School of Engineering
Department of Civil Engineering

Water Surface Profile Modelling for Pinjarra Flood Diversion Channel and Economic Evaluation of Assets at Risk from Flooding

Kamal A Khalil

This thesis is presented for the Degree of
Master of Engineering (Civil Engineering)
Of
Curtin University of Technology

November 2007

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT:

Shire of Murray has concerns regarding the negative impact that a 100 year flood could have on existing structures built before 1997. The increase cost in construction due to landfill has an adverse effect on development in Pinjarra. Feasibility of constructing a diversion channel at upstream of Murray River to attenuate the flood level from 1 in 100 year ARI to 1 in 50 year ARI, was investigated by Kiong (2003). The Murray River Water Surface Profile along three kilometres south of Greenlands Road was modelled. Flood damages on each flood occurrence were assessed and Average Annual Damage (AAD) was calculated. The AAD is used to estimate the monetary benefit against the construction cost of the diversion channel. Groundwater along Greenlands and Fauntleroy Drains was also modelled to determine the viable depth of the designed channel, as well as the analysis of backwater. The proposed channel is designed at different scenarios (invert level at breakout point, culvert or causeway design, and diversion channel variations). The benefit cost ratio of the proposed diversion channel is calculated. Other mitigation options are suggested including detention basins for structural measure, or building a new flood-proof township for non-structural measure.

Indexing Terms:

Diversion channel, flood, flood damage, flood mitigation, flood risk, flood level, flood fringe, floodway, floodplain management, groundwater, Pinjarra, Murray River, Peel Inlet, Greenlands Drain, Fauntleroy Drain, culvert, causeway, backwater analysis, Shire of Murray, benefit cost ratio, Average Annual Damage, impacts of flooding, feasibility study.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to the Shire of Murray for providing me the opportunity of this research project. It is with sincere gratitude that I thank my previous supervisor, Dr. Azam Khan and my current supervisor Professor Hamid Nikhraz, who had given so much of his valuable time and attention to the preparation of this report. I am also grateful to Dr. Ian Chandler, the unit coordinator, for his vital role in improving the style and format of this report. Gratitude is also extended to Mr. Richard Bretnall from Water & Rivers Commission who had provided valuable information on the constraints and provisions.

SUMMARY

In the past 60 years, there has been no severe flooding in Pinjarra which is at the downstream reach of the Murray River except the 1945 flooding with a recorded flood event of 1 in 30 year Annual Recurrence Interval (ARI). The 1440 mm annual rainfall in the catchment of Murray River in 1945 flooding at Pinjarra had an intensity of 731 m^3/s. This was the second largest flood since 1862, which had an estimated flow of 1553 m^3/s. Public Works Department, WA had completed Murray River Flood Study in 1984 to provide detailed information on flood flow behaviour, flood levels, and floodplain maps along the Murray River. As a consequences, floor levels of all new buildings built after 1997 were required to be at least 500 mm above the designated 100 year flood level as part of the floodplain management in Pinjarra.

Feasibility study has been undertaken in 2003 By Mr. Chong Vui Kiong who investigated detailed background analysis regarding flood history in the Town of Pinjara and several options to mitigate the potential flood that could be caused by a 1 in 100 year storm. The finding and outcome outlined in Mr Kiong’s report has been used in this research. The “Diversion Channel” was the preferred future flood mitigation measure by the Shire of Murray. Therefore this research is considered to be a continuation of the study started by Mr Kiong.

The proposed diversion channel is intended to address the current non-structural floodplain management (building levels restriction) which has hindered the development in Pinjarra due to the uneven building heights.

The objectives of this research project were to investigate and evaluate the economic costs and benefits of constructing proposed diversion channel against the risks, hazards and adverse consequences caused by flooding. The current floodplain management was evaluated for its effectiveness. The flood damages in Pinjarra were assessed in the events of 10, 25, 50 and 100 year ARI flood. It was intended that flood mitigation ‘Diversion channel’ would reduce the effect of a 1 in 100 year ARI flood to that of a 1 in 50 year ARI flood (Risk of damage for 50 year flood is acceptable to the Shire. The benefit cost ratio of the channel was evaluated to determine its viability. In addition to the diversion channel other floodplain management options were also developed and assessed to mitigate the floodwater.

Hydrological analysis was carried out by Public Works Department (PWD) in 1984 and further reviewed in 1999 by Sinclair Knight Merz (SKM). PWD used the Baden Powell station to calibrate the flow data while SKM used Pinjarra station to calibrate the flow data after the development of Runoff Routing (RORB) hydrological model for Murray River in 1992. The results had shown a 5% reduction compared to the 1984 calibrated flow. However, Water & Rivers Commission (WRC) further re-assessed the flow with considerations for today's clearing and efficient drainage system, and the new peak flow was 1,415 m^3/s for 1 in 100 ARI flood event. The reduction of flow from 1 in 100 year flood to 1 in 50 year flood was 300 m^3/s. This flow was considered in the research project to design the capacity of a diversion channel.

Hydraulic modelling of the project was prepared comprehensively in Murray River Flood Study 1984. The map showing the extent and depth of flooding during the flood events of 10, 25, 50 and 100 year ARI was produced. SKM confirmed that construction of the Dawesville Channel, which opened out the Harvey and Peel to the ocean in 1992, did not affect the flood level in Murray River after the investigation on tidal fluctuation (backwater) analysis.

Main Roads WA is currently investigating the upgrade of Peel Deviation (Extension of Freeway South to Bunbury). A new bridge crossing Murray River has been designed and the road will pass through the proposed diversion channel. The Peel Deviation, together with the South-Western Highway have formed artificial levees that blocked the natural "break out" of floodwater at the low area just south of Greenlands Road.

The current floodplain management strategy by raising the building level to 500 mm above the designated 100 year flood level implemented in Pinjarra is deemed not sufficient in reducing the flood risk. The properties will still be flooded either above or below floor level in the event of flooding. Global weather changes, degree of awareness, low preparedness for flood and numerous other factors highlight Pinjarra's need for immediate mitigation measures to reduce the flood risk. Although the cost of implementation is prohibitive, the return (benefit) has been assessed to be significant in the long term.

Previously four options for mitigation of the impact of flooding were investigated. The options were outlined in the report. The "Diversion Channel" was the preferred future flood mitigation measure by the Shire of Murray Kiong (2003). The proposed diversion channel was studied in detail and a suitable design was carried out.

The proposed diversion channel entry is at Station 8 indicated in the River Geometry, 2.2 km South of Pinjarra Town site and 1200m south of Greenlands Road, where the natural breakout point is situated. The cross-section resulted from the analysis indicated several break points, however the cross-section at station 6 located 900m and station 8 located 1200 south of Greenlands Road will be the entry points to the channel. The floodwater will breakout to the South-Western Highway and spread over the land between Greenlands and Fauntleroy Drains before subside to Peel Inlet in 1 in 40 year flood event. The total length of the diversion channel is approximately 10 km. Two existing drains (Greenlands and Fauntleroy Drains) currently spaced at 1.2 km apart with catchment areas of 1.4 km^2 at Greenlands Drain and 22.53 km^2 at Fauntleroy Drain. The capacity of current drains to cope with extra flow from floodwater is herein investigated. Evidence shows that the drains were designed to drain groundwater. A series of piezometers has been installed along the Greenlands Drain and Fauntleroy Drain to measure groundwater level. From the groundwater modelling conducted, the groundwater levels were shown to peak from April to August and then decline slowly after September. The highest recorded level was 10.4 m AHD which is approximately 0.55 m below ground level. These levels are required for determining the diversion channel design.

Although the proposed diversion channel provided a suitable path for diverting the flow, the existing drains are not capable of coping with the extra flow in the range between 250 - 300 m^3/s. Investigation has been made at the breakout point (Station 8 in the River Geometry figure) to determine the suitable invert level to the proposed channel. Two sub-options have been adopted either breakout at RL 11.0 m or at RL 11.3 m Kiong (2003). Option 1b seems more viable due to lesser excavation work. To get the floodwater through the highway, three approaches have been investigated: (i) placing culverts under the highway, (ii) construct a causeway, and (iii) partial culverts placing, partial causeway construction). When the floodwater passes the highway, several variations have been suggested at the spreading land, from “do nothing” to construct a proper channel. Table below shows different scenarios created for the proposed diversion channel and their construction cost.

Scenario	Description	Estimated Cost
1	Option 1a, Culverts and Causeway, Do Nothing	$2,700,000
2	Option 1b, Culverts and Causeway, Do Nothing	$ 2,200,000

3	Option 1b, Culverts Only, Do Nothing	$2,900,000
4	Option 1b, Causeway Only, Do Nothing	$ 1,200,000
5	Option 1b, Culverts Only, Embankment Around Affected Residential	$ 2,900,000
6	Option 1b, Culverts Only, Embankment Along Greenlands Drain	$11,800,000
7	Option 1b, Culverts Only, Diversion channel Excavation & Embankment at Both Drains	$40,000,000

Scenario 4 was the cheapest option investigated, followed by Scenario 2. By construct a causeway, the Shire has to realise the impact of closing the highway for two to three days during the severe floods. The most expansive construction cost investigated is Scenario 7 where a proper channel is excavated with embankments at both drains to provide freeboard for approximately 10 km.

Benefits of the proposed scenarios were estimated by assembling flood damage data from the flood damage assessment using Rapid Appraisal Method (RAM). The flood damage model was used with design flood levels for flood events of 10, 25, 50 and 100 year ARI. The reduction in damage from mitigation measure undertaken provides a monetary estimate of the benefits. Expressed in Average Annual Damages (AAD), flood damages would be reduced from $ 480,000 per annum to $ 430,000 per annum, a sustainable benefit of $ 50,000 per annum.

The benefits have a present value of $ 860,000, assuming an effective project life of 30 years and a discount rate of 4%. The preliminary estimate of benefit cost ratio (BCR) for Scenario 4 is 1.07. However, this ratio would increase if the benefits from downstream of Pinjarra Townsite and intangible costs were included over a sustained period.

Other mitigation options such as detention basins and new flood-proof township were recommended in this report.

This report would enable the Shire of Murray to make the decision for possible future floodplain management measures. The flood damage assessment for Pinjarra Townsite also assists Water & Rivers Commission in identifying the impacts of flooding in Pinjarra.

GLOSSARY

AAD	Average Annual Damage, the average damage per year that would occur in a particular area from flooding over a very long period of time. This provides a basis for comparing the economic effectiveness of different projects.
AEP	Annual Excedance Probability, the likelihood of occurrence of a flood of a given size or larger occurring in any one year. A 1% AEP event is effectively a 100 year ARI flood.
AHD	Australian Height Datum, height above sea level.
ARI	Average Recurrence Interval, the likelihood of occurrence of flooding, expressed in terms of the long-term average number of years between the occurrences of a flood as large as or greater than the flood being referred to. For example, a flood with a discharge as large or greater than the 100 year ARI flood will occur on average every 100 years.
Flood fringe	The area of the floodplain, outside the floodway, which is affected by flooding. This area is generally covered by still or very slow moving waters during the 100 year flood.
Floodplain	The portion of a river valley next to the river channel which is or has been periodically covered with water during flooding.
Flood prone land	All land subject to flooding including the floodway, flood fringe and flood plain.
Floodway	The river channel and portion of the floodplain which forms the main flow path of floodwaters once the main channel has overflowed.

Flood - 100 year Refers to a severe flood which has a statistical probability of occurring once in 100 years. The 100 year flood level is generally defined as a contour through the floodplain to which this flood will rise. The flood has a 1% chance of occurring on any given year; on average it will occur once in every 100 years.

Floodplain Management The planning and flood impact prevention/minimisation activities of flood management together with related environmental activities.

Freeboard A factor of safety above design flood levels, generally expressed as a margin above the design flood level, typically used in setting floor levels and levee crest heights. It is intended to compensate for flood prediction uncertainties and for factors that affect the level of protection. These include wave action, localised hydraulic effects and settlement of levees. Freeboard should not be relied upon to provide protection for events larger than the design flood.

Hydraulics The study of water flows, in particular to evaluation of flow parameters such as water level and flow velocity in a river, stream or adjacent floodplain.

Hydrology The study of the rainfall and runoff process as it relates to the derivation of flow in watercourses.

Risk Management The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring risk.

Runoff The portion of rainfall which actually ends up as streamflow.

Hec-Ras — Software to calculate water surface profile in rivers and streams. The software has the capability of modelling hydraulic structures such as bridges, culverts.

Reach — The main channel along the river

Station — The location at which river cross-section is assessed.

1 INTRODUCTION

1.1 Overview

The historic town of Pinjarra, situated 86 km south of Perth, is one of the inundated areas in Western Australia. Heavy rainfall in the 7670 km^2 catchment of Murray River could cause severe flooding at Pinjarra Townsite and areas downstream. Floods causing damage and affecting the increasing population and development of Pinjarra Townsite has been a major concern to the Shire of Murray.

The major flood recorded is 731 m^3/s in 1945 with an annual rainfall of 1440 mm and flood level 8.3 m AHD at Pinjarra Bridge. The flood level would increase to 8.95 m AHD at 1 in 100 year ARI event according to a flood study done by Public Works Department (PWD). (George 1984)

Based on the 1984 flood study, non-structural measure (building floor levels) was recommended. PWD had adopted a Floodplain Development & Management Policy to determine the designated 100 year flood level in all flood fringe areas. Therefore all new development in flood fringe areas must have a minimum building floor level of 500 mm above the designated 100 year flood level.

Shire of Murray has concerns regarding the negative impact that a 1 in 100 year ARI flood would have on existing structures built prior to the current building height requirements. It is also a concern that the current building level requirements add a significant cost to construction and this is having an adverse effect on development in Pinjarra Townsite and areas downstream of it.

A preliminary investigation (Davies 1999) by Sinclair Knight Merz estimated that 100 to 200 m^3/s could potentially “breakout” during the 100 year flood at the low area, upstream of the town, just south of Greenlands Road (chainage 29,730) based on the peak flow from the 1984 PWD flood study (1,273 m^3/s). The investigation assumed that half of the flow above the “breakout” flow rate would continue down the river floodplain and the other half would “breakout” over the highway. This would result in a drop of the 100 year flood level about 100 to 200 mm in the floodplain just upstream of the South Western Highway Bridge (Pinjarra Bridge) over the Murray River at the northern end of Pinjarra Townsite.

Therefore, the Shire of Murray wanted to investigate the feasibility of constructing a diversion channel near Greenlands Road as a potential means of reducing the current floodplain restrictions. It is intended that the flood mitigation will reduce the effect of a 1 in 100 year ARI flood to that of a 1 in 50 year ARI flood

1.2 Aims of Research Project

The primary objectives of the research project were to investigate the economic costs and benefits of conducting the mitigation measure (i.e. diversion channel) against the risks, hazards and adverse consequences caused by flooding.

Part of the research project intended to evaluate the current floodplain management strategy for Murray River flooding and at the same time estimate the damages for Pinjarra Townsite due to flood events with ARI of 10, 25, 50, and 100 years.

Other structural and non-structural flood mitigation options were also suggested in this research project.

1.3 Scope of Research Project

Shire of Murray commissioned Curtin University of Technology to investigate the feasibility of constructing the flood diversion channel as a potential mean to reduce the current floodplain restrictions for the Pinjarra Townsite and the lower reaches of the Murray River.

This research project used the hydrology data from the “Flood Study and Floodplain Mapping of the Town of Pinjarra in 1984” prepared by Public Works Department (George 1984) and “Flood Review Study 1999” prepared by Sinclair Knight Merz. (Davies 1999) and the outcome of the feasibility research conducted by Kiong in 2003.

Rapid Appraisal Method (RAM) was conducted to assess the flood damages for Pinjarra Townsite. Floodplain mapping showing the extent of flooding in Pinjarra Townsite was produced, and the average annual damage (AAD) for each event of flooding was estimated.

The result of groundwater modelled by Kiong in 2003 along the proposed flood diversion channel (Greenlands and Fauntleroy Drains) is used in this research. These levels are required for determining the depth of the proposed diversion channel.

The research project estimated the new building height requirements in Pinjarra from the amount of flood flow being diverted. By diverting the flood flow from 1 in 100 year ARI flood to 1 in 50 year ARI flood, the flood levels in Pinjarra Townsite and areas downstream would attenuate 300 mm from the designated level.

Risk management approach was used to determine the suitability of constructing the flood diversion channel against the clearing of land and other social environmental impacts.

The viability of the proposed mitigation option was determined using benefit cost ratio from net present value.

1.4 Outcomes of the Research Project

The following outcomes of the research project will be achieved:

(i) Water Surface profile along the Murray River to identify the break points

(ii) The review of the current floodplain management strategy.

(iii) Detailed analysis and design of diversion channel

(iv) The complete assessment of flood damages for Pinjarra Townsite using the Rapid Appraisal Method.

(v) Suggestion of structural and non-structural floodplain management strategies.

(vi) The various scenarios for the proposed diversion channel and the potential impacts on the mitigation option.

(vii) The benefit cost ratio of the proposed diversion channel.

2 BACKGROUND

2.1 Introduction

In this chapter, a brief review of floods in Australia has been presented to recognize the causes and impacts of flooding in Australia. The type of flood damages and the general floodplain management procedures are introduced to understand the impact of flooding on people and their community. A brief introduction to groundwater and the modelling method is defined. The benefit cost ratio is also explained as the ratio is used to determine the feasibility of this research project.

The chapter concludes with examination of recent floods in Carnarvon, Moora and Busselton. These case studies were used to investigate the various floodplain management options and flood damages assessment practised in Western Australia.

2.2 Floods in Australia

Floods occur in most part of Australia caused by intense thunderstorms, or heavy rain over the catchments of established river systems. The later is more widespread and longer-lived inundations. During significant floods lives can be lost, stock losses may be in the tens of thousands, and damage to homes, businesses, roads, and other infrastructure can run into hundreds of millions of dollars. Lost production can add considerably to the costs, as can the intangible costs, such as effects on health. Overall, flooding is Australia's costliest form of natural disaster, with losses estimated at over $ 400 million a year [WRC1 2003]. On the positive side, floods have some beneficial aspects, such as cleansing excess salt from the soil and recharging underground aquifers.

2.2.1 Causes of Flooding

The tropical cyclones or intense monsoonal depressions in northern Australia generate most of the big floods occurring in summer or early autumn. These systems can produce staggering quantities of rainfall - as much as 1,000 millimetres in a few days. Outside the tropics, coastal areas of eastern Australia mostly receive their flood rains from so-called "east coast lows" that develop over the Tasman Sea. In the southern states, flooding is mostly a winter-spring phenomenon, associated with unusually frequent low-pressure systems and fronts. However some major events have occurred in the summer half-year as systems of tropical origin extend or move south. Some inland floods, notably those of Lake Eyre, may be initiated by rain falling many hundreds of kilometres away.

2.2.2 Flooding and La Niña / El Niño

Flooding is often quite localized, and therefore not as closely tied to broad-scale controls like the El Niño-Southern Oscillation phenomenon. However, the La Niña years of 1916, 1917, 1950, 1954 through 1956, and 1973 through 1975, were accompanied by some of the worst and most widespread flooding this century. It can safely be said that, over much of Australia, flooding is more likely than usual during La Niña years, and less likely in El Niño years [BOM 2003]. Figure 2-1 explains the relationship between Southern Oscillation Index (SOI) and flooding.

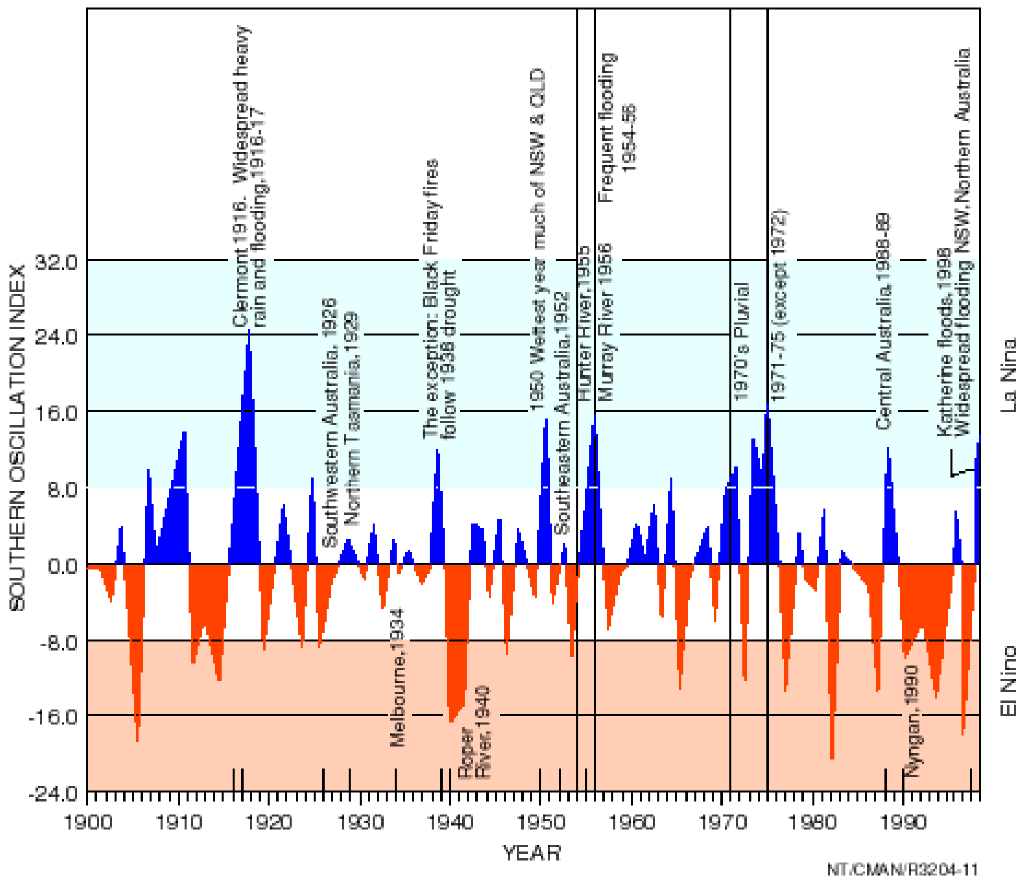


Figure 2-1: Time-Line Showing Major Australian Flood Episodes as a Function of the Southern Oscillation Index. [BOM 2003]

Extended periods of high SOI in 1916/17, the mid-1950s, and the early to mid-1970s, shown in Figure 2-1 were periods of widespread, frequent flooding.

2.3 Flood Damages

2.3.1 General

Figure 2-2 is a brief overview of flood damages summarized in Rapid Appraisal Method (RAM) for Floodplain Management. (Sturgess 2000)

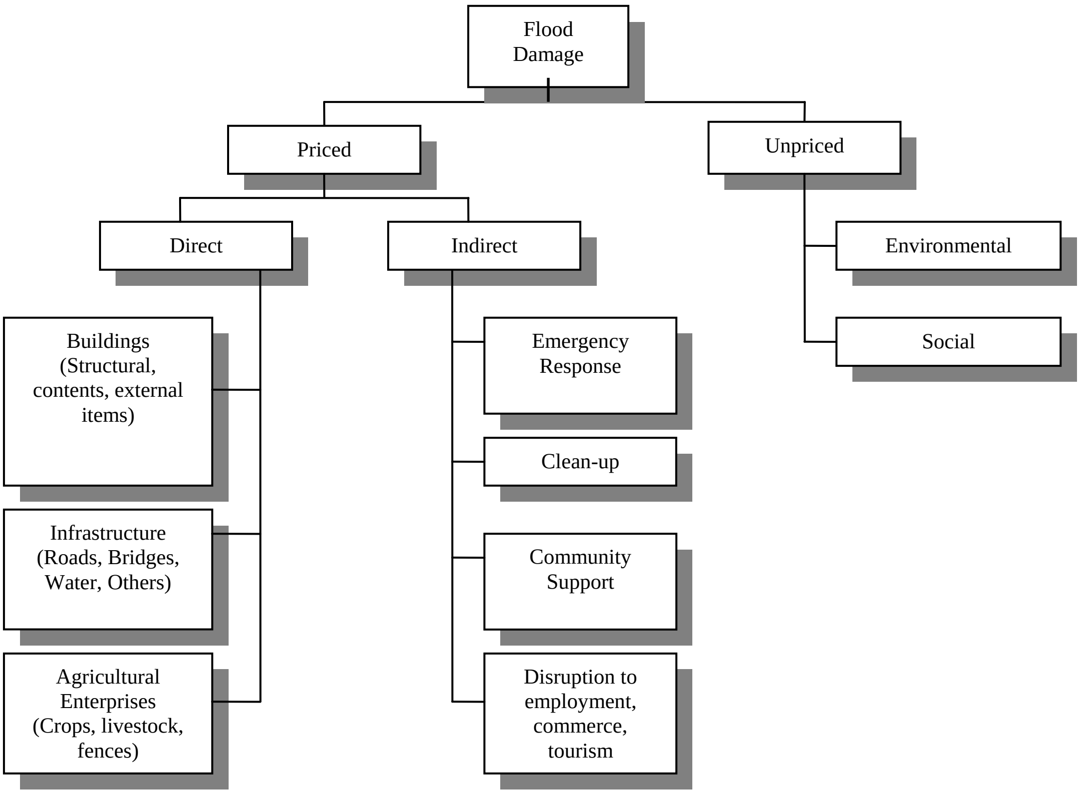


Figure 2-2: Type of Damages (Sturgess 2000)

Priced and Unpriced Damages

The primary division of impacts is into priced and unpriced damages (sometimes referred to as tangible and intangible damages). Priced or tangible damages are costs that can be measured in monetary terms – that is they may be traded in markets and can be measured by reference to prevailing market prices. Priced damages can be further subdivided into direct and indirect damages.

i Direct Damages

Direct damages are caused by floodwaters wetting structures, equipment and personal items both within and outside buildings. Some items may be repairable and others may need to be replaced. In the first case the value of the damage is equal to the cost of repair plus the loss in value of the repaired item. In the second case the direct damage is equal to the pre-flood value of the item or its replacement cost.

ii Indirect Damages

Indirect damages are the additional financial costs caused by the flood. These costs can include lost income or production (financial costs), reduced levels of service provided by public infrastructure (opportunity cost) and clean-up costs.

Unpriced or intangible damages are losses to the community that are usually nonmaterial and are termed unpriced because they are not traded in markets. Flooding causes a range of such losses including trauma, increased levels of insecurity, depression and relationship stress. While it is theoretically possible to value unpriced damages, it is generally necessary to treat these costs in non-monetary terms.

Potential and Actual Damages

Damages are also subdivided into potential and actual damages. This more readily applies to priced damages, although the same principle can be applied to unpriced damages. Potential damages are the maximum damages which could be incurred if no preventative action is taken. Actual damages are derived as a factor of the potential damages. Actual damages allow for community preparedness and flood warning. For example, given warning time and general awareness, many residents will be able to raise furniture, lift carpets and remove valuables from their homes and businesses. Vehicles can be driven out of flood prone areas and pumps moved away from riverbanks. Actual damages are typically assumed around 50% - 70% of potential damages (closer to 50% for external damages, and 70% for internal damages), however this depends considerably on several factors, particularly available warning time and the flood experience of the community.

2.3.2 Estimation of Flood Damages in Historical Floods

The basic concept of estimating flood damages is to relate economic data to the physical quantification of flood behaviour. Commonly, flood damages are related to the depth, velocity, duration and extent of flooding.

The relationship between flood behaviour and estimated direct cost is often referred to as a Flood Damage Curve. This is the key to the estimation of the direct economic impacts due to flooding on a community.

Normally, flood damage curves are expressed as a function of Damage Amount ($, $/Area, %Property Value) vs. Flood Depth, but may also be related to flood duration and flood velocity.

A comprehensive assessment of flood damages caused by the 1980 flood was available, however the physical changes made in the Lower Gascoyne floodplain since then make this inapplicable to current conditions. No assessments had been made of the total damage incurred in the March 2000 flood, although news articles published very soon after the event suggested that total damages were of the order of $20 million. It is not known how that estimate was made.

In order to calibrate a flood damage model with actual damages incurred by Lower Gascoyne flooding, preliminary estimates were made of the priced damages incurred in the floods of 1995 and 2000. Many information sources were tapped in order to make the estimates.

2.3.3 Agricultural damages

information Available

Department of Agriculture maintained records of the costs of works to replace topsoil eroded from plantation areas during floods, as it was responsible for administering emergency relief approved by the State government for this specific purpose. Annual production statistics prepared for Department of Agriculture were also available. These permitted estimates of loss of production to be made, although it is emphasised that interpretation of the data is difficult and the results are very imprecise. Some information on hours spent on preparation before the floods and hours directed to clean-up and restoration work after the flood were available for the March 2000 flood, and some advice was also received verbally from stakeholders.

General Comments

Damage incurred depends on the type of crop being cultivated and its stage of development. Vegetable crops and tomatoes are currently popular because they can provide a quick return for investment, market prices have been favourable and they allow flexibility and adaptation to changing market conditions. These are easily damaged by floods, and provide little protection from soil erosion. The sandy, friable soils which characterise the plantation areas are unconsolidated sediments deposited by flood action in the past, and are readily erodible unless there is good ground cover. Damage in orchards of grapefruit and mango, for example, are typically much lower, particularly if grass cover is encouraged between trees and depth of flooding is moderate. The time required to secure a return on investment in these crops is a deterrent for some growers. Banana plantations generally retard flow of water, with major silt deposition inside banana stands and increased velocities and scour around the perimeters or between stands. They are vulnerable to crop damage if inundation is prolonged.

In their study of flood mitigation options, Sinclair Knight & Partners (1981) remarked on the importance of season on the potential damages incurred in the plantation areas. Generally, potential damages increase during the autumn and winter, and then decline to a minimum in late spring and early summer.

2.3.4 Quantification of Damages

Types of damages included were:

1. Replacement of soil loss
2. Loss of production
3. Structural damage to tanks, sheds and non-residential buildings
4. Damage to equipment *eg*. pumps, pipes, machinery, plastic sheeting, *etc.*
5. Reinstatement of plantings – vegetables
6. Preparation and clean-up costs

1. In March 2000, 164 ha of plantation land was eroded on 132 properties according to Department of Agriculture records (V Kesavan, *pers.comm*.). The volume of soil replaced was 332,400 m3, an average depth of approximately 0.2 m. Soil for replacement was donated by neighbouring landholders. Machinery hire cost was $1.417 million. If a (very low) value of $1 per m3 is assigned to the soil used in replacement, the real cost of replacement of soil loss was $1.75 million. Even this

estimate does not include allowance for the time, both volunteered and salaried, that was directed to the soil restoration effort.

2. The annual production statistics provided by the Department of Agriculture are subject to numerous influences and may be interpreted in different ways, providing estimates of loss of production due to the flood in March 2000 from $3.31 million up to $8.05 million. An intermediate estimate of loss was determined based on changes in quantities of bananas, grapes, papaya and stone-fruits. Vegetable crops were mostly newly planted at the time of the flood, so it was assumed that no significant loss of (annual) production of vegetables was incurred – although costs would have been incurred in re-planting, which is considered elsewhere.
The reduction in value of production of the crops noted above provided an estimate for loss of agricultural production of $6.00 million.

3. The numbers of non-residential structures damaged is unknown, but it is known that at least three water storage tanks were undermined and damaged. Based on discussions with Department of Agriculture and private landholders, a provisional amount of $200,000 is assumed for this type of loss. Damage to buildings and sheds is included in the separate category of rural residential damages.

4. Again, no proper survey of equipment damage is available. The estimate is based on discussions with selected landholders, and may not be representative or accurate. It is known that damage of equipment on some plantations was substantial. An estimate of $500,000 was made for the March 2000 flood.

5. Labour involved in work of reinstatement of plantings, and for preparation and clean-up costs, has been nominally valued at $20 per hour. An allowance of $200,000 is estimated for reinstatement of plantings.

6. Times spent on preparation and clean-up are based on responses to a questionnaire distributed after the 1980 flood, reported in Sinclair Knight & Partners (1981). The average time spent on preventive activity was 20 hours, and approximately 160 hours was subsequently spent on clean-up and recovery after that flood. It was similar in magnitude to the March 2000 flood, so those time estimates have been used without adjustment. Applied to the 133 plantations which were damaged in 1980, these times provide a cost estimate of $520,000 for preparation and clean-up.

Table 2-1 presents a summary of agricultural damages in the March 2000 flood. The total damages in the agricultural sector were estimated to be $9.17 million. Note that this includes direct and indirect damages, and these are actual damages not potential damages. These damages are high, but the opinions of some of those canvassed in the industry are that it is a realistic estimate.

Table 2-1 Summary of Estimated Agricultural Damages in March 2000

Category of Loss Estimated Damage

Category of Loss	Estimated Damage ($ million)
Replacement of top soil	1.75
Loss of production (income)	6.00
Structural damage (non-residential)	0.20
Equipment damage / loss	0.50
Re-establishment of plantings	0.20
Preparation and clean-up	0.52
Total:	**$9.17 M**

On a similar basis, agricultural damage in the flood of 1995 was estimated to be approximately $1.5 million. The information on the damage caused in 1995 is more sparse, however, with the exception of data on top soil replacement ($270,000 according to the Ministerial Taskforce on Floodplain Management, 1998) and annual crop production statistics obtained from Department of Agriculture. A key figure, that for the loss of production (or income), was very difficult to establish from the crop production statistics of 1995 and other years, and a value of $0.9 million was assumed.

2.3.5 Commercial Damage

Information Available

The Gascoyne Development Commission undertook a preliminary survey of businesses soon after the flood. Feedback was provided by operators of 44 businesses in and around Carnarvon. The sample included many businesses along Robinson Street east of Boundary Road, several scattered plantations and several enterprises in or near the town centre that were not flooded.

A small sample of businesses incurring direct flood damages in the Robinson Street east of Boundary Road area were contacted during this study to gain a better appreciation of the impact of the 2000 flood.

General Comments

These sources of information do not represent a rigorous survey of flood damages, but they do provide enough fragments to piece together a reasonable appraisal of the extent of damage.

Excluding damage in plantations, covered under Agricultural Damages, it was very apparent that direct commercial damages were very concentrated in a distinct area along Robinson Street from Boundary Road to north of Brown Range. Caravan parks and roadhouses accounted for much of the direct damage to business enterprises. A trucking company, a packing shed and a road maintenance depot were also flooded. Some of these businesses had to close down or trade at a lower than normal level for periods varying from several days to many months. Loss of trade should not be converted directly to flood damage. It is only the net value of that trade – after deducting the cost of providing the goods or service – which is lost to business operators. As a percentage of the gross value of trade, the net value of trade is highly dependent on the nature of the business – in particular, the extent to which the business is providing goods or services. The operating margin may be very low in a business such as a roadhouse providing mainly goods (fuel, food), but can be much higher in other businesses such as those providing hair styling, clothing or tourism services, for example.

It can be argued that even the margin or the net value of trade should not be considered in flood damages because it may not be a net loss to the nation or the region. People unable to purchase goods in one town may simply shift their trade, usually but not always temporarily, to another town. This argument is not accepted in the case of Carnarvon. Travel distances to alternative commercial centres are prohibitive, and the losses to the economy of Carnarvon are of paramount interest here. It is also sometimes argued that a temporary loss of trade can be made up for at a later time when the community has recovered, and while it is true to some extent that trade would have been suppressed for about two weeks because many outlying residents could not easily make it to town, in the Carnarvon district the impact of flooding on the plantation industry was substantial enough to have a more sustained depression on the regional economy. Furthermore, some of the businesses reported laying off staff either temporarily or permanently, and this would further impair the spending power of the community in Carnarvon. A few of the respondents considered it would take years to recover their financial position prior to the flood.

Quantification of Commercial Damages:

Direct damages to property and stock were incurred by some businesses in the Robinson Street east of Boundary Road area. Property damage included offices, caravans, paving and landscaping, fences, power connections, furniture, machinery and equipment. Indirect damages were more widespread, caused by depressed trade

for weeks or months after the flood. In some instances, those businesses incurring direct flood damages were forced to close or restrict trading because of loss of access, loss of amenities, damage to accommodation and time required to clean up. Clean up costs were another component of the indirect damage. Direct damages to caravan parks along Robinson Street are stimated to amount to $520,000, with a further $193,000 in indirect damages. Roadhouses near or at the corner of Robinson Street and the North West Coastal Highway incurred direct
damages estimated to be $985,000, with additional indirect damages amounting to $331,000. Although indirect damages were estimated independently, they are equivalent to 37% of direct damages in the case of caravan parks and 34% of direct damages in the case of roadhouses.

Damages for other businesses incurring direct flood damage were estimated to be
$57,000 direct damages plus $62,000 indirect damages. Note that this does not include damage to plantations. Damage to plantations are included under agricultural damages or, in the case of buildings on plantations, under residential damages. Damages were estimated for transport companies. These businesses incurred no direct damages, but the North West Coastal Highway was cut because of flooding around Carnarvon for about 7 days. Normal traffic over the Nine Mile Bridge is 180 heavy vehicles per day. Vehicles travelling between Perth and Port Hedland had to add 90 km to their journey via the Northern Inland Highway, and transports travelling between Perth and Karratha would have 310 km added to their journey. Assuming 80% of heavy traffic was headed for these destinations, extra costs incurred by transport companies were then estimated to amount to approximately $540,000.
Loss of income through depressed trading in the town by businesses not directly affected was estimated by considering the loss of trade reported by traders, and also by onsidering the likely level of reduced spending by those families directly affected. This produced an estimate of $90,000 indirect damages to other businesses. This may underestimate the real value, however, as the impact of the tourist trade is not easily accounted for this way. Investigations by Read Sturgess, for example (NRE Victoria, 2000) suggest that indirect damages may be 50% higher than average in areas that enjoy a strong tourist trade. Considering the importance of tourism in Carnarvon, the estimate of indirect damages in the town has been upgraded to $135,000.
Total commercial damages arising from the March 2000 flood were estimated to be
approximately $2.82 million. A summary is provided in Table 2-2.

Table 2-2 Summary of Commercial Damages, March 2000

Category of Business Damage Incurred

Category of Business	Damage Incurred
Caravan Parks	$713,000
Service Stations / Roadhouses	$1,316,000
Heavy Transport	$540,000
Other businesses	$254,000
Total Estimated Commercial Damage:	**$2.82 million**

It is not known how many houses and premises were flooded above floor level in the 1995 flood. Based on the flood levels estimated by the hydraulic model the extent of damage can be compared with that in March 2000. Most commercial properties directly affected were also affected in the 1995 flood, although effects were much less severe. Indirect damages to business generally would also have been incurred, but also much lower than in March 2000. The estimate of commercial damages derived is $0.72 million for the 1995 flood.

2.3.6 Residential Damages

Sources of Information

The main source of information on residential flood damage were claims for assistance made to the Shire of Carnarvon, which administered State disaster relief aid on behalf of the Department of Family and Childrens Services. Details are confidential, but numbers were obtained. The Country Housing Authority also makes loans for rural housing and was contacted for advice, however many who incurred damage could be reluctant to enter into a loan at a time of hardship or would not need one, so this source does not provide an accurate assessment.

No information is available on floor levels. This is important information for estimation of damages using flood level data. Site inspections were made to evaluate in fairly general terms the heights of floor levels above ground in different parts of the study area. Using GIS software ArcView, the assumed floor levels were compared with the calibrated flood levels from the MIKE 21 hydraulic model for the March 2000 flood.

Floor levels were then adjusted to approximate the correct number of houses flooded above floor level as obtained from the Shire’s claims summary. As street names for buildings flooded above floor level were available, the spatial distribution of buildings so affected could also be approximated.

Quantification of Damages

Claims for assistance were verified by the Shire by property inspection. The claims revealed:

73 residential dwellings, mainly in plantation areas;

5 residential flat units;

3 service stations;

3 caravan parks;

2.4 Floodplain Management Strategy

Generally, the floodplain management strategy can be divided into structural measures and non-structural measures as shown in Figure 2-3.

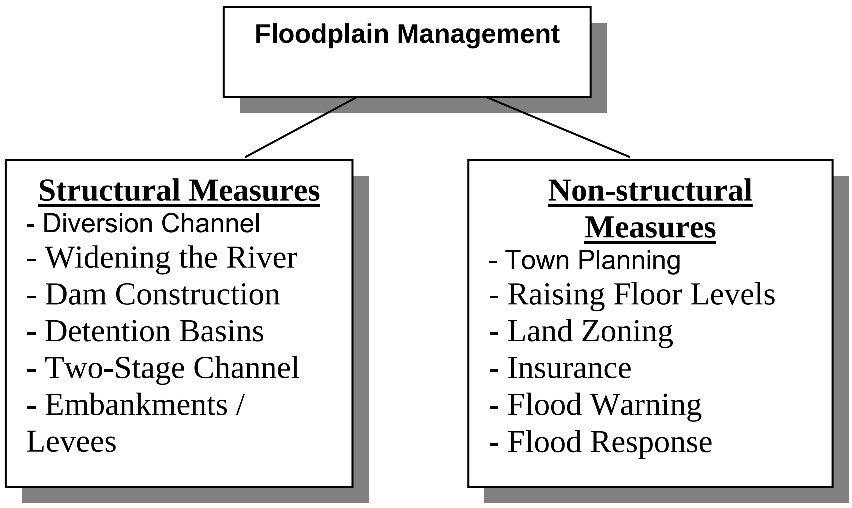
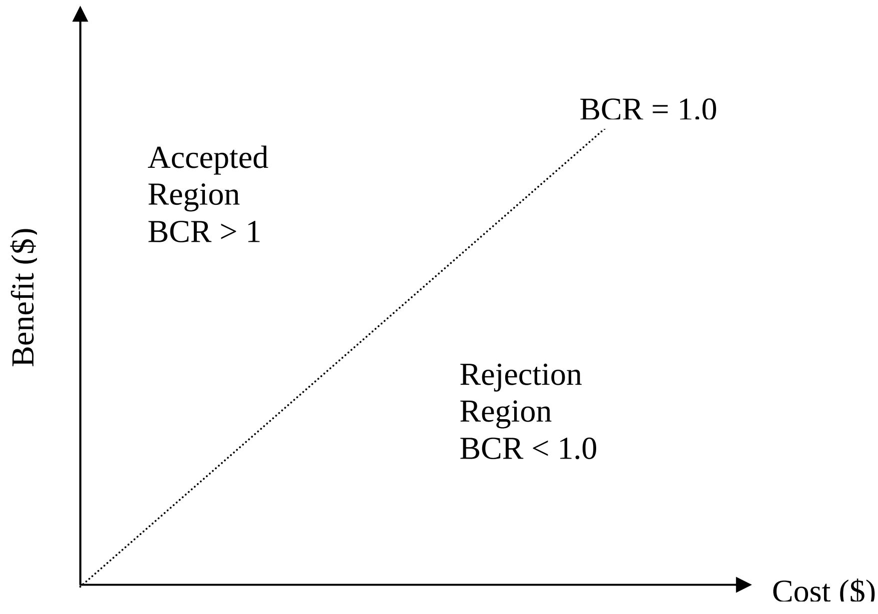


Figure2-3:
General Classification of Floodplain Management

In order to mitigate the effects of flooding, both structural and non-structural measures were examined. Structural measures, in general, modify behaviour of floods, and reduce the risk associated with flood inundation in selected parts of the floodplain. These often have the effect of aggravating the consequences of flooding elsewhere, and it is important to evaluate impacts over a large range of magnitudes. Non-structural measures, also known as planning measures, do not modify the flood behaviour. Instead, these measures aim to minimise development in certain areas of higher risk, or otherwise modify land use in areas of flood hazard to reduce risk of property damage, personal injury or loss of life. Structural measures are better suited for protection to existing development, and non-structural measures are better suited for reducing the flood damages incurred by future development (Porter 2002). Although to completely remove the risk of flood is impractical, it is possible to reduce the flood risk effectively.

