day flood volume of 25800 ML. The RORB modelled design hydrograph, while having a peak flow consistent with the flood frequency analysis, had only 30% of the volume for a 100 year 5DV event. Figure 4-9 displays a comparison of the calibration events and design flood hydrographs.

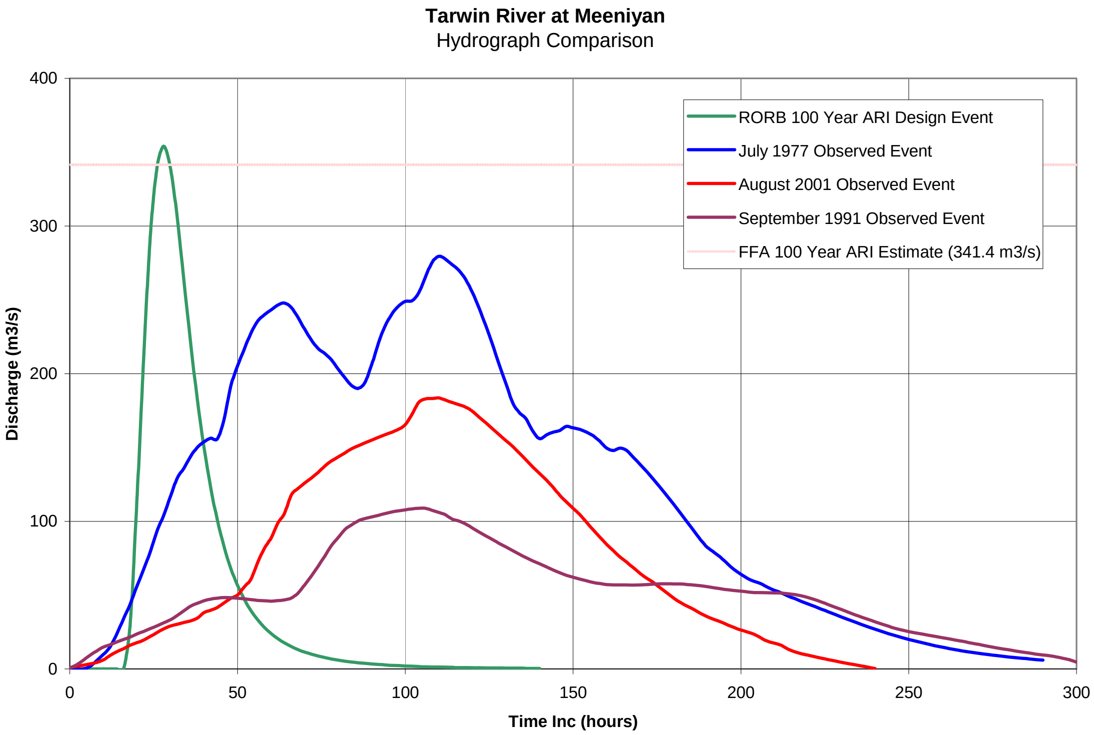


Figure 4-9 Hydrograph Comparison – Tarwin River at Meeniyan Gauge

As discussed in Section 4.1, flood volume is considered to be an important flood characteristic influencing flood behaviour. It is clear from Figure 4-9 that the design hydrograph is not consistent with observed hydrographs at Meeniyan. The RORB model is considered to be adequately calibrated against these observed events using observed rainfall intensities and distributions (see Figure 4-2 to Figure 4-4). However, applying the 100 year design rainfall intensity and distribution to the RORB model results in a hydrograph much steeper and shorter than observed data. This design hydrograph clearly has much less volume (the area under the curve) than observed hydrographs.

This disparity between observed flood hydrographs and design hydrographs is not uncommon. The design methodology uses idealised temporal distribution of rainfall (called temporal patterns or rainfall hyetographs) based on data from areas with similar characteristics and are applicable in “zones” throughout Australia. The Tarwin River lies in Zone 1, which extends along the coast from Melbourne to northern NSW and also covers Tasmania (see Figure 4-10). Within this zone it is assumed that design temporal rainfall patterns are the same. This assumption is not always valid, and in this case results in an inappropriate design hydrograph at Meeniyan.

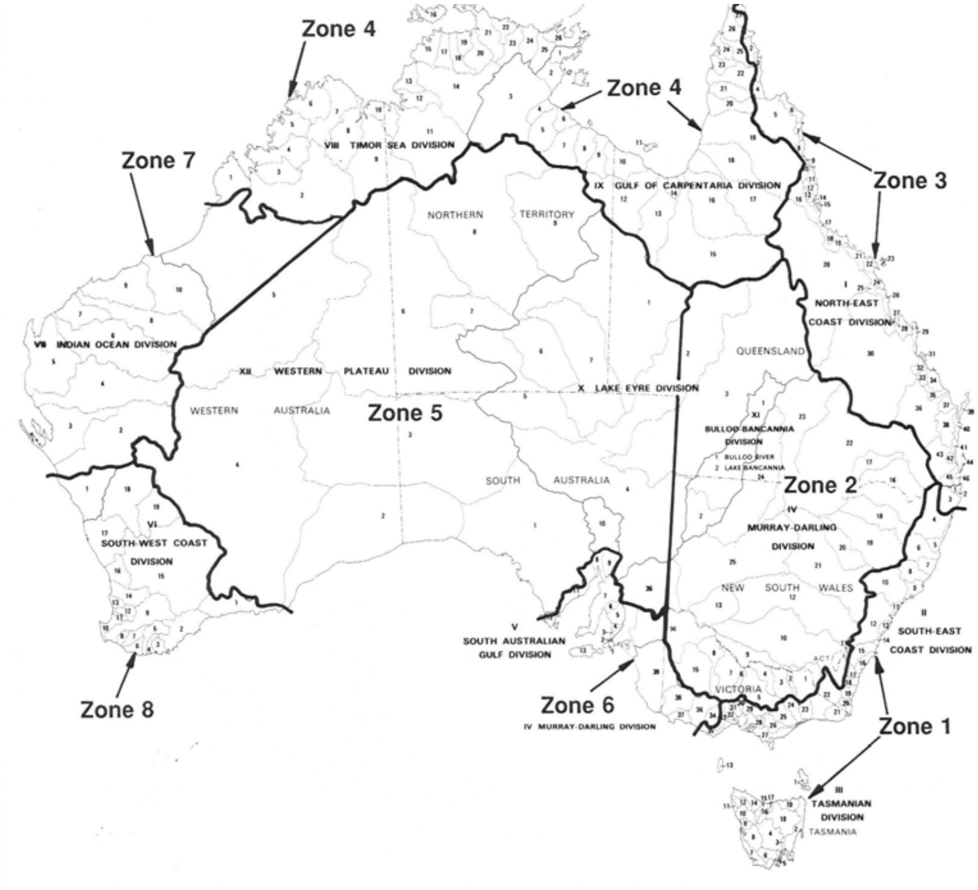


Figure 4-10 **Temporal Pattern Zones throughout Australia (ARR 1987)**

4.4 Scaled historical hydrograph

Flood volume is considered a key flood behaviour issue at Tarwin Lower as there are large areas of floodplain that fill during flood events. The design hydrograph is out of character with observed events and may significantly underestimate flood levels and inundation duration at Tarwin Lower. An alternative approach was sought to develop a design hydrograph that was consistent with observed flooding behaviour and provided confidence that the correct flow *and* volume was considered in determining design flood levels at Tarwin Lower.

The alternative approach adopted involved the scaling of historical hydrographs.

The process of scaling appropriate significant historical flood events for design estimates is outlined in Section 10.12 of ARR 87. It describes the process of analysing the relationship between event peak flow and peak volume (within a design duration) to assess the correlation for each particular year in the historical record. If coincidence is acceptable, the shape of the design hydrograph can be based on a study of the hydrographs of significant historical floods.

A slight variation of this method was undertaken to develop the design hydrographs for this study. While the Meeniyan gauge utilised for calibration and flood frequency analysis is located approximately halfway down the catchment, an annual flood frequency analysis estimate of the 100 year ARI flood event was required at Tarwin Lower. The Tarwin Lower FFA estimate was then used as the basis for a ratio to scale up an appropriate historical event.

The 100 year ARI flood event estimated via an annual flood frequency analysis at Meeniyan was extrapolated to Tarwin Lower via a weighted areal ratio. The relationship was thus:

$$Q^{TL}_{100FFA} = Q^{M}_{100FFA} \times (A_{TL} \div A_{M})^{0.7} \qquad (1)$$

The exponent 0.7 is a measure of catchment storage non-linearity where 0.7 is a commonly used value although the appropriate degree of nonlinearity to be adopted cannot be determined with certainty (ARR, 1987).

The Tarwin Lower estimated FFA, together with the 1977 calibration event peak flow at Tarwin Lower, was used to develop a ratio with which to scale-up the observed 1977 hydrograph to a 100 year ARI design flood event. The calibrated 1977 event was routed through the RORB model to develop a hydrograph at Tarwin Lower, and then scaled up via the ratio between the routed hydrograph peak flow and the area-extrapolated flood frequency estimate. This results in a peak flow at Tarwin Lower of 535m^3/s. Figure 4-11 depicts the scaled 100 year ARI flood event, routed 1977 flood event and the original design event result.

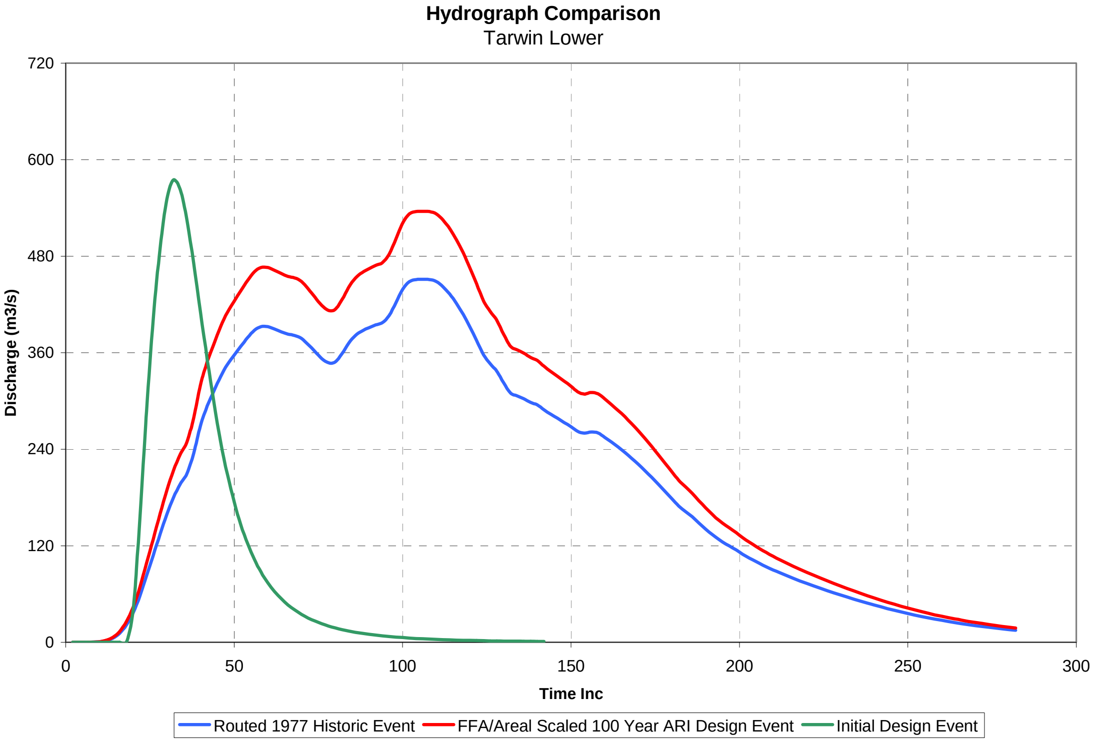


Figure 4-11 Hydrograph Comparison – Tarwin River at Tarwin Lower

4.5 Design flood hydrograph

Figure 4-12 depicts the adopted 100 year ARI design flood event utilised in the hydraulic analysis based on the scaled historical hydrograph approach. The adopted 100 year ARI peak flow is 535 m^3/s.