2.5 Benefit Cost Ratio (BCR)

The benefit cost ratio is a common method of evaluating the relative worth of a proposed project. This method consists of comparing the “equivalent net worth” of the benefits to the “equivalent net worth” of costs. Usually, the net annual worth or present value (pv) is used. For example, a proposal with estimated benefits of $ 20,000 a year and estimated costs of $ 10,000 per year has a ratio of BCR = $ 20,000 / $ 10,000 = 2.0. The BCR value would then be evaluated using Figure 2-4. The ratio either falls under the accepted region or rejection region. Normally, BCR would have to be more than one to allow for uncertainty.



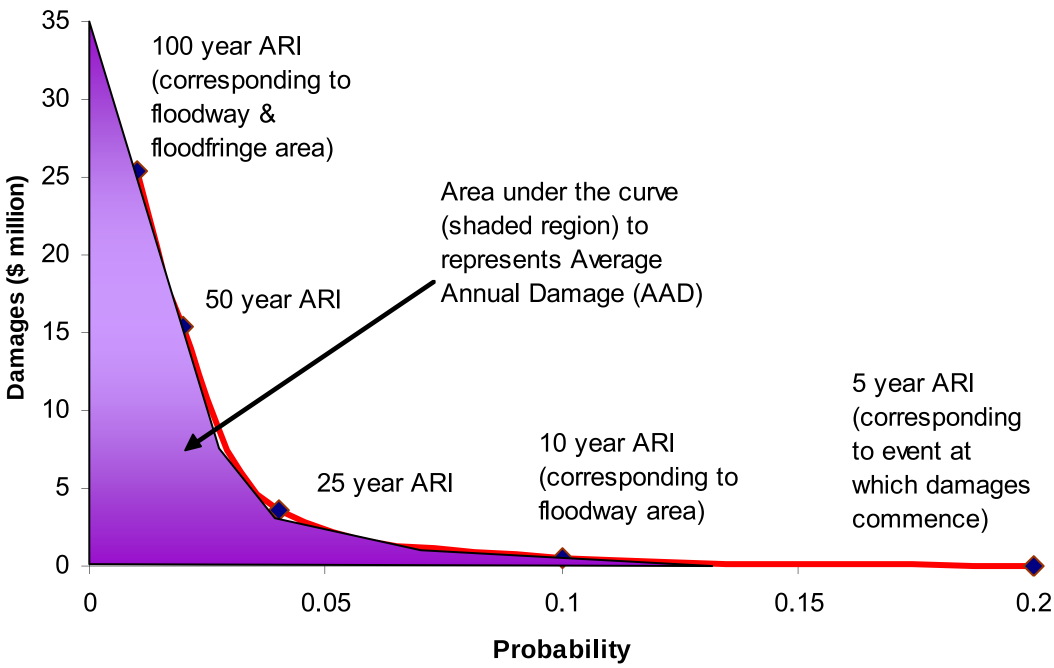


Figure 2-4: Benefit Cost Ratio

US Federal Government's Flood Control Act of 1936 (Dale, cited in Press 1986) stated that the federal funding for improvements to the waterways for flood control would be justified only "if the benefits to whomsoever they may accrue are in excess of the estimated costs." Thus, the BCR ratio can be used to evaluate projects involving benefits to persons other than organisation incurring the costs. The use of BCR analysis associated with the "user-cost" is now being adopted by most governments because the public insistence that the funds be spent in the most advantageous way possible. The cost and benefit to the user is now part of the equation in determining project selection and it is also becoming part of the modern bidding and contracting approaches.

2.6 Current Flood Disaster Mitigation Strategy In Asia (Escap Region)

To date, the principal thrust of the water-related disaster mitigation strategies employed in many countries has concentrated on disaster preparedness, rather than on disaster prevention. Whilst this approach has in many countries been successful in reducing the overall death toll associated with these hazards, the amount of physical damage has continued to mount.

In summary, these mitigation measures attempt to lessen the impact of the hazard by adopting both structural and non-structural approaches. The objective of the structural approach is to control the effects of the hazard by using specific engineering works as the best means of protecting life and property. On the other hand, the objective of the non-structural approach is to modify susceptibility to the hazard through a range of controls and other non-engineering devices.

The most successful preventive measures employed to curb the destructive and injurious effects of tropical cyclones are building design and construction standards, established to assist buildings and other structures to resist wind and water damage. The range of measures available for protection against the effects of flooding is much wider than that available to reduce the impact of tropical cyclones. It includes civil engineering-oriented structural measures, such as channel modifications, flood storages and levees, as well as non-structural measures such as planning controls and flood proofing of buildings. These measures are designed and implemented in order to reduce the incidence or extent of flooding and storm surges and/or to minimize their effects.

2.6.1 Programme Development

2.6.1.1 Overview

As part of its contribution to the mid-term review of the IDNDR Programme, the Water Resources Section Secretariat of ESCAP prepared an overview of the status of the natural disaster mitigation efforts of its members. It found that there has been a growing recognition in the region of the significant benefits of disaster prevention and mitigation, rather than *ad hoc* relief reduction activities. Some countries had a long-established framework for responding to the disaster mitigation requirements of the country. Others had either strengthened their institutional mechanisms or were in the process of overhauling them.

Substantial progress had been achieved in meteorological forecasting and warning of tropical cyclones, and the capability to forecast floods had improved considerably through the individual efforts of various countries, with assistance from the support given by ESCAP, the World Meteorological Organization (WMO), UNDP and other organizations. Useful programmes and the capability to forecast tropical cyclones and floods had improved considerably through the establishment of the Typhoon Committee and the Panel on Tropical Cyclones. These two bodies had cooperated in the forecasting and warning of cyclones, information exchange, provision of training and other forms of activity relating to the reduction of the impact of water-related natural disasters (see below).

The development and use of radar for forecasting and measuring rainfall events and the increased number of telemetric rainfall stations in some countries had increased their capability for the rapid collection and processing of precipitation data and the forecasting of floods. There was still considerable variation among countries of the region with regard to the availability and reliability of equipment needed for effective cyclone and flood forecasting and warning. Prediction of drought had also become more reliable by taking into account such factors as the El Niño phenomenon and the undertaking of appropriate mitigation and preparedness measures.

It was determined that each country needed to improve the quality of forecasts and warnings in relation to water-related natural hazards and to increase the lead time of warnings, to enable areas likely to be affected to make adequate advance preparations. The need for emphasis to be given to the improvement of communication links for the transmission of basic data and providing related warning information about natural hazards was seen to be a priority issue.

Risk assessment and mapping had not been undertaken by most of the countries of the region. There was a need for comprehensive vulnerability analysis to be undertaken for disaster-prone areas, incorporating information about past disaster events, the socio-economic conditions of the population living in the affected area, and inventories of major structures liable to damage. Risk assessment and hazard mapping would then be used to delineate areas vulnerable to natural hazards and determine the frequency, intensity, impact, return period and other data in relation to each category of hazard.

Almost all countries in the Asian and Pacific region experienced severe flood problems at comparatively frequent intervals. Their traditional approach to the reduction of flood losses relied upon the use of structural flood mitigation measures such as the construction of dams, levees and channel improvements. Most of the earlier flood mitigation programmes adopted by individual countries had been specific to a city or to a discrete agricultural area and had employed a narrow range of engineering works to provide solutions to the flooding problem. Although some projects were successful, some of them have actually exacerbated flood damage. In recent years, most countries have recognized the inadequacy of programmes based solely on structural measures. Numerous attempts had been made to employ non-structural flood loss prevention measures to assist in minimizing losses, principally through exercising control over development in flood-prone areas. These measures were usually associated with a mix of structural measures and, in some circumstances, provided a comprehensive means of coping with a flood problem. In many cases, however, attempts to formulate programmes which included some non-structural measures had met with limited success, particularly those involving planning controls, acquisition of land and the relocation of people.

Disaster preparedness is designed to minimize loss of life and property damage and to organize and facilitate timely and effective rescue and relief in the case of a disaster. It must be supported by legislation which can ensue readiness to cope with disaster situations when they cannot be avoided. It also includes forecasting and warning, the education and training of the population, and organization for and the management of disaster situations, including the preparation of operational plans, training of relief groups, stockpiling of supplies and provision of necessary funds. Furthermore, it should include flood fighting and evacuation, relief and rehabilitation. To be effective, such disaster preparedness measures, including those which are taken when the occurrence of a tropical cyclone, flood or storm surge imposes the threat of a disaster, must be planned in advance.

The most important of these measures for helping to mitigate the effects of tropical cyclones and floods is the development and implementation of effective forecasting and warning systems. These can be particularly effective in reducing the potential damage by increasing the time between the prediction and onset of an event. To be effective they must include not only the latest techniques for the formulation of accurate forecasts, but also related communications systems designed to disseminate timely and accurate advice to the general public.

2.6.2 Success Story – Bangladesh

Bangladesh is predominantly a rural country, relying heavily upon agricultural production for its existence. Unfortunately, its topographic and climatic systems make it one of the most water-related disaster prone countries in the Asian region. It is frequently struck by destructive cyclones, devastating floods and crippling droughts. These hazards cause severe agricultural losses and place great strains on country's economy and its ability to achieve sustainable development.

Cyclones frequently sweep out of the Bay of Bengal and impact on the coastline with devastating effects. These cyclones generate dangerous floods, which are exacerbated by storm tides and wreak havoc along the entire coastal belt. Further upstream, in the delta formed by the three great rivers, the Padma, the Jamuna and the Meghna, frequent major flooding can inundate up to 70 percent of the entire country. The effects of these floods in terms of loss of life and property, ecological damage and lost production have crippled the country's economy and set back development programmes by years. In addition to the loss of production caused by cyclones and floods, Bangladesh has also experienced severe drought conditions which have resulted in disastrous crop failures. The loss of agricultural production caused by droughts has also imposed significant strains on the socio-economic structure of the country.

In order to combat the many major disasters which have afflicted Bangladesh in recent years, the government has pursued a vigorous programme of disaster management. This programme gave the initial priority to improvement in the forecasting and early warning systems for cyclones and floods, along with emphasis on emergency response and relief. Subsequent initiatives have involved prevention and preparedness measures with a bias towards infrastructure development, such as the construction of coastal dykes and river embankments. More recently, multi-level initiatives are being pursued which include: awareness and education programmes; decentralized planning and community participation in disaster mitigation and response; involvement of NGOs in disaster mitigation and response; and incorporation of disaster management and reduction component in development projects.

Up to the present time, the disaster management programme has been successful in mitigating the effects of water-related natural disasters. For example, the severe 1991 cyclone resulted in the death of 140,000 people and property losses of US$ 2.0 billion. A cyclone of similar intensity to the 1991 event occurred in 1993 and resulted in the loss of only 126 lives. The reduction in the death toll was directly attributable to the improved forecasting and warning services and the provision of cyclone shelters. Although the 1998 flood was the worst in living memory and inundated more than 70 percent of the entire country, the limited number of casualties compared to earlier floods was also attributable to the effectiveness of the disaster management measures implemented over time.

Bangladesh is aware that although the comprehensive control of water-related natural hazards is not entirely possible and the population will have to continue to live with the associated disasters which they bring, continuing effort is required in the development of a national disaster management plan to ameliorate their future impact.

Adequately constructed and equipped cyclone shelters had considerably reduced the number of lives lost to typhoons and tropical cyclones. As a preventive measure, cyclone-resistant designs for dwellings had helped reduce the number of casualties and reduce serious damage to buildings. Progress had been achieved in developing mitigation measures to improve the safety of non-engineered structures such as ordinary dwellings and simple public buildings constructed with local materials in the traditional manner. In some countries of the region there was a need for preparation or review of cyclone resistant design codes for buildings and other engineering structures and for their enforcement, as well as the undertaking of proper arrangements for the infrastructure to be able to deal with natural hazards.

These achievements can be attributed to improved disaster management planning and the initiatives associated with the plan. The most significant initiatives have involved the following: a strengthening of the institutional framework for natural disaster prevention and preparedness by concentrating the overall responsibility for the task into a single agency; a comprehensive revision of the Natural Disaster Countermeasures Act to incorporate comprehensive disaster prevention measures, provision of adequate funding for operational aspects and the encouragement of private participation in disaster mitigation; the placing of greater emphasis on scientific research in the field of disaster prevention; and the formulation of a 5-year Disaster Prevention Plan directed towards the implementation of measures covering afforestation, flood control, disaster prevention and technology development.

To cope with the fact that disasters are becoming more varied and larger in scale, the Korean Government is continuing its efforts in the field of disaster reduction by concentrating on such aspects as: streamlining land development regulations; availability of flood insurance; greater investment in flood control; systematic scientific research for disaster prevention; development of a national disaster management system; and active international cooperation.

Most countries of the region had enacted legislation to provide for the controls and responsibilities necessary to cope with disaster situations. This legislation has permitted the relevant authorities to govern the long-term requirements of disaster prevention and the short-term needs of disaster preparedness. Although statutory controls were available to govern the relevant aspects of community planning and development, including zoning, subdivision controls and environmental issues pertaining to disaster prevention, many Governments were reluctant to invoke them. Many Governments had appointed a central organization to coordinate the disaster mitigation activities of the various government bodies and other interested groups, so that a comprehensive approach was adopted. In certain countries, some of these organizations were established on an *ad hoc* basis only when a natural disaster had occurred or was expected to happen. It was only the more developed countries of the region that had cohesive institutional arrangements in place.

Most countries had upgraded their civil defence capability for the rescue of people from endangered areas, through the mobilization of armed forces or the organization of the local community in response to threats of disaster through cooperative activities involving volunteers. A number of countries had introduced programmes to provide information and educate the public on hazard situations, particularly floods.

2.6.3 The Typhoon Committee

The Typhoon Committee was established by the participating countries under the auspices of ESCAP and WMO and has been functioning and holding annual sessions since 1968. The Typhoon Committee covered a wide range of activities on typhoon-related disaster reduction for which several important initiatives were launched under its framework, particularly those aiming at improving typhoon and flood forecasts. Among the initiatives undertaken, the two most important ones were the Typhoon Operational Experiment (TOPEX) programme and the SPECTRUM (Special Experiment Concerning Typhoon Recurvature and Unusual Movement) which laid down important infrastructure and established human resources and facilities for subsequent contribution to disaster prevention and preparedness. It may be noted that the objective of TOPEX was to carry out, through international co-operation in the prompt and reliable collection and exchange of observational data, an operational test of the functioning of the various systems used for typhoon analysis, forecasting and warning. TOPEX consisted of three components the meteorological hydrological and warning dissemination and information exchange components. TOPEX was an exercise that tested the effectiveness of the totality of the system built up over more than a decade for flood warnings, typhoon warnings and dissemination of information to the public. For flood loss prevention, the Committee had carried out the following activities:

- evaluation of the established system for forecasting and warning of the hydrological effects of floods and/or storm surges by comparison of their outputs with actual observed data in the fields;

- identification of simple deterministic forecasting models used by, or available to services in the typhoon area, selection of specific models for application to each designated area and comparison of the models' results in real-time forecasting operational mode;

- evaluation of separate and/or combined hydrological effects of typhoons, particularly river and storm surge flooding, and thereby determination of associated flood risk.

In parallel, other regular activities have been in operation include:

- operation, maintenance and improvement of existing flood forecasting and warning systems;

- establishment of flood forecasting and warning systems in other river basins;

establishment of pilot areas for comprehensive flood loss prevention and management which included investigation, survey and study of the pilot areas, preparation of comprehensive plans for flood loss prevention and management within the context of overall water resources development of the pilot areas and implementation of selected aspects of the comprehensive plans by stages, if necessary.

In terms of activities for disaster preparedness, the Committee provided assistance in establishment of appropriate national organizations at all levels, and in formulation of plans; improvement of facilities and services for emergency communications; improvement of effectiveness of warnings and community reaction; training in disaster preparedness; improvement of techniques for assessment and reporting of damage and consequent needs; preparation and implementation of pilot projects for pre-disaster planning, including analysis of hazards and resources at all levels, and case studies on such plans and their effectiveness in practice; and development of measures to reduce damage associated with storm surge.

The advent of IDNDR has strengthened the cooperation among the Committee members and also helped enhance awareness on the importance of natural disaster reduction. The membership of the Committee continued to increase from 7 to lately 15, consisting of the Governments of Cambodia, China, Democratic People's Republic of Korea, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Macau, Philippines, Republic of Korea, Singapore, Thailand, United States, Viet Nam and Hong Kong, China.

2.6.4 Example of the WMO/ESCAP Panel on Tropical Cyclones

In parallel with the operations of the Typhoon Committee, the Panel on Tropical Cyclones was also established under the auspices of WMO and ESCAP to promote measures to improve tropical cyclone warning systems in the Bay of Bengal and the Arabian Sea. The Panel aims to direct their common endeavours towards successful implementation of a comprehensive cyclone operational plan to facilitate the most effective tropical cyclone warning system for the region with existing facilities.

As part of the common endeavour, the Panel adopted a comprehensive cyclone operational plan for this subregion. The basic purpose of the operational plan was to facilitate the most effective tropical cyclone warning system for the region with existing facilities. In doing so the plan defined the sharing of responsibilities among Panel countries for the various segments of the system and records the co-ordination and co-operation achieved. The plan recorded the agreed arrangements for standardization of operational procedures, efficient exchange of various data related to tropical cyclone warnings, issue of cyclone advisories from a central location having the required facilities for this purpose, archival of data and issue of a tropical weather outlook for the benefit of the region.

The operational plan contains an explicit formulation of the procedures adopted in the Bay of Bengal and Arabian Sea region for the preparation, distribution and exchange of information and warnings pertaining to tropical cyclones. Experience has shown that it is of great advantage to have an explicit statement of the regional procedures to be followed in the event of a cyclone, and this document is designed to serve as a valuable source of information always available for reference by the forecaster and other users, particularly under operational conditions.

A technical plan aiming at the development and improvement of the cyclone warning system of the region has been drawn up by the Panel. Implementation of some items under the technical plan would lead to a strengthening of the operational plan. The operational plan is evolutionary in nature. It is intended that the text of the plan be updated or revised from time to time by the Panel and that each item of information given in the annexes to the plan be kept up to date by the member country concerned. The plan included a hydrological programme comprising two main components:

i. hydrological network and flood forecasting systems, and
ii. storm surge project.

Cooperation among the members continues to be strengthened with the implementation of these components in addition to work on meteorology. An important point to note in this respect is that through the implementation of the plan, the exchange of hydrological data among the member countries for flood warnings has been greatly improved.

2.6.6 Community Awareness

In many countries of the region it was recognized that the initial and most vital response to a disaster must be at the local level and that the community must be well informed about disaster-preparedness measures and be alert in the time of disaster. It was considered essential that the building of disaster awareness in the general population, starting with the individual, was essential in reducing casualties. In order to promote community involvement in disaster prevention and preparedness, community awareness programmes and educational programmes relating to warning systems and other aspects of disaster preparedness were developed and implemented, and committees that included representatives of non-governmental organizations and the public were established at the local level to monitor and guide disaster-relief operations.

2.7 Case Study: A Review of Flood Mitigation Options

2.7.1 Introduction

The Western Australia Planning Commission and local governments generally seek advice from Water and Rivers Commission (WRC) regarding flood mitigation strategies, either structurally or non-structurally. In general, WRC will weigh between the political and economical impacts against social and environmental impacts on each flood mitigation option and apply the most feasible option that has significant benefit cost ratio, or has the greatest net benefits.

Various flood mitigation options suggested in Busselton, Carnarvon, and Moora have been investigated. The chosen options for mitigation in each town were assessed. Each of these are summarised in the following section.

2.7.2 Flood Mitigation Works at Moora

Moora is a town that has been historically affected by flooding with major flooding occurring in 1917, 1955 and 1963. In March 1999, 180 mm of rainfall fell in the Moore River catchment over a three day period with 320 residences being affected by flooding, and as a result, two thirds of the town was evacuated. The total flood damage was estimated at $ 17 million. In May 1999, 105 mm of rainfall fell over a three day period and major flooding again occurred with 100 residences being affected by flooding. In August 1999 further flooding occurred with 7 houses being affected.

In response to these flood events, WRC conducted studies to review the town's flooding and floodplain management strategies. The study found that the March 1999 flood had an average recurrence interval (ARI) of 100 to 250 years with the May 1999 flood having an ARI of 50 to 100 years.

The study evaluated various non-structural and structural flood management options. Planning and emergency response measures were identified as the most economic measure to reduce the town's potential flood damages. A number of non-structural flood management strategies were recommended including appropriate land zoning, building and development controls, flood-proofing of existing houses, public flood awareness and education and timely flood warnings. It was recommended that the March 1999 flood be used as the benchmark to set future development levels.

The study also assessed seven structural flood management options to lessen the impact of flooding on the town. These included detention basins (Figure 2-5), river diversions with levees (Figure 2-6 & 2-7) and the widening of the Moore River. The most promising option that would significantly mitigate major flooding in the town is a 9 m high wall detention basin located upstream of the town at Longpool and is estimated to cost $ 3.5 million. However, based on an economic evaluation, the benefit cost ratio of this option is only 0.33. The Shire has asked for community feedback on all the structural flood management options.

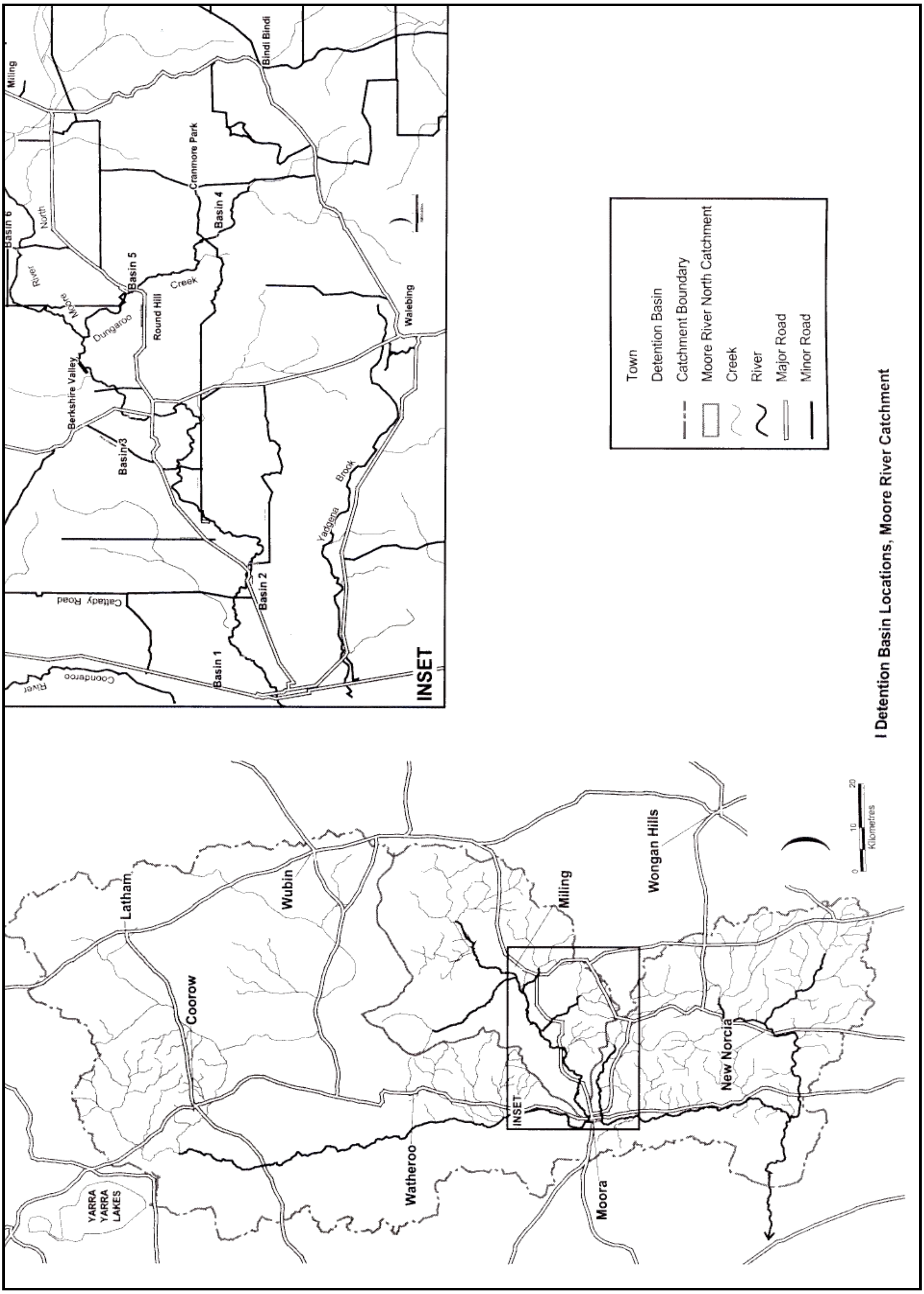


Figure 2-5: Detention Basin in Moora [WRC 2000]

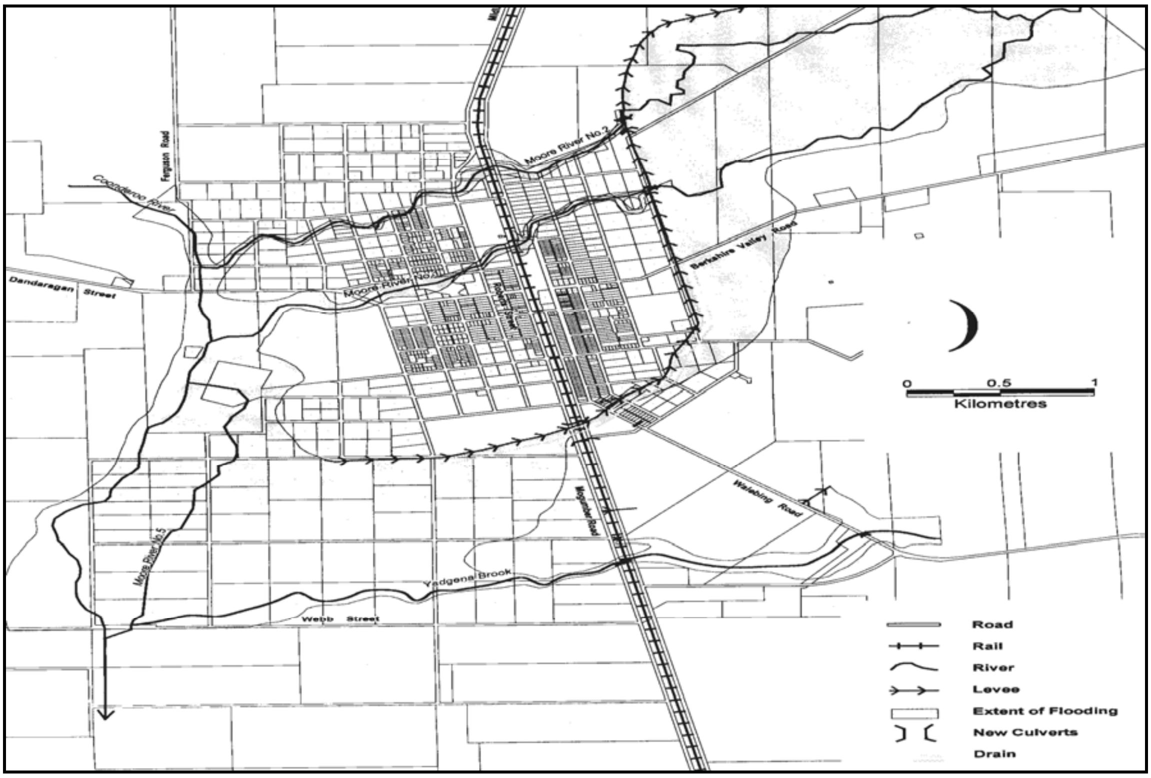


Figure 2-6: Location and Alignment of Southern Diversion Drain and Levee

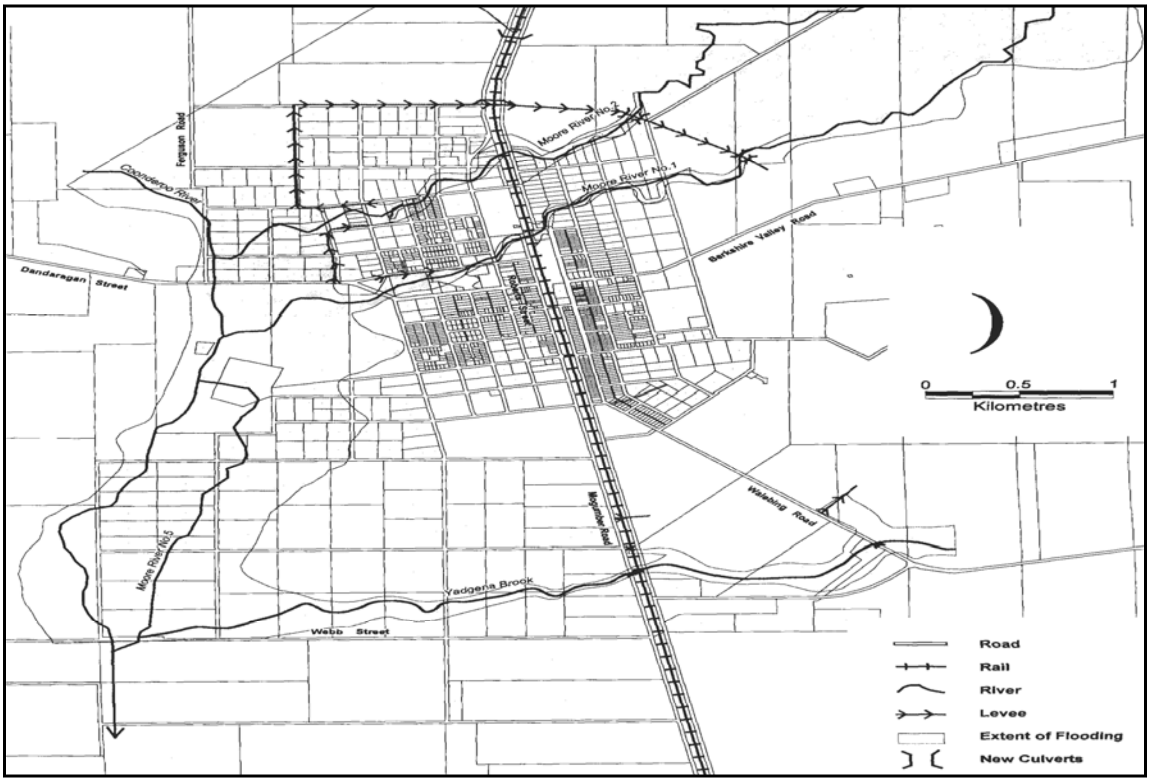


Figure 2-7: Location and Alignment of Northern Diversion Drain and Levee

The Shire of Moora's Council has now adopted the non-structural flood management recommendations and has resolved to further investigate the Longpool detention basin option subject to community feedback. The Shire will be seeking Federal-funding assistance through the Regional Flood Mitigation Programme to carry out a more detailed study of this option. The study would also address the concerns about the salinity / groundwater recharge effect of the detention basin and its potential impact on salinity.

The State Government is providing funding assistance of $163,000 to the Shire of Moora's project of raising 70 houses by re-stumping above the March 1999 flood level. The Water and Rivers Commission has also installed a flood forecasting and warning system for the town.

2.7.3 Busselton Flood Mitigation Works

Busselton is located about 200 km south of Perth. The catchment area included in the study is 280 km^2 with 1 in 100 year ARI flow is 180 m^3/s. The most recent flood was in August 1997 due to 19 hours of rainfall (69 mm–107 mm) at the upper catchment of the Vasse and Sabina Rivers. The peak flow was 128 m^3/s in the Town of Busselton. The original designed Vasse River Diversion Drain to protect Town of Busselton was overtopped with floodwater.

Five flood mitigation options were suggested in "JDA Consultant Hydrologists' Study Review, 1998" for Busselton flood mitigation work as listed below: (Davies. J 1998)

(a) Option 0 = Do Nothing
(b) Option 1 = Upgrade Vasse Diversion Drain (VDD)
(c) Option 3 = Re-divert Upper Sabina River to Lower Sabina River
(d) Option 4 = Partial VDD upgrade and Construct Detention Basin
(e) Option 5 = Partial Upgrade, Construct & Re-divert

Option 1 involved the upgrading of existing VDD to convey the revised 100 year ARI design flood of 188 m^3/s with 0.5 m freeboard. The current VDD's base width of 10 m is only able to provide 1 in 20 year ARI flood protection. It has to be widened to 15 m to accommodate for the 188 m^3/s capacity of flow. The total estimated earthwork is 550,000 m^3 and all existing road bridges and access crossings would remain. Some costs were allowed for improving the inlet and outlet transitions of these structures.

Option 2 involved constructing detention basins in the upper catchment of the Vasse and Sabina Rivers to mitigate the floodwater in Busselton. Detention basins are very effective in managing peak discharge in either urban or rural environment. By providing storage for 50% of the inflow flood volume and having a small control outlet at the basin, the peak discharge can be reduced by about 50%. The sizes of the basin would depend considerably on the topography of the land. The embankment height of 2 m was recommended for the costal plain topography. However, the storage would only be used when major floods occur. There may be potential to use the land for grazing. Detention basins have the potential to reduce nutrient load to the estuaries and ocean by reducing the flow velocity and trapping sediment and nutrient-bound particulates. The basin can be configured to store water for potential irrigation use in summer.

Option 3 involved re-diverting upper Sabina River to Lower Sabina River to reduce the flow in VDD. The catchment area of VDD is approximately 277 km^2 and includes 85 km^2 of the upper catchment of the Sabina River. This would increase the flow in the Lower Sabina River by 250%, and it would not solve the flooding problem in VDD, as the estimated flow at VDD is 135 m^3/s as compared to the 100 m^3/s original design flow for VDD.

Option 4 involved upgrading partial VDD and constructing detention basins, which is to widen VDD to hold 120 m^3/s and construct less detention basin. This option needs significant costs in upgrading the VDD, but fewer problems in acquisition of land to construct detention basin.

Option 5 involved upgrading partial VDD, constructing detention basins, and partial re-divert 14 m^3/s into Lower Sabina River as the Lower Sabina River originally would have had a channel that is capable of carrying more flow.

All the six flood management options were evaluated against technical, economic, social and natural environment factors. The summary of cost is shown in Table 2-1.

If no action was taken (Option 0), the expected damage was $ 21.5 million. Option 1 has the highest implementation cost of $ 6.5 million due to the significant earthworks required for upgrading the VDD to 100 year ARI flow capacity. Option 2 has the highest net benefit ($ 15.8 million), followed by Option 4 ($ 15.6 million), Option 5 ($ 15.2 million) and Option 3 ($ 14.6 million).

Option 2 has least cost of all the feasible options ($ 4.0 M) and gives the highest net benefit of $ 15.8 Million. The highest benefit cost ratio (BCR) is Option 3 due to the low implementation cost. However, it has lower net benefit and has not been considered by WRC as practical implementation option. The detention basins have social impact on landowners, but this would be reduced if basins were configured to integrate with existing land use. There is no environmental impact on water levels in Vasse and Wonnerup Estuaries too.

Table 2-3: Summary of Costs for Various Mitigation Options (Davies. J 1998)

Description	Option 0	Option 1	Option 2	Option 3	Option 4	Option 5
Option Cost ($ M)	0.00	6.53	4.00	0.46	4.21	4.61
Present Value Before Option Implementation ($ M)	21.53	21.53	21.53	21.53	21.53	21.53
Present Value After Option Implementation ($ M)	21.53	1.55	1.73	6.40	1.73	1.73
Expected Damage Reduction ($ M)	0.00	19.98	19.80	15.10	19.80	19.80
Net Benefit	0.00	13.45	15.8	14.60	15.59	15.19
Benefit Cost Ratio	0.00	2.06	3.95	31.74	3.70	3.30

In the conversation with Rick Bretnall of the Water & Rivers Commission WA on 10 October 2003, he mentioned that State Cabinet approved the implementation of the Busselton Flood Protection Project in November 2000. The approved scheme is to construct up to 9 detention basins in the rural catchment of the Vasse River Diversion Drain. At that time the Minister for Water Resources advised that land for the basins would be purchased only by commercial negotiation with interested landowners and not by compulsory acquisition. A total cost of "around $ 10 Million" was estimated, with the qualification that the final cost would depend on land availability and prices.

Two detention basins have been built, and land for a third basin was acquired in May 2003. Although a number of planning and design issues remain to be resolved, it is now expected that only four detention basins will be required to complete the scheme.

The first detention basin, located on the Vasse Research Station site, was completed in June 2001. A second detention basin, located on the Vasse River near Doyle Road, was completed in May 2003. Together, these two basins provide 45% of the design flood storage capacity for the scheme. Once the detention basin network has been completed, it will attenuate the 1 in 100 year ARI flow to 100 m^3 and Vasse River Diversion is able to cope with this flow. The locality of the revised detention basins and the river system in Busselton is shown in Figure 2-5.

2.8 Case Study: Evaluation of Flood Damages in Carnarvon and Moora

2.8.1 Introduction

Flood damages have been used as an estimate to evaluate the impact of flooding from the economic factor. The damages calculated are from tangible damages such as residential, commercial, agriculture and infrastructure damages. Town of Carnarvon and Moora had assessed the flood damages using different method. Carnarvon used Rapid Appraisal Method (RAM), (Porter 2002) and Moora used MIKE 11 [WRC 2000] to assess the damages caused by flooding.

2.8.2 Residential Damages

The source of information such as number of residential properties can normally be obtained from the Shire or the Council. However, insurance company also can provide the insured value of each house.

<u>March 2000 flood in Carnarvon</u>	
Rapid Appraisal Method (RAM) suggest	$ 20,500 per house
Total residential damage	= $1.54 million
<u>March 1999 flood in Moora</u>	
Estimated residential damage by Shire of Moora	= $ 6.0 million
Re-evaluated by Water Studies Pty Ltd	= $ 4.5 million

2.8.3 Commercial Damages

Direct commercial damages were subjected to properties and stocks concentrated in a district area. Property damage included offices, caravans, paving and landscaping, fences, power connections, furniture, machinery and equipment.

Indirect damages like depressed trade for weeks, limited trading because loss of access, amenities, accommodation and clean-up cost were valued.

March 2000 flood in Carnarvon

Direct damages	=	$ 2.7 million
Indirect damages	=	$ 0.14 million

March 1999 flood in Moora

Total commercial and industrial damages, estimated by WRC

	=	$ 3.6 million
Re-evaluated by Water Studies Pty Ltd	=	$ 2.3 million

2.8.4 Agricultural Damages

Conversation has been made to Mr. Ian Kinamonth from Agriculture Department on 14 July 2003 regarding agriculture damages, and the reply was: "*Agriculture Department is responsible for administering emergency relief approved by State government for replacement of topsoil eroded from plantation areas during floods.*"

March 2000 flood in Carnarvon

Total replacement cost for soil loss	=	$ 1.75 million
Soil replacement	=	$ 1 per m^3

According to Department of Agriculture records, 164 ha of plantation land were eroded on 132 properties. The volume of soil replaced was 332,400 m^3 with an average depth of 0.2 m.

Machinery hiring cost	=	$ 1.42 million
Total loss of production (estimated)	=	$ 6.0 million
Structural and Equipment damages	=	$ 0.7 million
Reestablishment and clean-up	=	$ 0.72 million
The total estimated agricultural damages	=	$ 9.17 million

This cost included direct and indirect damages and these were actual damages not potential damages. Therefore, the damage was a realistic estimate.

March 1999 flood in Moora

The direct damage predicted to rural farm properties was well in excess of $ 1.0 M. The total estimated agricultural damage was not mentioned.

2.8.5 Infrastructure Damages

Main Roads WA has a reasonable good estimate of the cost of repair for freeway, highway and main roads. The Shire would provide costs of repairs to local roads. Western Power is unable to provide any numbers as repairs are categorised under general maintenance. Telstra and Water Corporation have a special account to identify post-flood repairs and restoration of services.

March 2000 flood in Carnarvon

Roads	=	$ 3.76 million
Power (electricity)	=	$ 0.1 million
Telecommunication	=	$ 0.25 million
Water supply and sewerage	=	$ 0.55 million
Total Infrastructure Damage	=	$ 4.66 million

March 1999 flood in Moora

Estimated public authority and utility damages by Shire of Moora

= $ 1.0 million

Re-evaluated by Water Studies Pty Ltd = $ 0.8 million

2.8.6 Cost of Response and Recovery

State Emergency Service relies upon the support of volunteers. The cost includes accommodation cost for external volunteers, helicopter and other expenses associated with response and recovery activities. Therefore, it is reasonable to allow 5% of total damages for cost of response and recovery.

2.8.7 Tangible and Intangible Damages

From the estimates of past history flood damages study in Carnarvon and Moora, the costs can be compared and evaluated based on the intensity of the flooding. Table 2-2 shows the breakdown of the tangible costs incurred to Carnarvon 2000 flood and Moora 1999 flood.