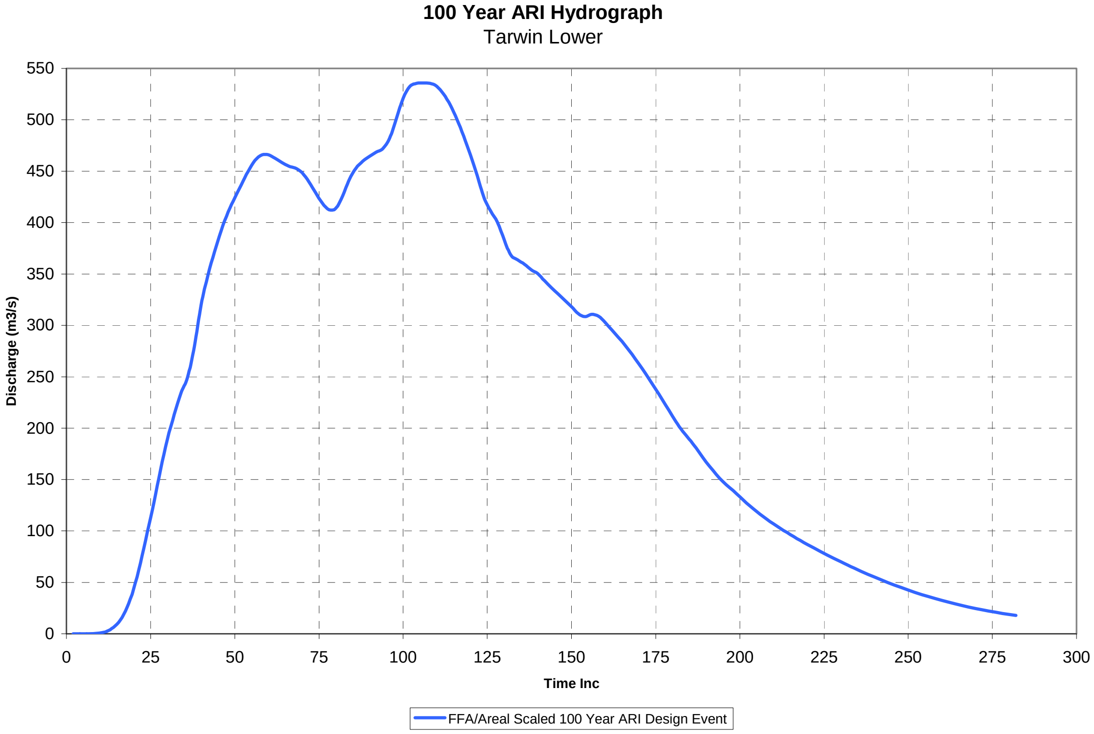


Figure 4-12 Tarwin River at Tarwin Lower – 100 year ARI Hydrograph

The adopted hydrograph is considered to represent a realistic design flood hydrograph, consistent with the design peak flood flow, 5 day flood volumes and characteristic of observed flood behaviour within the catchment.

5 FLOOD HYDRAULICS

A hydraulic model has been used to investigate the flood flow characteristics in Tarwin Lower for the design 100 year flow condition. This section documents the findings of these investigations. Storm surge related flooding is described in Section 6.

5.1 Model Description

A numerical model of Tarwin Lower and surrounding floodplain area was established to assist in assessing flood behaviour. The model was developed with a grid size of 5m, providing very detailed information on flood flow distribution and behaviour.

The two-dimensional model used for these assessments was developed using DHI Software's MIKE 21 Flow modelling system. MIKE 21 Flow is a comprehensive modelling package for simulating two-dimensional free-surface flows. It is applicable for modelling hydrodynamic and related phenomena in lakes, wetlands and floodplain areas where the effects of flow stratification can be neglected. MIKE 21 Flow is a proven and accepted numerical modelling tool for the assessment of flood behaviour.

MIKE 21 solves the full non-linear equations describing conservation of mass and momentum in two horizontal directions. Water levels and velocities are computed at each grid point as a function of the local ground level, bed resistance, hydraulic grade and any shear stresses from flow in adjacent grid points.

5.2 Modelling Overview

5.2.1 Topography

The topography representing the study area was derived from information provided by photogrammetry from AAM Hatch and supplemented with field survey by Redborough mapping. This information was established with Water Technology’s GIS system and combined with available data for Anderson Inlet. The combined topography is illustrated in Figure 5-1 below.

5.2.2 Model Boundary Conditions

Tarwin River flood flow conditions were established from hydrological modelling discussed in Section 4. These included an estimate of the August 2001 flood event (for calibration) and the 100 year design event.

Downstream water levels in Anderson Inlet were derived from model simulations of tidal conditions in the estuary. Ocean tides propagate into the estuary and define conditions near the confluence of the river with the inlet.

5.2.3 Model Calibration

Observations following the August 2001 flood event were used to assist in model calibration.

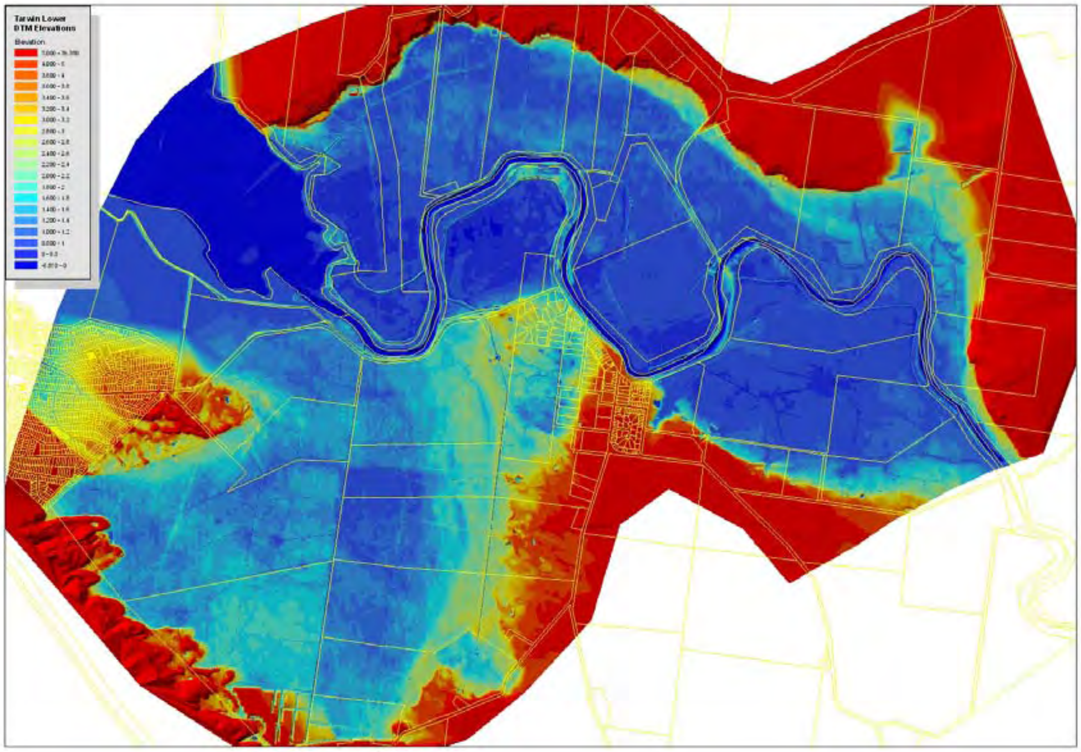


Figure 5-1 Topography for Flood Model

5.3 Model Calibration

5.3.1 Calibration Data

In August 2001, a moderate flood occurred in the Tarwin River. The West Gippsland CMA undertook an aerial survey of the event to document flooding throughout the catchment. Video was recorded and from this an estimate of the 2001 flood extent for Tarwin Lower was derived, illustrated in Figure 5-2 below.

Figure 5-2 August 2001 Observed Flood Extent

The August 2001 flood extent has been interpreted from the WG CMA video. Accurate interpretation of the flood extent is difficult, due to the following issues:

- ☐ We understand that the video was recorded at a time several hours after the peak of the flood, and the flood extents observed may not exactly match the peak flood extent
- ☐ The video is shot some distance from Tarwin Lower, and the low angle and distance make accurate determination of flood extent difficult
- ☐ In some areas, extensive vegetation prohibits identification of an area as flooded or dry, as observation beyond the vegetative cover is not practical.
- ☐ No observations of measured flood level for this event have been made available to the study team

Together these issues can limit the accuracy of the derived flood extent. Nevertheless, the spatial coverage of the observations is extremely useful as an indicative guide to the 2001 flood behaviour.

5.3.2 Boundary Conditions

Tarwin River flows were prepared using the RORB model and are representative of the August 2001 flood event. Figure 5-3 illustrates the estimated flows at Tarwin Lower for this event. Peak flow is estimated at 298m^3/s.

Tidal conditions in Anderson Inlet were determined from measured ocean water levels.

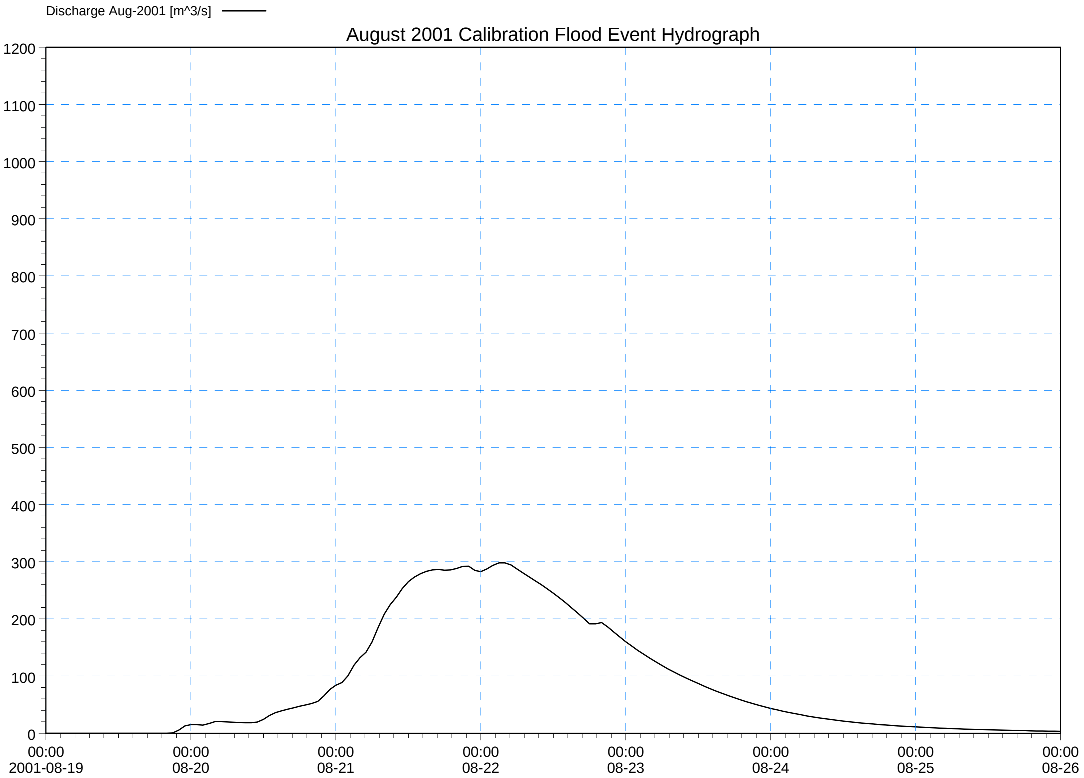


Figure 5-3 August 2001 Flow Hydrograph at Tarwin Lower

5.3.3 Flood Results

Modelled August 2001 flood extent and water surface elevation are presented in Figure 5-4 and Figure 5-5 illustrates depth of inundation.

Comparison of the observed and modelled flood extent is favourable, given the limitations of the calibration data. The generally observed flood behaviour is replicated including the extent of inundation and observations at key locations including:

- ☐ Cutting of the Tarwin Lower – Inverloch Road
- ☐ Limited or no flooding in the township
- ☐ Tarwin Lower – Venus Bay road remained open

The calibration provides sufficient confidence in the model performance to allow simulation of the design 100 year flood event.

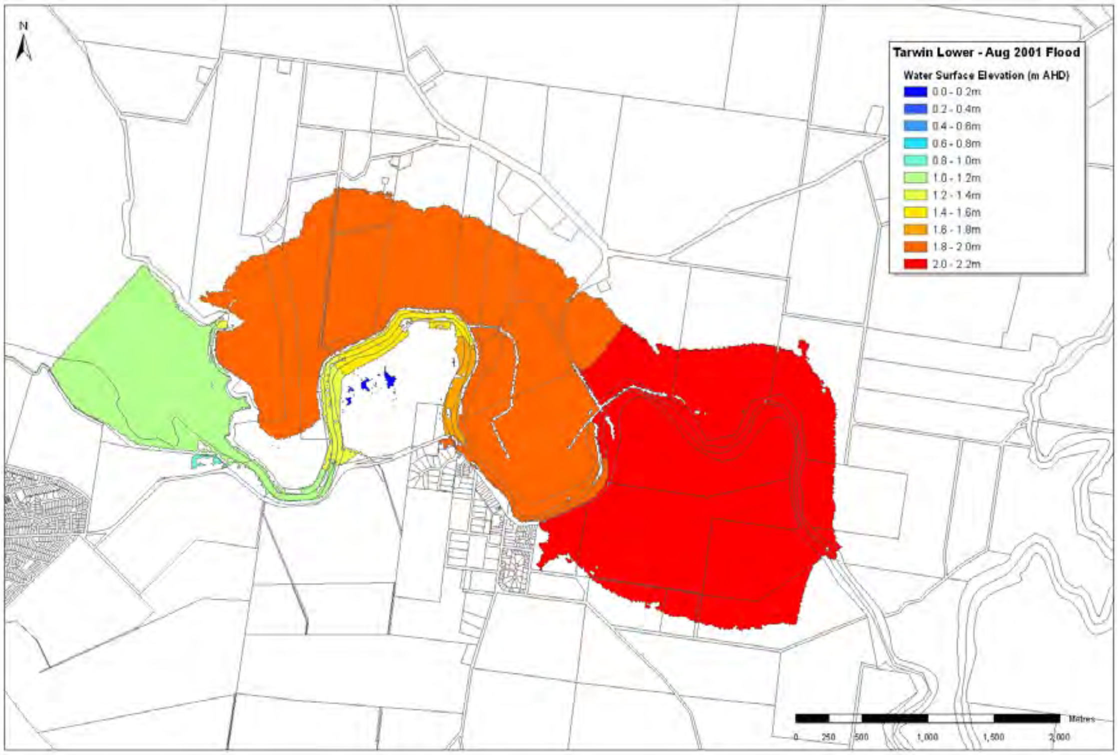


Figure 5-4 August 2001 Flood Surface Elevation

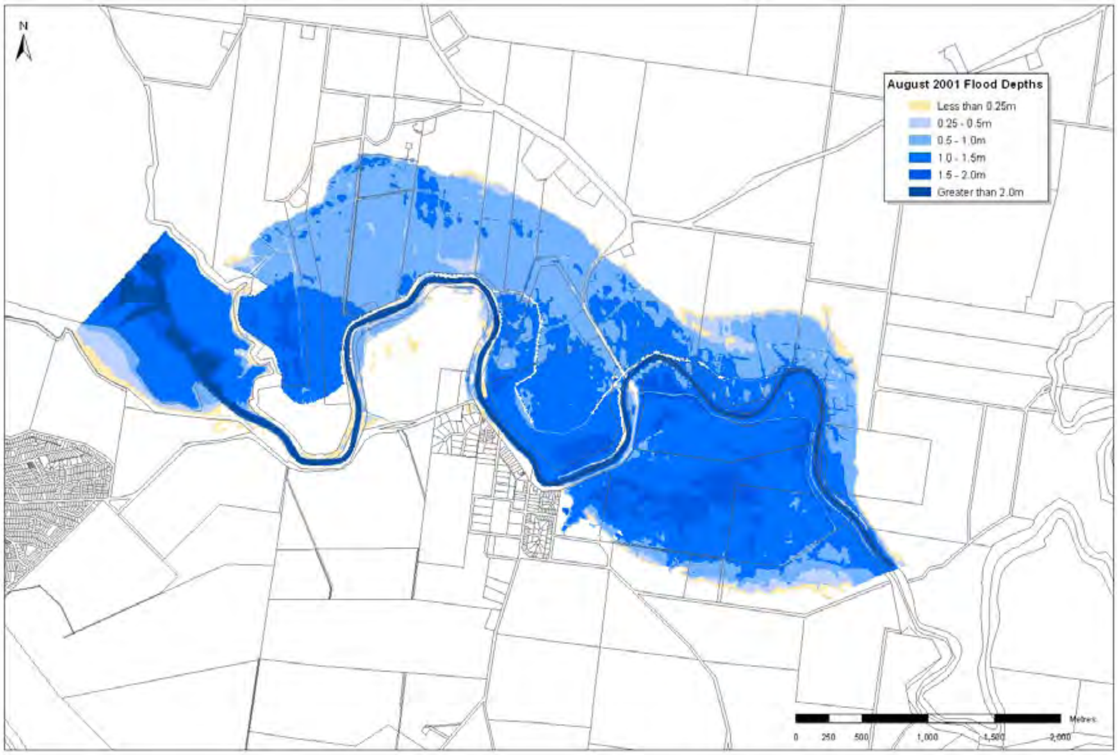


Figure 5-5 August 2001 Flood Inundation Depth

5.4 100 Year Design Flood

5.4.1 Boundary Conditions

Design 100 year Tarwin River flows were prepared using the RORB model. Figure 5-6 illustrates the estimated flows at Tarwin Lower for this event. Peak flow is estimated at 535m^3/s based on methods outlined in Section 4.4.

Mean spring tidal conditions in Anderson Inlet were adopted at the downstream boundary of the model.

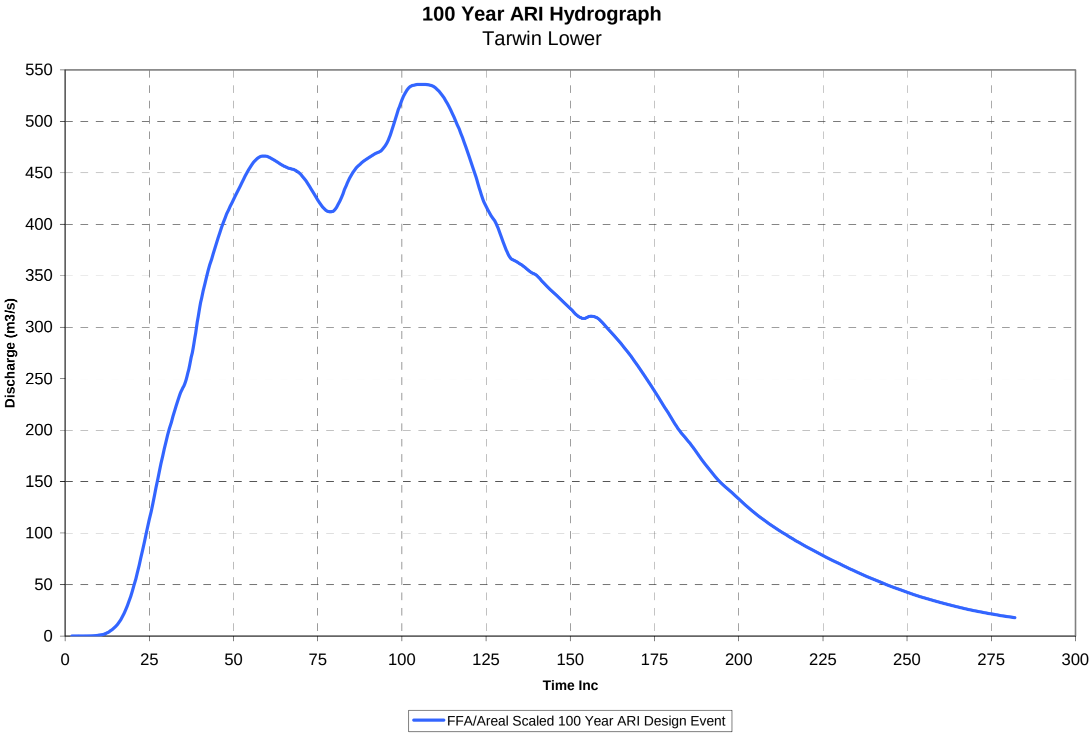


Figure 5-6 Design 100 Year Flow Hydrograph at Tarwin Lower

5.4.2 Flood Results

Modelled 100 year flood extent and water surface elevation are presented in Figure 5-7 and Figure 5-8 illustrates depth of inundation.

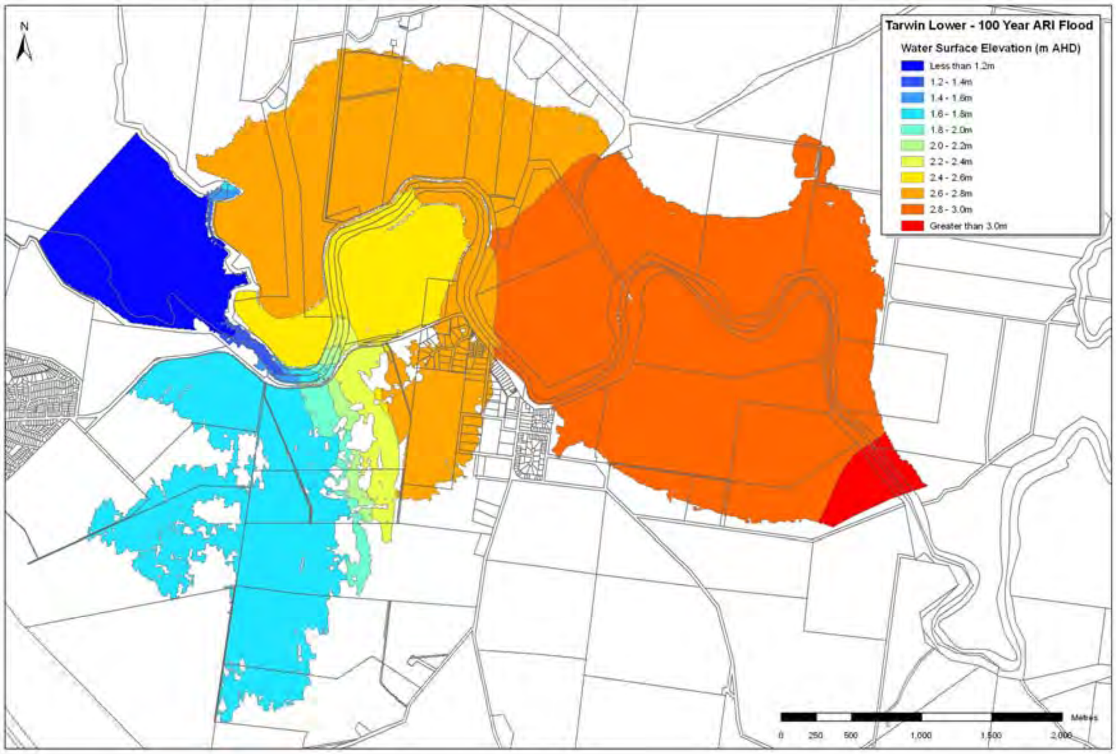


Figure 5-7 Design 100 Year Flood Surface Elevation

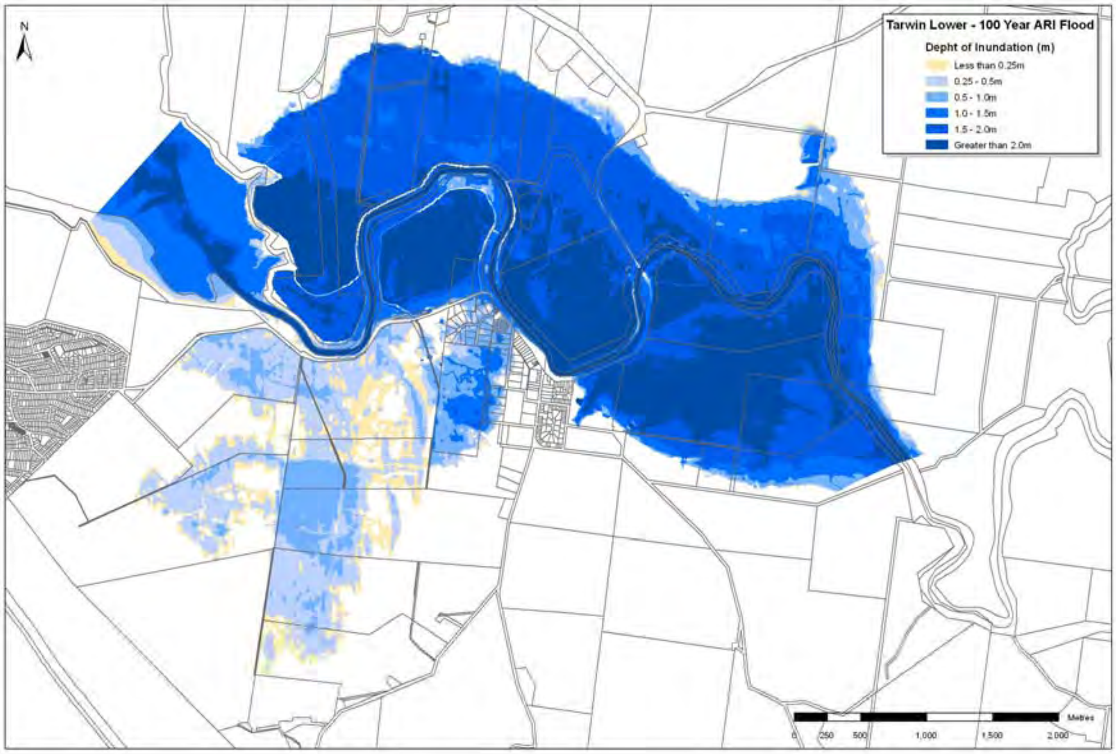


Figure 5-8 Design 100 Year Flood Inundation Depth

5.4.3 Discussion

The design 100 year flood modelling results indicate the following:

- ☐ Flood levels in the river adjacent to Tarwin Lower generally range between 2.7m AHD at the western end of the township and 2.9m AHD at the eastern end.
- ☐ The levee at the north-western end of the floodplain, adjacent to Anderson Inlet, and other levees within the northern floodplain significantly restrict the propagation of flood flows from the northern floodplain to the inlet
- ☐ Accordingly, the primary control on flooding is the capacity of the Tarwin River channel to convey flood flows from central sections of the floodplain to Anderson Inlet
- ☐ Inundation depths on the northern floodplain are significant, with depth generally greater than 1.0m observed, comprising the bulk of the flood conveyance and storage
- ☐ On the southern floodplain, inundation depths are generally much shallower, resulting from minor overtopping of levees/roadways
- ☐ Flooding at the western end of Tarwin Lower is caused by overtopping of a very low section of the Tarwin Lower – Inverloch Road (approx 1.8m AHD)
- ☐ The levee/road between Tarwin Lower and Venus Bay on the southern side of the river is generally relatively low, typically 2.4m AHD
- ☐ With the exception of the Tarwin River itself, flood flow velocities are generally very low (<0.2m/s)

The key control on flood behaviour within the Tarwin Lower floodplain is the north-western levee. This levee has a crest level generally in excess of 3.3m AHD, but has a limited number of floodgates and/or culverts to provide floodplain drainage. Accordingly, flood waters tend to build up behind the levee causing water to spill over into other areas of the floodplain where levee/road crest levels are much lower than 3.3m AHD. Other levees throughout the floodplain tend to reduce the floodplain conveyance capacity, limiting the rate at which flood waters are conveyed to Anderson Inlet.

6 STORM SURGE HYDRAULICS

An hydraulic model has been used to investigate storm surge related flooding in Tarwin Lower for the design 100 year ocean conditions. This section documents the findings of these investigations.

6.1 Model Description

A numerical model of Anderson Inlet was established to assist in assessing storm surge behaviour. The model was developed with a grid size of 25m, providing adequate detail on tidal behaviour in the inlet.

The two-dimensional model used for these assessments was developed using DHI Software's MIKE 21 Flow modelling system. MIKE 21 Flow is a comprehensive modelling package for simulating two-dimensional free-surface flows. It is applicable for modelling hydrodynamic and related phenomena in lakes, wetlands, estuarine and floodplain areas where the effects of flow stratification can be neglected. MIKE 21 Flow is a proven and accepted numerical modelling tool for the assessment of tidal behaviour.

MIKE 21 solves the full non-linear equations describing conservation of mass and momentum in two horizontal directions. Water levels and velocities are computed at each grid point as a function of the local ground level, bed resistance, hydraulic grade and any shear stresses from flow in adjacent grid points.

6.2 Modelling Overview

6.2.1 Topography

The topography representing the study area was derived from RAN Charts and supplemented with field survey by Redborough mapping. This information was established within Water Technology’s GIS system and is illustrated in Figure 6-1 below.

6.2.2 Model Boundary Conditions

Design 100year storm surge ocean boundary conditions are derived as a combination of tide and surge in Bass Strait. Design winds are applied to establish set up across/along the estuary.

Results from the tidal model are used to define conditions in Anderson Inlet near the Tarwin River mouth. Storm surge inundation modelling is carried out with the flood model described in Section 5, with boundary conditions derived from the tide model.

6.2.3 Model Calibration

Measured tidal elevations have been used to demonstrate model performance.

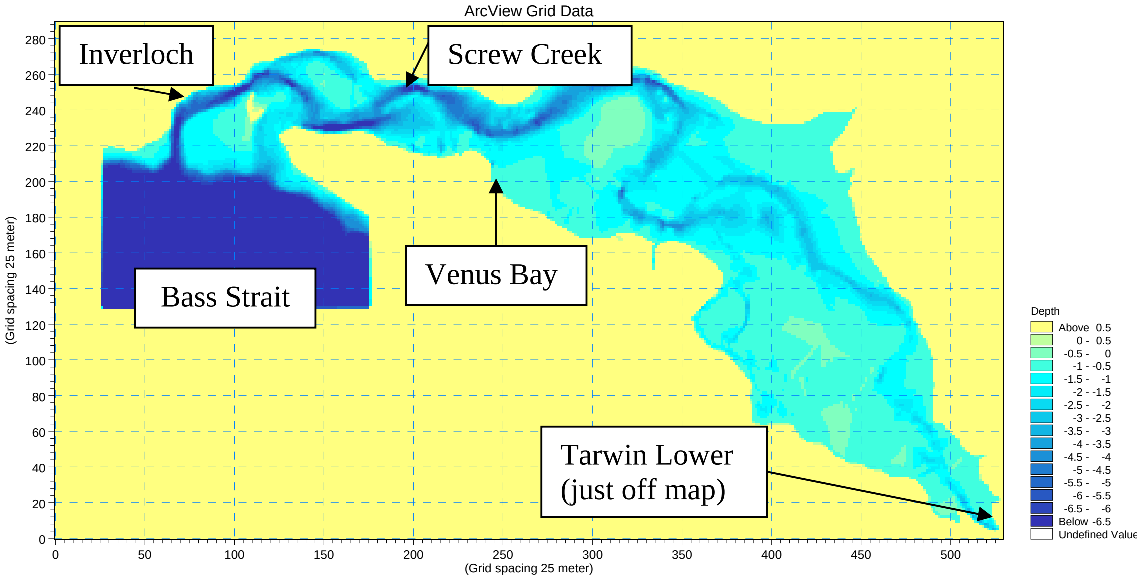


Figure 6-1 **Topography for Tidal Model**

6.3 Model Calibration

6.3.1 Calibration Data

In Sept-Oct 2004, tide recorders were deployed in Anderson Inlet to monitor tide levels and provide calibration data for model calibration purposes. The location of 4 deployed tide recorders is shown in Figure 6-1.

6.3.2 Boundary Conditions

Ocean water levels were generated from known tidal constituents at Waratah Bay.

6.3.3 Tide Model Results

Modelled and measured September-October 2004 water levels are included as Appendix A.

Comparison of the observed and modelled tidal elevations is favourable and demonstrates the ability of the model to adequately represent tidal phenomenon.

The calibration provides sufficient confidence in the model performance to allow simulation of the design 100 year storm surge event.

6.4 100 Year Design Storm Surge

6.4.1 Boundary Conditions

Design 100 year storm surge in Anderson Inlet results from a combination of tide, ocean surge, wind and an allowance for sea level rise. These components are defined below in Table 6-1.

Table 6-1 Storm Surge Components

Storm Surge Component	Contribution	
Tide	Mean Spring Tide	±0.98m
Surge	Bass Strait surge	+1.00m
Sea Level Rise	50yr rise estimate	+0.20m
Wind	100yr design WSW	27.1m/s

A mean spring tide is considered representative of tidal conditions and can occur independent of the surge event. Design Bass Strait surge levels have been derived from comparison of measured tidal residual (the difference between measured and predicted tidal elevation) at Melbourne, Stony Point and Rabbit Island. Guidance for adopted sea level rise is taken from the National Committee on Coastal and Ocean Engineering's *Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering.* Wind has been adopted based on the Wind Code AS1170.2.

Together these result in peak water levels near the mouth of the Tarwin River of 2.75m AHD as illustrated in Figure 6-2.

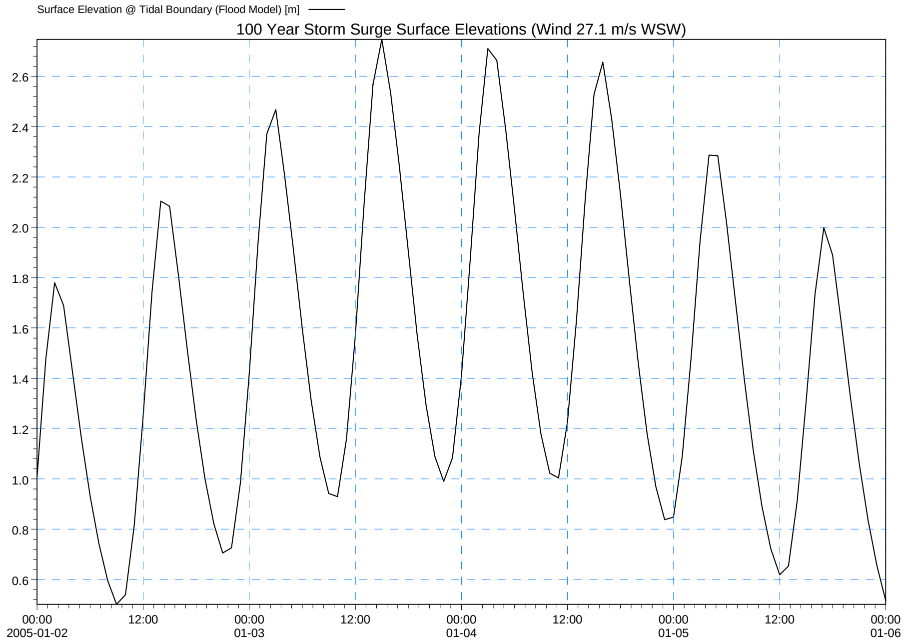


Figure 6-2 Design 100 Year Storm Surge

The modelled storm surge condition is applied as a downstream boundary condition to the flood model described in Section 5.

6.4.2 Flood Results

Modelled 100 year storm surge flood extent and water surface elevation are presented in Figure 6-3 and Figure 6-4 illustrates depth of inundation.