Table 2-4: Summary of Damage Estimates for Carnarvon Flood & Moora Flood

Type of Damages	Carnarvon 2000 Cost of Damage	Moora 1999 Cost of Damage
Residential	$ 1,540,000	$ 4,500,000
Commercial	$ 2,820,000	$ 2,300,000
Agricultural	$ 9,170,000	Not Included
Infrastructure	$ 4, 660,000	$ 800,000
Response & Recovery (@5%)	$ 910,000	Not Included
TOTAL DAMAGE	**$ 19,100,000**	**$ 7,600,000**

In addition to these tangible damages, there are the intangible damages. Items such as loss of life, trauma, depression and feeling of powerlessness, family stress, break-up of relationships, and health problems can affect the community and spread wider through community especially on economic hardship. For those directly affected or experienced, concern about the flood happening again can lead to residual lack of confidence and uncertainty about planning for the future.

It is difficult to place a value on the adverse effect of flooding. In considering the benefits of mitigating the effects of floods, intangible damages should also be remembered. However, the costs shown in Table 2-2 only incorporate tangible cost.

2.8.8 Summary

The background knowledge and both case studies discussed in this chapter would have provided enough background knowledge and information especially on flood damage and floodplain management options. These sections will be further covered in Chapter 5 and Chapter 6 after the background chapter of Pinjarra and evaluation of current floodplain management in Pinjarra.

3 MURRAY RIVER, PINJARRA BACKGROUND

3.1 Introduction

After a general understanding of floods from previous chapter, this chapter covers the background to this research project. The project study area is Pinjarra Townsite and more specifically Greenlands and Fauntleroy Drains.

The catchment areas for Murray River and both Greenlands and Fauntleroy Drains are discussed first. Then, the rainfall pattern and history of flooding in Pinjarra is studied. The hydrology and hydraulics study of Murray River which had been completed by Public Works Department in 1984 (George 1984) and Sinclair Knight Merz in 1999 (Davies 1999) will be compared and used in the research project. The data from the recent study of Peel Deviation by GHD Consultants (Tucak 2003) regarding the catchment areas in Greenlands and Fauntleroy Drains has been be used in this project. The data on history flood and the estimation of design flood discharges are plotted on a hydrograph. Designated flood levels for Pinjarra Townsite are evaluated for assessment of flood damage in Chapter 5.

3.2 Background to Pinjarra Flood Study

Public Works Department (PWD) completed a flood study and floodplain mapping of the Murray River in 1984. In December 1999, Sinclair Knight Merz produced the Murray River Flood Study Review. The revised 100 year peak flow rate at the Baden-Powell gauging station from flood frequency analysis using additional available data was 1,014 m^3/s compared with 1,250 m^3/s in 1984 study. The 100 year peak flow rate in Pinjarra Townsite had reduced from 1,273 m^3/s to 935 m^3/s. However, Water and Rivers Commission (WRC) completed another comprehensive hydrological review in 2000 and claimed that the flow had increased from 1,273 m^3/s to 1415 m^3/s in Pinjarra Townsite. The increase in flow also translated to a water rise of 0.10 m.

For the purpose of this study, the latest available data from WRC is used in the hydrology analysis and the flood damage assessment using the recommended 1 in 100 year ARI flood levels annotated in the 1984 Murray River Flood Study. The study area extends from intersection of South Western Highway with Greenlands Road to the Peel

Inlet. Murray River also forms part of the study area but was not investigated to the same degree as Greenlands and Fauntleroy Drains.

The locality of Pinjarra from Perth CBD is shown in Figure 3-1. Figure 3-2 shows the aerial view of Pinjarra Townsite, approximately 10.5 km^2 and population of 10,924 (Census 2000). The research project area is shown in Figure 3-3.

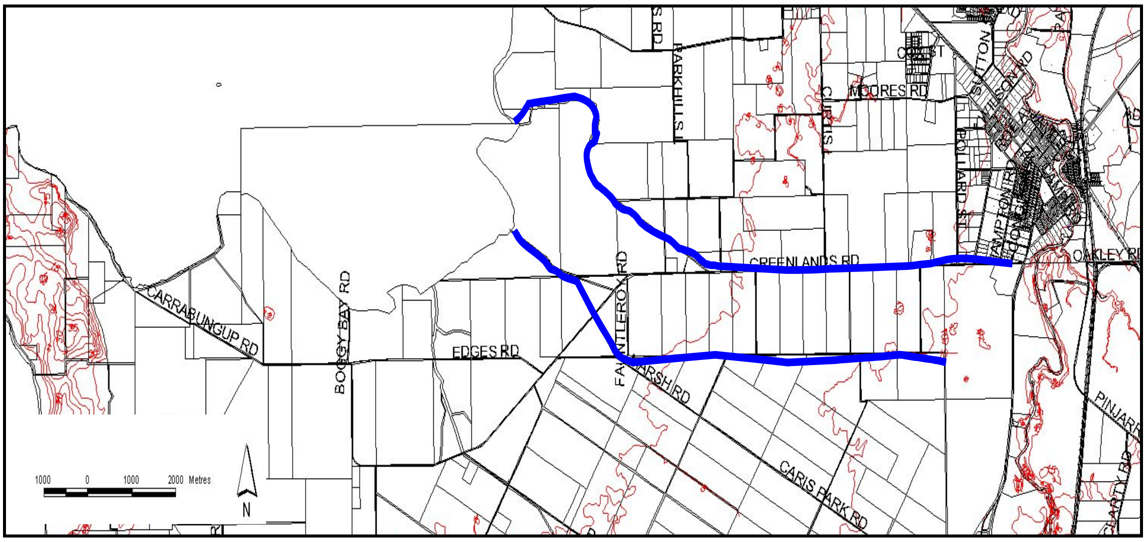


Figure 3-1: Research Project Area (Greenlands and Fauntleroy Drains

Figure 3-2: Aerial Photograph of Pinjarra Townsite

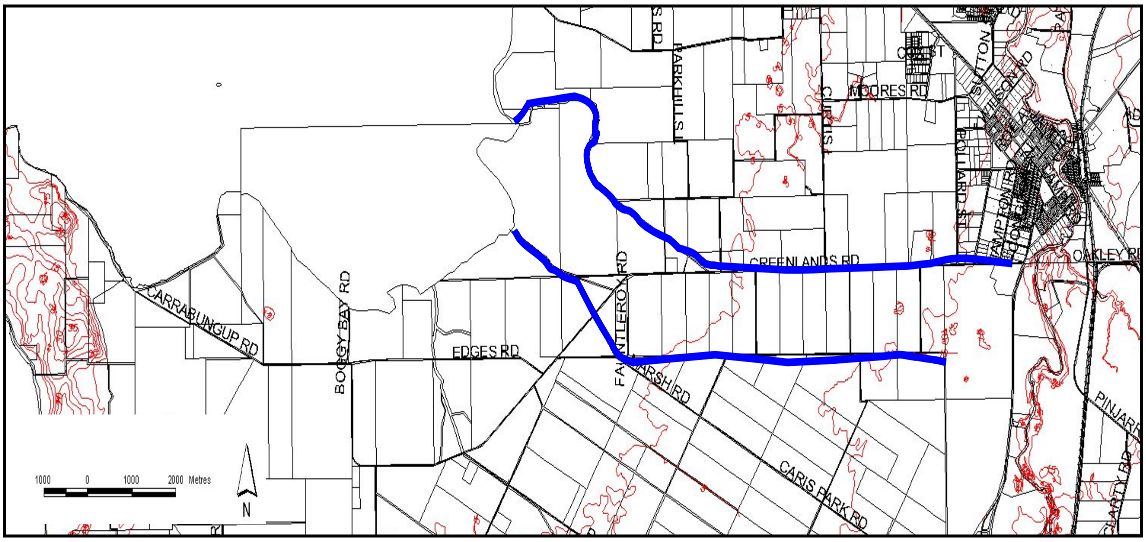


Figure 3-3: Research Project Area (Greenlands and Fauntleroy Drains)

3.3 Catchment and Data Description

3.3.1 Murray River

The Murray River Catchment is located in the south west of Western Australia. It extends about 150 km east from Mandurah as is shown in Figure 3-4.

In Murray River Study Review (Davies 1999, p.6) the catchment in Murray River has been described as such: "*The catchment area is 7,670 km^2 of which approximately 500 km^2 is dammed (North Dandulup and South Dandulup Dams). The headwaters consist of the Hotham and Williams Rivers situated in the wheat belt region. The downstream reaches form-braided channels that discharge into the Peel Inlet, a large estuary just south of Mandurah and east of Pinjarra."*

"The catchment has average annual rainfall varies from about 500 mm in the upper catchment to 1,300 mm over the escarpment. The geomorphology is typically low to moderate relief, undulating to dissected plateau with lateric soils over Archean granite and gneissic rocks."

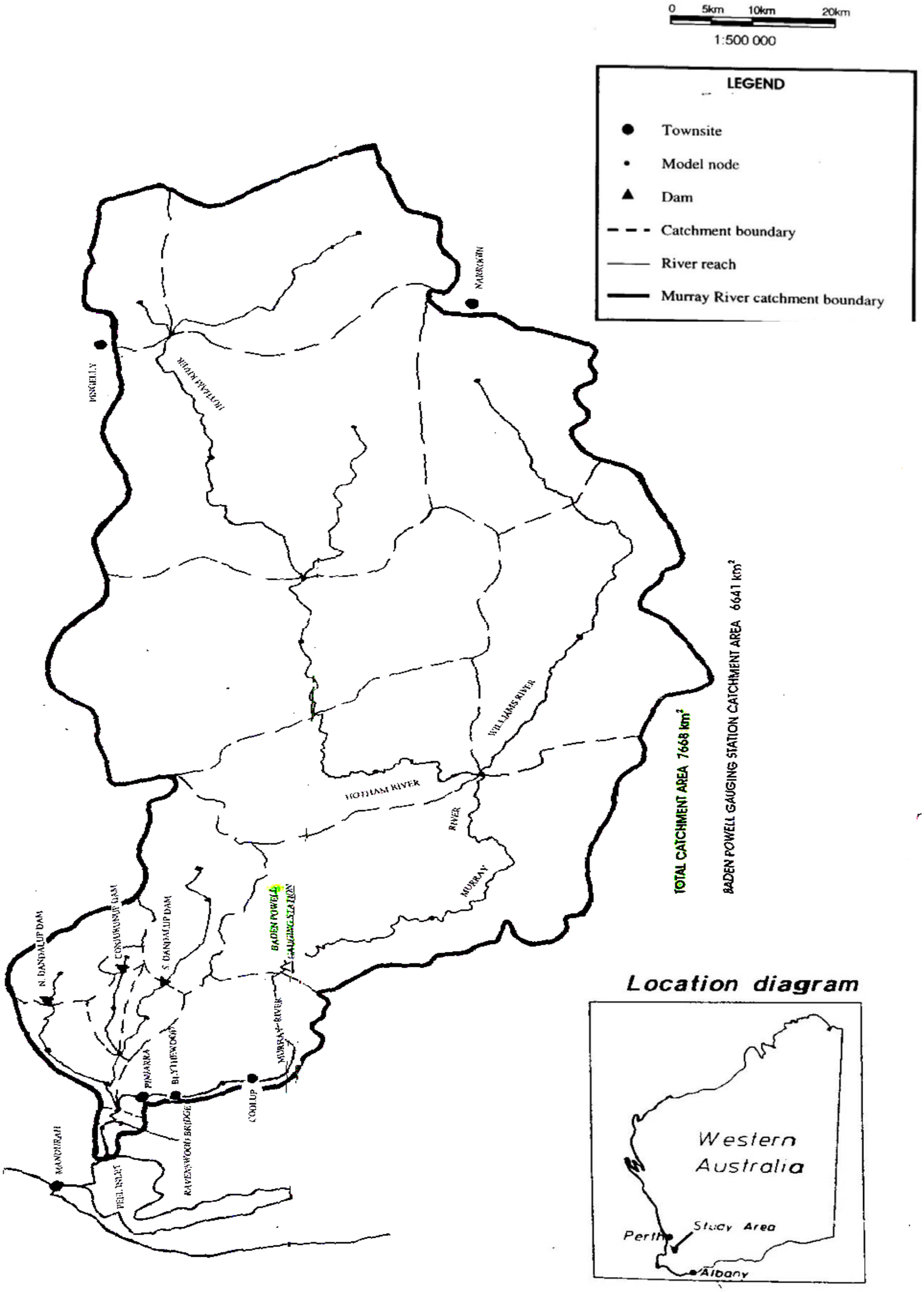


Figure 3-4: **Catchment Area of Murray River**

The land use in Shire of Murray is typically made up of 47% of state forest, 35-40% of cleared areas for grazing and 12% urbanization in the lower reaches.

Davies further described the vegetation around the catchment area in Murray River: *"The natural vegetation consists of Jarrah – Marri Forest on uplands, Marri-Wandoo Woodlands in valleys and Wandoo-York gum Woodlands on dissected laterite in the upper catchment. Roughly 75% of the Murray River catchment has been cleared. Valley clearing and broad acre clearing occurred from the 1980's and 1950's respectively."* (Davies 1999, p.6)

There are numerous streamflow-gauging stations centred in the lower reaches of the catchment. Baden-Powell Waterspout Streamflow Gauging Station (614 006) has the longest period of record (1940 to 1988). It is located at the lower portion of the catchment as shown in Figure 3-4.

The laboratory and site testing on the quality of water of Murray River had been carried out during January 2003. Several stations along Murray River were tested on temperature, pH, Conductivity, Salinity, Oxygen concentration, Turbidity and Bacteria (Thermotolerant Coliforms and Enterococci). The result proves the quality of water in Murray River is above the Health and Safety Requirement. Water & Rivers Commission (Mandurah) and Shire of Murray regularly monitor the water quality in Murray River. Results from a typical water sampling are shown in Appendix A.

3.3.2 Greenlands and Fauntleroy Drains

Greenlands and Fauntleroy Drains are located approximately 2.2 km south west of Pinjarra Townsite. Greenlands Drain at present is divided into two sections. The first section of the drain flows from South-Western Highway and turns into Curtis Lane towards South Yunderup and Peel Inlet. The second section starts from Curtis lane intersection and ends in Peel Inlet. The catchment area of Greenlands Drain is 1.4 km^2, from the second section of the drain only (Tucak 2003).

The Fauntleroy Drain has a catchment area of 22.53 km^2. (Tucak 2003) It is situated 1.2 km south of Greenlands Drain. The drain extends from Blythewood (50 m north-west of North Coolup Drain) and ends in Peel Inlet.

The land between both drains is cleared farmlands with seven residential properties. There are 500 hectares of CALM land near the outlet of the drains.

The climate and type of soil are similar to Murray River catchment. However, catchments are usually running full in wet season due to the average annual rainfall of 197 mm and the rise of groundwater.

3.3.3 Rainfall in Pinjarra

Bureau of Meteorology (BOM) has been keeping the rainfall data since 1877. For the purpose of this research, the average monthly rainfall from 1877 to 2003 was plotted against monthly rainfall in 2003 and 1945 as shown in Figure 3-5. The flood flow in 1945 was 731 m^3/s, which had a 1 in 30 year ARI magnitude.

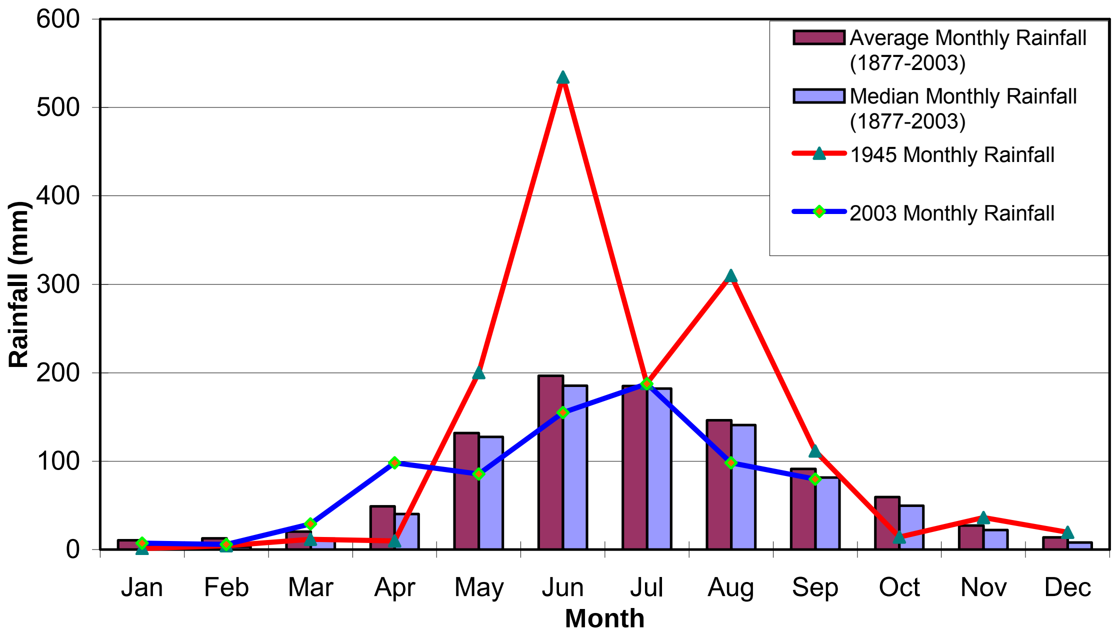


Figure 3-5: Relationship of 2003 Monthly Rainfall to 1945 Monthly Rainfall and Average Monthly Rainfall (1877-2003)

The rainfall recorded in Pinjarra for year 2003 (up to September) was considered as moderate, besides month of April, as the rain intensity is high. The rainfall pattern for year 1945 was very high, where rainfall escalated in May and June 1945 with the highest recorded rainfall of 534 mm. This has proven the significance of rainfall towards flooding.

3.3.4 History of Flooding in Pinjarra

Pinjarra has experienced flooding from the Murray River. Anecdotal flood levels prior to 1940 were recorded at two locations in Pinjarra. In 1862, a flood level of 9.5 m AHD was recorded at Saint John's Church. In 1904 and 1920 flood levels of 5.9 m AHD and 6.1 m AHD respectively were recorded at Pinjarra Bridge. The floodplain downstream of Saint John's Church has undergone changes but these have been limited to clearing. The flood levels at Saint John's Church were adopted to estimate historical peak flow rates.

The most severe flooding with recorded data was in June 1945 where Pinjarra Townsite was entirely flooded as shown in Figure 3-6. The flood flow of 731 m^3/s had 1 in 40 year ARI magnitude and caused a lot of damage. The actual total amount of damage was not recorded. The level of flood was 8.75 m AHD (RL 131.46 – datum) marked on the church wall as indicated in Figure 3-7.

Figure 3-6: Flooding Around St John's Church, Pinjarra – June 1945 (Richards, cited in George 1984)

Figure 3-7: Sign Attached on the Church Wall as a Reminder

The occurrence of the floods in Pinjarra and its severities has been summarized in the Table 3-1.

Table 3-1: Floods event in Murray River and its severity, from Murray River Flood Study 1984, Review 1999 & Water & Rivers Commission 2003

Year	Flow (m^3/s)	Annual Recurrence Interval (year)
1862	1553	120
1904	193	< 7
1920	220	< 7
1933	46.5	< 7
1945	731	40
1964	566	15
1982	348	7
1996	350	7

Disruption to social and commercial activity in and around Pinjarra commences with moderate flooding in flood event of greater than 1 in 10 year ARI. Major floods can cause substantial damage to infrastructure in Pinjarra Townsite. Loss of horticultural production from the farming areas can be severe, depending on the season, and loss of topsoil means that substantial costs are often incurred to rehabilitate productive land.

3.4 Design Flood Discharge and Flood Level Estimation

Section 3.4 describes the estimation of design discharges in Murray River Catchment. The estimation of design discharges was analysed by PWD in 1984, and incorporated with the most recent data provided by SKM 1999 and WRC 2000.

3.4.1 Hydrology of Murray River

The average rainfall varies from about 500 mm in the upper catchment to 1,300 mm over the escarpment (Davies 1999).

The 1984 Murray River Flood Study used flood frequency analysis and the 1999 Murray River Flood Study Review used RORB modelling. It was agreed with Shire of Murray that these values would be adopted without the requirement to complete an independent assessment of the hydrology in Pinjarra.

Methodology adopted for estimation of design flood discharge

Estimation of design flood discharges for large catchments such as the Murray River Catchment is generally undertaken using either flood frequency analysis, or a rainfall-based technique such as runoff routing.

Flood frequency analysis has the advantage of incorporating variability in all catchment processes. However, a large body of stream flow data is required to obtain confident estimates of design discharges for extreme events. Furthermore, the results cannot be transposed to other locations within the catchment. In contrast, runoff-routing models can provide design discharge estimates at different locations within a catchment, rather than at a single stream gauge location.

Flood Frequency Analysis by PWD in 1984

The methodology used by PWD was similar to Australian Rainfall and Runoff (Pilgrim 2001) to fit log-normal and log-Pearson Type III distributions to the annual series of recorded peak flood discharges at Baden Powell Water Spout (Gauging Station No. 614006). The highest peak instantaneous flow recorded at the Gauging Station is 718 m^3/s. the flood frequency analysis indicates that this magnitude of flow has an average recurrence interval of 40 years.

Based on the two curves, Log-Normal was found to be more representative as an average of the recorded flows above 500 m^3/s while the Log-Pearson Type III was a good average representation of recorded flows below 300 m^3/s. Therefore, the Log-Normal distribution was adopted in the calculation of flood discharge. *(George 1984)*

The catchment area to the gauging station at Baden Powell is 6641 km^2. To allow for the flow contribution from additional catchment areas downstream of the gauging station, the relationship shown in Equation 3-1 is generally applied to forested catchments in the southwest of the state like Murray River catchment.

$$Q_1 = \left(\frac{A_1}{A_2}\right)^{0.7} \times Q_2 \qquad \textbf{(Equation 3-1)}$$

where Q_1 = Peak instantaneous flow at gauging station
Q_2 = Peak instantaneous flow at downstream location
A_1 = Catchment area to gauging station
A_2 = Catchment area to downstream location

Based on these relationship, instantaneous peak discharges relating to various flood events, both historical and statistical, were calculated and the results are shown in the Table 3-2.

Table 3-2: Flood Frequency of Various Flood Events (George 1984)

Flood Recurrence Interval based on Log-Normal Curve	Catchment Area = 6641 km^2	Catchment Area = 7668 km^2
	Peak Discharge at Baden Powell Station (m^3/s)	**Peak Discharge between South Dandulup River & Peel Inlet (m^3/s)**
7 YEAR ARI	348 (JAN 82)	330
10 YEAR ARI	430	476
16 YEAR ARI	555 (AUG 64)	614
20 YEAR ARI	620	686
25 YEAR ARI	690	763
26 YEAR ARI	718 (JUN 45)	794
50 YEAR ARI	960	1062
100 YEAR ARI	1250	1382

The peak discharges given in Table 3-2 for the January 1982 flood were not calculated by the method of aerial transposition given above but were based on river gauging at the gauging station and at Ravenswood Bridge. The method could not applied for that particular flood event partly because of the extremely dry state of the catchment prior to the 'flood-producing' rainfall, most of which occurred over a period of two days (Jan 21 & 22). Furthermore, as the flood wave moved down the river with no additional rain occurring on the catchment, channel storage played a significant part in attenuating the peak discharge as indicated by the discharge values shown in Table 3-2.

Runoff-Routing RORB Model by SKM 1999

The model RORB (Laurenson and Mein, cited in Davies 1999) is one of the most widely used runoff-routing techniques in Australia which divide the catchment into sub-catchments. A loss model is used to calculate rainfall excess hyetographs for each sub-catchment. These hyetographs are then routed through a conceptual storage model to produce surface runoff hydrographs. The storage discharge relationship shown in Equation 3-2 was formed in SKM's Murray River Flood Study Review 1999 from Australian Rainfall & Runoff (ARR87) (Jenkins 1998).

$$S = 3600KQ^m \qquad \textbf{(Equation 3-2)}$$

where S = storage in m^3
Q = discharge in m^3/s
m = constant relating to catchment non-linearity = 0.8
K = constant relating to catchment storage effects = k_ck_r
k_c = empirical coefficient = 227
k_r = relative delay time

Using the above parameters in the runoff coefficient, the RORB model adjusted to reproduce the flood frequency peak flow at the Baden Powell Waterspout Gauging Station. A runoff coefficient of 0.32 was found to reproduce the 100 year flood frequency peak flow at the gauging station. The storage levels in dams were estimated to be at median levels prior to the storm events to avoid calculating joint probability events and the result was presented in Table 3-3.

Table 3-3: RORB Modelling Result (Davies 1999)

Location	Catchment Area (km^2)	Critical Duration (hours)	Peak Flow (m^3/s)
Baden Powell	6641	36	1013
Pinjarra Townsite	6818	72	935
Peel Inlet	7668	72	940

Comparison between PWD and SKM's Hydrology Analysis

The main difference for the peak flow calculation between the two studies is the location for modelling. PWD used Baden Powell station to calibrate the flow data for 1984 flood study, while SKM used Pinjarra station to calibrate the flow data in 1999. The RORB hydrologic routing model has been developed for the Murray River catchment in Pinjarra since 1992. The calibrated data on RORB model in 1992 showed that there is some attenuation (reduction) between Baden-Powell and Pinjarra. However, the reduction in peak flow is probably not more than 5%. This would indicate that the flood frequency values might be reduced by approximately 5% to estimate the flood frequency at Pinjarra. SKM also believes the dam catchments had an insignificant effect on the peak flow rates in Pinjarra and at the Peel Inlet. In addition to that, the calibration of k_c and m based on historical flow rates and rainfall data is not required for this study, as ARR 87 gave a sufficient level of accuracy.

Hence, the Water & Rivers Commission (WRC) re-assessed the peak flow for a 1 in 100 year ARI event at the Pinjarra station using RORB modelling in the year 2000. WRC concluded that the peak flow was 1415 m^3/s for 1 in 100 year ARI flood event. Taking into account of today's cleared catchment or change in land use and efficient drainage system, WRC recommended that the 1 in 100 year ARI flood levels determined in the 1984 Murray River Flood Study would still be used as the basis for establishing minimum building floor levels to ensure adequate flood protection to future development.

Flood Hydrographs

Hydrographs of the Murray River recorded at the gauging station for the floods of 1964 and 1967 were examined in 1984 PWD Study. The flood of August 1964, being the larger of the two records, was used to estimate the hydrograph at the Peel Inlet by graphical means. The 100 year flood hydrograph was estimated by scaling up from the 1964 flood hydrograph using the ratio of the peak discharges of the two floods. The comparison for the 100 year flood hydrograph between PWD 1984, SKM 1999, and WRC 2000 is also included in the hydrograph as indicated in Figure 3-8.

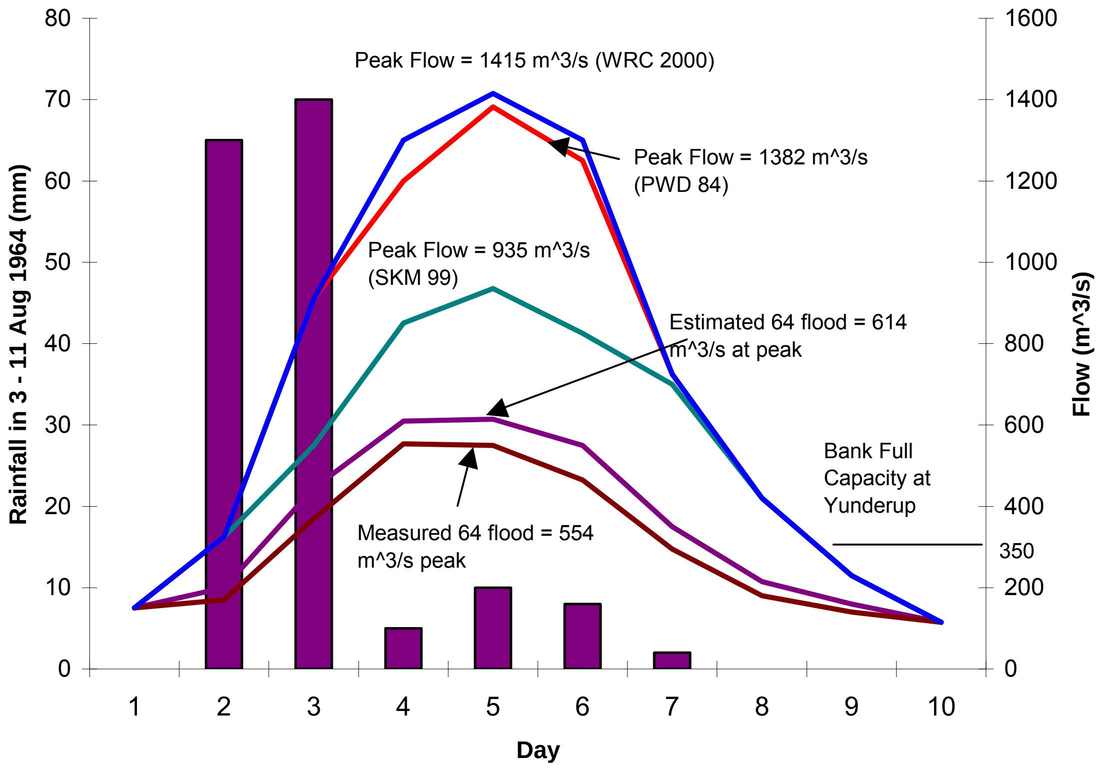


Figure 3-8: Estimated 100 year Flood Hydrograph in Pinjarra

3.5 OPEN CHANNEL HYDRAULICS THEORY

3.5.1 Physical Hydraulic Elements

a. General.

The physical hydraulic elements concerned in hydraulic design of channels consist of invert slope (So), cross-sectional area (A), wetted perimeter (P), and equivalent boundary surface roughness (k). The hydraulic radius (R) used in resistance formulae is the ratio A/P. The invert slope of proposed channel improvement is controlled primarily by elevations of the ground along the alignment as determined by preliminary layout. A center-line profile between controlling elevations along the proposed alignment will indicate a preliminary channel slope

b. Channel cross section.

The proper channel cross section for a given reach is the one that has adequate hydraulic capacity for a minimum cost of construction and maintenance. The economics must include the costs of right-of-way and structures such as bridges. In rural areas a trapezoidal cross section may be least costly, whereas in urban areas a rectangular cross section is often the least costly.

C. Roughness.

The concept of surface roughness as the basic parameter in flow resistance is almost universally accepted. Absolute roughness is determined from the physical dimensions of the wetted surface irregularities and is normally of theoretical interest only. Equivalent roughness is a linear dimension (effective roughness height) directly related to the boundary resistance of the channel.

d. Composite roughness.

Where there is material variation in roughness between various portions of the wetted perimeter that might be found in natural channels or channels with protected banks and natural inverts, an equivalent or effective roughness or friction coefficient for each stage considered should be determined.

e. Hydraulic efficiency.

The problem of the most efficient cross section is treated by Brater and King (1979) and Chow (1959)

3.5.2 Hydraulic Design Aspects

Material.

The use of k is emphasized herein because computational results are relatively insensitive to errors in assigned values of k . However, use of Manning's n has been retained in several procedures because of its wide acceptance and simplicity of use. This applies particularly to varied flow profiles, pulsating flow, and the design of free-surface hydraulic models.

Friction losses.

(1) The importance that friction plays in the determination of flow characteristics in channels cannot be overstressed. Three equations (Chezy's, Manning's, and Darcy's) are in general use for the determination of losses due to friction. These equations expressed as friction slope S_f , i.e., slope of the energy grade line, are

(a) Chezy

$$S_f = \frac{V^2}{C^2 R} \qquad (3\text{-}3)$$

(b) Manning:

$$S_f = \frac{V^2 n^2}{2.21 R^{4/3}} \qquad (3\text{-}4)$$

(c) Darcy:

$$S_f = \frac{fV^2}{8Rg} \qquad (3\text{-}5)$$

where

V = Velocity

C = Chezy coefficient

f = Darcy-Weisbach resistance coefficient

g = acceleration of gravity

The relation between the coefficients in these equations can be expressed as

$$\frac{C}{1.486} = \frac{R^{1/6}}{n} = \frac{10.8}{f^{1/2}} \qquad (4\text{-}6)$$

(2) When determining friction coefficients, it should be recognized that the energy grade line and therefore the friction coefficient include uniformly occurring turbulence and eddy losses as well as the friction loss. Equivalent roughness for the same reason. Special, locally occurring turbulence and eddy losses are to be determined separately.

Friction coefficients.

The equations for using equivalent roughness to determine friction coefficients are:

(a) For hydraulically smooth channels

$C = 32.6 \log_{10} [5.2R_n /C]$ (3-7)

(b) For hydraulically rough channels

$C = 32.6 \log_{10} [12.2R/k]$ (3-8)

where R_n is the Reynolds number.

(b) For the channel surface to be hydraulically

smooth, the equivalent roughness must be less than the critical value Chow (1959).

$k_c = [5c/\sqrt{g}][V/V]$ (3-9)

where V is the kinematic viscosity of water.

Most channels (including concrete-lined channels) with appreciable velocity are hydraulically rough.

To prevent undesirable undulating waves, ratios of flow depth to critical depth between 0.9 and 1.1 should be avoided where economically feasible Chow (1959). These values will normally be much larger than the spherical diameters of the bed materials to account for boundary irregularities and sand waves. When friction coefficients can be determined from experienced flow information, k values should then be computed using the relations described in Equation 7-3. The k values so determined apply to the surfaces wetted by the experienced flows.

3.5.3 Flow classification.

There are several different types of flow classification. Those treated in this paragraph assume that the channel has a uniform crosssectional rigid boundary. The concepts of tranquil and rapid flows are discussed in (i) below. The applicability of the newer concepts of steady rapid flow and pulsating rapid flow to design problems are treated in (ii) below.

All of these concepts are considered from the viewpoint of uniform flow where the water-surface slope and energy grade line are parallel to the bottom slope. Flow classification of nonuniform flow in channels of uniform solid boundaries or prismatic channels is discussed in (iii)

below. The design approaches to flow in nonprismatic channels are treated in other portions of this manual.

(i) Tranquil and rapid flows.

(a) The distinction between tranquil flow and rapid flow involves critical depth. The concept of specific energy H_e can be used to define critical depth. Specific energy is defined by

$H_e = \alpha V^2/2g$ (3-10)

Where

α= energy correction factor

$V^2/2g$ = velocity head

It may be noted that the critical depth occurs when the specific energy is at a minimum. Flow at a depth less than critical ($d < dc$) will have velocities greater than critical ($V > Vc$), and the flow is described as rapid. Conversely, when $d > dc$ and $V < Vc$, the flow is tranquil.

3.6 Hydraulic Analysis in Murray River

Hydrological analysis was used to map the extent and depth of flooding during design floods of 1 in 10, 25, 50 and 100 year ARI. The hydraulic analysis assists in evaluating structural mitigation options and effectiveness of the current floodplain management.

Hec-Ras - Open channel hydraulic modelling software developed by United States Army Corp. of Engineers. The function of the Hec-Ras model is to calculate water surface profile in rivers and streams. The software has the capability of modelling hydraulic structures such as bridges, culverts and weirs therefore the effect of these structure can be analysed.

During the set-up of the model different types of data were required, these data come from different sources and in different format therefore different tools such as ArcView to transform data into Hec-Ras format were required.

3.6.1 Geometric Data:

Geometric data consist of connectivity information for the stream system, cross-sectional data and hydraulic data. Geometric data is developed by first drawing the schematic diagram of the river system. The river system is a diagram of how the stream system is connected together on a reach-by-reach basis from upstream to downstream. Each reach is identified with a river name and a reach name. Each Reach must have at least two points defining the start and end of the reach. In addition to river reach, storage areas, storage area connections and pump station can be drawing into the network. The Geometric diagram shown in figure 3-9 consist of the following:

- Reach: The primary stream network which is the portion of the channel within the river to be modelled that receive run-off from various areas. A primary stream which extended for approximately 3.0 kilometres south west of Greenlands Road was created as shown in Figure 3-9**.** The schematic diagram consist of a single reach with 18 points at a distance of 150m to give more description to the shape of the river.

- Cross-sections: cross-sections are needed to describe the geometry of the channel and its adjacent flood plain. At the points along the reach details describing the X & y coordinates are entered in a tabular format. The **X & Y** coordinates represent the station and elevation of the cross section. Cross-section stationing must be in increasing order. Cross-sections were located at a distance of 150m perpendicular to the primary stream net work. Figure 3-9 indicate the stations numbered from 1 to 18 where cross section across the main stream channel were performed. Manning's "n" values and contraction and expansion coefficients are in the same table.

  In general cross-sections are required at representative locations throughout the stream and at locations where changes occur in discharge, slope, shape, roughness, at locations where levees begin and end and at hydraulic structure.

- Flow length: Hec-Ras requires an average flow length between cross-sections. The flow length should cover a line that represents the right over-bank flow, the channel flow, and the left over-bank flow. Flow length could be determined from topographic information and filed survey.

- Boundary Conditions: Internal and external boundary conditions will be needed in the modelling. Internal boundaries exist at a junction between the downstream end of one reach and the upstream end of a second reach. External boundaries exist at the primary stream network and at a down stream end of the lowermost reaches of the primary stream network main channel. The boundary conditions above are required to compute super-critical water surface elevation and sub-critical water surface elevation.

- Manning's (n) Values: Multiple Manning's (n) value can be assigned to each cross-section in Hec-Ras. For the main channel an initial value will be assigned and then will be adjusted depending on the stream order and field observations. For the overbanks a polygon shapefile of (n) value will be created using the aerial photography, *Methodology for hydraulic Model Development, Northeast Johnson County Water shed Study (The Larkin Group Nov. 2001).*

- Where required Bridges and Culvert details could also be entered.

3.6.2 Hydrologic data

Peak flows for 10, 25, 40, 50 and 100 years ARI were selected 430M3, 690M3, 731M3, 960M3 and 1415M3 respectively and entered into the Hec-Ras model. Once all the hydrologic and boundary conditions are entered into the Hec-Ras software, the hydraulic computation was then performed. There are three types of calculations that can be performed and these are: -

Steady flow analysis
Unsteady flow analysis and
Hydraulic design function.

Steady flow hydraulic analysis was performed for each of the 10, 25, 40, 50 and 100 years ARI flows. Cross sections extracted at each of the stations indicates the water elevation for each of the peak flows. Several of the cross sections extracted indicate that the River will break its bank in several locations between station 8 to 10. The cross section extracted at station 8 (figure 3-10) which is located 1200m south west of

Greenlands Road shows that of the 100 year peak flow of 1415M3/s which flows within the river channel at upstream, a flow of volume of 200M3/s will break the bank and flow towards the natural low ground area. This flow need to be diverted away from flowing towards the Townsite, therefore the proposed diversion channel between Greenlands and Fauntroy Drains need to be designed to accommodate at least 200M3/s.