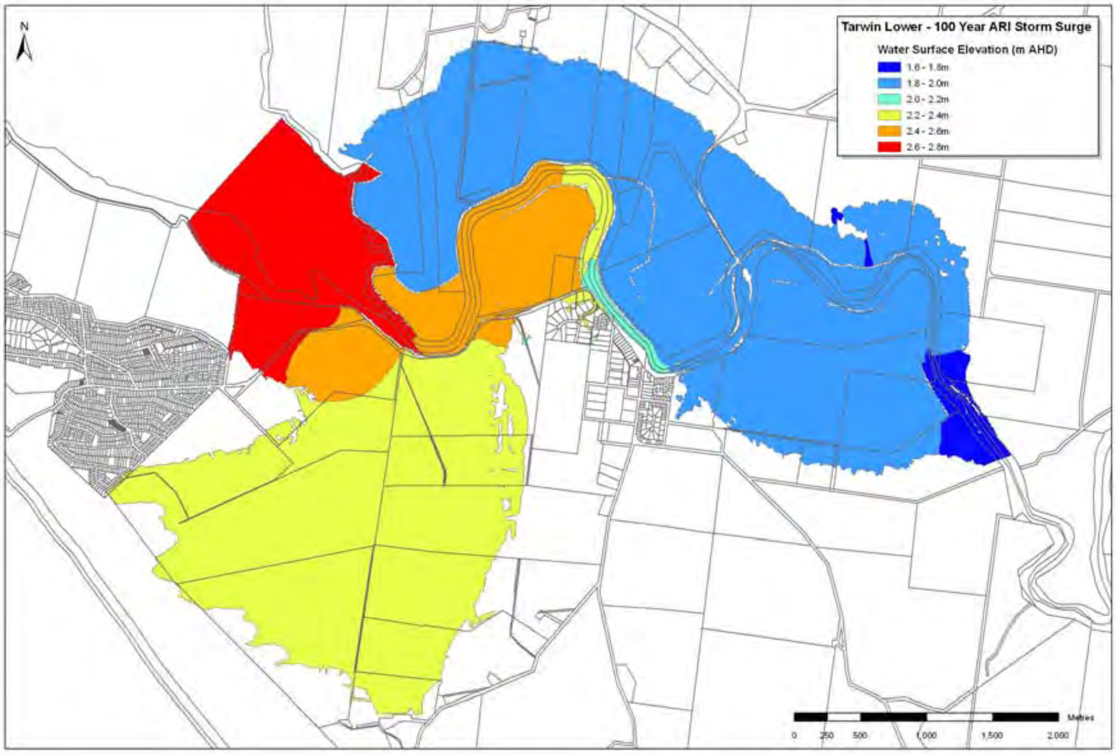


Figure 6-3 Design 100 Year Storm Surge Surface Elevation

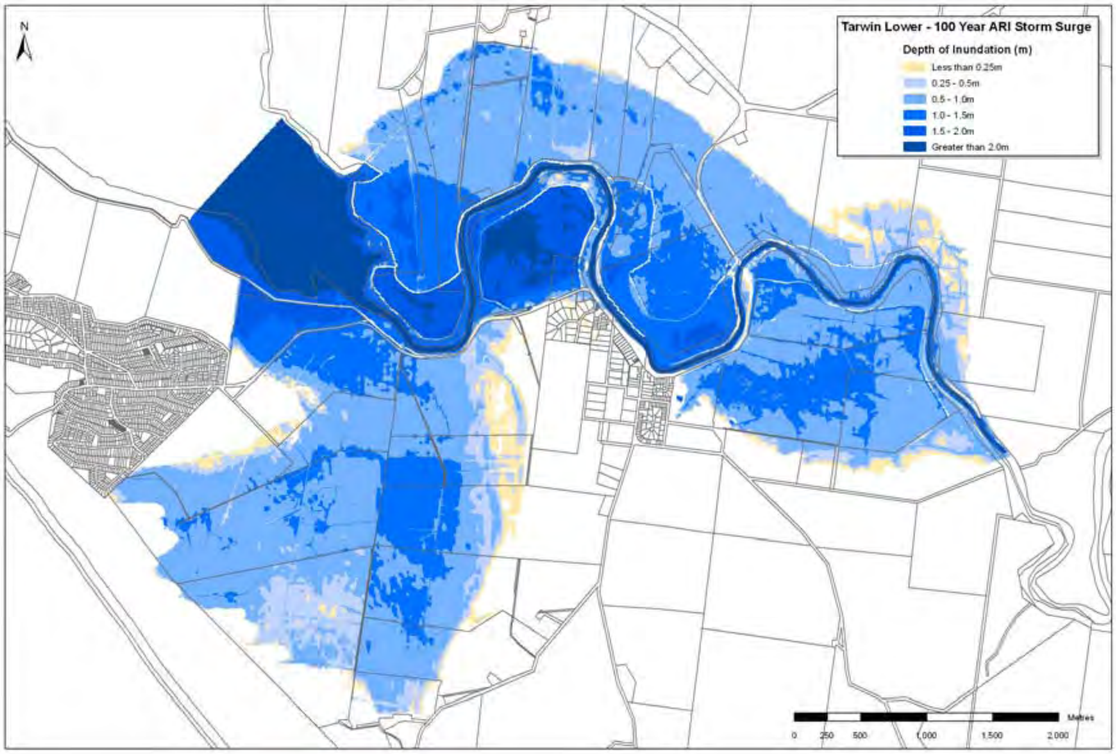


Figure 6-4 Design 100 Year Storm Surge Inundation Depth

6.4.3 Discussion

The design 100 year storm surge modelling results indicate the following:

- ☐ Design storm surge levels do not result in significant flooding within the township of Tarwin Lower
- ☐ Storm surge related flooding of the southern floodplain results from overtopping of the Tarwin Lower – Venus Bay road and is more extensive than catchment related flooding
- ☐ The north-west levee adjacent to Anderson Inlet is not overtopped by storm surge. Storm surge related flooding of the northern floodplain results from breaches of levees with lower crest elevation located farther upstream (eg. opposite the township of Tarwin Lower)

The key controls over storm surge behaviour are the coastal and other levees. The northwest levee has a crest level generally in excess of 3.3m AHD, and is not overtopped by a design storm surge of 2.75m. However flooding of the northern floodplain does occur during the 100 year storm surge event as storm surge levels propagate up the Tarwin River and breach levees with lower crest elevation. Storm surge waters then flow in a westerly direction through the northern floodplain before being trapped behind the northwest levee. The southern floodplain has levee and/or road crest (Tarwin Lower – Venus Bay Road) generally around 2.4m AHD and surge levels in excess of this propagate into this area.

7 100 YEAR DESIGN FLOODING

7.1 Overview

Design flood mapping at a given location has been prepared based on evaluation of the maximum of storm surge or catchment flooding. This approach has been adopted for a number of reasons, including the following:

- The synoptic driver for maximum storm surge at Tarwin Lower requires west to northwesterly winds, while maximum flooding in the catchment is typically associated with east coast lows (southeasterly winds) or south to southwesterly wind conditions. Clearly, the drivers for each type of flooding are quite different.
- An assessment of the joint probability of storm surge and catchment flooding requires flow and water level data that is not available at Tarwin Lower. Local Tarwin Lower data would need to be inferred from remote sites by extensive modelling and monte-carlo simulations beyond the scope of this assessment.

7.2 100 Year Design Flooding

As discussed above, design flood levels throughout the Tarwin Lower floodplain have been prepared as the maximum of either the 100 year storm surge event or the 100 year catchment runoff event. Figure 7-1 and Figure 7-2 present the composite surface elevation and depth of inundation of these two flood events respectively.

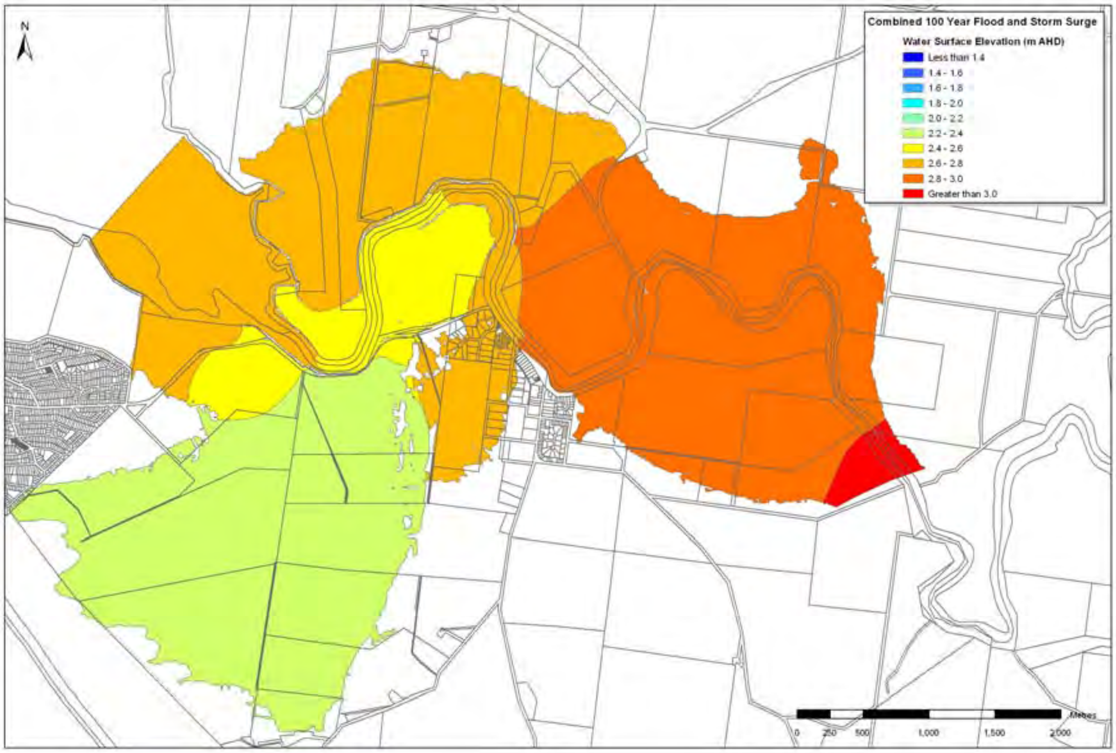


Figure 7-1 100 Year Design Flood Levels – Tarwin Lower

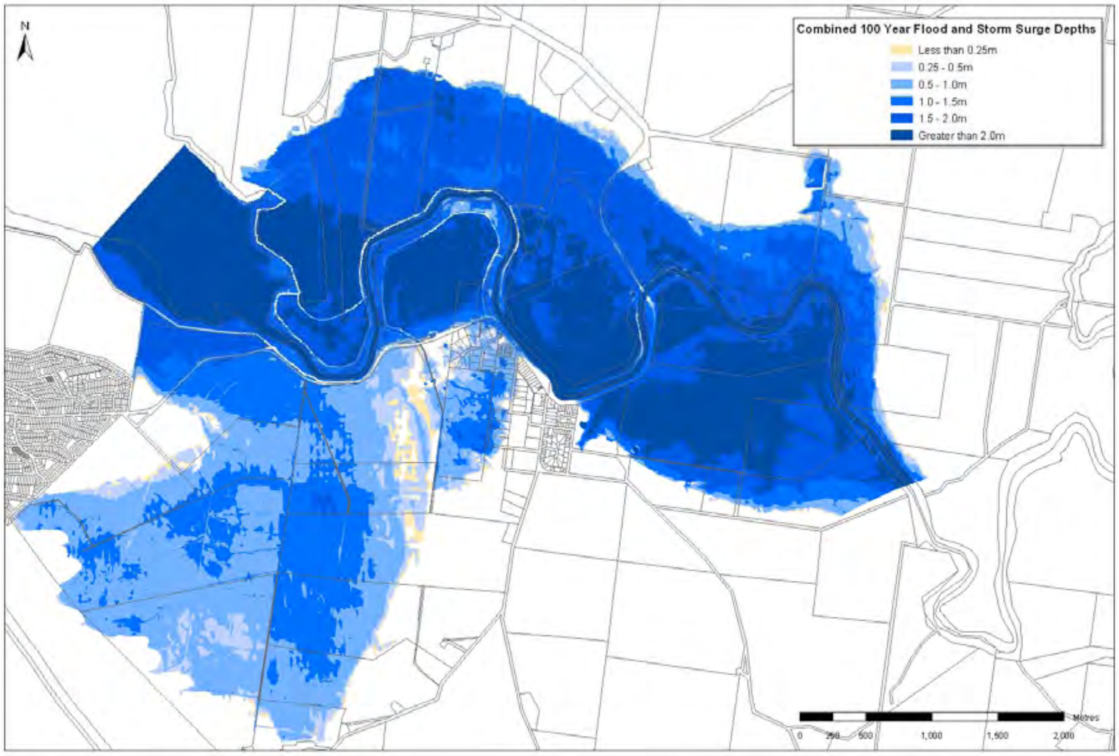


Figure 7-2 100 Year Design Flood Inundation Depth – Tarwin Lower

7.3 Floodway Mapping

7.3.1 Introduction

The process of floodway delineation described in this section was primarily guided by the 1998 DNRE Floodplain Management Unit (FPMU) document: "Advisory Notes for Delineating Floodways".

Floodways are broadly defined as those areas of the floodplain where significant discharge or storage of water occurs during major floods. Accordingly floodways are often associated with significant flood hazard. They are often aligned with naturally defined channels and include areas which, if filled or partially obstructed, would cause a significant redistribution of flood flow, or significant increase in flood levels.

A floodway overlay is a planning tool for identifying and maintaining main flow paths and, through appropriate controls for proposed development and works, ensuring the free passage and temporary storage of floodwaters through them.

The definition of a floodway can be linked to a risk management approach as advocated in the Victorian Flood Management Strategy and AS/NZ 4360:1996: Standards for Risk Management. This approach considers the assessment of a level of risk, based on the consideration of the probability or frequency of flooding and the consequences of flooding.

7.3.2 Floodway Delineation

Assessing flood risk requires consideration of numerous factors. Section 6.4 of the 1998 DNRE document describes the process to be used when levees are in operation within the floodplain. The issues related to levee function in a floodplain that need to be considered include:

- The frequency of flooding
- The standard of the levees
- Whether they are strategic or non strategic; and
- The flood hazard associated with their failure

A “strategic levee” is defined as a levee which, from a broader regional viewpoint, protects important areas or assets and may be a single levee, or part of a larger system. Water Technology considers that the extensive levee system in operation in the Tarwin River floodplain at Tarwin Lower represents a strategic levee system, due to its size and influence on flood behaviour. However, it should be noted that these levees do not provide full protection for the 1% flood or storm surge event.

Table 2 in the 1998 DNRE document sets out notes for the delineation of floodways for particular flooding characteristics. In Table 2, the section for ‘Rural levees which are regarded as strategic’ sets out the following guidelines for defining floodways in floodplains characterised by this description:

- Conservatively estimate 1% flows outside the levees assuming they fail. Treat each side of the river independently and allow for reasonable “worst case” scenarios. The sum of the flows will exceed the 1% flow.
- Estimate the corresponding average velocities and depths and use the chart depicted in Figure 7-3 to assist assessment of the flood hazard.
- If there are any levee spillways estimate the area immediately downstream where obstructions should be minimised to ensure the spillway is effective
- If portions of levee are located too close together and throttle flood flows, estimate the minimum desirable width between the levees. This may have been previously determined from flood studies or strategies. If it hasn’t been determined, adopt the median width for the general area as minimum.
- Identify effluent flowpaths and depressions which will fill to greater depths that the rest of the floodplain if levees overtop or fail, and/or areas with a history of catastrophic or frequent failure.
- On the basis of the above analysis, identify areas outside of the levees (if any) where the flood risk is significant enough to warrant being defined as floodway. Show these as a cross hatched, separate layer – “preliminary floodway”
- Consult with the FPMU and the relevant municipality prior to the finalisation of the floodway for these areas.

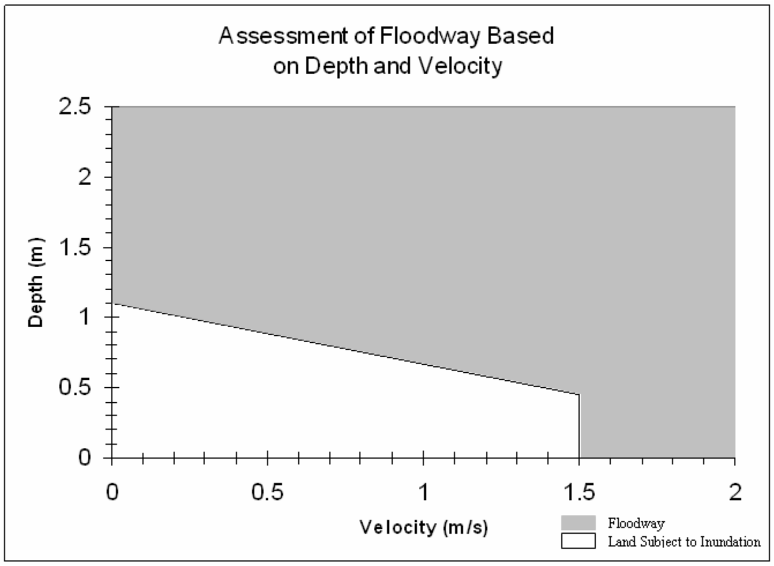


Figure 7-3 – Depth-Velocity Flood Hazard Floodway Assessment

7.3.3 Results and conclusions

Using the DNRE FPMU's guidelines, the Tarwin River at Tarwin Lower land subject to inundation and floodway areas have been delineated. This was achieved by utilising the flood hazard chart shown in Figure 7-3 to analyse the 100 year ARI flood event, and the 100 year storm surge event to develop event-based high hazard zones. Figure 7-4 illustrates the consequential high hazard zones resulting from the depth-velocity hazard analysis for the 1% storm surge and flood events. The land subject to inundation by the 1% flood event (flood or storm surge) is also shown.

Using these event-based high hazard zone layers, in consideration of the FPMU guidelines, and in liaison with the West Gippsland CMA, the area proposed for designation as floodway on the Tarwin Lower floodplain has been identified. The two delineated high hazard zones were combined such that an envelope high hazard zone was developed. The floodway was constructed through the delineation of the combined flood and storm surge high hazard zone layers. Small areas of high hazard disjoint from the main floodway have been excluded, and the floodway area edge has been smoothed. The floodway is shown in Figure 7-5.

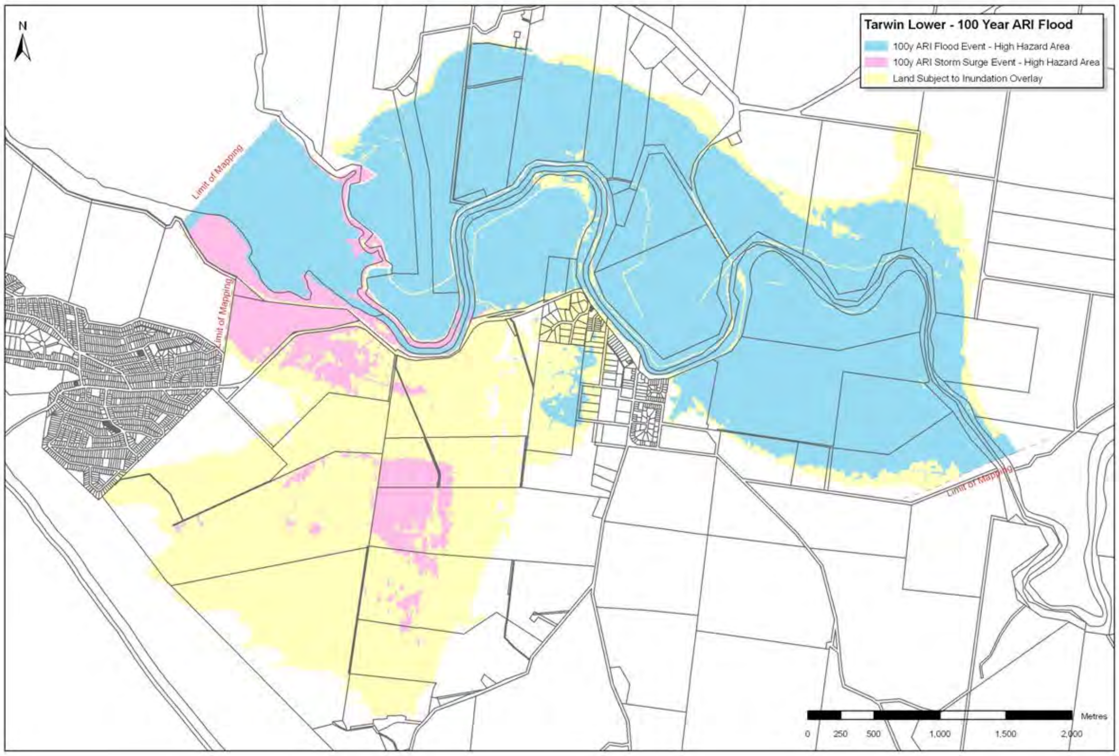


Figure 7-4 – Event-based Floodway Zones: Flood Event and Storm Surge

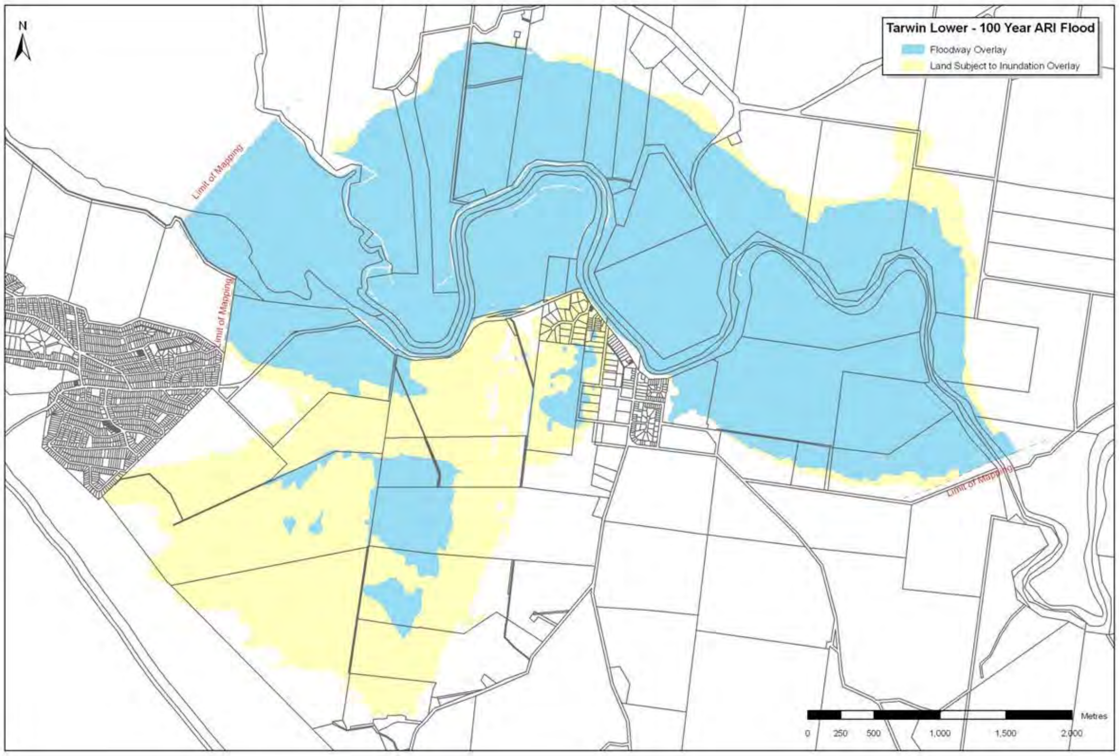


Figure 7-5 – Proposed Tarwin River floodway at Tarwin Lower

8 FLOOD MITIGATION OPPORTUNITIES

This section discusses some potential flood mitigation opportunities to reduce flood risks in the township of Tarwin Lower.

8.1 Flooding Behaviour

Generally, flooding in Tarwin Lower, the northern floodplain and areas upstream from the township is dominated by catchment related flooding. Downstream from the township and on the southern floodplain, flooding is dominated by storm surge.

A key floodplain control is the northwest levee, with a crest level typically in excess of 3.3m AHD. The levee is serviced by a limited number of floodgates and/or culverts to allow water trapped behind the levee to drain to Anderson Inlet. Catchment flood waters tend to build up behind the levee causing flooding in other areas of the floodplain where levee/road crest levels are much lower.

The levee is not overtopped by storm surge in Anderson Inlet, but breaches in levees elsewhere result in storm surge flooding on the northern floodplain.

Flooding on the southern side of the river and in the township result from storm surge or catchment flood waters spilling over levees/roads that have a relatively low crest level. In Tarwin Lower, the main road has a minimum crest level around 1.6m AHD and flood levels in excess of this spill out of the river and flow in a southerly direction. Farther downstream, the crest of the Tarwin Lower – Venus Bay Road is around 2.4m AHD and flood waters in the river in excess of this elevation spill over into the southern floodplain areas.

Further, flood depths along the Tarwin Lower – Venus Bay Road at the western end of Tarwin Lower are considerable (greater than 1.0m), prohibiting vehicular access during major flood events. This is considered a significant issue for the South Gippsland Shire Council to resolve, as this flooding not only restricts access to the properties in Tarwin Lower, but isolates the entire community of Venus Bay.

8.2 Flood Mitigation Opportunities

Opportunities for flood mitigation to diminish the risk of flooding by reducing flood levels and/or inundation extent on the Tarwin Lower floodplain can be divided into two themes:

A. Improve the conveyance of floodwaters through the floodplain to Anderson Inlet

B. Increase the flood protection offered by levees/roads in targeted locations

It is beyond the scope of this study to investigate specific flood mitigation measures and assess their relative benefit. It is recommended that future studies investigate flood mitigation via, but not necessarily limited to, the following methods:

☐ Increase the number and hydraulic efficiency of flood gates and flap gated culverts through the northwest levee

☐ Remove or lower levees that restrict the conveyance of floodwaters from the central Tarwin Lower floodplain to Anderson Inlet

☐ Increase the hydraulic capacity of culverts under the Inverloch – Tarwin Lower Road to improve conveyance across/through what is effectively another flood levee

☐ Increase the crest level of levees/roads associated with the Tarwin Lower – Venus Bay road to a minimum level of around 2.6-2.8m AHD

Our understanding of the behaviour of catchment and storm surge flooding in Tarwin Lower and the adjacent floodplain is such that these flood mitigation options are likely to have the greatest influence on flood behaviour, potentially resulting in significant reductions in flood level and/or inundation extent.

9 REFERENCES

CRCCH 1996. *Tarwin River (East Branch at Dumbalk) Catchment Study*. CRC of Catchment Hydrology 1996.

Laurenson E.M. and Mein R. G., (1992). RORB - *Version 4 Runoff Routing Program User Manual*. Monash University Department of Civil Engineering.

Ryan C (2005) *CatchmentSIM A stand-alone GIS based terrain analysis system. User Manual*. CRC for Catchment Hydrology June 2005

Institution of Engineers Australia (IEAust, 1987): *Australian Rainfall and Runoff*, Vols 1&2. (Ed: Pilgrim D.H.) Institution of Engineers, Australia.