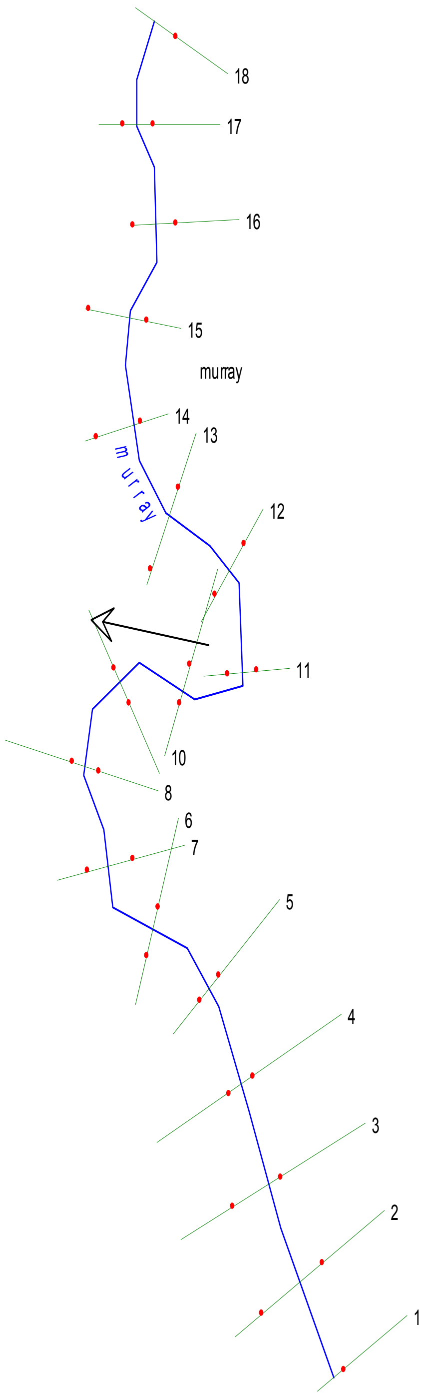


Figure 3-9 schematic diagram for section of Murray River & station numbers 1 - 18

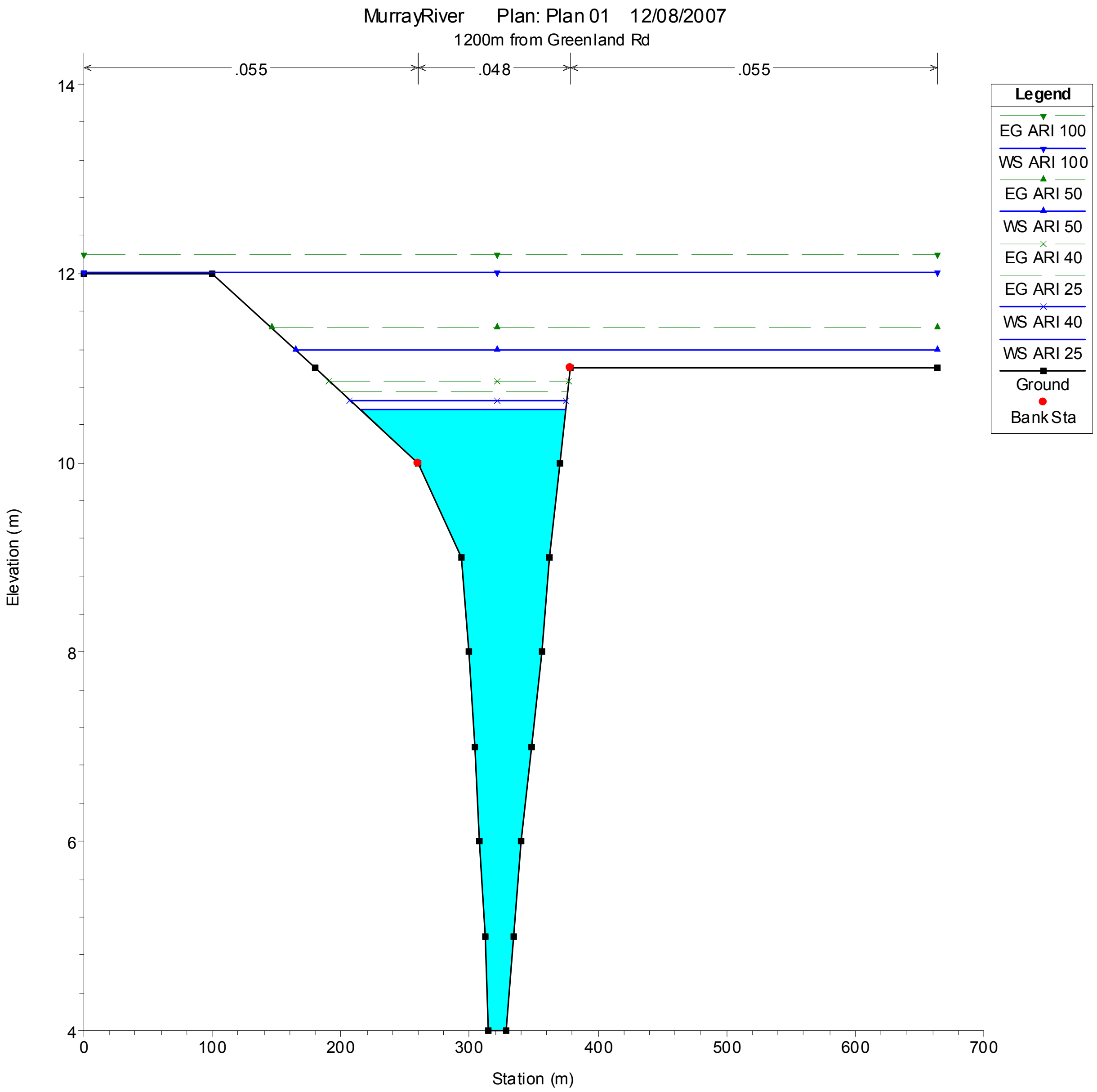


Figure 3-10 cross-section showing 100yr water surface profile

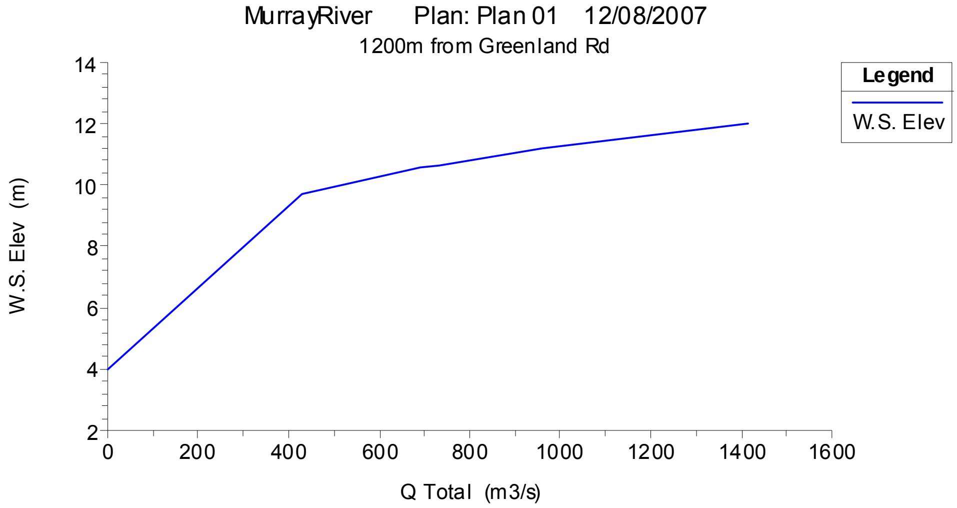


Figure 3-11 water level profile (rating curve)

Cross-sections, water level profiles, tabular out put for cross-sections and profile tables for the rest of the stations are shown in appendix A.

3.7 Diversion Channel Design at Greenlands and Fauntleroy Drains

The proposed diversion channel consists of using the existing Greenlands and Fauntleroy Drains to mitigate the extra 200 m^3/s floodwater. As indicated in the cross-section figure 3-10 and the Flood Studies reports for Murray that some floodwater would "breakout" from Murray River and entered the existing drains during 1 in 40 year ARI flood. The location of the proposed diversion channel is highlighted in Figure 3-12.

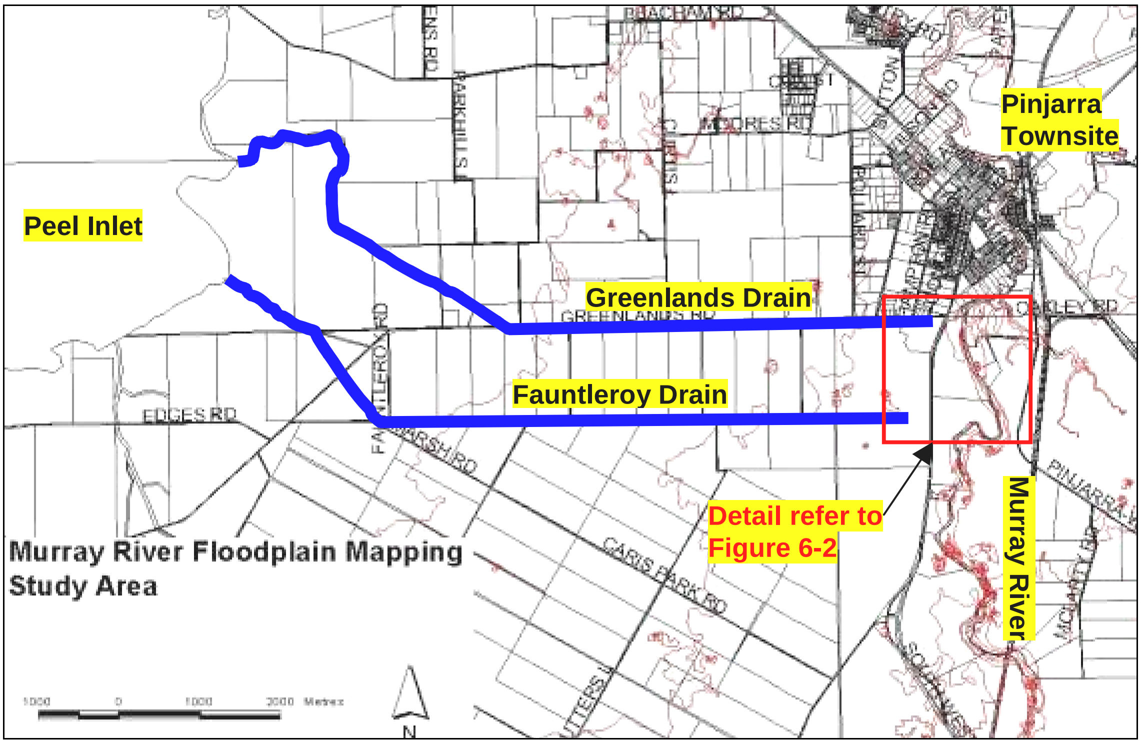


Figure 3-12 Location of the proposed diversion channel

The length of the existing Greenlands Drain and Fauntleroy Drain are 10.6 km and 10.3 km respectively. The existing drains are earth drains, gradually increasing in size of the drain 0.5 m wide by 0.6 m deep to 4.0 m wide by 1.5 m deep. All the drains had been designed with 0.3 m freeboards.

Evidence shows that part of the drains were infiltrated with 20 – 50 mm of groundwater during summer and the drains were running full during winter. Local residents live along Greenlands Road have very little information on the extent of historical flood to their area but they do confirm the drains do not overflow during a typical winter. Therefore, the existing drains were confirmed as not being capable of handling the extra floodwater. However, using this channel to convey a part of the flood away from Pinjarra Townsite may be possible by modifying the terrain model to form an excavated widened channel. Due to the restriction of bed level caused by high groundwater level around this area, the channel bed level cannot be lower than the groundwater level as the channel will be discharging groundwater which is another restriction from Water & Rivers Commission (WRC) and Department of Environmental Protection (DEP). Leaching of groundwater could result in losing the precious groundwater and rising of level at Peel Inlet. The rise in the level of Peel Inlet could cause backwater in Murray River, and caused more serious inundation and damages in North Yunderlup and South Yunderlup, near Murray River mouth.

Due to the drainage depth limitation, the channel had to be very wide. Figure 3-12 shows the schematic diagram of the proposed diversion channel. Cross sections were performed at every 500m interval along the channel. The shape and depth of the channel were adjusted to ensure that the channel has adequate capacity for at least 200M3/s of flood flow. The cross sections and tabular data are shown in appendix E. The existing slope of the ground is very flat with 0.0013 m/m gradient. In order to achieve a longitudinal slope to induce significant flow of 200 m^3/s, the excavation would need to be extended a considerable distance similar to the length of the drains. As a consequence, the volume of excavation and the associated cost could be prohibitive.

The 200 m^3/s floodwater is not really the guide estimate to design a channel as the floodwater was accumulated through rising of level. Therefore, the level of diverting the flow from Murray River to the Diversion Channel should be considered.

It was suggested that at least two detention basins should be placed at the upstream reach of Murray River where the Hotham and Williams Rivers meet. By constructing the detention basins, the catchment area of Murray River would reduce by 78.5%, given the catchment area of Hotham and Williams Rivers are 4290 km^2 and 1440 km^2 respectively.

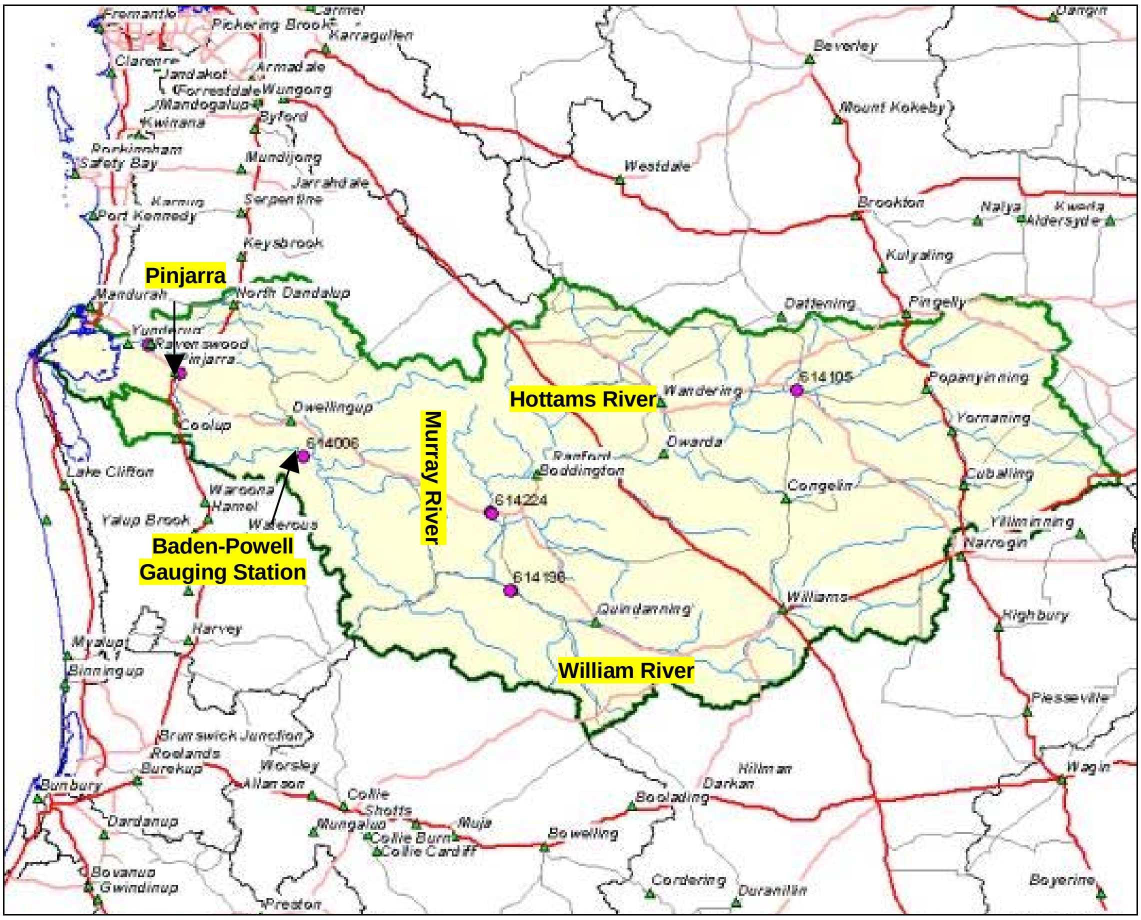


Figure 3-13 location of the proposed detention basins at Hotham and William Rivers

The likely cost if compared with the recently built detention basins in Busselton, would be approximately $30 million to store 200 m^3/s of floodwater. The cost would be greatly influenced by land acquisition. Therefore, separate study needs to be carried out to determine the size, number and locations of the basins. All other Shires in this Murray River catchment should take the construction of detention basins into consideration, as the benefit generated by this option would be beneficial not only to Pinjarra but areas downstream reach of Murray River.

3.7.1 Impacts of the Proposed Diversion Channel on Flood Mitigation In Pinjarra

Due to the high ground water table in the area the depth of diversion channel was proposed to be between 600mm to 400mm and width to cover the distance between the Greenland and Fauntleroy drains which is approximately 1050m.

(a) There are two proposed breakout points. Station 13 (Figure 3-9) which is 1950 m south east of Greenlands Drain and Station 8 which is about 900 m south east from Greenlands Drain. Station 13 has been identified to be the most suitable location to divert the floodwater to the proposed diversion channel as the terrain is sloping down towards the diversion channel. Station 13 also provides more lead time for diverting the floodwater before arriving to Pinjarra Townsite. Floodwater in the range between 400 to 350M3/s was needed to be diverted to attenuate the flood level at Pinjarra Townsite by 450mm Kiong (2003). The height of Groundwater table in the area caused restriction on the depth of the diversion channel which reduced the amount of floodwater that can be diverted. Several flow rates were tried, the proposed channel will have a capacity to divert only 200M3/s. The cross-sections at the station and rating curves is shown in appendix D

In order to control the amount of floodwater, three embankment as shown in Figure 3-14 has been considered.

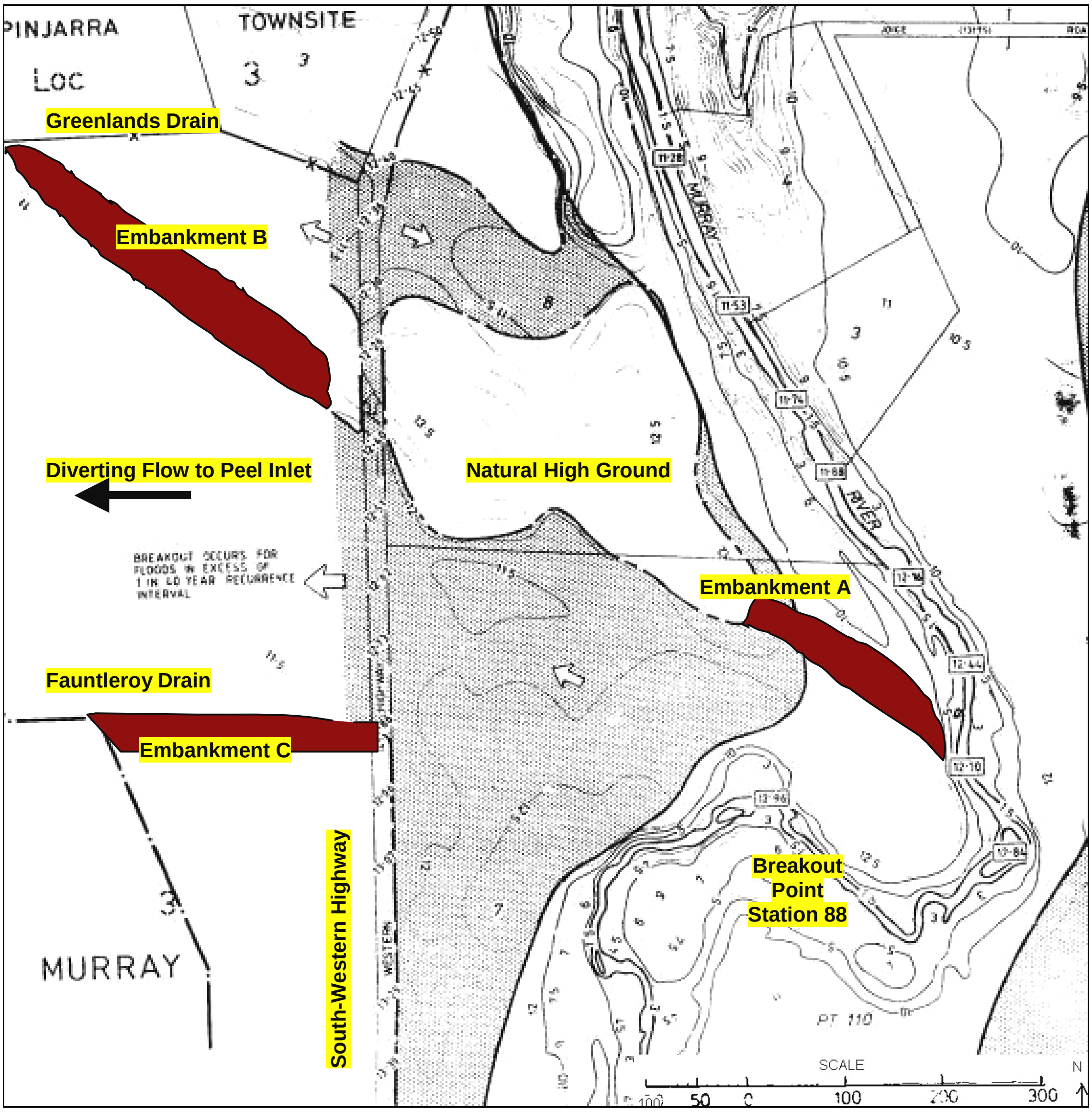


Figure 3-14: The Location of Station 8 and Illustration of the Proposed Work

The volume of excavation intends to match the volume of fill material for embankments, plus 300 mm freeboard from the attic level of the culvert. This requires a crest level of 12.9 m AHD.

The estimated excavation or shaping at the breakout point to South-Western Highway and at the receiving end of diversion channel is 118,000 m^3. The filled material needed is approximately 13,000 m^3. To achieve this, the benefit is quite minor, considering the cost for dumping and the site for dumping.

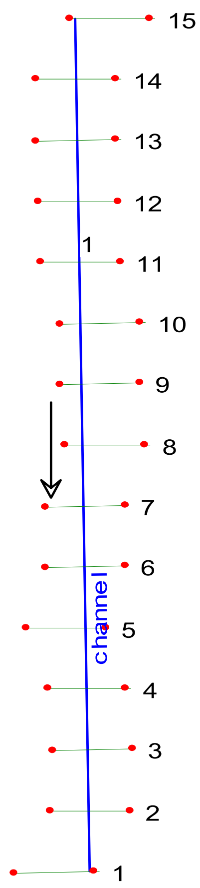
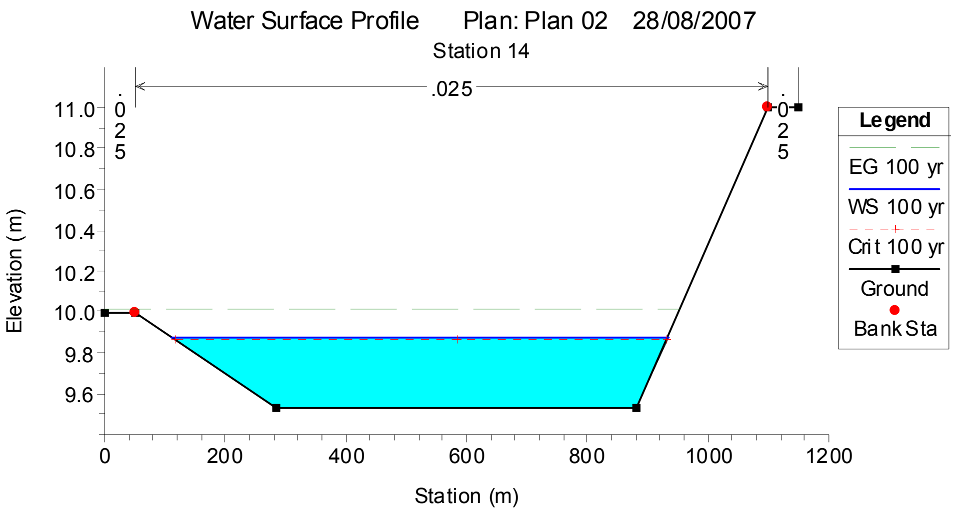


Figure 3-15 schematic layout of the diversion channel and cross-section locations



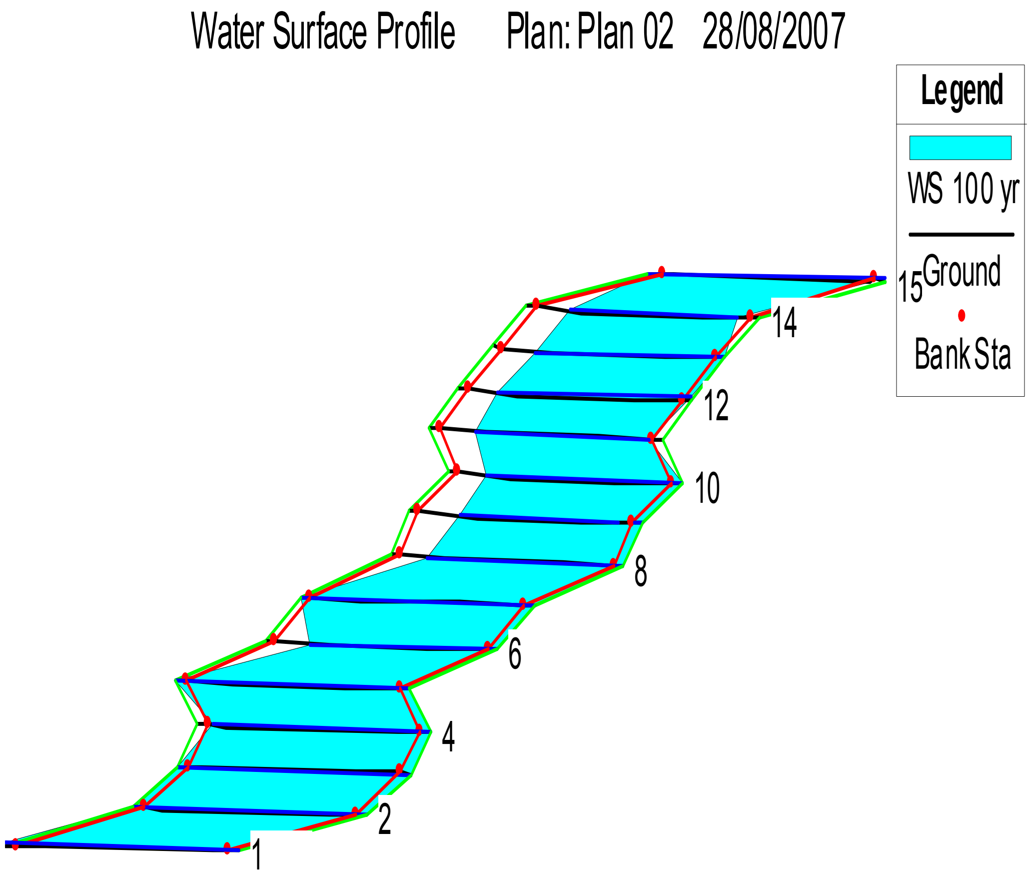


Figure 3-16 Water surface profile of the diversion channel

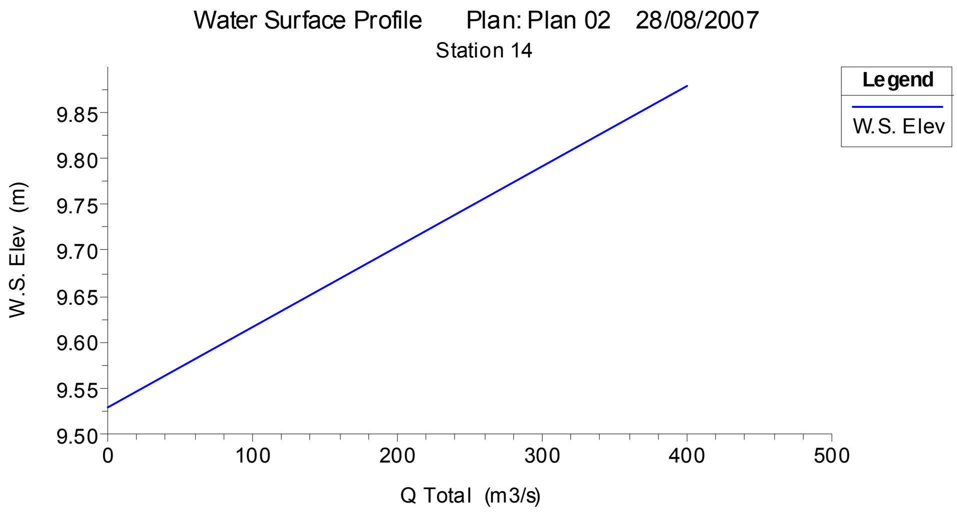


Figure 3-17 Rating Curve

3.8 Culvert Design or Causeway

The culvert size chosen depends on the relative level of the road to the channel invert level. Reinforced concrete box culverts (RCBC) are used in the calculation using CULVERTW software (Parkinson 1994). The headwater depth in the culvert signifies the level in Murray River. Therefore, it is very important to keep the headwater depth down to the desirable depth. The height of the box culvert is designed as either 750 mm or 900 mm with 2700 mm width culvert, which means the flood level is allowed to rise up to 12.0 m AHD from invert level at 11.3 m AHD. Nevertheless, the flow rate still stays in the probability of 1 in 40 year flood.

Adopting the WRC 100 mm backwater limit, the preliminary culvert size required to pass the 240 m^3/s breakout at Station 8 is roughly 70 RCBC (2700 mm by 900 mm), with the headwater depth at 900 mm. The first alternative will be using the existing floodway with the 70 RCBC.

The second alternative is to lay more culverts to accommodate roughly 420 m^3/s and raise the highway above flood level to provide the serviceability of highway during flood period. Third alternative is to construct a proper floodway and no culvert.

3.9 Freeboard

Freeboard is the additional depth required in a channel beyond the depth calculated for conveyance of the design discharge. The purpose of freeboard is to protect against hydraulic disturbance such as debris, unforseen obstruction, and inherent inaccuracies in assumptions and analyses techniques. It can be treated as a safety factor against the design flow for the channel.

Water Corporation WA has provided a consistent value of 0.5 m freeboards for man-made river diversions. One example is the Vasse River Diversion in Busselton and Five Mile Brook Diversion in Bunbury. In Section 3.1.5 of the Rural Drainage Design Standards (1977), Water & Rivers Commission has a standard rule of 0.3 m freeboard for man-made diversion drain to account for 1 in 100 year ARI flood.

Table 3-4 explains the safety factor in percentage of flow with each elevation of freeboard. The flow rate of 300 m^3/s is used to compare different percentages of flow increased. If the 0.5 m freeboard value is used, the channel can accommodate another 148% of flow. With the freeboard of 0.3 m, the channel can accommodate 620 m^3/s, which significantly reduces the flood risk in Pinjarra from 1 in 100 year ARI to 1 in 25 year ARI. This safety factor is far too big compared to the conventional drain which has a 50% safety factor. Therefore, freeboard of the drain should not be controlled, as the width of the drain is the major influence.

Table 3-4: Safety Factor in % of Flow with Each Elevation of Freeboard

Flow, Q= 300m^3/s		
Freeboard (m)	**Percentage increase of flow (%)**	**Capacity of the channel (m^3/s)**
0.05	17	349.7
0.1	33	398.8
0.2	68	504.5
0.3	107	620.0
0.4	148	744.7
0.5	193	878.5

3.10 Existing Services

An underground service from Telstra has been identified from Dial Before You Dig (1100). They are located along Greenlands Road and Fauntleroy Road, just right aside the drains. The relocation of the services should be organised prior to the excavation work and the associated cost could result in increasing the construction costs. There is one Western Power's cable tower shown in Figure 3-18 passing over the proposed flood diversion channel. However, it is measured that the intensity of flood does not have a major influence on the Western Power's cable tower.

Figure3-18: Existing Services at the Proposed Diversion Channel

3.11 Future Construction of Peel Deviation

The proposed construction of Peel Deviation (extension of Freeway South to Bunbury) would pass through the proposed diversion channel. The Peel Deviation will form an artificial levee system that will stop the floodwater from flowing to Peel Inlet. Thus, this has changed the whole centre part of Pinjarra, including the study area, being surrounded by two artificial levees which are South-Western Highway and the future Peel Deviation. A separate study should be conducted to investigate the effect of the Peel Deviation to Pinjarra. Consultation has been made with Jerome Goh from Main Road and Tim Tusak from GHD in January 2003 in regards to the proposed Peel

Deviation and the proposed diversion channel. They both agree to design culverts to transport the floodwater to Peel Inlet if the diversion channel was built.

3.12 Backwater study

A very brief backwater study has been conducted to estimate the highest water level in Peel Inlet. This is due to Peel Inlet is quite calm and does not have the big tidal fluctuation or seasonal variations. The highest backwater recorded is 1.6 m or 1.03 m AHD as shown in Figure 3-19 and Figure 3-20 The predicted value in 1984 study is 1.6 m AHD for a 100 year flood.

Figure 3-19: Backwater Height gauge at the End of Fauntleroy Drain (near Peel Inlet)

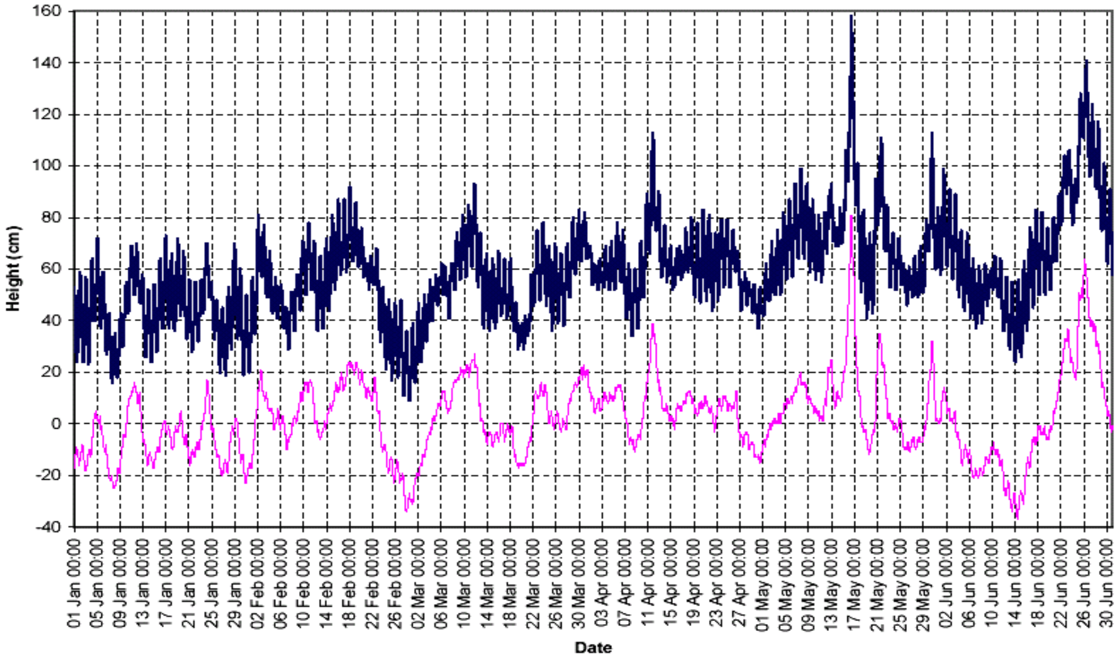


Figure 3-20: Tides/Residuals at Peel Inlet 2003 [DPI 2003]

4 EFFECTIVENESS OF CURRENT FLOODPLAIN MANAGEMENT STUDY

4.1 Introduction

This chapter covers the current floodplain management measures that have been practiced in Western Australia. Local governments, including Shire of Murray generally seek advice from Water & Rivers Commission in regard to floodplain management strategies. Therefore, the floodplain management strategy in Shire of Murray is investigated. At the same time, the risk and effectiveness of its current state would be analysed.

4.2 Floodplain Management in Western Australia

The Western Australian Planning Commission and local governments generally seek advice from Water and Rivers Commission regarding floodplain management strategies. In general, WRC floodplain management strategies have constraints on additional development within floodway of major rivers so as not to increase flood level upstream. Within flood fringe areas, restrictions are placed on habitable floor levels to provide adequate protection from major floods. A minimum freeboard of 500 mm above the designated 100 year ARI flood level is required. Figure 4-1 illustrates floodplain development such as floodway, flood fringe, flood level and designated flood level.

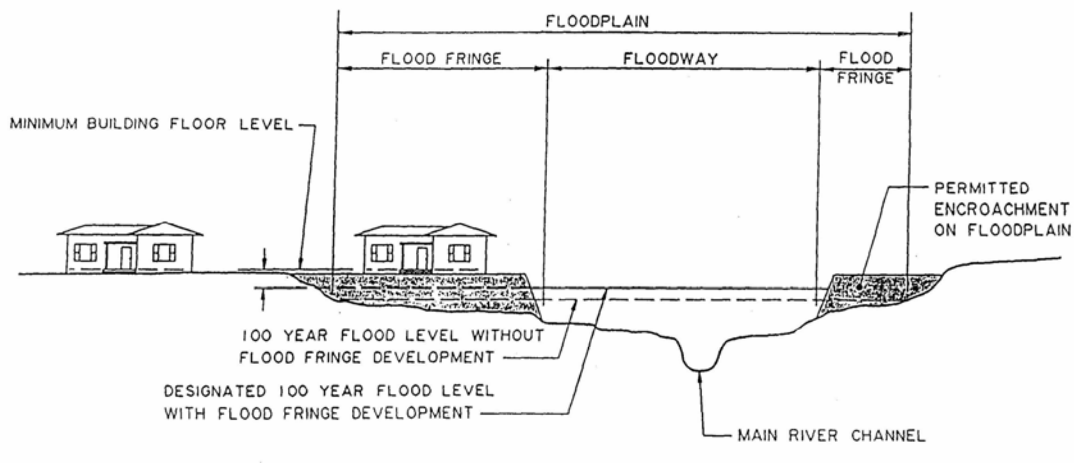


Figure 4-1: Illustration of Floodplain Development (Davies 1999)

4.2.1 Floodplain Management Strategy for Shire of Murray

The floodplain management strategy for the Shire of Murray is contained in their Town Planning Scheme No.4. Murray River also belongs to Peel Region and it is under "Peel Region Scheme – Floodplain Management Policy". Both documents are presented in Appendix B.

The current floodplain strategy relating to new development is summarised into the following four points:

(i) The land within the flood fringe in residential or canal development zones shall be not less than 300 mm above the 100 year ARI flood level.

(ii) Land within the flood fringe in the special rural zone shall have not less than 2,000 m^2 at or above the 100 year ARI flood level.

(iii) The building floor levels within the flood fringe areas shall be a minimum of 150 mm and 500 mm above the 100 year ARI flood level for existing and new subdivisions respectively.

(iv) Building extensions within the floodplain with a building licence issued prior to the gazettal date of the revised TPS4 (10/3/97) shall have floor levels of new habitable rooms above the 100 year ARI flood level.

4.2.2 Flood Risk in Pinjarra

The floodplain management strategy in Shire of Murray has caused negative impacts as the new developments are being built at much higher levels, varies from 500 mm to 1500 mm, than the existing adjoining old properties built prior to 1997. The negative impacts from social, aesthetic and street landscaping would hinder the development of Pinjarra.

Another problem arising from old properties near Murray River is the North and South Yunderlup areas where the properties are located in flood fringe area. New renovated house owners may refuse to raise the floor level to the designated 100 year ARI level. This could be achieved by reserving one pole (column) from the old house, and build a new house on an old level. Inevitably, this ignorant stance by residents would increase the flood risk in Pinjarra. This report has a comprehensive study on the flood damage for Pinjarra Townsite in Chapter 5. The assets at risk from floodwater are indicated in Table 4-1.

Table 4-1: Assets at Risk in Pinjarra Townsite

Properties	Flood Risk			
	1 in 100 year ARI	1 in 50 year ARI	1 in 25 year ARI	1 in 10 year ARI
Residential	302	217	46	2
Commercial	67	48	11	0
TOTAL	369	265	57	2

4.3 Flood Risk Analysis

According to the AS/NZS 4360 Standard for Risk Management (1999), key phases in the management of risk are:

- Establishing the context
- Risk Identification
- Risk Analysis
- Risk Evaluation
- Risk Treatment

Establishing the context involves developing an understanding of existing strategic planning, organisational arrangements and management policies. This has been explained in Section 4-2 where there is a non-structural floodplain management strategy applied in Pinjarra, which limits the building floor level to be 500 mm above the designated 100 year, ARI flood level.

Risk identification involves developing an understanding of what happened during the floods and how it happened. This can clearly be seen from the different height of the new development to the development prior to March 1997. There are substantial risks towards the existing buildings and the renovated buildings that refused to build above the designated 100 year ARI flood levels.

Risk analysis involves determining the important controls for flooding behaviour, and determining the probability and the consequences of flooding for floods over a full range of magnitude and severity. This involves the analysis of impacts to flooding such as economic, damages, and flood levels.

Risk evaluation involves considering the risk in terms of management criteria or objectives, and then setting priorities. The criteria for this are largely affected by the legal requirements and objectives set out by Water & River Commission including assessment of the possible diversion channel along Greenlands and Fauntleroy Drains. The risk criteria must correspond to the type of risks and the way in which risk levels are expressed.

Treatment of risk is the mitigation options (measures) being identified and evaluated which will be explained in Chapter 5. Treating the risk is not equivalent to eliminating the flood risk. Flooding is the natural disaster that cannot be stopped, but man can only manage the risk and live with floods.

The general flood risk analysis is explained in flow chart shown in Figure 4-2.

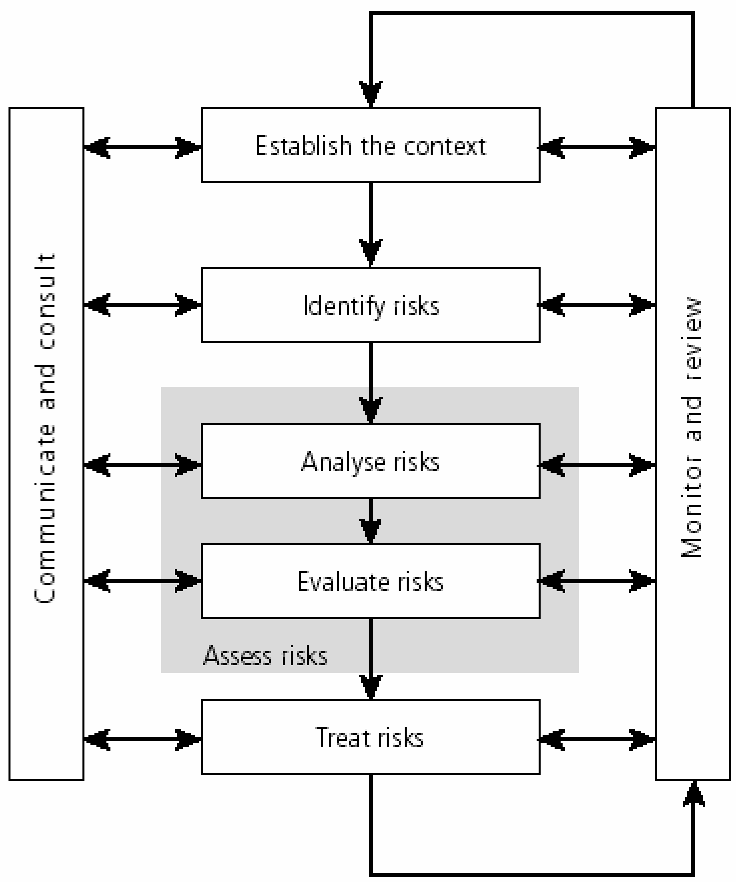


Figure 4-2: Risk Management Process (AS/NZS 4360 1999)

4.3.1 General Comment of Flood Risk in Pinjarra

The worst occurrence of recorded flood in Pinjarra is 731 m^3/s in 1945 with the intensity of 1 in 30 year ARI. Therefore, Pinjarra has not experienced a flood with the same intensity or larger intensity for the last half-century. The degree of damages in 1945 flood was only passed on to newer generation through words of mouth. Hence, it is true to say that majority of local residents have not experienced flooding, either due to the lack of recent flood events in Pinjarra or population turnovers. Lack of flood awareness can be a problem to local residents and this has positioned Pinjarra at a higher risk.

There is no doubt that the climate is changing in a way that will increase flood risk due to increase in rainfall as sea levels rise with expanding ocean. (Richardson 2002) However, this is not always the case as weather is unpredictable. Thus, Shire of Murray should be aware that the impact of climate change could increase or decrease the flood risk in Pinjarra.

Fleming (2002) noted that *"It is worth remembering that the source (precipitation) of flooding cannot be controlled, while the pathway (land and watercourses) can have a scope for management, and the receptor (people and property) can have the greatest control exerted."*

5 FLOOD DAMAGE ASSESSMENT IN PINJARRA

5.1 Introduction

To analyse the risk of flooding in Pinjarra, the flood damage assessment covered in this chapter would calculate the cost of damages for each flood event. The historical floods in Pinjarra had not provided enough information on the damages to compare with the assessment. The flood damage assessment conducted covered Pinjarra Townsite only.

The damages for residential and commercial properties are assessed using Rapid Appraisal Method (RAM). Agriculture and infrastructure damages are also added to the total direct damage. The damage for each occurrence of flooding is plotted in the graph to estimate the average annual damage (AAD) in Pinjarra Townsite. The complete assessment using RAM method is presented in Appendix C. The assessed damages is then used to provide monetary estimate benefits for mitigation work explained in Chapter 8.

5.2 Damages in Historical Floods

The Shire of Murray has a little record on history of floods, as the occurrence of flood is very rare. The most recent 1996 flood with intensity of 7 year ARI has not assessed any damage due to the impacts of flooding to the Shire and local residents in Pinjarra are negligible.