Institution of Engineers Australia (IEAust, 1997): *Australian Rainfall and Runoff*, (Ed: Pilgrim D.H.) Institution of Engineers, Australia.

APPENDIX A TIDAL MODEL CALIBRATION PLOTS

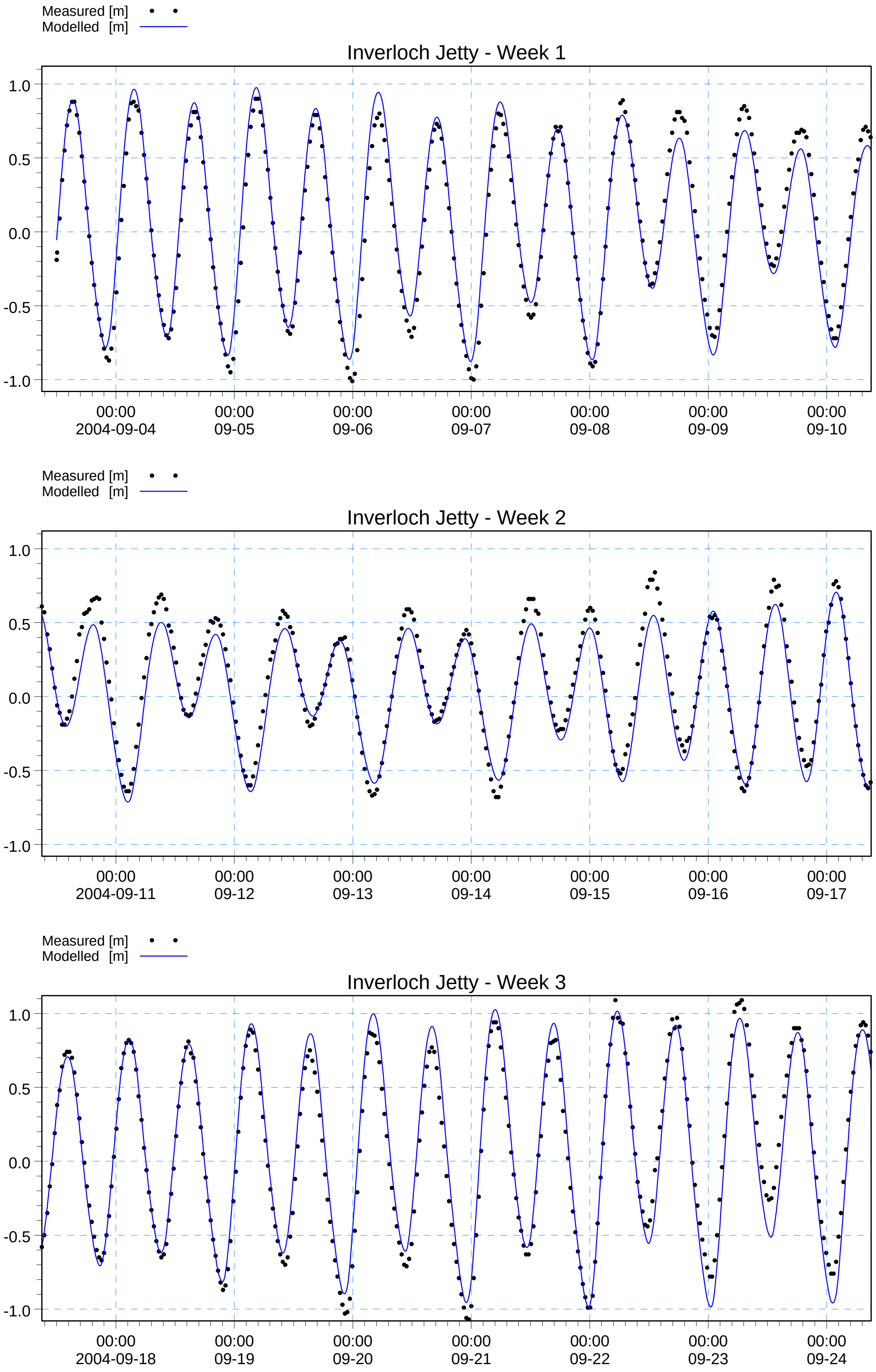


Figure B-1a **Tidal Calibration – Inverloch Jetty**

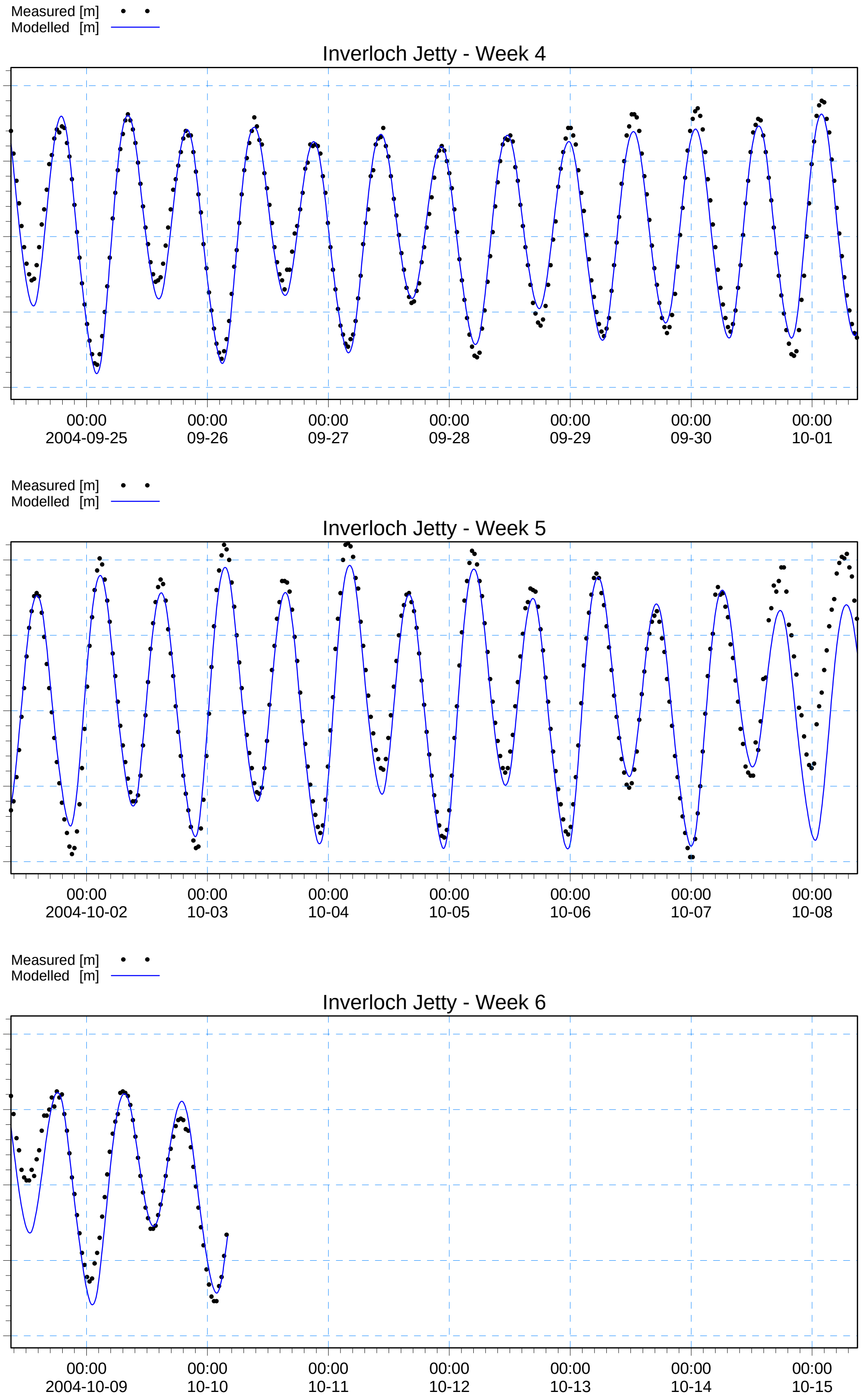


Figure B-1b **Tidal Calibration – Inverloch Jetty**

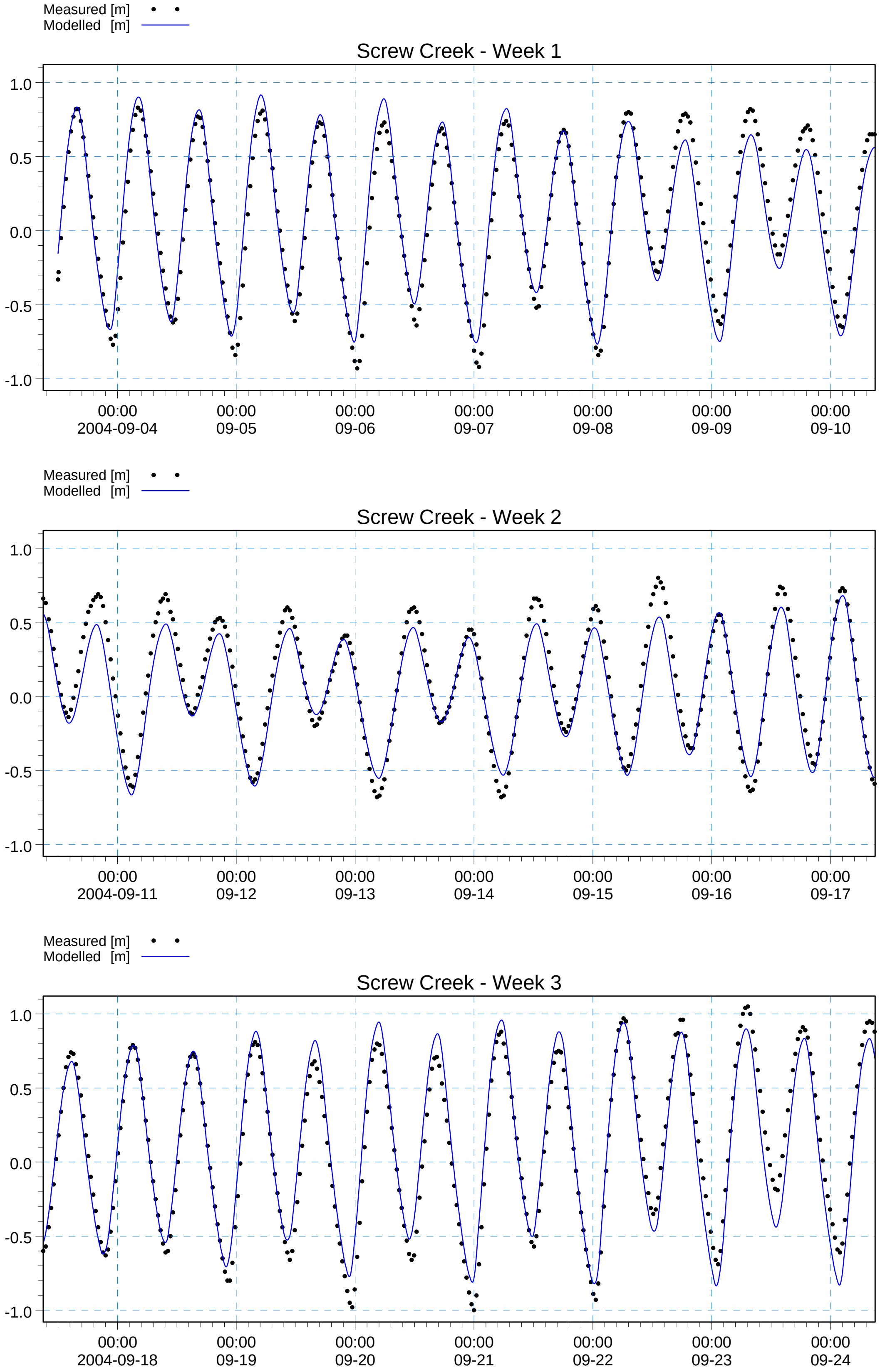
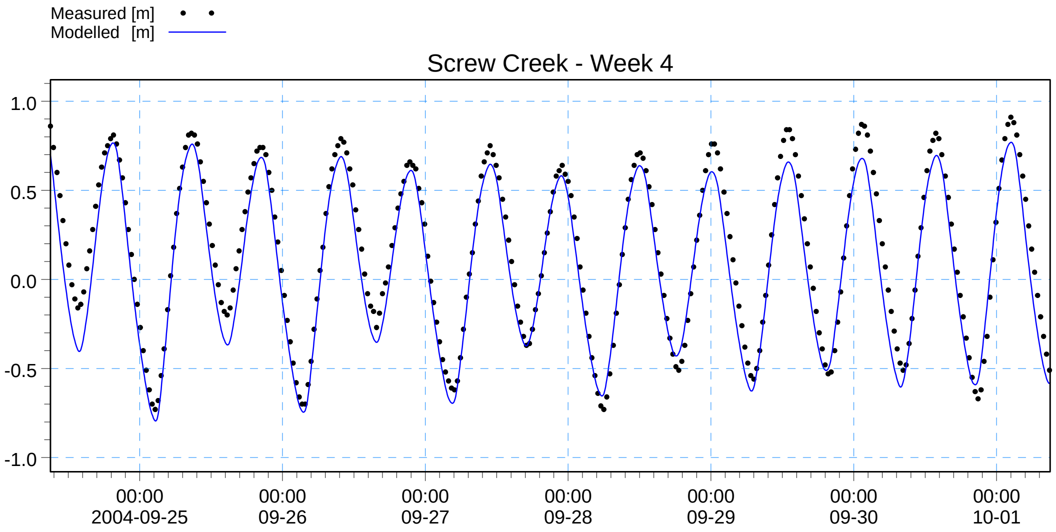
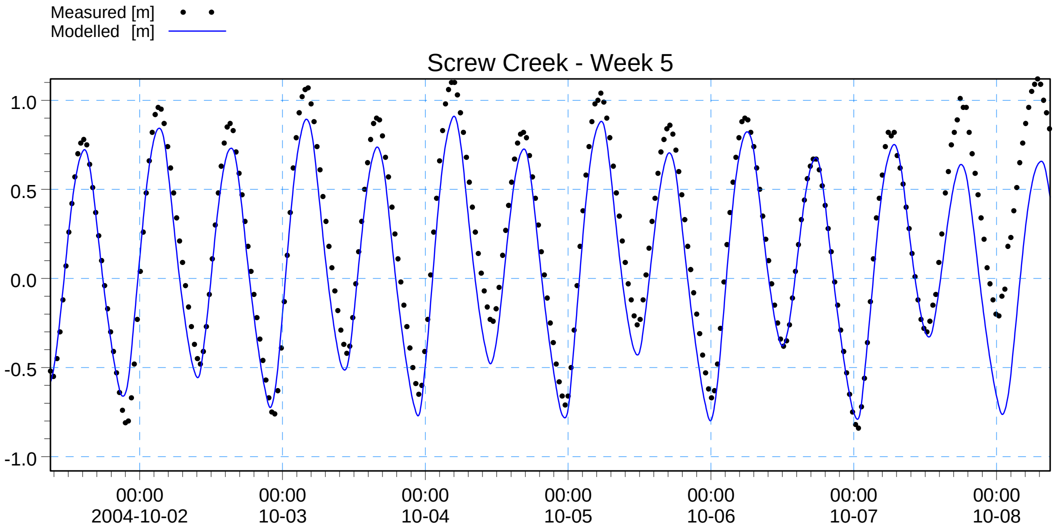