The flood damages in Carnarvon and Moora presented in Section 2.8 are used as a guide to estimate the actual damages that could result from Murray River flooding.

5.3 Evaluation of Damages in Design Floods

Design flood damages can be modelled and estimated for 1 in 10, 1 in 25, 1 in 50 and 1 in 100 year ARI (ie AEPs of 10%, 4%, 2% and 1%). Rapid Appraisal Method (RAM) has been used to estimate the residential and commercial damages in design floods. The design flood level is compared with building floor levels. Depths of the flooding above or below floor level could be determined and were indicated in Appendix C. The method using the depths of flooding relative to floor level with generalized functions was developed from Australian Flood Damage Data in ANUFLOOD (Smith & Greenway, cited in Sturgess 2000). Damages actually commence with flood levels below the floor level (and above ground level) because some external damages and foundation damage may be incurred. However, damage escalates rapidly when floods exceed floor level.

5.3.1 Residential and Commercial Damages

An extensive study done by Public Work Department 1984 has indicated the flood levels on each flood event. The affected areas in Pinjarra Town for each flood event are plotted on the contour map. Therefore, the number of houses and buildings affected can be calculated for each flood occurrence. Since the floor levels are unavailable, a car-survey has been conducted to estimate the floor levels relative to ground levels. The number of buildings flooded above (and below) floor level can be used to calibrate the damages caused by residential and commercial.

100 Year ARI Flood Event

Out of the 343 residential properties that were recorded, 302 residential properties (not including the vacant land) appear to be affected by the 1 in 100 year ARI flood (Kiong, 2003). This also shows that 88% of the Pinjarra Townsite will be flooded above floor level in an event of 1 in 100 year ARI flood. The extent of flooding covers 180 hectares of Pinjarra Townsite. The highest flood depth over-floor level is 2.49 m recorded at Apricot Street for Lot 511 for the 1 in 100 year ARI. There are 67 out of 76 commercial properties are affected in the event of 1 in 100 year ARI flood which consists of 88% of commercial properties in Pinjarra Townsite.

The estimated total actual property damage is $ 27.58 million. About 90% of the total damage arises from residential properties. The average annual damage for flooded residential properties is $ 196,000. The commercial properties contributing the remainder 9.6% with average annual commercial damage is $ 20,580.

50 Year ARI Flood Event

217 residential properties and 48 commercial properties appear to be affected by the 1 in 50 year ARI flood. 63% of both residential and commercial in Pinjarra Townsite will be flooded in the event of 1 in 50 year ARI flood. Lot 503 in Camp Road has been

recorded to have the lowest flooding with a depth of over-floor flooding of 10 mm for the 1 in 50 year ARI.

The estimated total actual property damage is $ 15.6 million. About 91% of total damage arises from residential properties. The average annual damage for flooded residential properties is $ 170,000. The commercial properties contributing the remainder 10% with average annual commercial damage is $ 16,940.

25 Year ARI Flood Event

There are 46 residential properties and 11 commercial properties are below the designated flood level in the event of 1 in 25 year ARI flood. Both residential and commercial, contributing 13.5% of total properties in Pinjarra Townsite, will be below the floor level in the event of 25 year ARI flood. The estimated total actual property damage for this event is $ 2.9 million. The average annual damage for flooded residential properties and commercial properties is $ 88,200.0 and $ 7140.0 respectively.

10 Year ARI Flood Event

Only 2 residential properties are flooded in 1 in 10 year ARI flood. There is no commercial property flooded in this flood event. The estimated total actual property damage for this event is $ 280,000.0 with average annual damage of $ 14,000.0.

Summary for Residential and Commercial Damage

Table 5.1 shows the estimated buildings inundated above and below floor levels in design floods associated with the damage costs. The estimated floor levels are based on observation, not measurement.

Table 5-1: Estimated buildings inundated and damage costs in design flood

Building Type	10 Year ARI	25 Year ARI	50 Year ARI	100 Year ARI
Property Below Flood Level	2	46	217	302
Estimated Damages	$ 280,000	$ 2,660,000	$ 14,280,000	$ 24,920,000

Commercial Premises Below Flood Level	0	11	48	67
Estimated Damages	$ 0	$ 238,000	$ 1,456,000	$ 2,660,000
Houses Above Flood Level	341	297	126	41
Commercial Premises Above Flood Level	76	65	28	9
Average Depth Above Flood Level (m)	0.04	0.30	0.36	0.52

Flood Damage Curve

The flood damage curves show the relationships between the properties damaged against the economic data.

The flood damages are calculated using ANUFLOOD Stage Damage Curves (Sturgess and Associates 2000). The residential and commercial properties in Pinjarra are classified as Class 1 as Pinjarra is a historical town.

Therefore, the damage of the properties can be calculated based on the depth of over-floor flooding. The depth of over-floor flooding is divided into three stages and each damage stage is shown in Table 5-2.

Table 5-2: Formulas to Calculate the Damages at Different Stages

Residential Class 1	Non-residential Class 1
ANUFLOOD Stage 1 For $0 \le x \le 0.09$m $f(x) = 306666.67x$	ANUFLOOD Stage 1 For $0 \le x \le 0.09$m $f(x) = 143750x$
ANUFLOOD Stage 2 For $0.091 \le x \le 0.586$m $f(x) = 85068.56x + 20774.8$	ANUFLOOD Stage 2 For $0.091 \le x \le 0.586$m $f(x) = 42500x + 10125$
ANUFLOOD Stage 3 For $x \ge 0.586$m $f(x) = 37570.72x + 48608.56$	ANUFLOOD Stage 3 For $x \ge 0.586$m $f(x) = 18750x + 24375$

* f(x) refers to the damage in $

The flood damage curves for each flood event are plotted for residential and commercial properties and are shown in Appendix C. The curves represent the estimate of damage for each event of flooding using the flood depth as a parameter.

By summing the three stages damage into one graph, a stage combine curve can be produced representing the ANUFLOOD in Pinjarra Townsite. The curves as shown in Figure 5-1 assist in calculating the damage cost from the known depth of floor flooding. These curves are applicable to all events of flooding in Pinjarra Townsite.

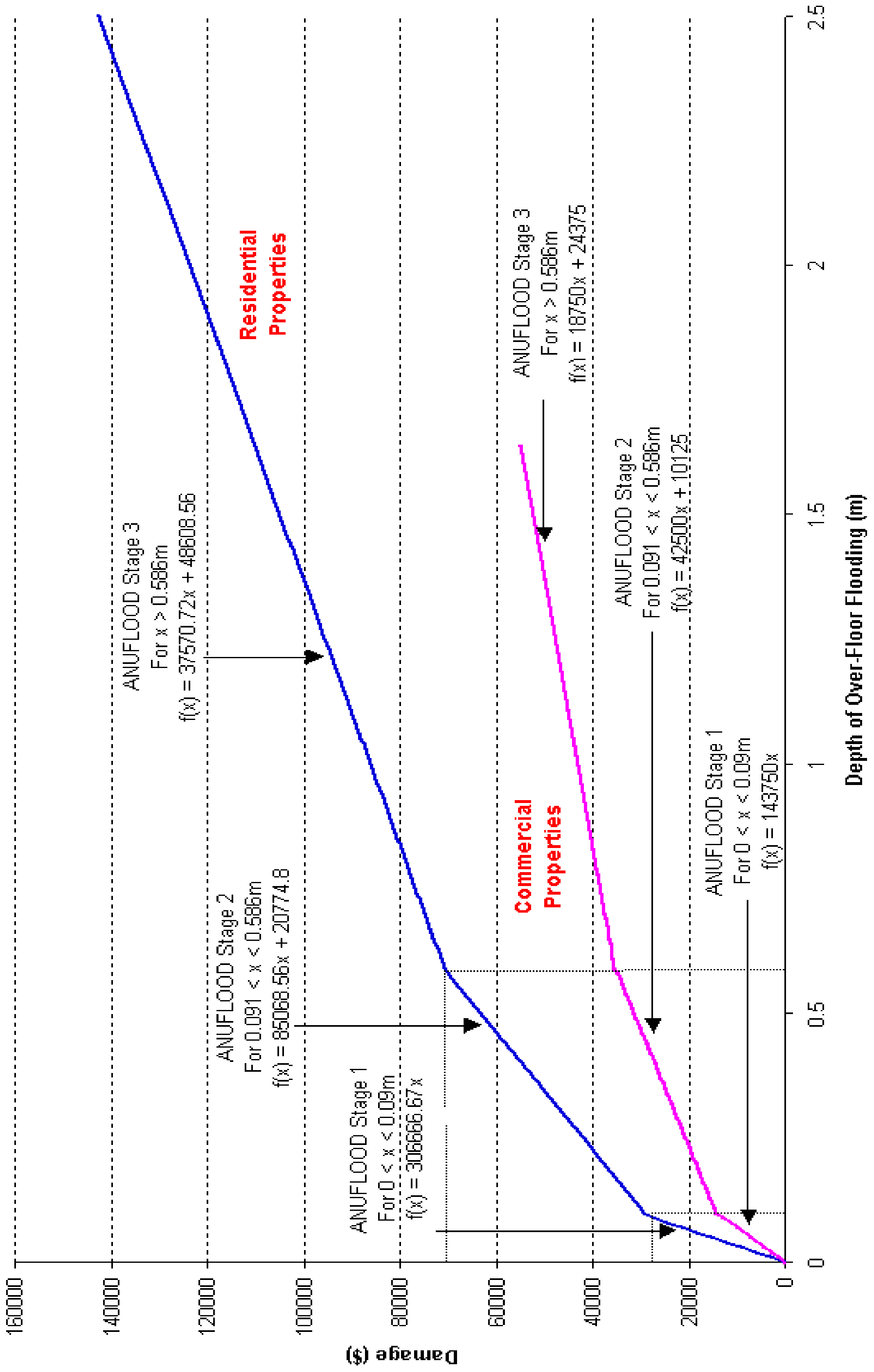


Figure5-1: Stage Combined Curves for Residential and Commercial Properties in Pinjarra for Any Event of Flooding

5.3.2 Agriculture and Infrastructure Damages

The historical damages recorded in Carnarvon and Moora were used to estimate the damages in Pinjarra according to the proportion of the volume of inundation. Area of roads or pastures with average depths of inundation determines the volume of inundation.

Agriculture Damages

In Carnarvon, the agriculture damage focused on the replacement of topsoil since plantation crops are the main activity of local residents. However, the agricultural damage in Pinjarra is loss of pasture and livestock as shown in Figure 5-2.

Figure 5-2: Agriculture Loss from Pasture and Livestock (Sturgess 2000)

The pasture area inundated for 1 in 100 year ARI is estimated to be approximately 250 hectares with average depth of flooding is 0.4 m and volume of floodwater inundating pasture areas is 1,000,000 m^3 around Pinjarra Townsite. The floodwater volume is conceivable to estimate the damages although the velocity of flood flow is another potential factor. The cost of pasture damage would be calculated as \$ 1 per m^3 for replacement of topsoil.

To calculate the livestock damage, Pinjarra has a regulation on 1 hectare of pasture for 1 cow. Therefore, 250 cows are estimated in Pinjarra. The estimated cost of one cow is \$ 500. The ‘cow’ also represents a sheep, a horse or two pigs. The summary of agriculture damage is shown in Table 5-3.

Table 5-3: Summary of Agriculture Damage

Type of Agriculture Damages	1 in 25 year ARI	1 in 50 year ARI	1 in 100 year ARI
Pasture (hectare)	0	150	250
Pasture Damage	$ 0	$ 1,500,000	$ 2,500,000
Livestock	0	150	250
Livestock Loss	$ 0	$ 100,000	$ 100,000
TOTAL DAMAGE	**$ 0**	**$ 1,600,000**	**$ 2,600,000**

Infrastructure Damages

Infrastructure damage in Pinjarra would be mainly the road damage. Flooding of road can cause erosion and shear failure. The dynamic effect of erosion would wash the fines of the road and all the submerging particles would cause the shear failure. The migration of fines would cause bridging effect as results after few cyclic loadings. In Western Australia, the road is constructed using natural aggregate instead of crush rock. Hence, the probability of the damage is higher. Figure 5-3 illustrates the flooding that can cause damage to roads.

Figure 5-3: Phot of Flood Causing Infrastructure Damage in Melbourne (Sturgess 2000)

Road Management System (RoMan) has been used by Shire of Murray to calculate the number of the roads and the length of road in Pinjarra Townsite. Mr. Chris Wilson from Shire of Murray has given the total length of road in Pinjarra Townsite. The length of inundated roads determined from the floodplain mapping is calculated for each flood event.

To repair the road, recycling of road method has been used since the damage is localised. The cost of recycling rural road is approximately $ 80,000 per km. Table 5-4 shows the damage caused by infrastructure at flood event

Table 5-4: Length of Roads Damaged by Various Event of Flood and Repairing Cost

Description	1 in 10 year ARI	1 in 25 year ARI	1 in 50 year ARI	1 in 100year ARI
Total Length of Road (km)	4.0	16.4	22.9	23.5
Cost of Repair & Resurface	$ 320,000	$ 1,310,000	$ 1,830,000	$ 1,880,000

5.3.3 Summary

Using the method describe above, damages were estimated for design floods of 10, 25, 50 and 100 year ARI. These damages are presented in Table 5-5.

Table 5-5: Summary of Design Flood Flow

Type of Damages	Cost of Damages ($ million)			
	10 year ARI	**25 year ARI**	**50 year ARI**	**100 year ARI**
Residential	0.20	1.90	10.20	17.80
Commercial	0.00	0.17	1.04	1.90
Agriculture	0.00	0.00	1.60	2.60
Infrastructure	0.32	1.31	1.83	1.88
Response & Recovery (@5%)	0.03	0.17	0.73	1.21
TOTAL DIRECT DAMAGE	**0.55**	**3.55**	**15.40**	**25.39**

5.3.4 Average Annual Damage (AAD)

Average Annual Damage (AAD) is commonly used as a relative probability and damage of a range of flood events. Average annual damage is determined by summing the product of annual flood probability and flood damage cost.

To determine the Annual Average Damages (AAD), it may be assumed that the flood damage commences at 1 in 5 year flood as the 1996 flood, which cause minor damage, had an estimated ARI of 1 in 7 year flood. AAD is then determined by the area under the curve of flood damages against probability of flood. Using the data from Table 5-5, Figure 5-4 shows the curve of damages increasing as the probability of occurrence or excedance decreases.

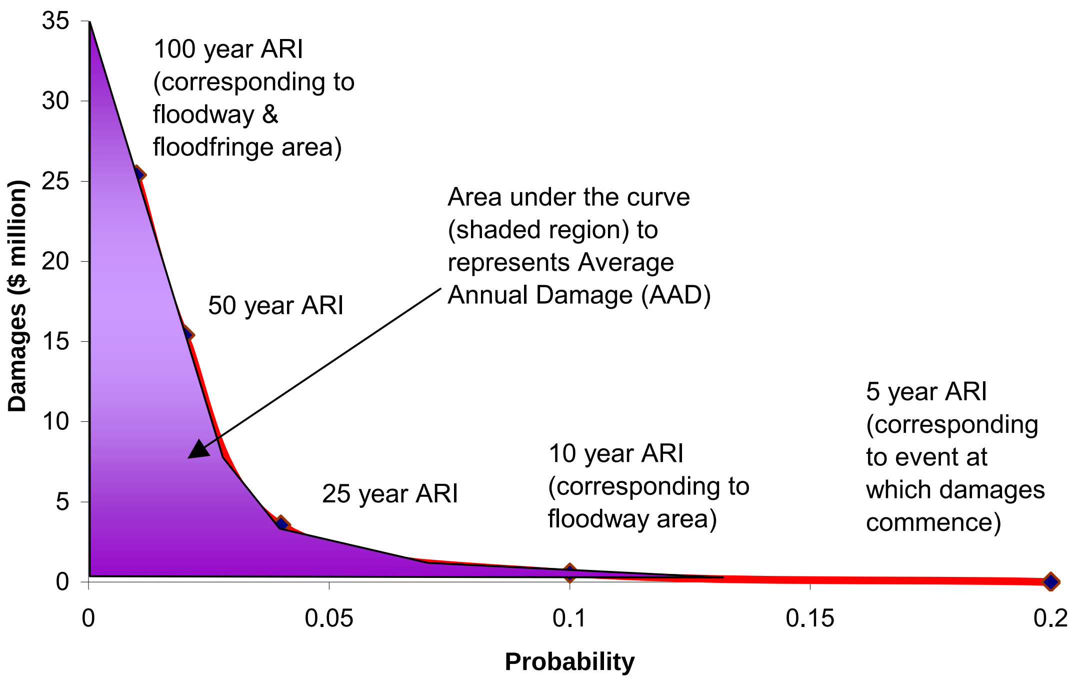


Figure 5-4: Estimation of Average Annual Damage (AAD)

The estimated average annual actual flood damage using ANUFLOOD method for properties in Town of Pinjarra under existing conditions is $ 770,000. Much higher damages could be incurred in larger floods higher than 1 in 100 year annual recurrence interval. Greater flood causes higher damages in AAD curve.

AAD can be calculated in term of flood event where area under the particular section of graph. The AAD of each flood event is summarised in Table 5-6.

Table 5-6: Summary of AAD for Each Occurrence of Flood

Flood Event	**10 year ARI**	**25 year ARI**	**50 year ARI**	**100 year ARI**
AAD	$ 28,000	$ 125,000	$ 200,000	$ 480,000

5.4 Potential Benefits of Mitigation

The elimination the flood risk completely is too excessive, and sometimes impossible. However, mitigating the impacts of floods can reduce the risk of flooding. Although the community would have to continue to live with the consequences of floods, the impacts of floods when they occur would be reduced, similarly with property damages and infrastructure damages. The mitigation work would have caused the increase of risk and impacts of floods in other areas, but it reduces flood levels and reduces risk of flooding in developed areas. Overall, the community would benefit.

The benefits that are most easily evaluated are the economic benefits. Effective flood mitigation can:

(a) Reduce the scale of agricultural damages

(b) Reduce damage to residential properties and commercial premises

(c) Reduce indirect commercial damages caused by interruption to business or provision of services

(d) Reduce damage to infrastructure

(e) Reduce the resources that need to be directed to post-flood recovery operations

Besides the tangible (priced) benefits, there are also intangible (unpriced) benefits like the confidence of the community, less stress and reduce health problems, and less disruption to agricultural production. Apart from economic benefits, effective mitigation would be highly valued and appreciated by the community in Town of Pinjarra.

5.5 Non-Structural Flood Mitigation Options

The Shire of Murray plays an important role in mitigating the risk of flooding and developing the effective floodplain management by development controls and building regulations.

5.5.1 Building Floor Levels Control

The current control on floor levels for new buildings is that the floor level must be constructed 500 mm above the designated 1 in 100 year ARI flood level. The Shire could reduce the floor level requirement only if the structural mitigation options are developed.

However, Water & Rivers Commission advised the development around the diversion channel (for example) needs to be built above the designated 100 year flood level as a safety measure against the hazards that could happen from the diversion channel.

Exemption from building height requirement should be given to buildings constructed with flood proof materials.

5.6 Flood Products

There is some circumstantial evidence of the performance of different building materials and forms of construction under flood conditions [CIRIA 2002]. Construction Industry Research & Information Association (CIRIA) from United Kingdom has done an extensive study on various building materials that can be used to reduce the risk of flooding at home. For example the wall can be built using airbricks and open joints in brickwork which are used to improve ventilation below suspended floors but can also act as flood routes.

5.7 Flood Warning

Water & Rivers Commission has a vital role in flood warning. There are six telemetered streamflow monitoring sites on the Murray River and its tributaries that provide real-time information on river levels.

The monitoring station at Baden Powell Water Spout (614006) has been recording river level information since 1940. It is expected that the monitoring station will provide 18 hours warning of a flood event likely to affect Pinjarra (WRC 2003).

By knowing the time and severity of flood, Shire of Murray would be able to evacuate the local residents at the affected area. These would help in reducing the damages and loss of life.

5.8 Summary

From the above structural and non-structural mitigation options investigated, the Shire of Murray should consider and plan an execution plan that would suit Pinjarra at the moment. The diversion channel proposed if implemented would mitigate the flood level at Pinjarra Townsite by 450mm. The high cost to construct the diversion channel could prohibit the implementation of the diversion channel. In addition to the excavation cost, the installation of culverts to cross Southestern Highway and an existing services might need to be relocated. The impact of the proposed diversion channel on the existing services would need to be investigated. The alternative option of constructing two detention basin at Hotham and Williams Rivers would need to be evaluated from economic point of view.

6 Assessment of Flood Mitigation Option - Diversion Channel

6.1 Impact on Flood Level

The (Rapid Appraisal Method) RAM model was used to investigate the impact of the diversion channel on flood levels throughout Pinjarra Townsite for the 10, 25, 50, and 100 year ARI design. The flood levels in Pinjarra Townsite and downstream areas for 1 in 40 year ARI flood and the above events will attenuate from the original designated peak levels. Table 6-1 shows the reduction in peak flood levels in several stations of Pinjarra after the construction proposed diversion channel.

Table 6-1: Reduction in Peak Flood Levels After the Construction of Diversion Channel at Various Flood Events

Description	Reduction in Peak Flood Level (m)			
	10 year ARI	25 year ARI	50 year ARI	100 year ARI
St. John Church	0	0	0.2	0.5
Shire of Murray	0	0	0.4	0.6
Pinjarra School	0	0	0.3	0.6
Station 13	0	0	0.8	1.0

6.2 Impact on Flood Damage

Besides the flood damage reduction from 100 year ARI flood event to 1 in 40 year ARI flood event, the damage also includes the new damage incurred to the affected landowners along Greenlands Road. There are seven residential properties and a Greyhound Racing along Greenlands Road (Lot 218, 217, 215, 214, 10, 273, and 272,). The damage includes properties loss, agriculture loss and infrastructure loss.

The effect of the damages is shown in Table 6-2 Table 6-3 and Table 6-4.

Table 6-2: Effect of Diversion Channel on Number of Properties Flooded

Building Type	Existing Condition 100 Year ARI	After Mitigation Option
Property Below Flood Level	302	157
Commercial Premises Below Flood Level	67	40
TOTAL	369	197

Table 6-3: Effect of Diversion Channel on Flood Damage in Pinjarra Townsite for 100 year ARI Flood

Type of Damages ($ million)	Existing 100 year ARI Flood Damage	After Mitigation Option
Residential	$ 17,800,000	$ 7,400,000
Commercial	$ 1,900,000	$ 800,000
Agriculture	$ 2,600,000	$ 1,100,000
Infrastructure	$ 1,900,000	$ 1,700,000
Response & Recovery (@5%)	$ 1,200,000	$ 600,000
Total Direct Damages	$ 25,400,000	$ 11,600,000

Table 6-4: Effect of Diversion Channel on Average Annual Damage (AAD)

	Existing Conditions	After Mitigation Option
Average Annual Damage (AAD)	$ 480,000	$ 430,000

The diversion channel has a measurable effect on the average annual damage (AAD), contributing a 10% of reduction.

7 ECONOMIC EVALUATION OF PROPOSED DIVERSION CHANNEL

7.1 Introduction

To assess the costs and benefits of the flood diversion channel, economic analysis of different scenarios have been undertaken. The estimated costs of the channel together with its financial benefits is calculated. Finally, the benefit cost ratio (BCR) is calculated to determine the feasibility of constructing the diversion channel.

7.2 Estimated Costs for Diversion Channel

The costs of the proposed works are estimated using the Australian Construction Handbook (Rowlinsons 2002). The costs are based on January 2002 unit rates for Perth, Western Australia. The estimated design and documentation costs and a 10% contingency allowance are included in the cost estimates. The total costs, as well as a breakdown of the estimated cost for each scenario of the diversion channel are given in the following section.

The assumptions for each unit rates are listed as follows:

- Construction of embankment including costs of transport, placement and compaction is \$ 12/m^3.
- For excavation work located near locations of embankment construction and could provide material for the embankment, the unit rate was reduced to \$ 7/m^3 due to low material and transportation costs.
- Excavations -- \$ 5/m^3
- Culvert -- \$ 2000/m
- Land Acquisition -- \$ 4,000/acre (Real Estate)

The operation and maintenance cost for each option has been assumed at 1% per annum of the total capital cost. The extra cost for the culverts for future Peel Deviation is not included in the capital cost. The cost also assumes the land at the breakout point before reaching the South-Western Highway belongs to the government.

Scenario 1: Option 1a, Culverts and Causeway, Do Nothing

The estimated cost to construct the diversion channel for Scenario 1 is shown in Table 7-1. The dumping cost for the access of excavation material of approximately 105,000 m^3 has not been included in the costing and assumes being used by the Shire for emergency purpose to retain the flood.

Table 7-1: Estimated Construction Costs for the Diversion Channel (Scenario 1)

Item	Estimated Cost
Excavation	$ 490,000
Embankment	$ 130,000
Culverts	$ 1,225,000
Causeway	$ 170,000
Side Track (gravel)	$ 26,000
Land Acquisition Cost	$ 340,000
Contingencies @10%	$ 240,000
TOTAL	**$ 2,621,000**

Scenario 2: Option 1b, Culverts and Causeway, Do Nothing

The estimated cost to construct the diversion channel for Scenario 2 is shown in Table 7-2. This is a more economical option, as the excavation is minimal. Dumping cost for 54,000 m^3 is not included.

Table 7-2: Estimated Construction Costs for the Diversion Channel (Scenario 2)

Item	Estimated Cost
Excavation	$ 280,000
Embankment	$ 130,000
Culverts	$ 1,225,000
Causeway	$ 170,000
Side Track (gravel)	$ 26,000
Land Acquisition Cost	$ 140,000
Contingencies @10%	$ 200,000
TOTAL	**$ 2,171,000**

Scenario 3: Option 1b, Culverts Only, Do Nothing

The estimated cost to construct the diversion channel for Scenario 3 is shown in Table 7-3. This scenario basically aims to diminish the impact on South-Western Highway in the event of flooding. The highway is raised at the higher level and more culverts replace the causeway.

Table 7-3: Estimated Construction Costs for the Diversion Channel (Scenario 3)

Item	Estimated Cost
Excavation	$ 280,000
Embankment	$ 130,000
Culverts	$ 1,800,000
New Road Section	$ 280000
Side Track (gravel)	$ 42,000
Land Acquisition Cost	$ 140,000
Contingencies @10%	$ 270,000
TOTAL	**$ 2,940,000**

Scenario 4: Option 1b, Causeway Only, Do Nothing

The estimated cost to construct the diversion channel for Scenario 4 is shown in Table 7-4. This option takes the risk of closing the highway for two to three days in the event of flooding as the road users can use the new Peel Deviation once it is completed.

Table 7-4: Estimated Construction Costs for the Diversion Channel (Scenario 4)

Item	Estimated Cost
Excavation	$ 280,000
Embankment	$ 130,000
Causeway	$ 500,000
Side Track (gravel)	$ 42,000
Land Acquisition Cost	$ 140,000
Contingencies @10%	$ 110,000
TOTAL	**$ 1,200,00**

Scenario 5: Option 1b, Culverts Only, Embankment Around Affected Residential

The estimated cost to construct the diversion channel for Scenario 5 is shown in Table 7-5. This option will have more embankment cost, and less dumping cost.

Table 7-5: Estimated Construction Costs for the Diversion Channel (Scenario 5)

Item	Estimated Cost
Excavation	$ 280,000
Embankment	$ 140,000
Culverts	$ 1,750,000
New Road Section	$ 280,000
Side Track (gravel)	$ 42,000
Land Acquisition Cost	$ 140,000
Contingencies @10%	$ 260,000
TOTAL	**$ 2,900,000**

Scenario 6: Option 1b, Culverts Only, Embankment Along Greenlands Drain

The estimated cost to construct the diversion channel for Scenario 6 is shown in Table 7-6. This option has less dumping cost, but has other extra costs from land acquisition and embankment construction.

Table 7-6: Estimated Construction Costs for the Diversion Channel (Scenario 6)

Item	Estimated Cost
Excavation	$ 280,000
Embankment	$ 520,000
Culverts	$ 1,750,000
New Road Section	$ 280,000
Side Track (gravel)	$ 42,000
Land Acquisition Cost	$ 7,850,000
Contingencies @10%	$ 1,072,000
TOTAL	**$ 11,800,000**

Scenario 7: Option 1b, Culverts Only, Excavation & Embankment at Both Drains

The estimated cost to construct the diversion channel for Scenario 7 is shown in Table 7-7. This option has immense excavation, land acquisition and embankments construction costs. Associated costs include relocation of services, fencing and maintenance.

Table 7-7: Estimated Construction Costs for the Diversion Channel (Scenario 7)

Item	Estimated Cost
Excavation	$ 25,480,000
Embankment	$ 280,000
Relocation of Services	$ 700,000
Fencing	$ 84,000
Culverts	$ 1,750,000
New Road Section	$ 280,000
Side Track (gravel)	$ 42,000
Land Acquisition Cost	$ 8,300,000
Contingencies @10%	$ 3,700,000
TOTAL	**$ 41,370,000**

7.3 Summary of Different Scenario Costs

Table 7-8 shows a summary of costs to construct the diversion channel for different scenarios. Note that the costs presented should be considered as preliminary and indicative only at this stage. Detailed investigations are necessary to obtain more accurate cost estimates.

Note that Scenario 4 has the lowest construction cost, the consideration should be made whether the loss of serviceability of highway during flood event is offset by the construction of a causeway.

Scenario 7 has the highest construction cost mainly because the grand scale of excavation costs and the land acquisition where the proposed diversion channel is to be located . This is the scenario that was discussed in detail in chapter

All the scenarios' construction costs have to be compared with the benefit before deciding the best scenario to construct a diversion channel for flood mitigation in Pinjarra.

Table 7-8: Summary of Estimated Capital Costs for Diversion Channel in Pinjarra

Scenario	Description	Estimated Cost
1	Option 1a, Culverts and Causeway, Do Nothing	$ 2,621,000
2	Option 1b, Culverts and Causeway, Do Nothing	$ 2,171000
3	Option 1b, Culverts Only, Do Nothing	$ 2,940,000
4	Option 1b, Causeway Only, Do Nothing	$ 1,200,000
5	Option 1b, Culverts Only, Embankment Around Affected Residential	$ 2,900,000
6	Option 1b, Culverts Only, Embankment Along Greenlands Drain	$11,800,000
7	Option 1b, Culverts Only, Excavation & Embankment at Both Drains	$**41,370,000**

7.4 Financial Benefits

The financial benefits for the identified flood mitigation option include reducing the property damages for a particular flood event and reducing the average annual damage (AAD) in Pinjarra Townsite. The benefit also includes the cost reduction in landfill. The sixty-eight vacant lands generate another $ 0.35 million savings in landfill, assume a provisional sum for earthwork is $ 5000 per house.

Estimated benefits from the property damages in Pinjarra Townsite and average annual damage are shown in Table 9-9 and Table 9-10 respectively.

Table 7-9: Estimated Benefits for Property Damages in Pinjarra Townsite

Item	Financial Benefits
Residential Property	$ 14,560,000
Commercial Property	$ 1,540,000
Vacant Lands	$ 490,000
TOTAL	**$ 16,590,000**

Table 7-10: Average Annual Damage Benefit

	Net Annual Benefit
Average Annual Damage (AAD)	$ 480,000 - $ 430,000 = $ 50,000

The net annual benefit permits a first idea of the benefit that can be achieved by implementing a mitigation measure (Construction of Diversion Channel). However, this value does not take any inflation rates, interest rates for bank loans or design lifetime of the mitigation options into account. In order to see whether or not a mitigation option actually results in economical benefit, a present value (pv) calculation can be made in determining the Benefit Cost Analysis.

7.5 Benefit Cost Comparison

Table 7-11 shows the estimated benefit cost ratios (BCR) of the flood mitigation diversion channel for discount rates of 4% p.a., 6% p.a., 8% p.a., and a nominal project life of 30 years has been assumed.

Equation 9-1 and 9-2 show the formula of present worth values and benefit cost ratio respectively:

$$pv = AAD \times \{\frac{[(1+rate)^{term} - 1]/rate}{(1+rate)^{term}}\}$$ **(Equation 7-1)**

where pv: present value of the mitigation
rate: interest rate per annum
term: design life of the option

$$BCR = \frac{Benefit}{Cost}$$ **(Equation 7-2)**

where BCR: Benefit-cost ratio
Benefit: Benefit achieved with the mitigation option
Cost: Cost of the mitigation option

Table 7-11: Estimated Benefit Cost Ratio

Design Life: 30 years			
AAD before mitigation: $ 480,000 AAD after mitigation: $ 430,000			
Adopted Discount Rate	4%	6%	8%
Present Value before Mitigation	$ 11,620,000	$ 9,240,000	$ 7,560,000
Present Value after Mitigation	$ 10,360,000	$ 8,260,000	$ 6,720,000
Expected Damage Reduction	$ 1,260,000	$ 980,000	$ 840,000
Benefit Cost Ratio (BCR) of Different Scenario = Damage Reduction / Capital Cost			
Scenario 1 ($ 2,621,000)	0.48	0.37	0.32
Scenario 2 ($ 2,171,000)	0.58	0.45	0.39
Scenario 3 ($ 2,940,000)	0.43	0.33	0.28
Scenario 4 ($ 1,200,000)	1.05	0.82	0.7
Scenario 5 ($ 2,900,000)	0.43	0.33	0.29
Scenario 6 ($ 11,800,000)	0.11	0.08	0.07
Scenario 7 ($ 41,370,000)	0.03	0.02	0.02

The analysis of cost and benefit of constructing a diversion channel shows the BCR value is low due to the reduction in AAD compared to the existing situation is not significant. To construct a diversion channel, Scenario 4 (Construct a Causeway) seems feasible, followed by Scenario 2 (Culverts and Causeway).

It is noted that the above analysis has not taken into account the flood damage to public infrastructure (roads, railway, footpaths, etc) and the rural properties downstream of Pinjarra Townsite. Furthermore, the intangible benefits (social benefits) and unquantifiable benefits such as property value improvements and business attracted to Pinjarra, a net economic return on investment would likely make the above BCR more attractive.

8 CONCLUSION & RECOMMENDATIONS

8.1 Conclusions

The current practice of floodplain management strategy in Pinjarra is not efficient in reducing the flood risk as Pinjarra Townsite will be flooded regardless the floor levels are being raised or not. The old properties, with several historical buildings, are confronted with very high flood risk. The flood risk in Pinjarra is increased because the clearing of lands in the 80's and global weather changes. Evidence also shows few renovated houses along Murray River refuse to raise the floor level, or more recently two houses are built in the floodway at their own risk.

The flood damage for Pinjarra Townsite has been identified for 10, 25, 50 and 100 year ARI flood events. An estimate of 369 properties will be flooded above floor level for the 100 year ARI flood event. Another 50 properties will be above the designated flood levels. The total estimated damage to Pinjarra Townsite associated with this event is estimated at $ 28 million. The estimate average annual damage for properties in Pinjarra Townsite under existing conditions in 2007 is $ 1,078,000.

A range of structural and non-structural mitigation options for Pinjarra was investigated. The structural measure investigated in detail is a diversion channel. The non-structural measures suggested were creating a new flood-proof township, and using flood products in construction. These options are achievable in Pinjarra as Pinjarra is located at the downstream reach of Murray River where flood flow is the greatest and the cost for structural mitigation is prohibitive.

It was found that the Scenario 4 (Divert at RL 11.3 m AHD, construct a causeway and do nothing in diversion channel) is the most viable option to reduce the flood risk and damages in Pinjarra. Scenario 4 reduces the flood risk from 1 in 100 year ARI flood event to 1 in 40 year ARI flood event. The benefit cost ratio yields between 0.69 and 1.07 depending on the adopted discount rate, but the reductions in the number of flooded properties and associated flood damage are significant.

Note that the benefit cost ratio is considered under-estimated as the research project area is based on the local Pinjarra Townsite only. There will be more benefit generated from areas downstream and the intangible benefits that cannot be priced.

Hydraulic analysis to construct a diversion channel to a depth of 500mm and 1050m wide between Fauntroy and Geenlands drain was performed. The estimated cost of constructing a diversion channel with the dimensions as mentioned above and a length of up to 10.5km is very significant and has very low benefit cost ratio.

8.2 Recommendations

Detailed topographic survey of Murray River and the surrounding ground need to be conducted to determine the exact level at which the River will break its banks. An appropriate level of detailed investigation should be undertaken for designing the diversion channel prior to works being approved. A comprehensive hydrological computer model should be carried out to understand the rainfall pattern in the catchment and the characteristic of the flow rate in Murray River. A more precise hydrograph at the breakout point (Station 13) is recommended to produce.

A separate study on the river system is required to implement Option 2 (detention basin). The quantity of flow retained can be calculated and the diverted flow if any, will be diverted to the diversion channel (Option 3).

It is recommended the mitigation of flood should also be carried out at the upper catchment. Since the headwaters of Murray River consist of the Hotham and Williams Rivers, the Shire should propose the mitigation work at the upper catchment with other Shires. By mitigating the floodwater at upper catchment, the catchment area of Murray River will be reduced by approximately 80%. This would have reduce a significant flood risk and flood damage in Pinjarra. A detailed investigation should be undertaken to this approach with other Shires.

Proper design of the flood-proof areas in Pinjarra should be carried out to attract the investors and local residents. This includes shifting the administration to the new flood-proof areas.

Flood damage in Pinjarra Townsite is recommended to verify with the occurrence of real flood to determine its precision. Recommendation to continue to model the groundwater along Greenlands and Fauntleroy Drain is to study the trend on groundwater behaviour with several years of data.

Detailed environmental study is recommended to assess the impact of constructing a diversion on groundwater and the existing vegetation.

References:

C.V Kiong, Oct. 2003, Relief Diversion Channel for Flood Mitigation in Pinjarra.

Haestad Methods Inc. 2003, Floodplain Management using Hec-Ras, first edition.

US Corp. of Engineers, Oct 1993, River Hydraulics Engineering Manual.

Iweaver, 2003, Peel Deviation Waterways.

Chow, 1959, Open Channel Hydraulics, McGraw Hill Singapore.

AS/NZS 4360, 1999, Risk Management, Retrieved, May 2005 2205 from 80online.standards.com.au.dbgw.lis.curtin.edu.au/online/autologin.asp

G.whitehouse & J.R Burton, March 1999, International Decade for Natural Disaster Reduction (IDNDR) – The Economic and Social Commission Asia Pacific (ESCAP)

Porter.D.J Nove. 2002, Carnavon Flood Management Study, Sinclair Knight Merz Pty. Ltd. Western Australia.

George, P.L 1984, Murray River Flood Study, Public Works Department, Western Australia.

DPI, 2003, Tides/Residuals at Peel Inlet 2003, Tides and Waves section, Department for Planning and Infrastructure, Western Australia.

Davies.J,Ng.R, Robinson.J, Yan.M 1998, Busselton Regional Flood Study Review. JDA Consultant Hydrologist, Western Australia.

Biza, P. 2001, Benefit Cost Analysis for Flood Mitigation Retrieved June 2006 from WWW.dhisoftware.com/uc2001/abstracts_proceedings/papers01/006.

BOM, 2003, Floods in Australia. Retrieved: May 2005 from www.bom.gov.au.announcement/sevwx.vance.shtn

Jenkins, B.D 1994, Australian Rainfall & Runoff – A Guide to Flood Estimation, The Institute of Engineers Australia.

SKM, 2002, Western Australia Floodplain Management Strategy (1): Background Sinclair Knight Merz, Wstern Australia.

WRC, 2000, Moora Flood Management Study, Water Studies Pty Ltd. Western Australia.

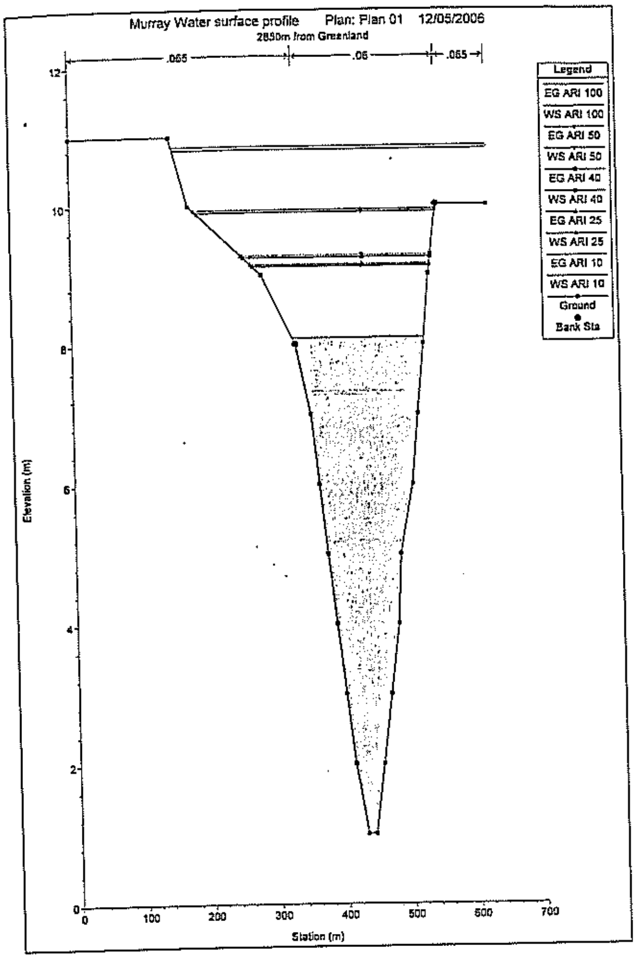
Sturgess, R. 2000, Rapid Appraisal Method (RAM), Department of Natural Resources and Environment, Australia.