Figure B-2a **Tidal Calibration – Screw Creek**





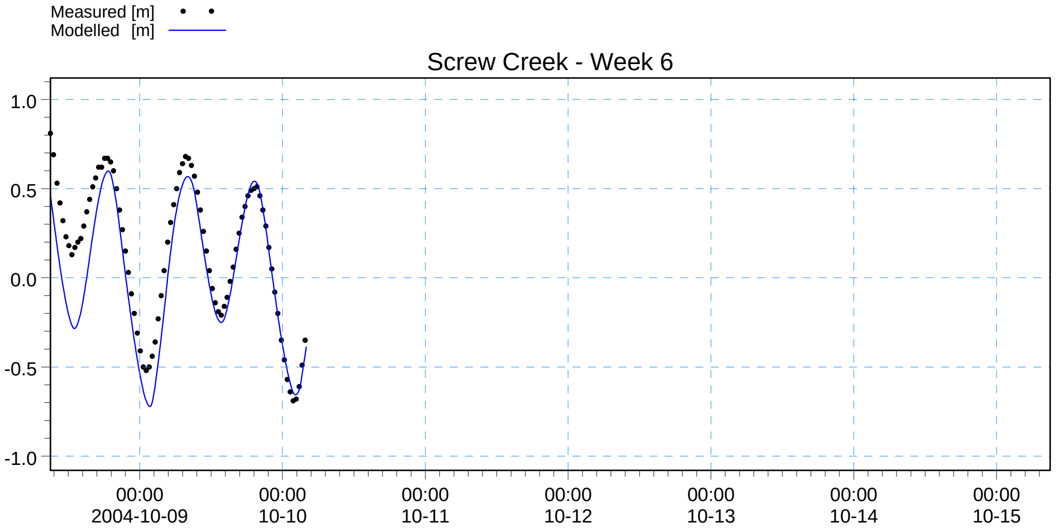


Figure B-2b **Tidal Calibration – Screw Creek**

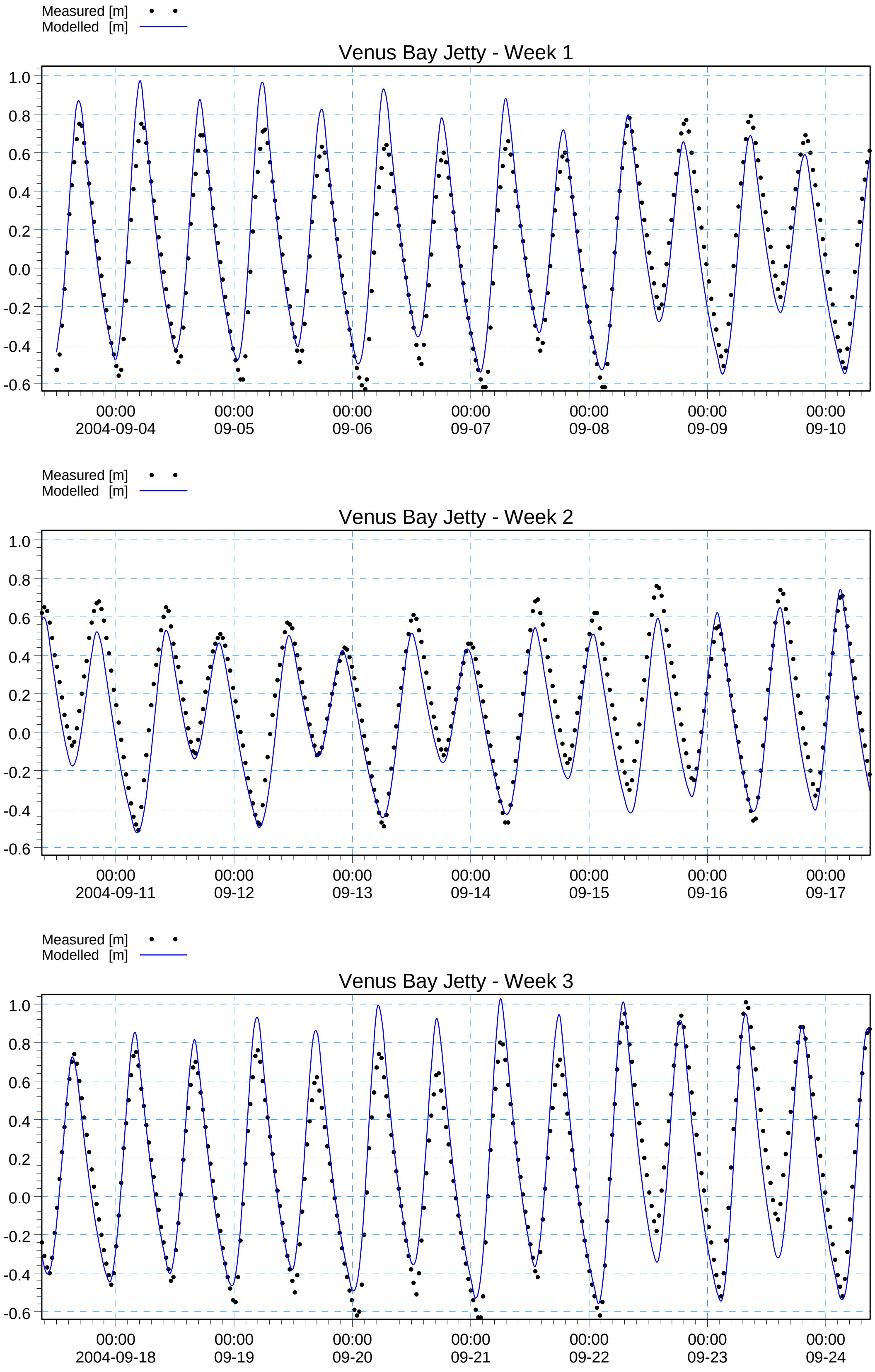


Figure B-3a **Tidal Calibration – Venus Bay Jetty**

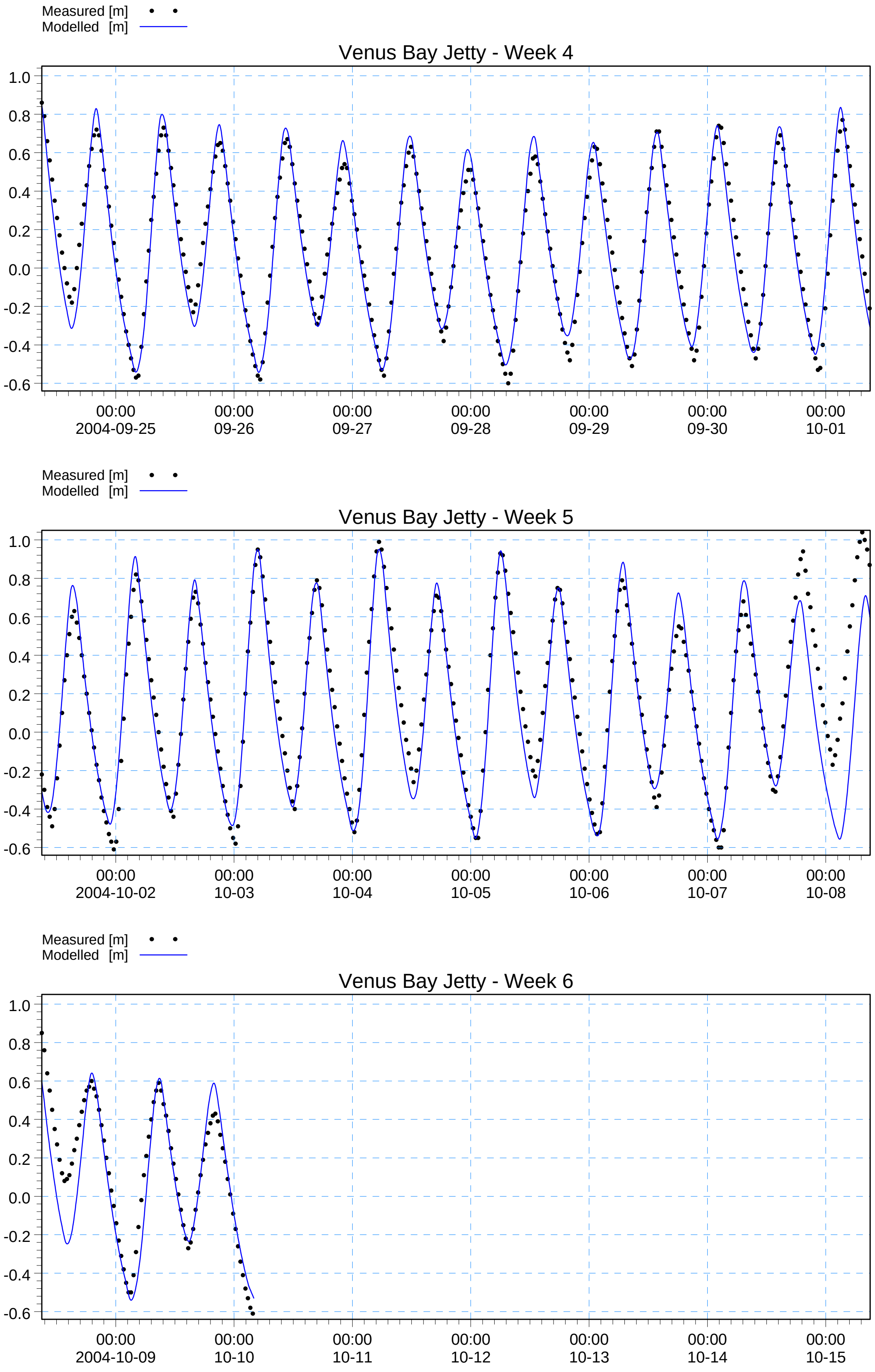


Figure B-3b **Tidal Calibration – Venus Bay Jetty**