APPENDIX A

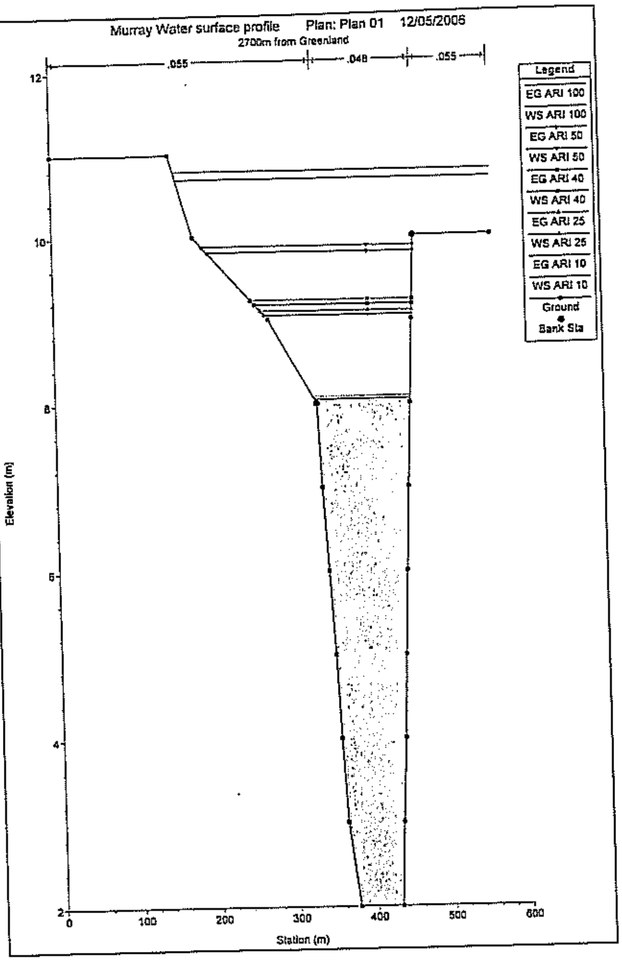
CROSS-SECTION AND RATING CURVES OF SURFACE WATER PROFILE FOR MURRAY RIVER.

APPENDIX A

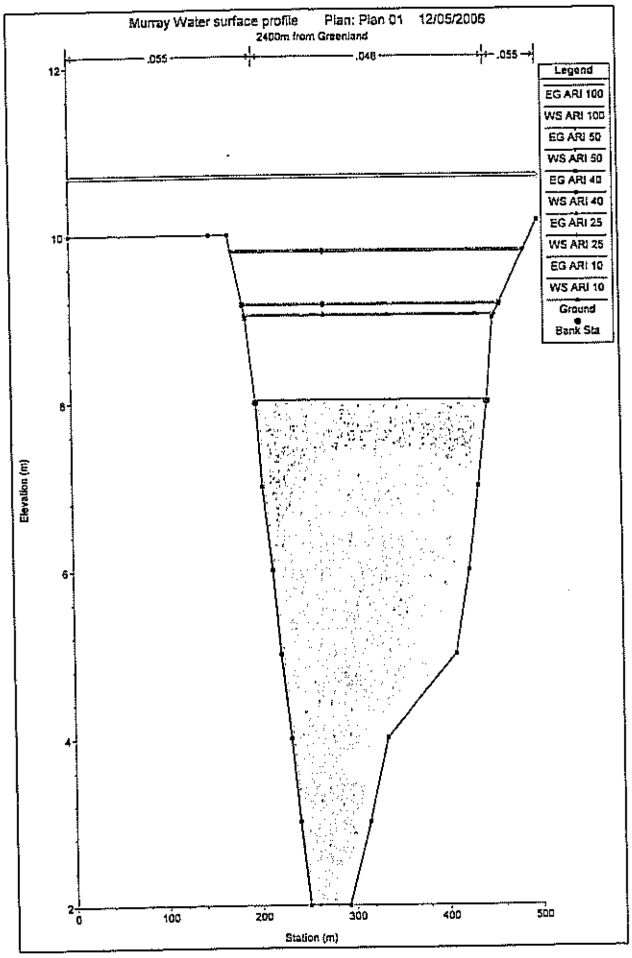
CROSS-SECTION AND RATING CURVES OF SURFACE WATER PROFILE FOR MURRAY RIVER.



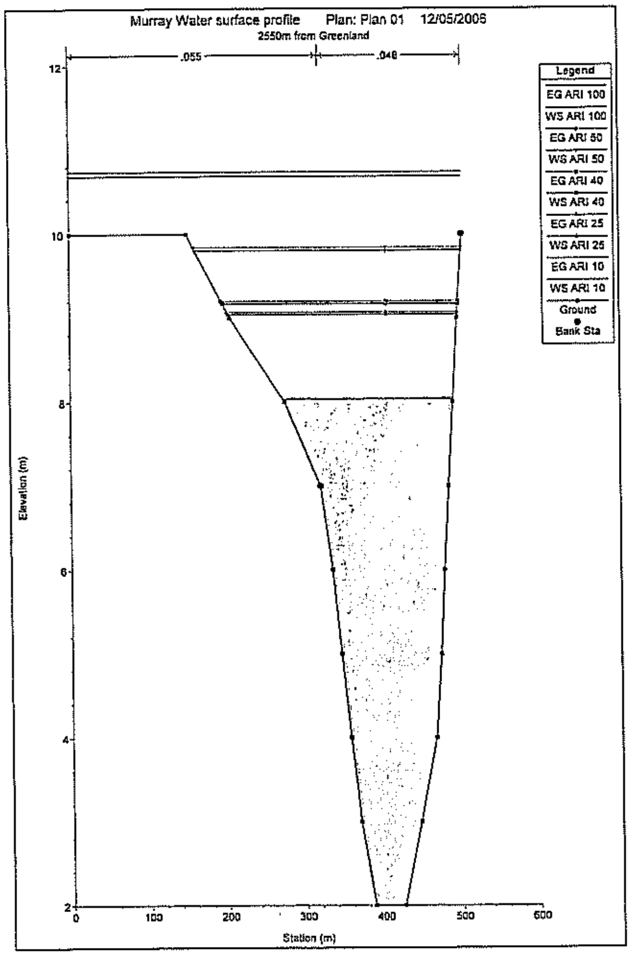
Murray Water surface profile Plan: Plan 01 12/05/2006
2850m from Greenland
.055
.06
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)



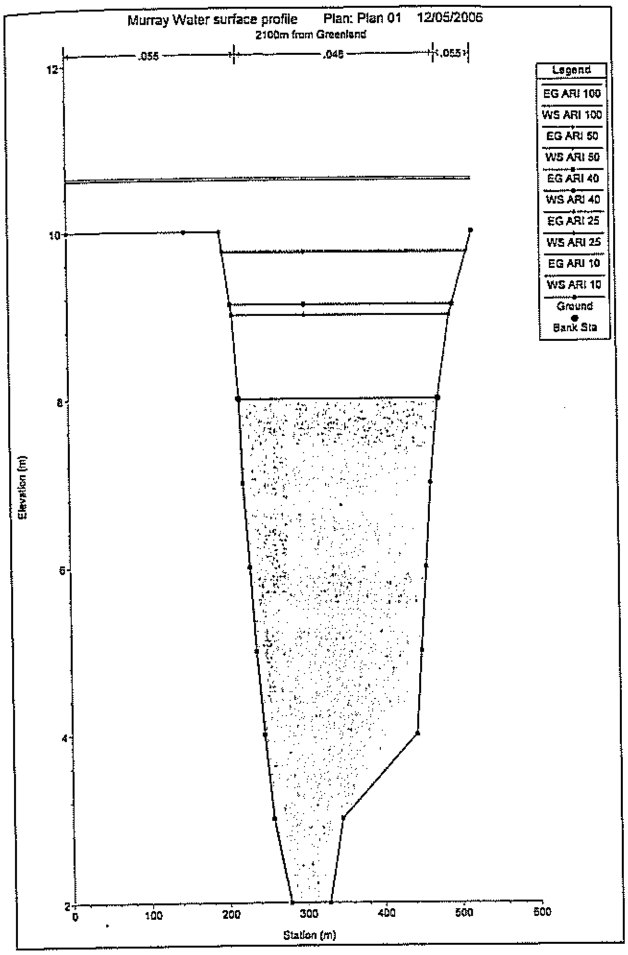
Murray Water surface profile Plan: Plan 01 12/05/2006
2700m from Greenland
.055
.048
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)



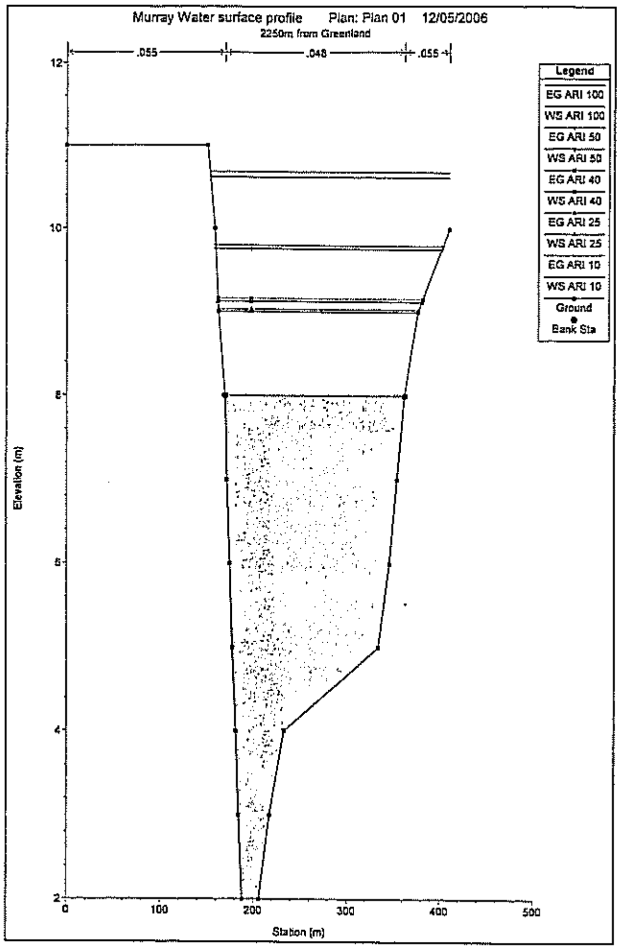
Murray Water surface profile Plan: Plan 01 12/05/2006
2400m from Greenland
.055
.048
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)



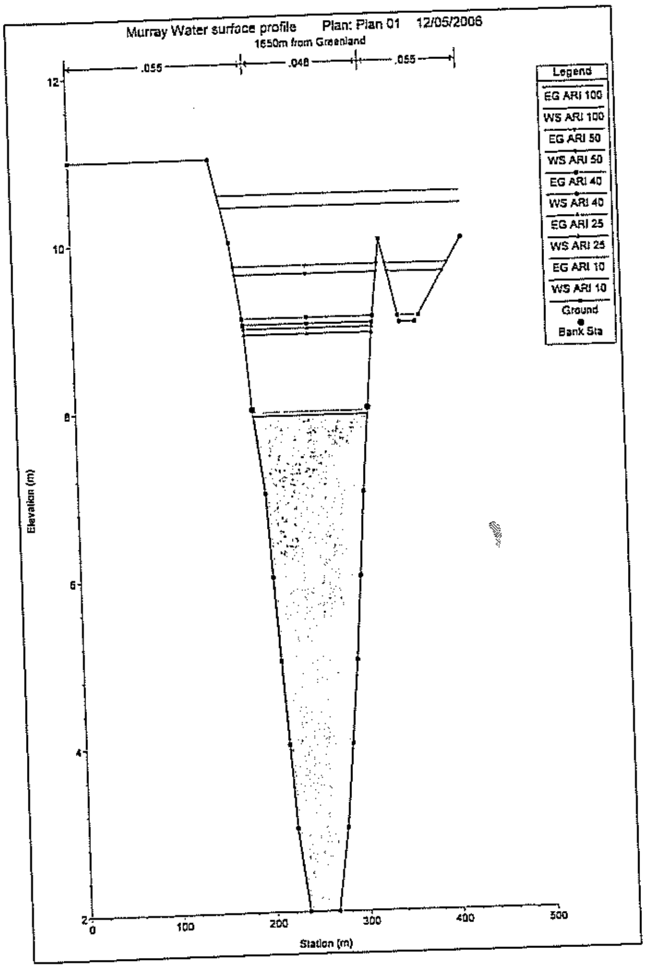
Murray Water surface profile Plan: Plan 01 12/05/2006
2550m from Greenland
.055
.048
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)



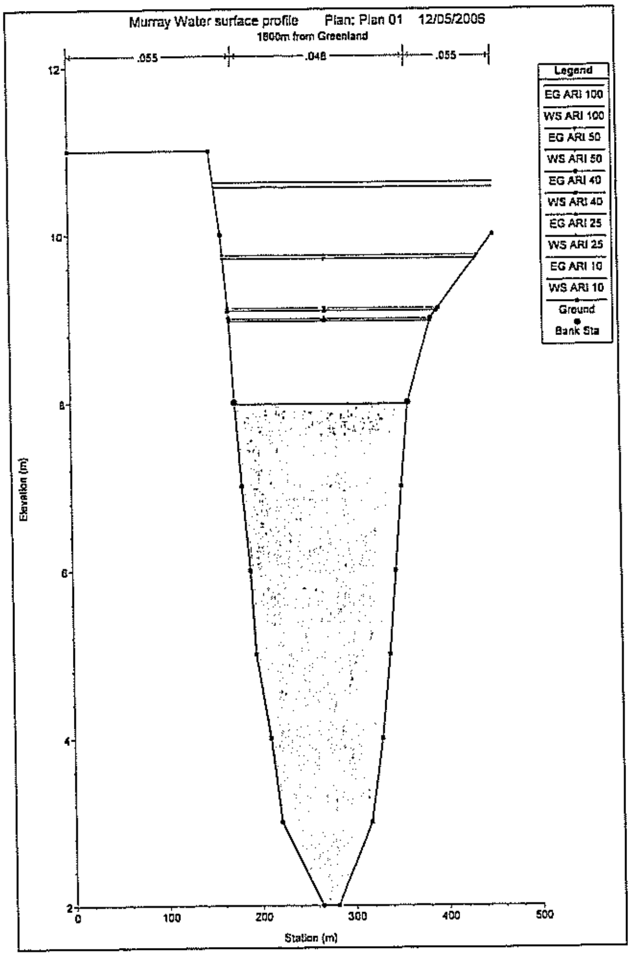
Murray Water surface profile Plan: Plan 01 12/05/2006
2100m from Greenland
.055 .048 .055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)



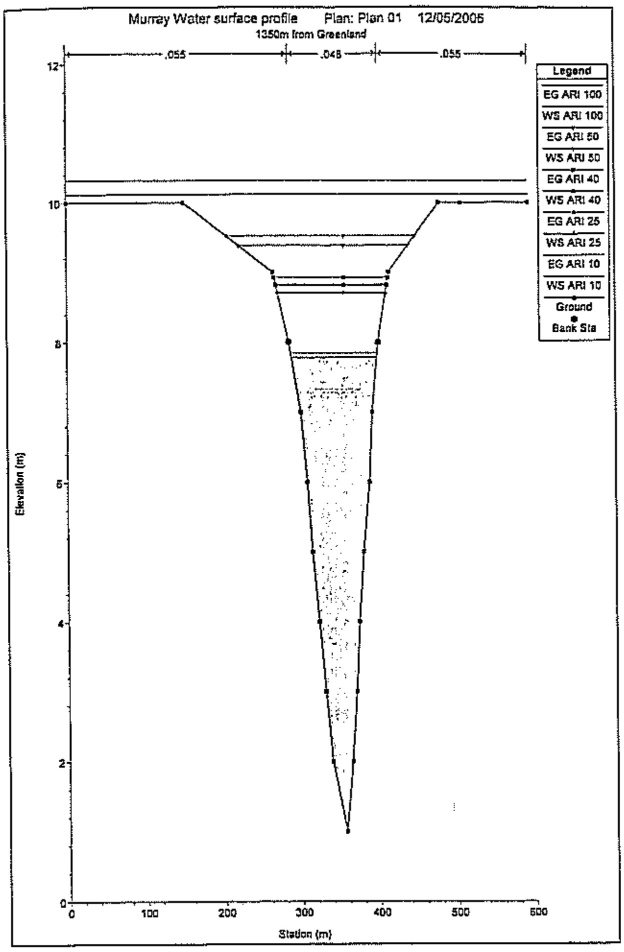
Murray Water surface profile Plan: Plan 01 12/05/2006
2250m from Greenland
.055 .048 .055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

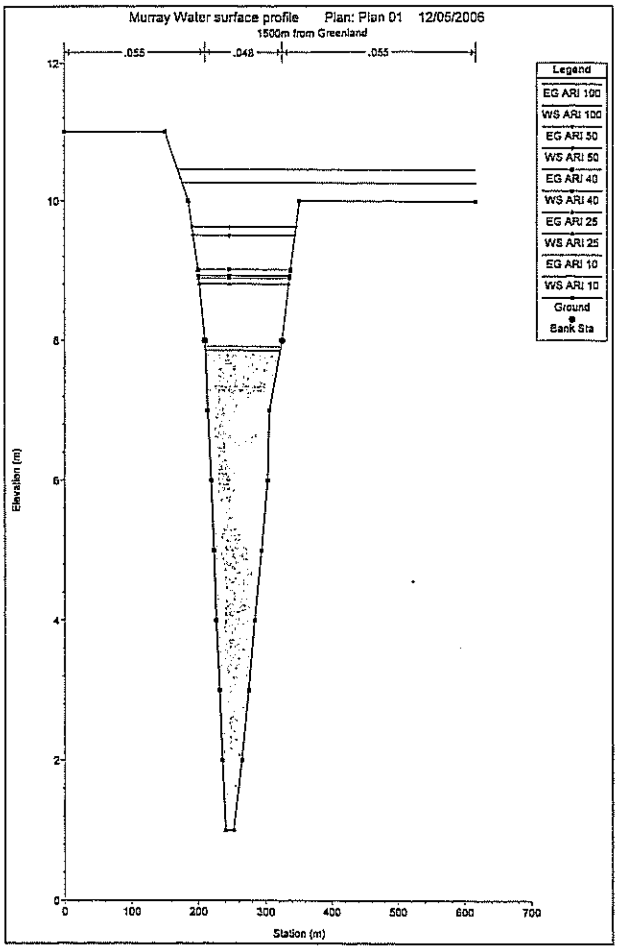


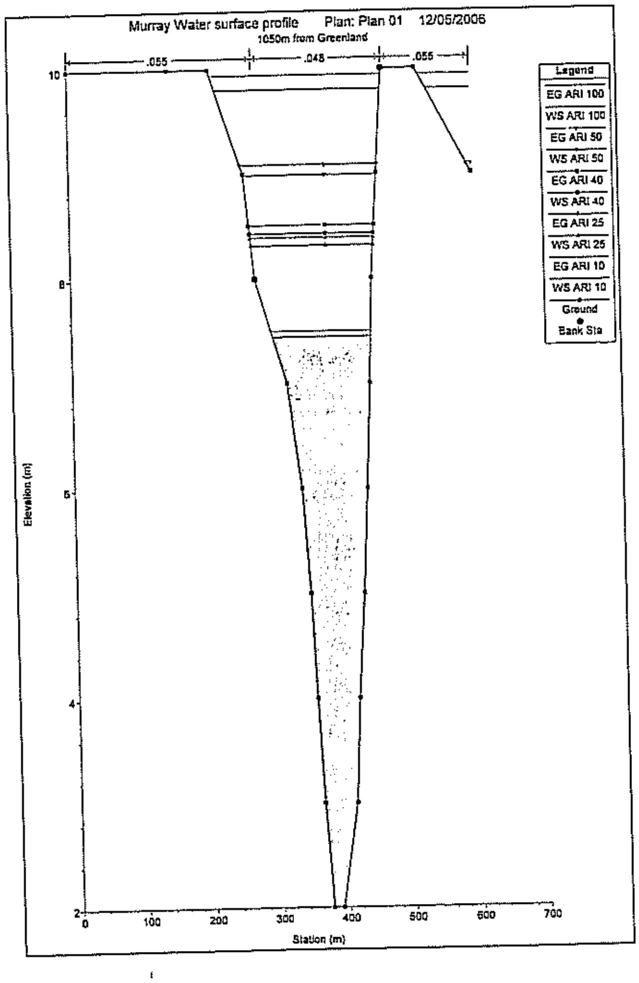
Murray Water surface profile Plan: Plan 01 12/05/2006
1650m from Greenland
.055 .048 .055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

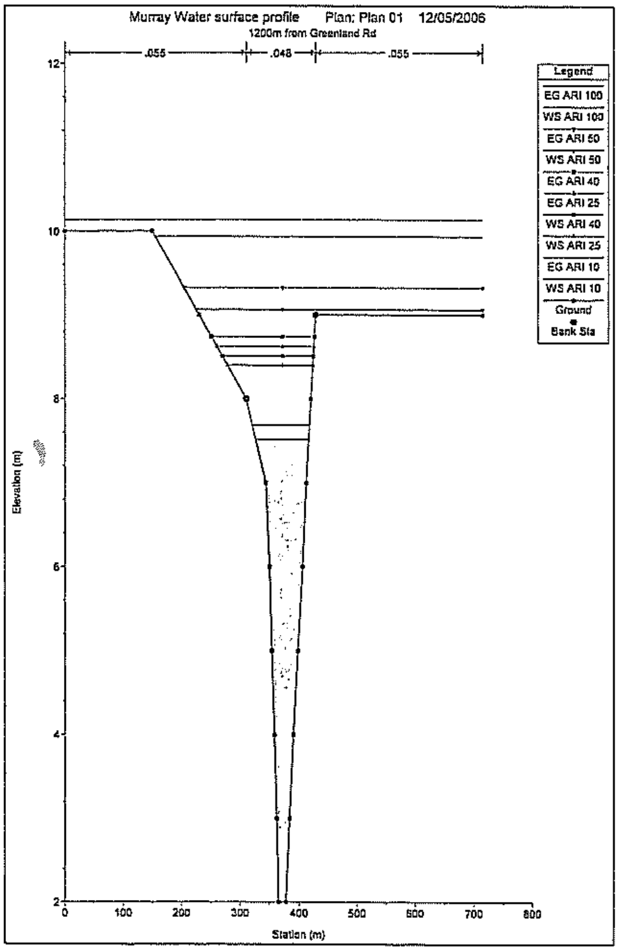


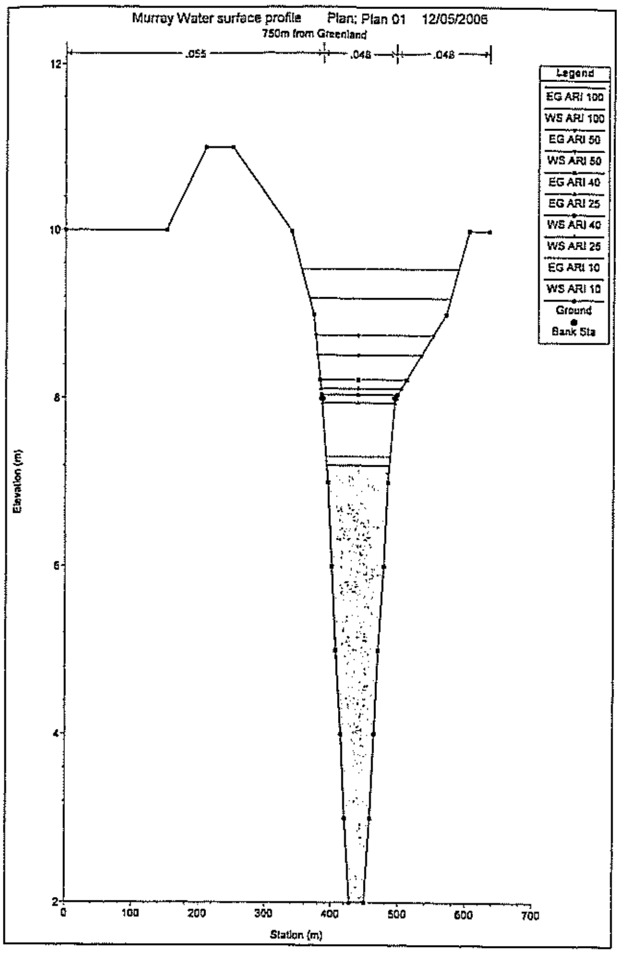
Murray Water surface profile Plan: Plan 01 12/05/2006
1800m from Greenland
.055 .048 .055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

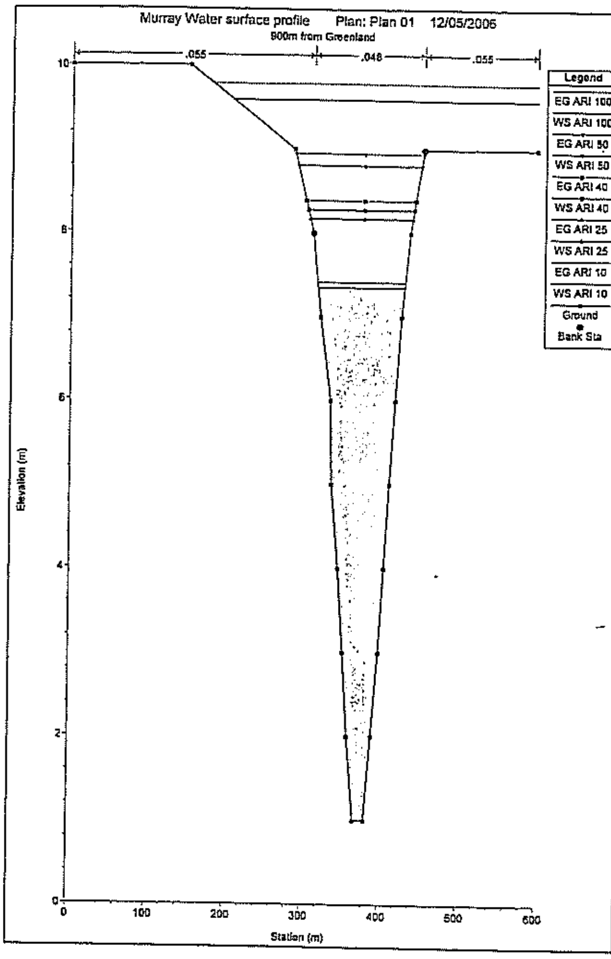

Murray Water surface profile Plan: Plan 01 12/05/2006
1350m from Greenland
.055
.048
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

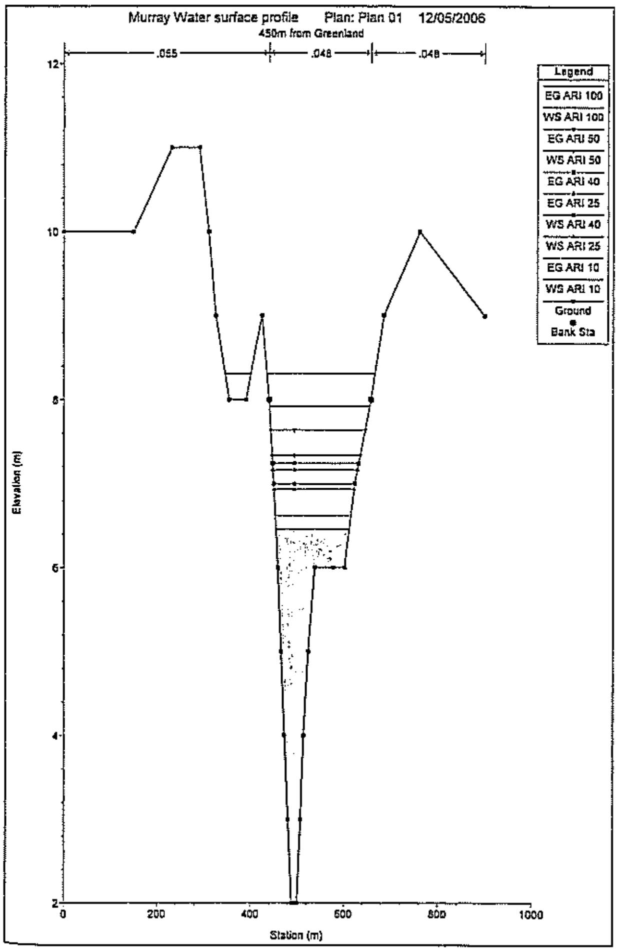

Murray Water surface profile Plan: Plan 01 12/05/2006
1500m from Greenland
.055
.048
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

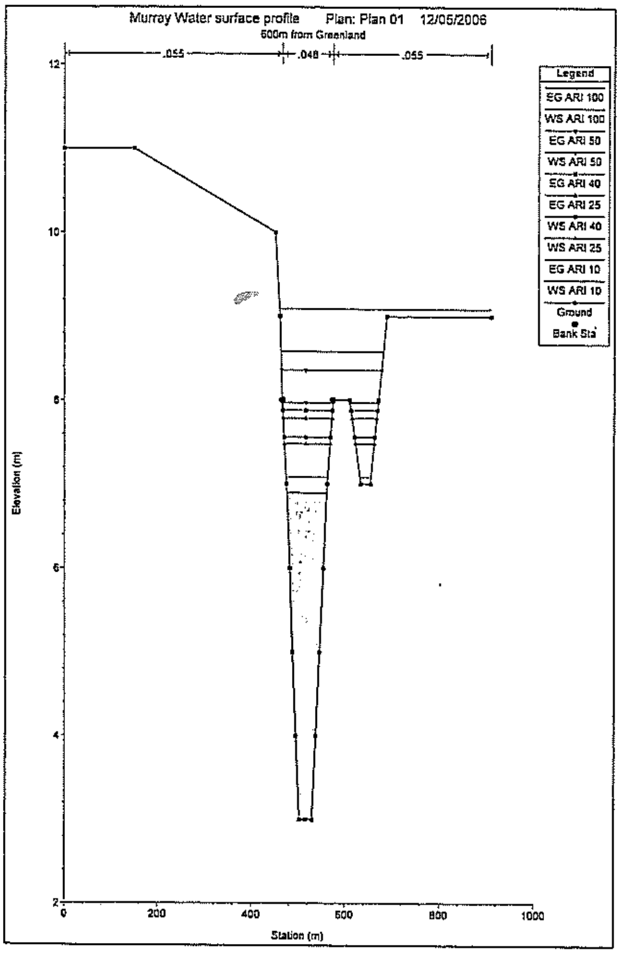

Murray Water surface profile Plan: Plan 01 12/05/2006
1050m from Greenland
.055
.048
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

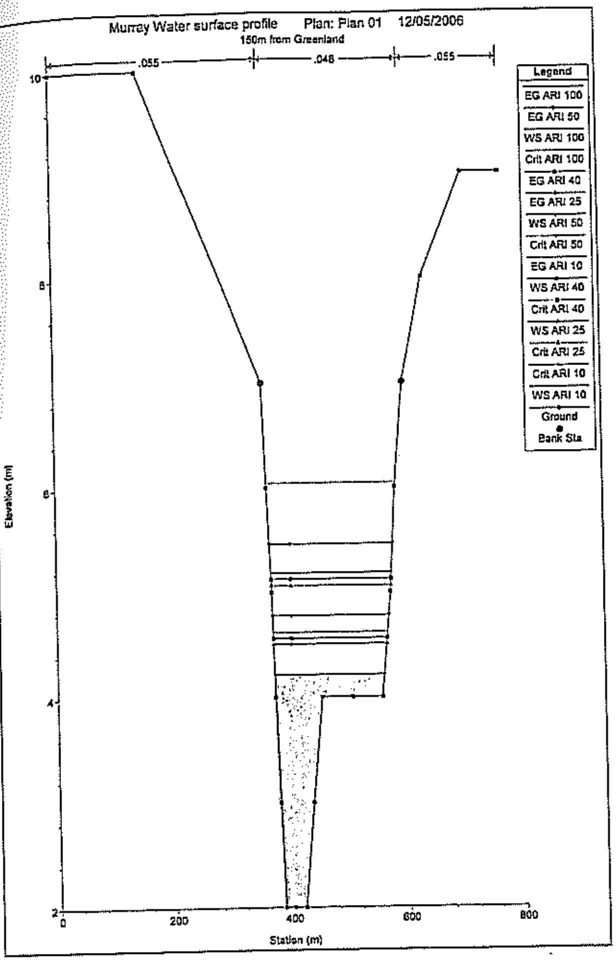

Murray Water surface profile Plan: Plan 01 12/05/2006
1200m from Greenland Rd
.055
.048
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
EG ARI 25
WS ARI 40
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

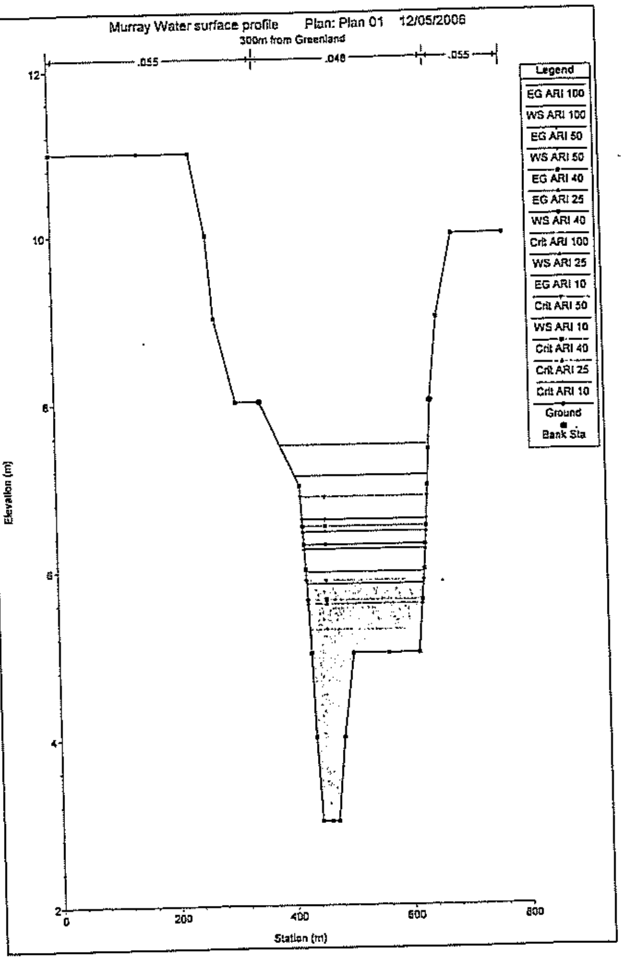

Murray Water surface profile Plan: Plan 01 12/05/2006
750m from Greenland
.055
.048
.048
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
EG ARI 25
WS ARI 40
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

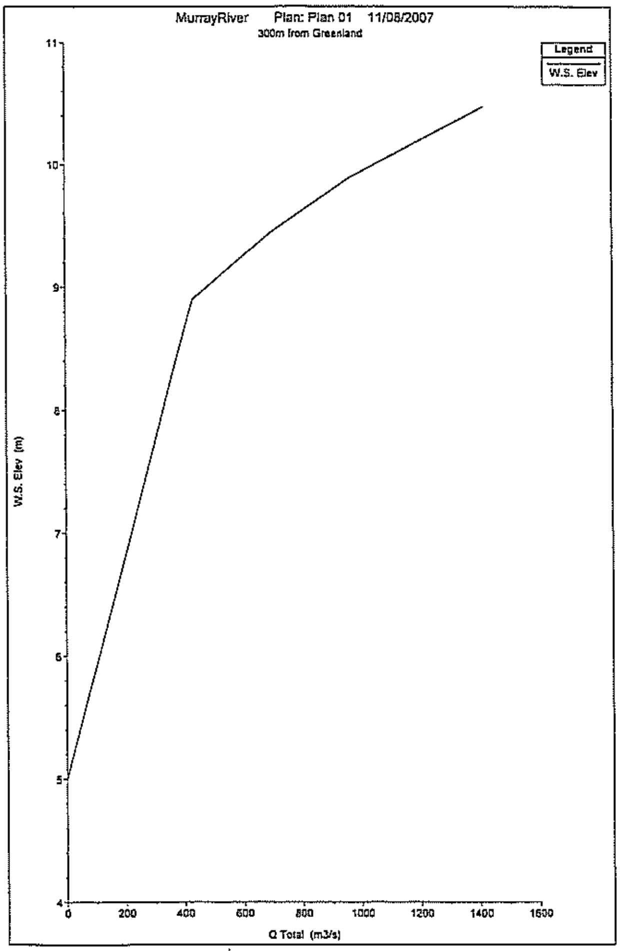

Murray Water surface profile Plan: Plan 01 12/05/2006
900m from Greenland
.055
.048
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
WS ARI 40
EG ARI 25
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

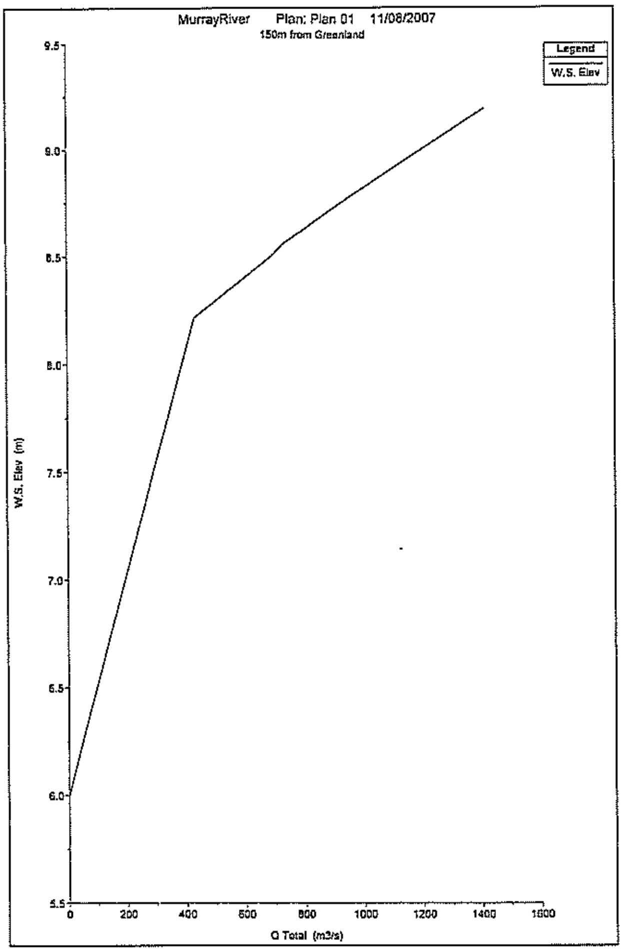

Murray Water surface profile Plan: Plan 01 12/05/2006
450m from Greenland
.055
.048
.048
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
EG ARI 25
WS ARI 40
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

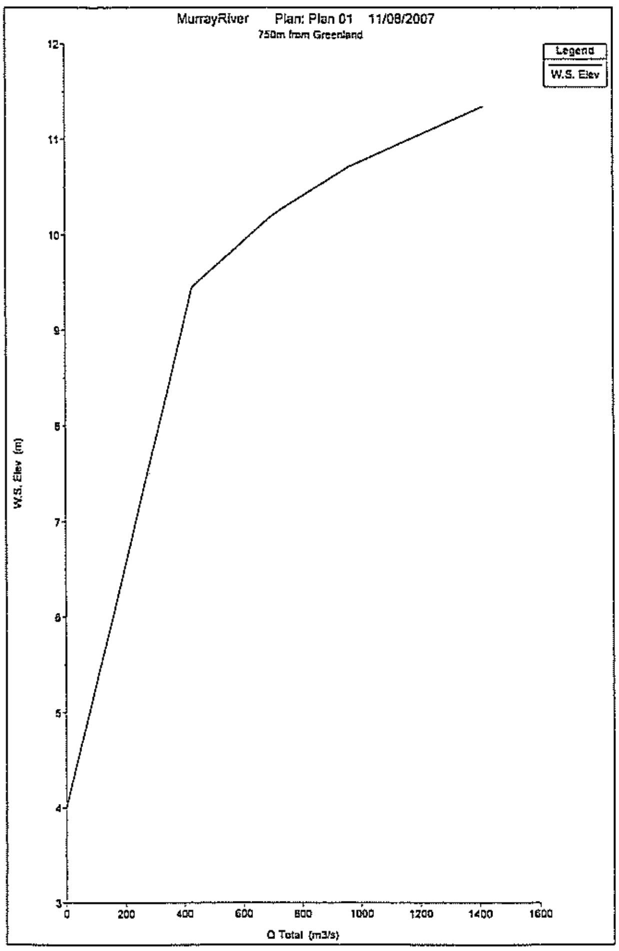

Murray Water surface profile Plan: Plan 01 12/05/2006
600m from Greenland
.055
.048
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
EG ARI 25
WS ARI 40
WS ARI 25
EG ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

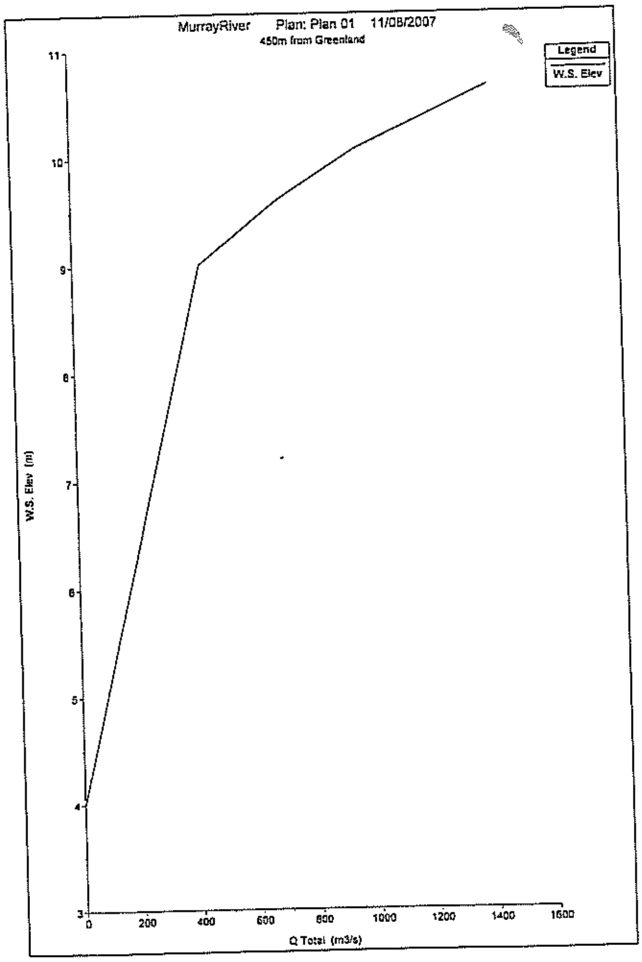

Murray Water surface profile Plan: Plan 01 12/05/2006
150m from Greenland
.055
.048
.055
Legend
EG ARI 100
EG ARI 50
WS ARI 100
Crit ARI 100
EG ARI 40
EG ARI 25
WS ARI 50
Crit ARI 50
EG ARI 10
WS ARI 40
Crit ARI 40
WS ARI 25
Crit ARI 25
Crit ARI 10
WS ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

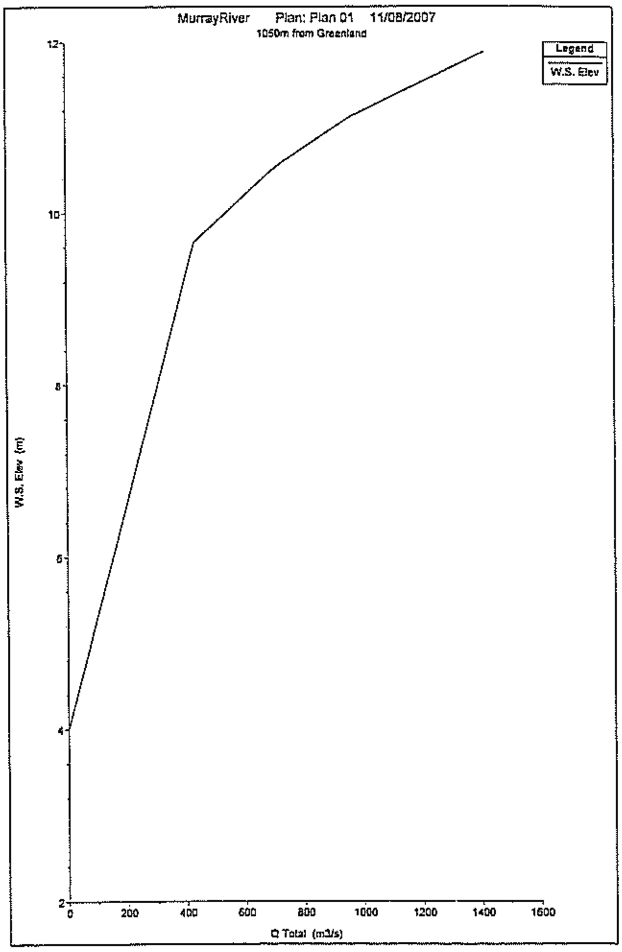

Murray Water surface profile Plan: Plan 01 12/05/2006
300m from Greenland
.055
.048
.055
Legend
EG ARI 100
WS ARI 100
EG ARI 50
WS ARI 50
EG ARI 40
EG ARI 25
WS ARI 40
Crit ARI 100
WS ARI 25
EG ARI 10
Crit ARI 50
WS ARI 10
Crit ARI 40
Crit ARI 25
Crit ARI 10
Ground
Bank Sta
Elevation (m)
Station (m)

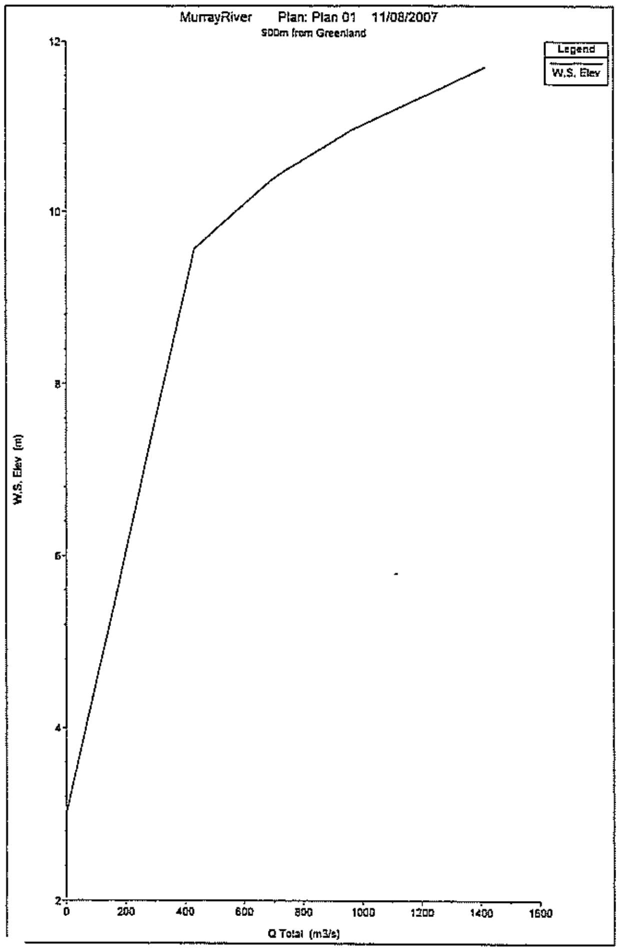

MurrayRiver Plan: Plan 01 11/08/2007
300m from Greenland
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)

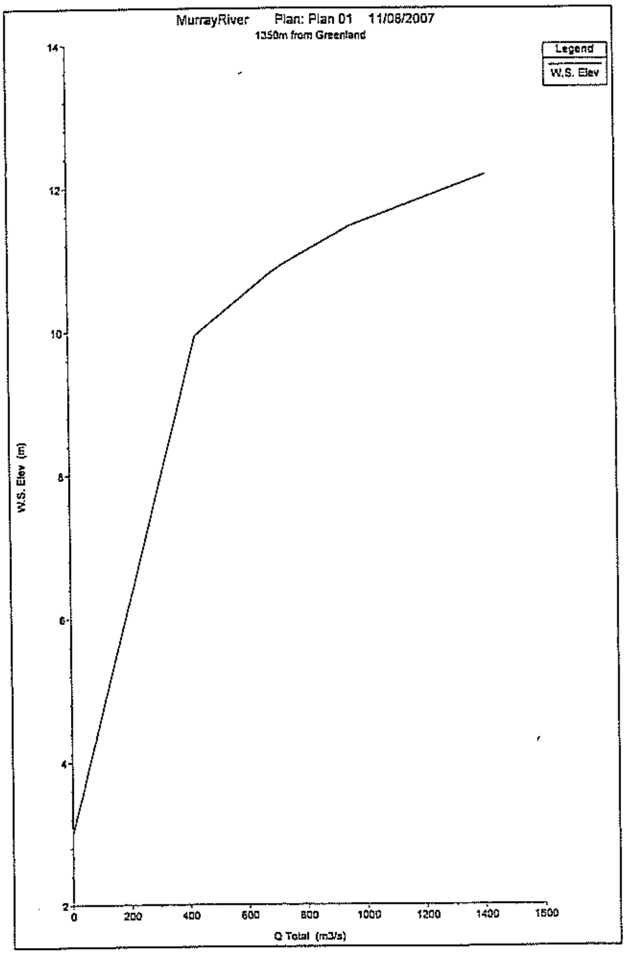

MurrayRiver Plan: Plan 01 11/08/2007
150m from Greenland
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)

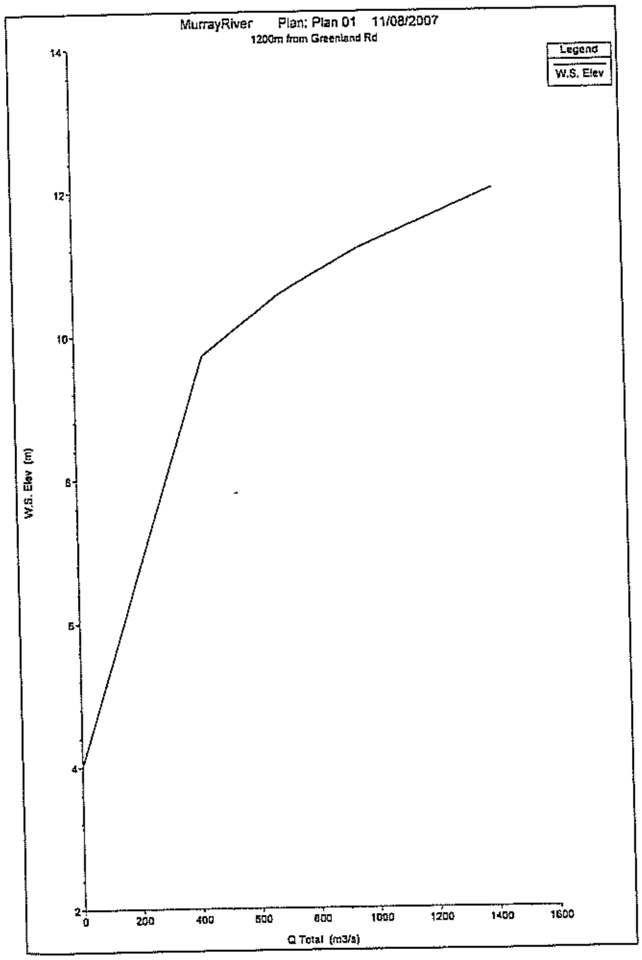

MurrayRiver Plan: Plan 01 11/08/2007
750m from Greenland
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)

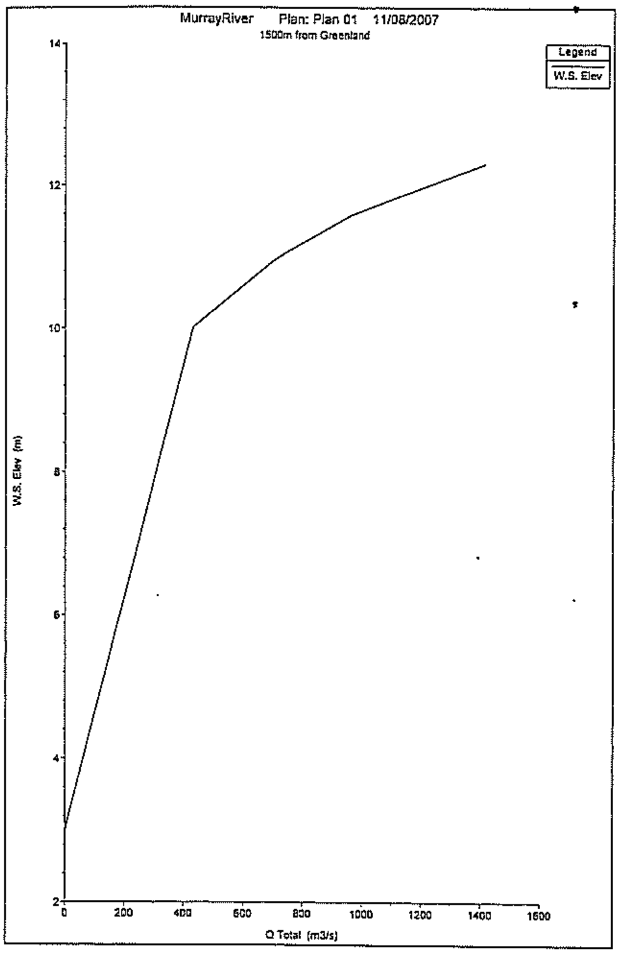

MurrayRiver Plan: Plan 01 11/08/2007
450m from Greenland
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)


MurrayRiver Plan: Plan 01 11/08/2007
1050m from Greenland
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)
2 4 6 8 10 12
0 200 400 600 800 1000 1200 1400 1600


MurrayRiver Plan: Plan 01 11/08/2007
900m from Greenland
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)
2 4 6 8 10 12
0 200 400 600 800 1000 1200 1400 1600


MurrayRiver Plan: Plan 01 11/08/2007
1350m from Greenland
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)
2 4 6 8 10 12 14
0 200 400 600 800 1000 1200 1400 1600


MurrayRiver Plan: Plan 01 11/08/2007
1200m from Greenland Rd
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)
2 4 6 8 10 12 14
0 200 400 600 800 1000 1200 1400 1600


MurrayRiver Plan: Plan 01 11/08/2007
1500m from Greenland
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)
14
12
10
8
6
4
2
0
200
400
600
800
1000
1200
1400
1600

HEC-RAS Plan: Plan 01 River: murray Reach: murray

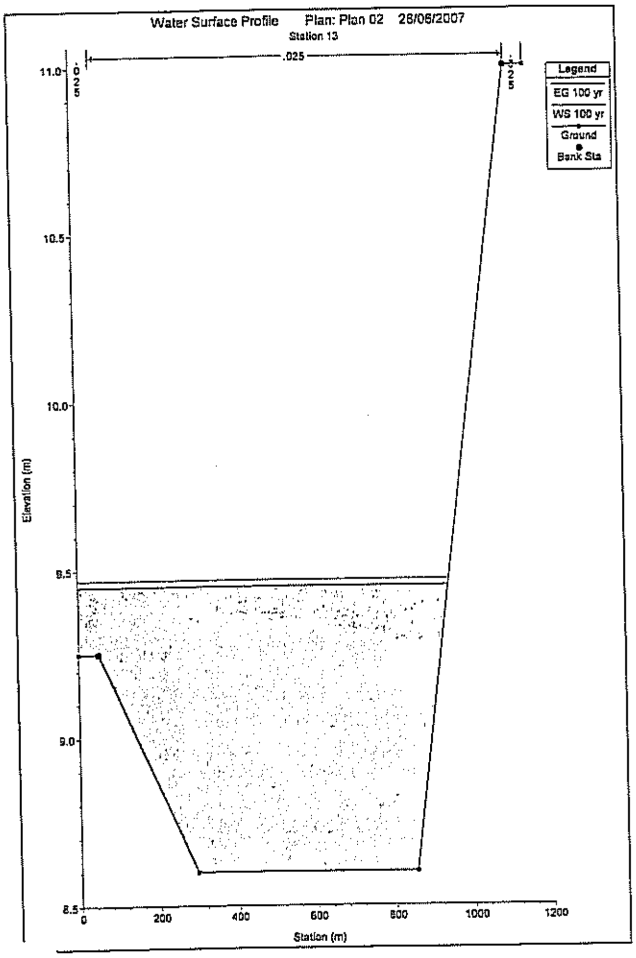
Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
murray	18	ARI 10	430.00	3.00	10.26		10.28	0.000182	0.56	770.16	208.23	0.09
murray	18	ARI 25	690.00	3.00	11.25		11.27	0.000230	0.71	1005.01	280.58	0.10
murray	18	ARI 50	960.00	3.00	12.00		12.04	0.000273	0.83	1251.40	391.06	0.12
murray	18	ARI 100	1415.00	3.00	12.89		12.94	0.000319	1.00	1610.55	415.12	0.13
murray	18	ARI 40	731.00	3.00	11.37		11.40	0.000237	0.73	1041.97	295.97	0.11
murray	17	ARI 10	430.00	4.00	10.22		10.25	0.000166	0.75	573.26	134.23	0.11
murray	17	ARI 25	690.00	4.00	11.19		11.23	0.000233	0.99	732.86	202.38	0.13
murray	17	ARI 50	960.00	4.00	11.92		11.99	0.000291	1.16	908.82	275.31	0.15
murray	17	ARI 100	1415.00	4.00	12.79		12.89	0.000353	1.42	1243.65	406.79	0.17
murray	17	ARI 40	731.00	4.00	11.31		11.36	0.000243	1.02	758.95	214.76	0.14
murray	16	ARI 10	430.00	4.00	10.21		10.23	0.000100	0.56	793.88	231.15	0.08
murray	16	ARI 25	690.00	4.00	11.18		11.20	0.000130	0.72	1052.00	301.98	0.10
murray	16	ARI 50	960.00	4.00	11.92		11.95	0.000157	0.84	1292.13	347.80	0.11
murray	16	ARI 100	1415.00	4.00	12.79		12.84	0.000195	1.03	1599.67	353.00	0.13
murray	16	ARI 40	731.00	4.00	11.30		11.33	0.000135	0.74	1090.38	309.76	0.10
murray	15	ARI 10	430.00	4.00	10.20		10.21	0.000066	0.43	1000.93	250.46	0.07
murray	15	ARI 25	690.00	4.00	11.17		11.18	0.000083	0.55	1250.26	268.54	0.08
murray	15	ARI 50	960.00	4.00	11.91		11.93	0.000101	0.67	1455.47	288.44	0.09
murray	15	ARI 100	1415.00	4.00	12.77		12.81	0.000135	0.85	1723.06	311.00	0.11
murray	15	ARI 40	731.00	4.00	11.29		11.31	0.000086	0.57	1284.08	271.92	0.08
murray	14	ARI 10	430.00	4.00	10.18		10.20	0.000132	0.58	738.59	195.84	0.10
murray	14	ARI 25	690.00	4.00	11.14		11.17	0.000160	0.75	936.29	219.23	0.11
murray	14	ARI 50	960.00	4.00	11.87		11.91	0.000191	0.89	1105.95	246.89	0.12
murray	14	ARI 100	1415.00	4.00	12.72		12.78	0.000249	1.12	1321.96	257.73	0.14
murray	14	ARI 40	731.00	4.00	11.26		11.29	0.000165	0.77	953.72	223.93	0.11
murray	13	ARI 10	430.00	4.00	10.18		10.19	0.000042	0.37	1167.37	250.31	0.06
murray	13	ARI 25	690.00	4.00	11.14		11.15	0.000056	0.49	1427.35	286.10	0.07
murray	13	ARI 50	960.00	4.00	11.86		11.88	0.000072	0.60	1647.91	318.91	0.08
murray	13	ARI 100	1415.00	4.00	12.72		12.75	0.000099	0.76	1956.97	370.00	0.09
murray	13	ARI 40	731.00	4.00	11.26		11.27	0.000059	0.51	1463.16	291.68	0.07
murray	12	ARI 10	430.00	6.00	10.12		10.17	0.000465	0.92	466.07	157.87	0.17
murray	12	ARI 25	690.00	6.00	11.06		11.12	0.000517	1.11	620.33	171.90	0.19
murray	12	ARI 50	960.00	6.00	11.77		11.85	0.000587	1.29	745.74	182.52	0.20
murray	12	ARI 100	1415.00	6.00	12.58		12.71	0.000708	1.58	901.17	203.36	0.23
murray	12	ARI 40	731.00	6.00	11.18		11.25	0.000527	1.14	641.20	173.72	0.19
murray	11	ARI 10	430.00	4.00	10.07		10.11	0.000285	0.88	489.11	124.03	0.14
murray	11	ARI 25	690.00	4.00	10.99		11.06	0.000365	1.14	608.85	136.88	0.17
murray	11	ARI 50	960.00	4.00	11.68		11.77	0.000447	1.38	735.74	217.48	0.19
murray	11	ARI 100	1415.00	4.00	12.46		12.61	0.000585	1.72	927.18	257.24	0.22
murray	11	ARI 40	731.00	4.00	11.11		11.18	0.000379	1.18	627.25	163.36	0.17
murray	10	ARI 10	430.00	3.00	10.02		10.06	0.000364	0.97	443.36	115.36	0.16
murray	10	ARI 25	690.00	3.00	10.91		11.00	0.000463	1.26	555.90	135.13	0.18
murray	10	ARI 50	960.00	3.00	11.58		11.70	0.000571	1.52	651.75	153.80	0.21
murray	10	ARI 100	1415.00	3.00	12.32		12.50	0.000774	1.93	857.18	442.08	0.25
murray	10	ARI 40	731.00	3.00	11.03		11.11	0.000479	1.30	571.49	137.84	0.19
murray	9	ARI 10	430.00	3.00	9.94		10.00	0.000475	1.06	407.13	113.72	0.18
murray	9	ARI 25	690.00	3.00	10.82		10.92	0.000588	1.35	519.68	142.99	0.21
murray	9	ARI 50	960.00	3.00	11.47		11.60	0.000706	1.62	634.87	232.80	0.23
murray	9	ARI 100	1415.00	3.00	12.18		12.38	0.000904	2.01	864.24	442.00	0.27
murray	9	ARI 40	731.00	3.00	10.93		11.03	0.000606	1.40	535.79	146.77	0.21
murray	8	ARI 10	430.00	4.00	9.72		9.87	0.001878	1.69	254.40	98.27	0.34
murray	8	ARI 25	690.00	4.00	10.56		10.75	0.002099	1.98	358.19	158.89	0.35
murray	8	ARI 50	960.00	4.00	11.20		11.42	0.002012	2.17	533.88	499.68	0.37
murray	8	ARI 100	1415.00	4.00	12.02		12.20	0.001455	2.12	972.61	564.00	0.32
murray	8	ARI 40	731.00	4.00	10.66		10.87	0.002105	2.02	375.61	168.25	0.37
murray	7	ARI 10	430.00	4.00	9.66		9.70	0.000516	0.95	451.84	157.83	0.18
murray	7	ARI 25	690.00	4.00	10.49		10.56	0.000628	1.16	597.67	187.24	0.20
murray	7	ARI 50	960.00	4.00	11.13		11.22	0.000699	1.34	722.61	217.64	0.22
murray	7	ARI 100	1415.00	4.00	11.89		12.02	0.000834	1.62	931.42	325.96	0.25
murray	7	ARI 40	731.00	4.00	10.60		10.67	0.000636	1.19	617.91	189.92	0.21
murray	6	ARI 10	430.00	3.00	9.57		9.63	0.000453	1.03	415.58	115.50	0.17
murray	6	ARI 25	690.00	3.00	10.37		10.46	0.000677	1.34	514.63	139.36	0.22
murray	6	ARI 50	960.00	3.00	10.96		11.10	0.000882	1.61	605.53	164.49	0.25
murray	6	ARI 100	1415.00	3.00	11.70		11.88	0.001025	1.93	861.87	404.60	0.28
murray	6	ARI 40	731.00	3.00	10.47		10.57	0.000709	1.39	528.99	143.62	0.22
murray	5	ARI 10	430.00	4.00	9.45		9.54	0.000802	1.31	328.45	98.55	0.23
murray	5	ARI 25	690.00	4.00	10.17		10.32	0.001181	1.71	405.59	124.33	0.28
murray	5	ARI 50	960.00	4.00	10.71		10.92	0.001433	2.06	484.90	171.97	0.32
murray	5	ARI 100	1415.00	4.00	11.35		11.67	0.001832	2.55	611.76	221.58	0.37
murray	5	ARI 40	731.00	4.00	10.26		10.42	0.001220	1.76	417.36	132.49	0.29

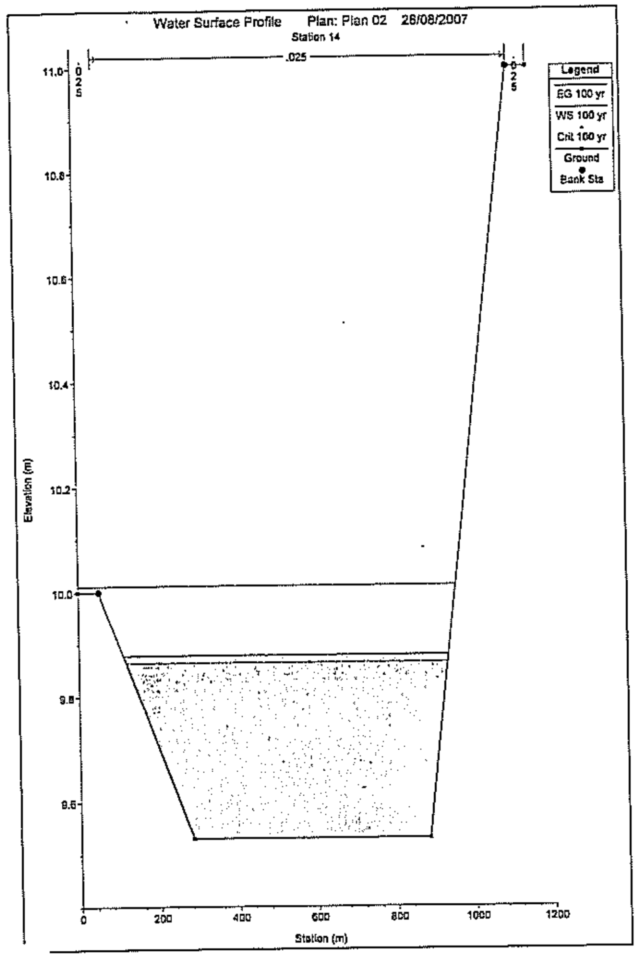
HEC-RAS Plan: Plan 01 River: murray Reach: murray (Continued)

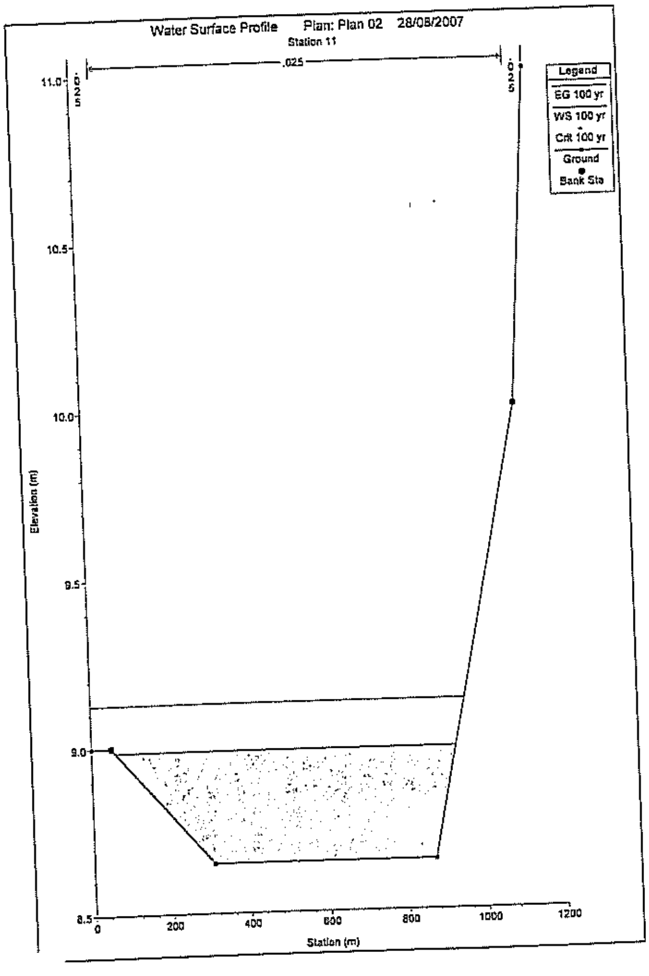
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
murray	4	ARI 10	430.00	5.00	9.22		9.36	0.001733	1.69	258.82	121.61	0.33
murray	4	ARI 25	690.00	5.00	9.84		10.07	0.002436	2.12	347.36	161.09	0.39
murray	4	ARI 50	960.00	5.00	10.34		10.62	0.002730	2.45	444.41	214.74	0.42
murray	4	ARI 100	1415.00	5.00	10.92		11.31	0.003089	2.89	574.55	228.25	0.46
murray	4	ARI 40	731.00	5.00	9.92		10.16	0.002526	2.18	360.81	166.27	0.40
murray	3	ARI 10	430.00	4.00	9.01		9.09	0.001583	1.28	335.94	174.50	0.29
murray	3	ARI 25	690.00	4.00	9.59		9.71	0.001930	1.55	444.39	200.53	0.33
murray	3	ARI 50	960.00	4.00	10.07		10.23	0.002118	1.76	548.44	262.37	0.36
murray	3	ARI 100	1415.00	4.00	10.66		10.87	0.002195	2.06	721.31	324.78	0.38
murray	3	ARI 40	731.00	4.00	9.67		9.79	0.001980	1.59	459.66	203.93	0.34
murray	2	ARI 10	430.00	5.00	8.90		8.94	0.000542	0.90	479.65	216.35	0.19
murray	2	ARI 25	690.00	5.00	9.43		9.50	0.000931	1.14	603.57	249.70	0.23
murray	2	ARI 50	960.00	5.00	9.89		9.98	0.001159	1.33	724.14	282.77	0.26
murray	2	ARI 100	1415.00	5.00	10.47		10.60	0.001280	1.57	918.41	354.16	0.29
murray	2	ARI 40	731.00	5.00	9.50		9.57	0.000975	1.18	621.09	254.78	0.24
murray	1	ARI 10	430.00	6.00	8.22	8.22	8.62	0.023978	2.81	153.13	188.31	0.99
murray	1	ARI 25	690.00	6.00	8.50	8.50	9.06	0.023316	3.32	207.57	194.01	1.03
murray	1	ARI 50	960.00	6.00	8.78	8.78	9.46	0.021403	3.66	262.62	199.60	1.02
murray	1	ARI 100	1415.00	6.00	9.20	9.20	10.04	0.019251	4.07	347.43	207.34	1.00
murray	1	ARI 40	731.00	6.00	8.56	8.56	9.13	0.022071	3.34	218.98	195.18	1.01

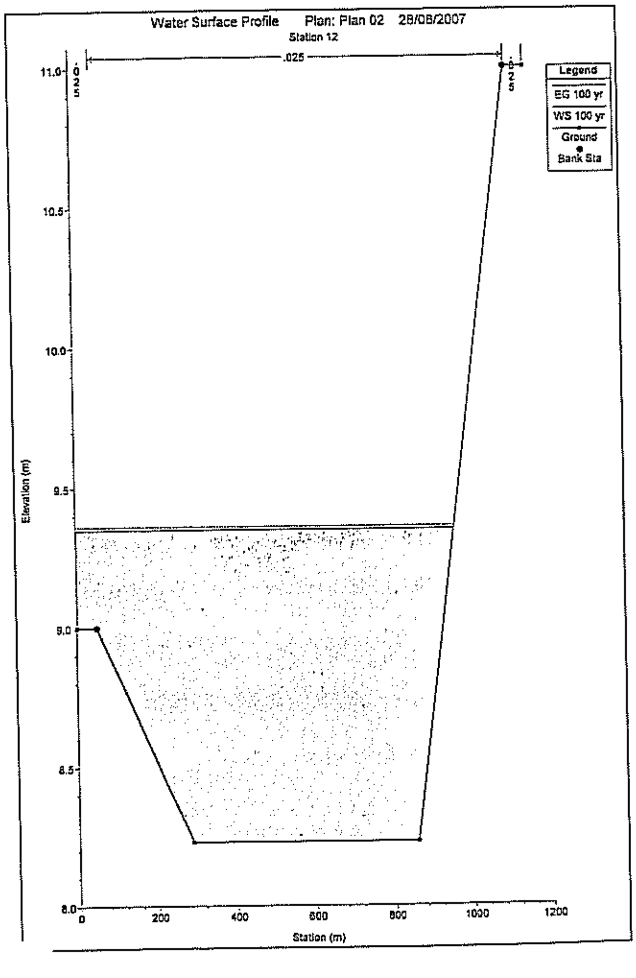
APPENDIX B

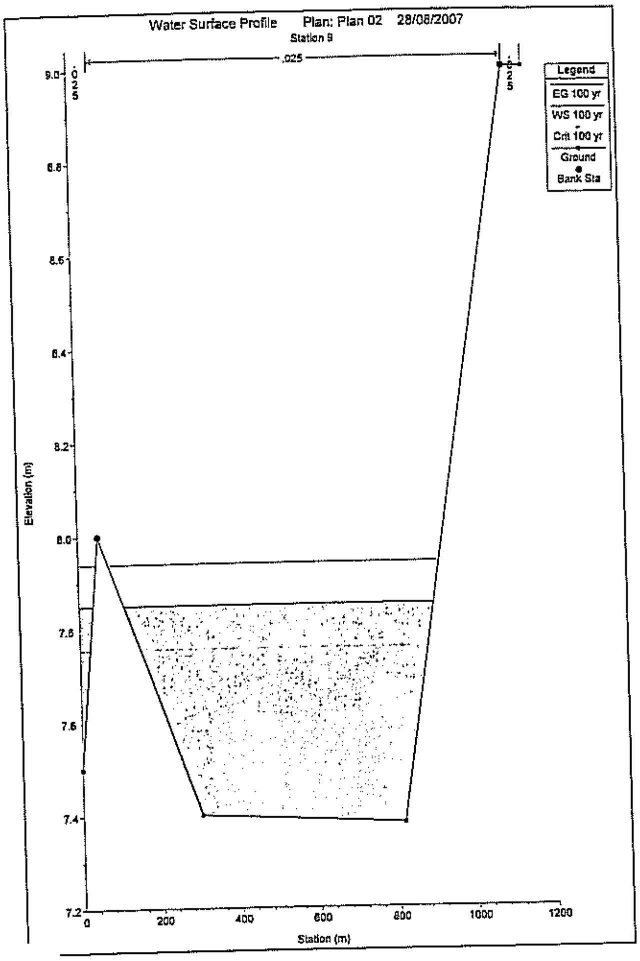
CROSS-SECTIONS AND RATING CURVES OF WATER SURFACE PROFILE FOR THE PROPOSED DIVERSION CHANNEL

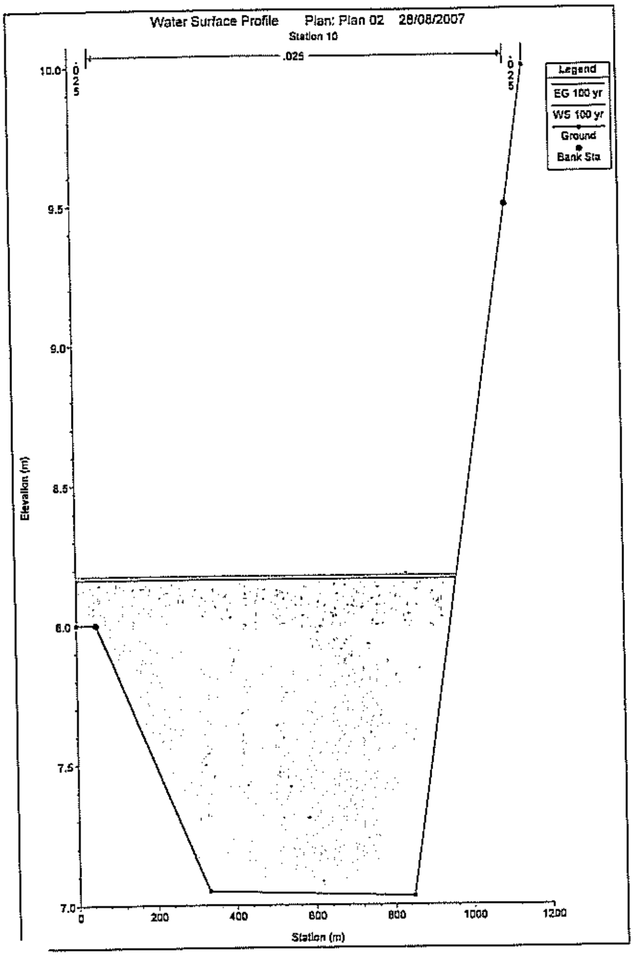

Water Surface Profile Plan: Plan 02 28/08/2007
Station 13
.025
Legend
EG 100 yr
WS 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

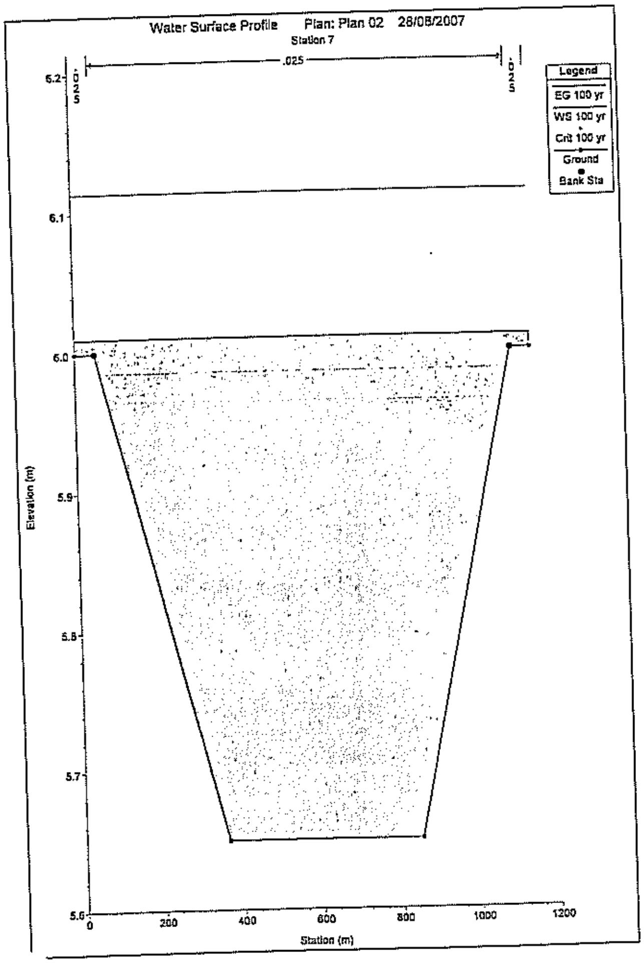

Water Surface Profile Plan: Plan 02 28/08/2007
Station 14
.025
Legend
EG 100 yr
WS 100 yr
Crit 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

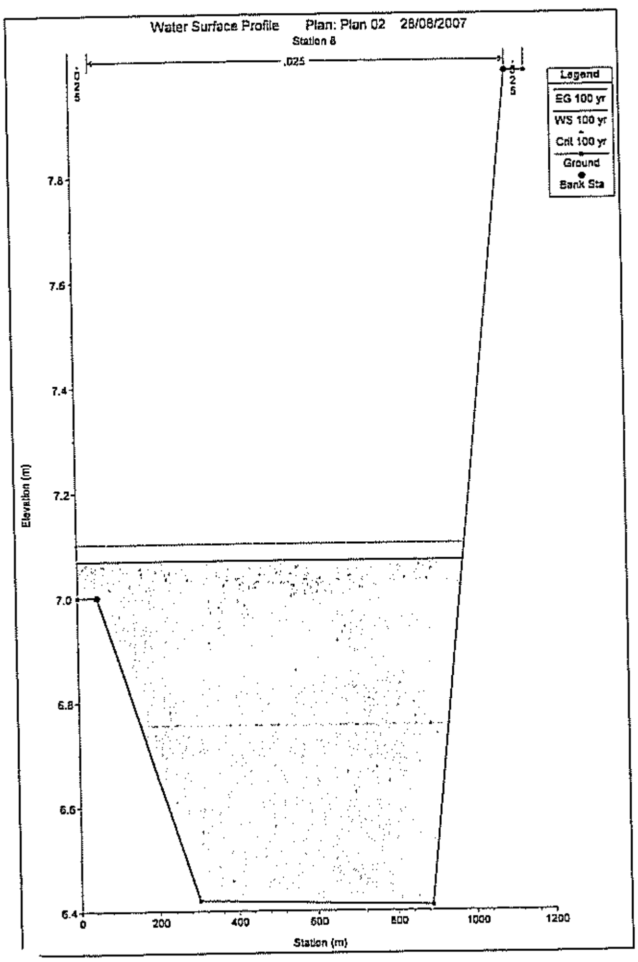

Water Surface Profile Plan: Plan 02 28/08/2007
Station 11
.025
Legend
EG 100 yr
WS 100 yr
Crit 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

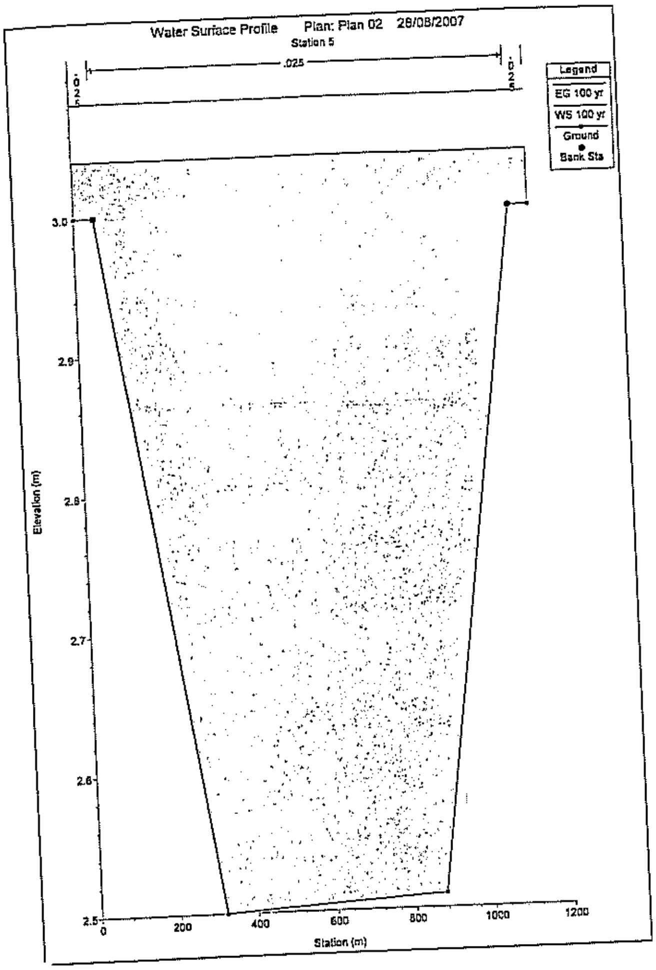

Water Surface Profile Plan: Plan 02 28/08/2007
Station 12
.025
Legend
EG 100 yr
WS 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

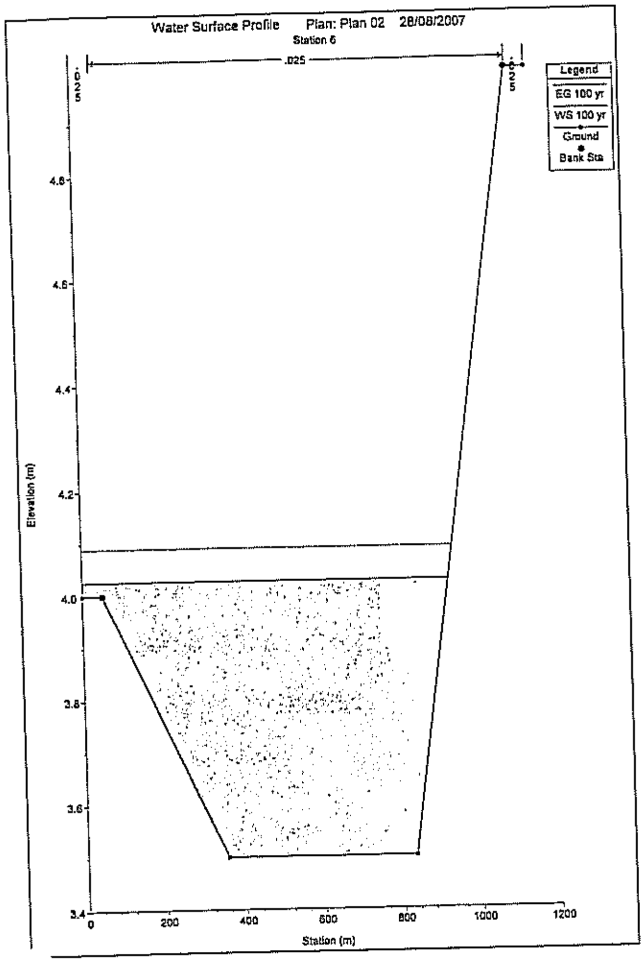

Water Surface Profile Plan: Plan 02 28/08/2007
Station 9
.025
Legend
EG 100 yr
WS 100 yr
Crit 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

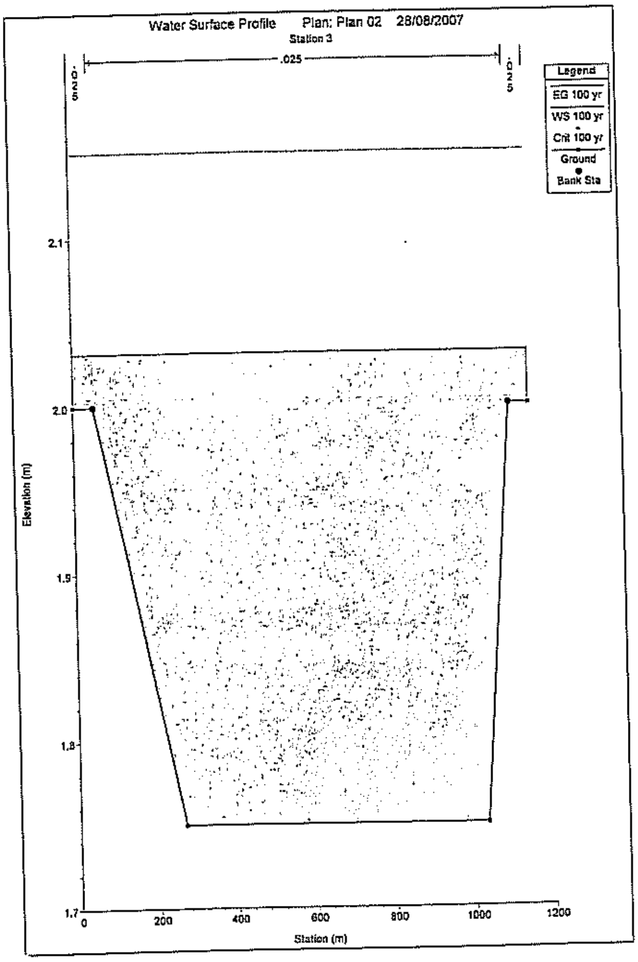

Water Surface Profile Plan: Plan 02 28/08/2007
Station 10
.025
Legend
EG 100 yr
WS 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

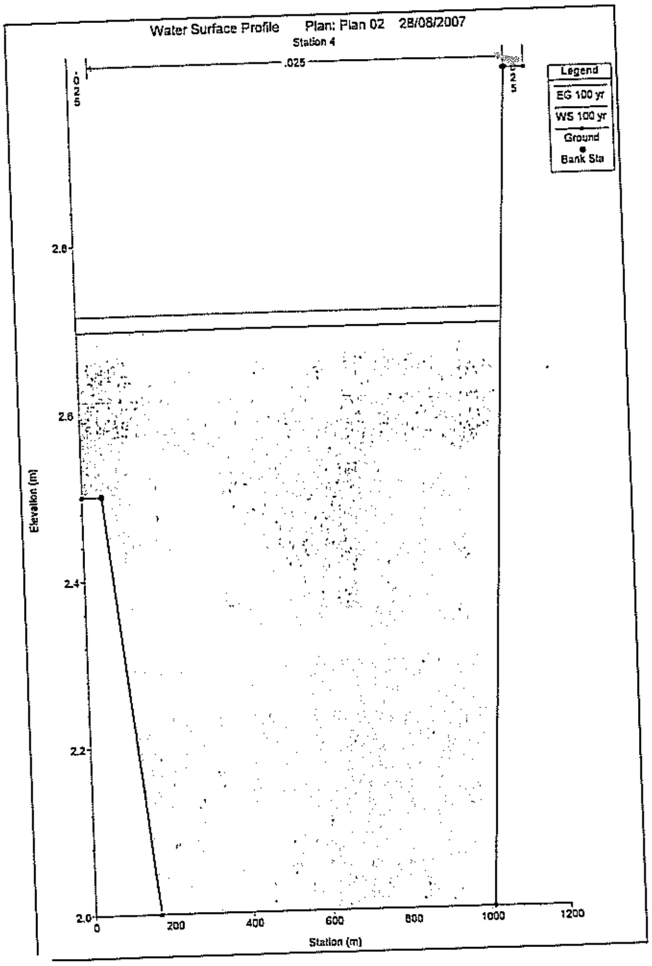

Water Surface Profile Plan: Plan 02 28/08/2007
Station 7
.025
Legend
EG 100 yr
WS 100 yr
Crit 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

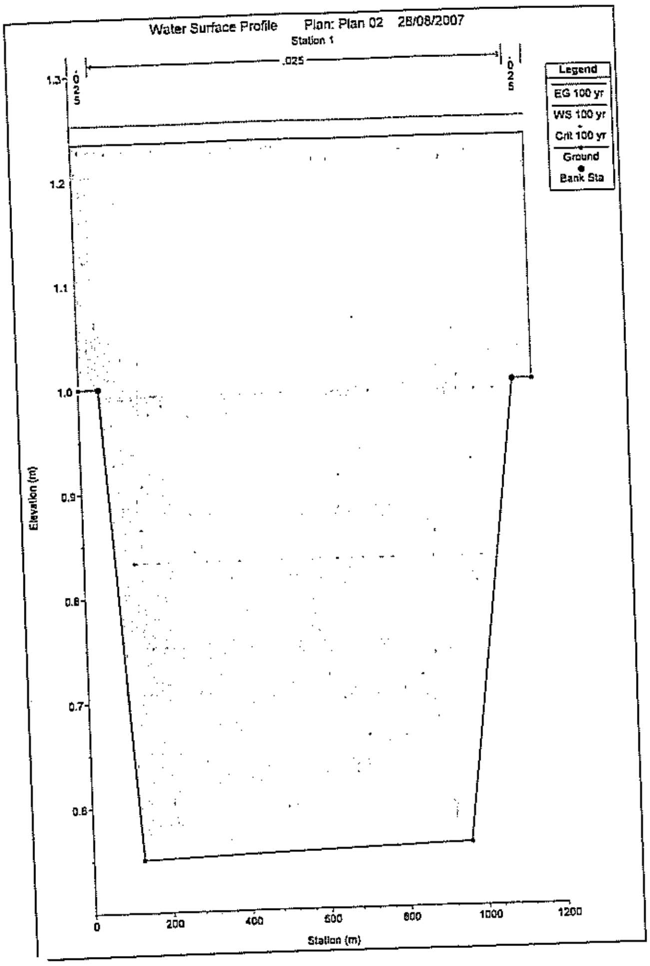

Water Surface Profile Plan: Plan 02 28/08/2007
Station 8
.025
Legend
EG 100 yr
WS 100 yr
Crit 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)


Water Surface Profile Plan: Plan 02 28/08/2007
Station 5
.025
Legend
EG 100 yr
WS 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

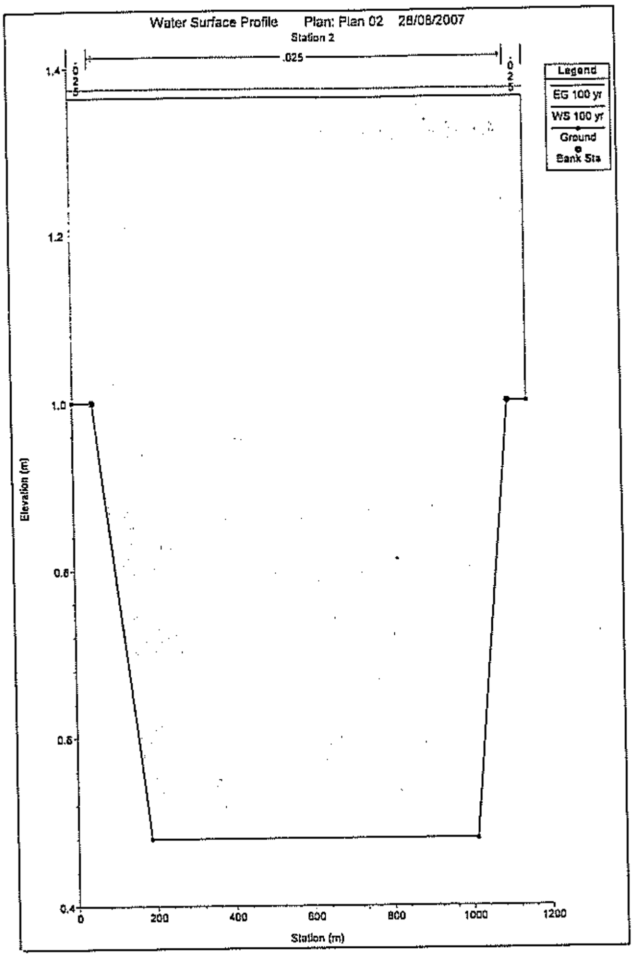

Water Surface Profile Plan: Plan 02 28/08/2007
Station 6
.025
Legend
EG 100 yr
WS 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)


Water Surface Profile Plan: Plan 02 28/08/2007
Station 3
.025
Legend
EG 100 yr
WS 100 yr
Crit 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

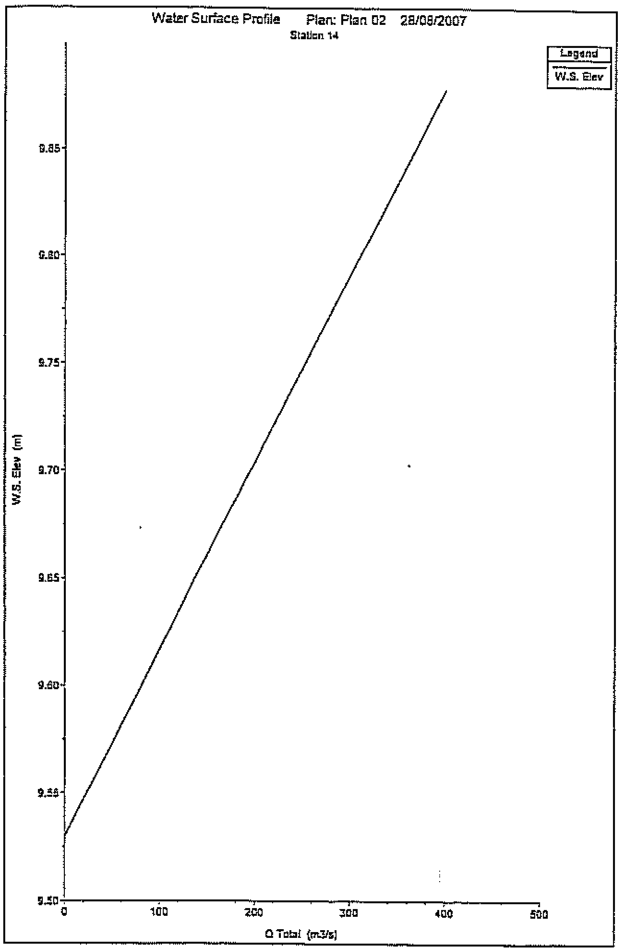

Water Surface Profile Plan: Plan 02 28/08/2007
Station 4
.025
Legend
EG 100 yr
WS 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

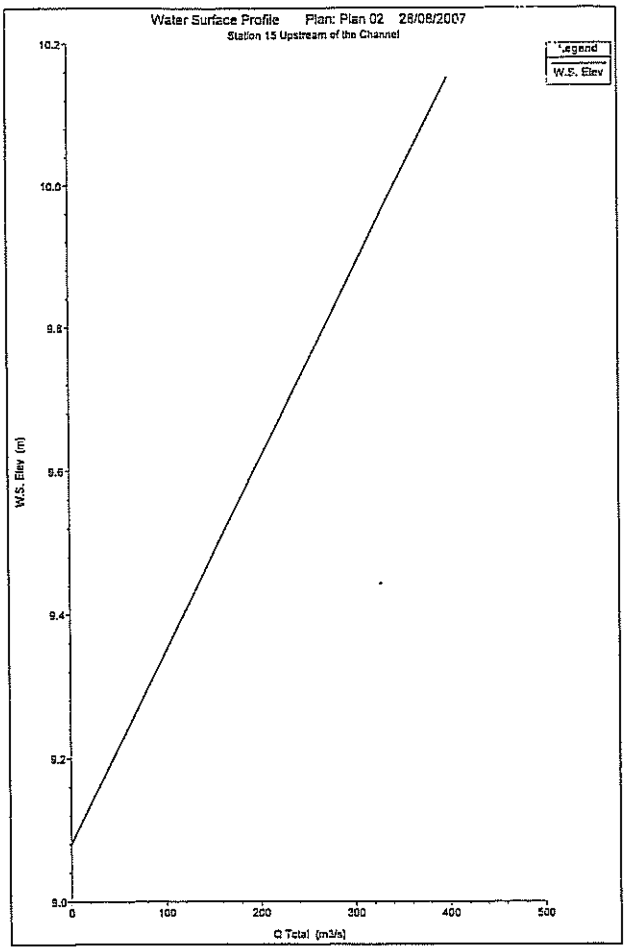


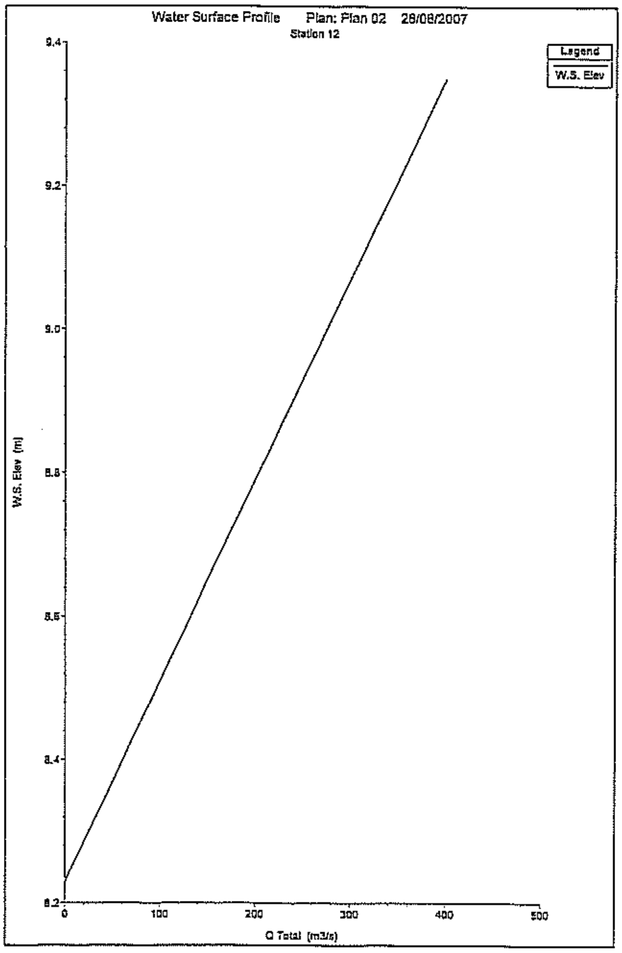
Water Surface Profile Plan: Plan 02 28/08/2007
Station 1
.025
Legend
EG 100 yr
WS 100 yr
Crit 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

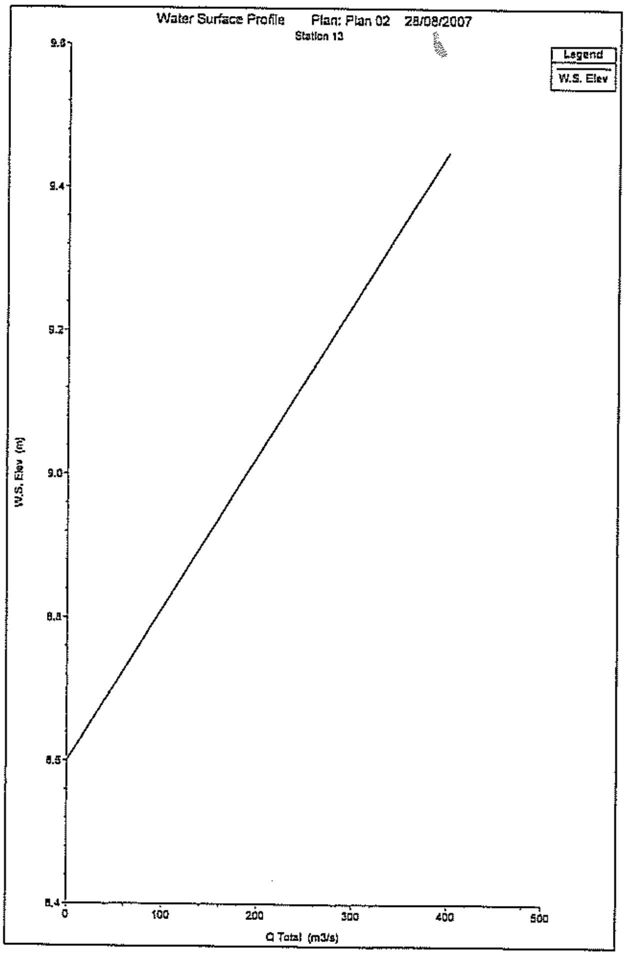


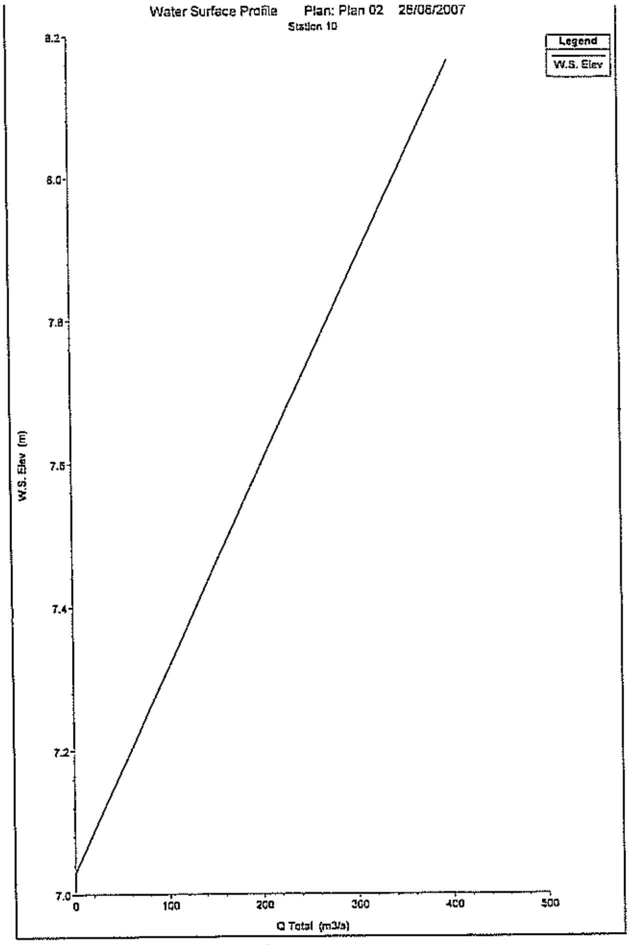
Water Surface Profile Plan: Plan 02 28/08/2007
Station 2
.025
Legend
EG 100 yr
WS 100 yr
Ground
Bank Sta
Elevation (m)
Station (m)

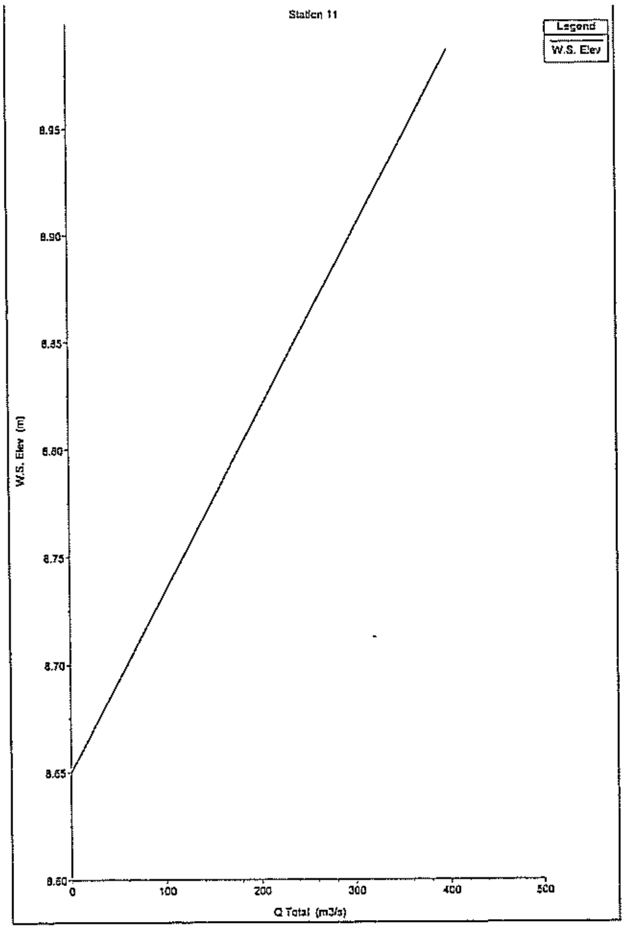

Water Surface Profile Plan: Plan 02 28/08/2007
Station 14
Legend
W.S. Elev
W.S. Elev (m)
9.85
9.80
9.75
9.70
9.65
9.60
9.55
9.50
0
100
200
300
400
500
Q Total (m3/s)

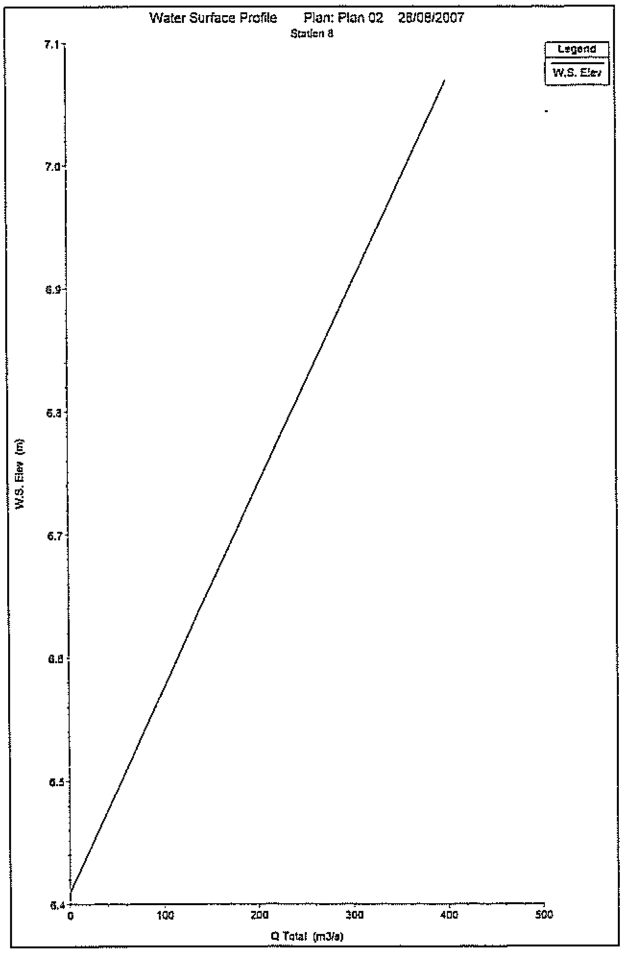

Water Surface Profile Plan: Plan 02 28/08/2007
Station 15 Upstream of the Channel
Legend
W.S. Elev
W.S. Elev (m)
10.2
10.0
9.8
9.6
9.4
9.2
9.0
0
100
200
300
400
500
Q Total (m3/s)

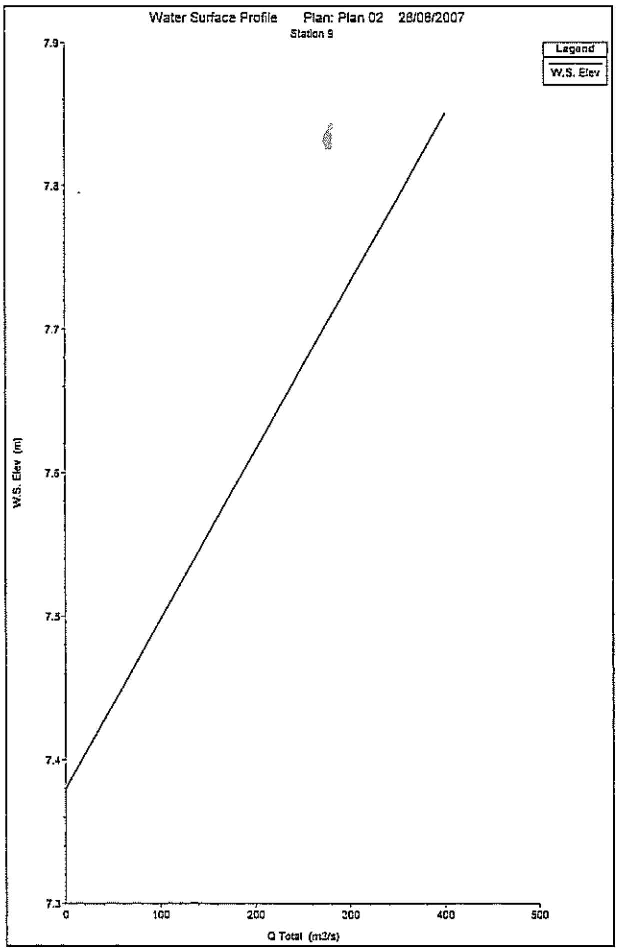

Water Surface Profile Plan: Plan 02 28/08/2007
Station 12
Legend
W.S. Elev
W.S. Elev (m)
9.4
9.2
9.0
8.8
8.6
8.4
8.2
0
100
200
300
400
500
Q Total (m3/s)

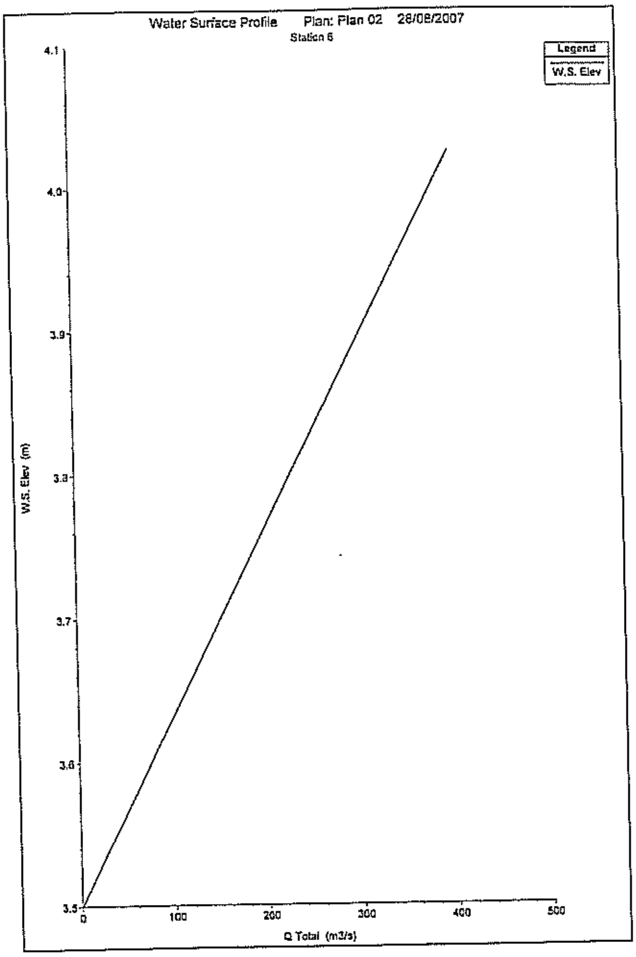

Water Surface Profile Plan: Plan 02 28/08/2007
Station 13
Legend
W.S. Elev
W.S. Elev (m)
9.6
9.4
9.2
9.0
8.8
8.6
8.4
0
100
200
300
400
500
Q Total (m3/s)

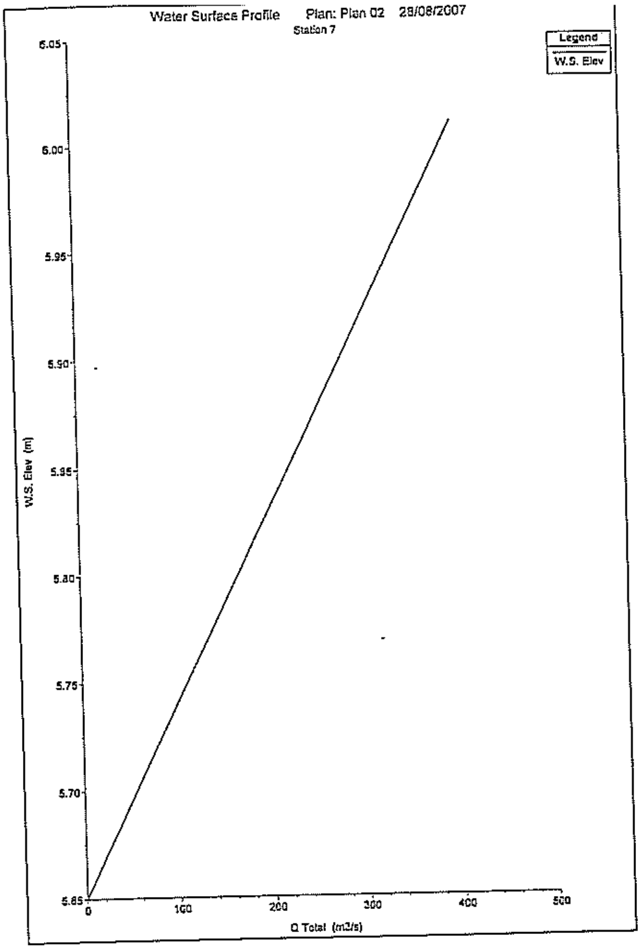

Water Surface Profile Plan: Plan 02 28/08/2007
Station 10
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)

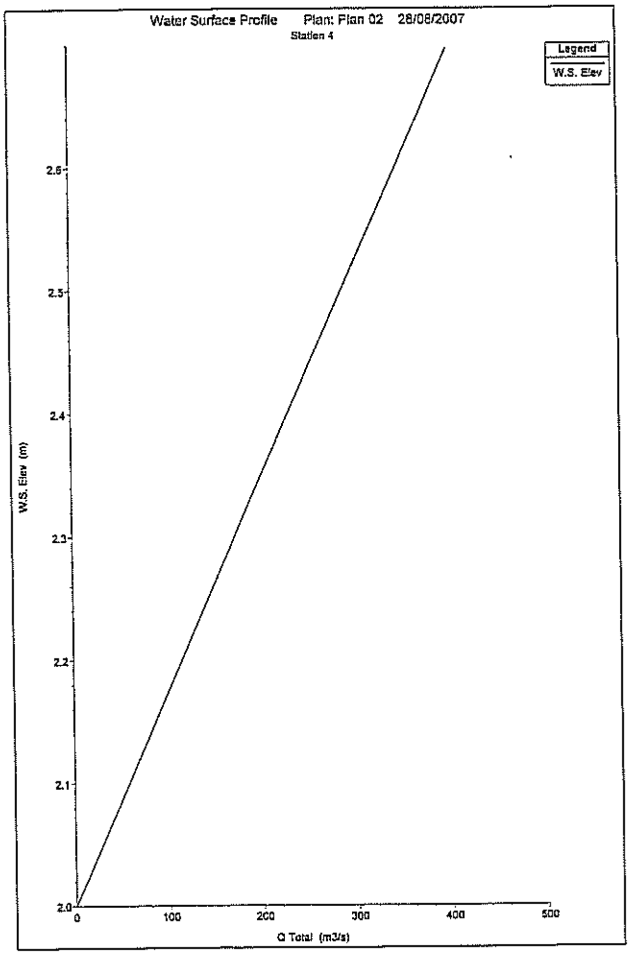

Station 11
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)

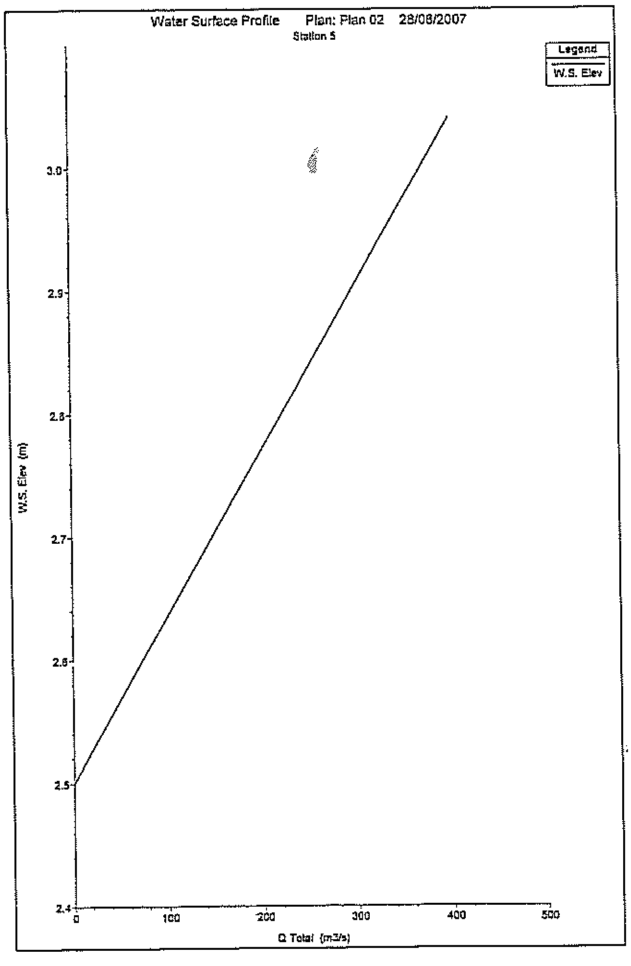

Water Surface Profile Plan: Plan 02 28/08/2007
Station 8
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)

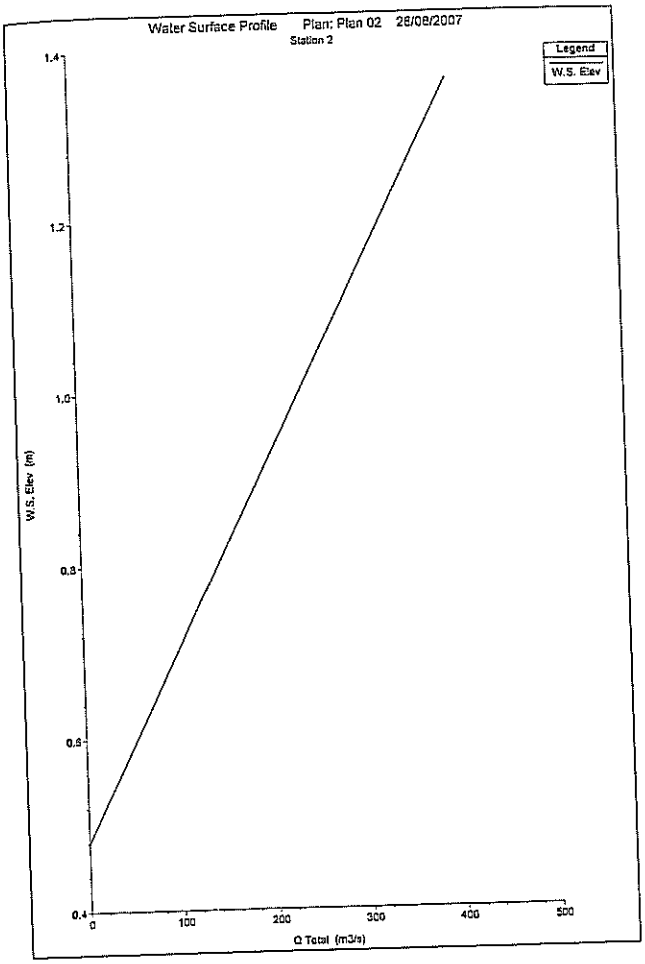

Water Surface Profile Plan: Plan 02 28/08/2007
Station 9
Legend
W.S. Elev
W.S. Elev (m)
Q Total (m3/s)

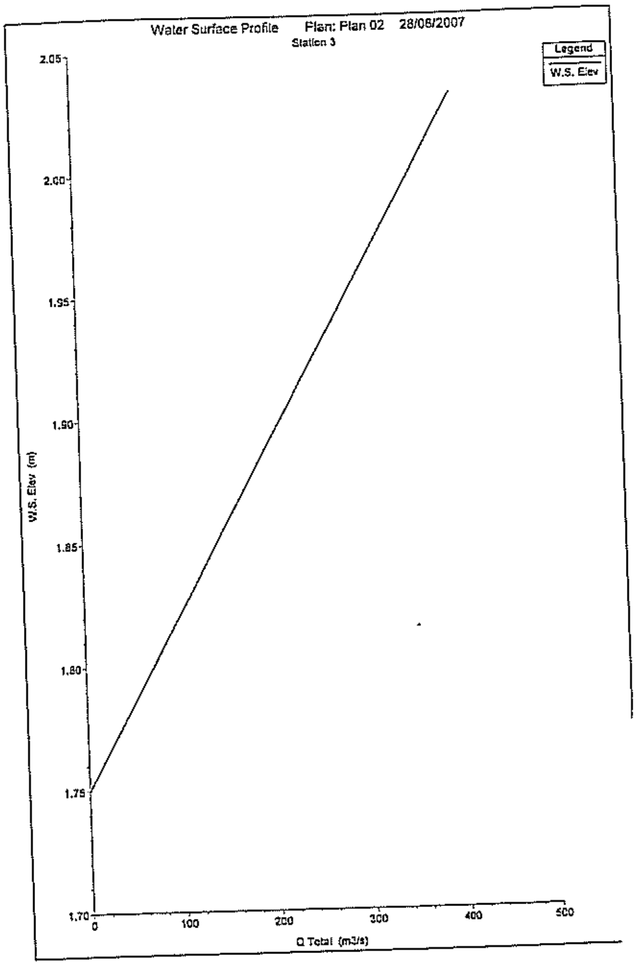

Water Surface Profile Plan: Plan 02 28/08/2007
Station 6
Legend
W.S. Elev
W.S. Elev (m)
3.5
3.6
3.7
3.8
3.9
4.0
4.1
0
100
200
300
400
500
Q Total (m3/s)

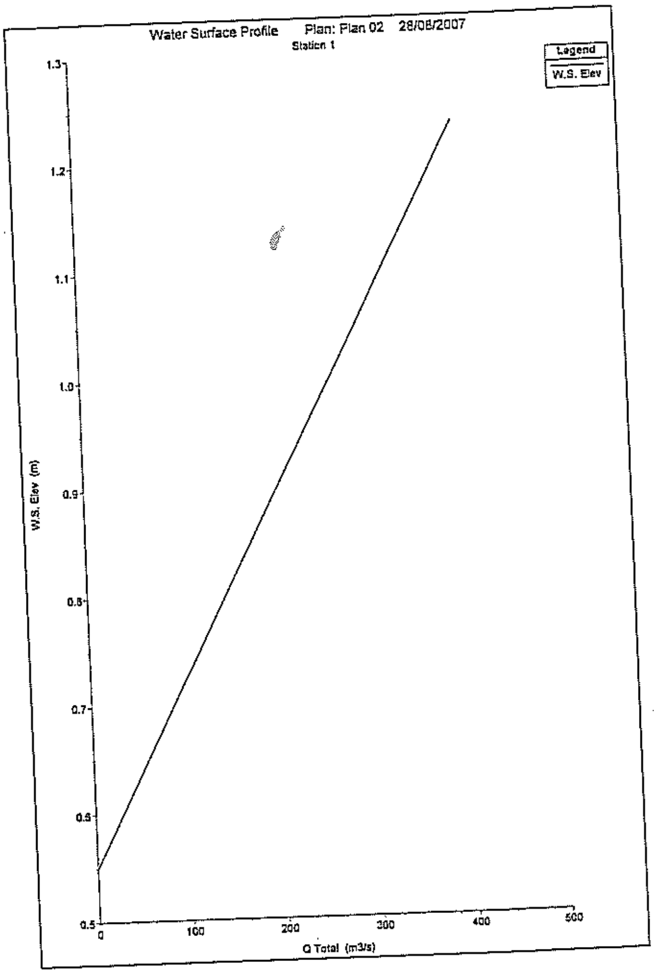

Water Surface Profile Plan: Plan 02 28/08/2007
Station 7
Legend
W.S. Elev
W.S. Elev (m)
5.65
5.70
5.75
5.80
5.85
5.90
5.95
6.00
6.05
0
100
200
300
400
500
Q Total (m3/s)


Water Surface Profile Plan: Plan 02 28/08/2007
Station 4
Legend
W.S. Elev
W.S. Elev (m)
2.0
2.1
2.2
2.3
2.4
2.5
2.6
0
100
200
300
400
500
Q Total (m3/s)


Water Surface Profile Plan: Plan 02 28/08/2007
Station 5
Legend
W.S. Elev
W.S. Elev (m)
2.4
2.5
2.6
2.7
2.8
2.9
3.0
0
100
200
300
400
500
Q Total (m3/s)


Water Surface Profile Plan: Plan 02 28/08/2007
Station 2
Legend
W.S. Elev
W.S. Elev (m)
1.4
1.2
1.0
0.8
0.6
0.4
0
100
200
300
400
500
Q Total (m3/s)


Water Surface Profile Plan: Plan 02 28/08/2007
Station 3
Legend
W.S. Elev
W.S. Elev (m)
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
0
100
200
300
400
500
Q Total (m3/s)


Water Surface Profile Plan: Plan 02 28/08/2007
Station 1
Legend
W.S. Elev
W.S. Elev (m)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0
100
200
300
400
500
Q Total (m3/s)

HEC-RAS Version 3.1.1 May 2003
U.S. Army Corp of Engineers
Hydrologic Engineering Center
609 Second Street, Suite D
Davis, California 95616-4687
(916) 756-1104

```
X     X  XXXXXX   XXXX        XXXX     XX    XXXX
X     X  X       X    X       X   X   X  X   X
X     X  X       X            X   X  X    X  X
XXXXXXX  XXXX    X      XXX   XXXX   XXXXXX   XXXX
X     X  X       X            X  X   X    X       X
X     X  X       X    X       X   X  X    X       X
X     X  XXXXXX   XXXX        X    X X    X  XXXXX
```

Project Description:
Murray River

Flow Data (m3/s)

River	Reach	RS	ARI 10	ARI 25	ARI 50	ARI 100
ARI 40						
murray	murray	18	430	690	960	1415
731						

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
murray	murray	ARI 10		Critical
murray	murray	ARI 25		Critical
murray	murray	ARI 50		Critical
murray	murray	ARI 100		Critical

CROSS SECTION
RS: 18

CROSS SECTION OUTPUT Profile #ARI 10

E.G. Elev (m)	8.11	Element	Left OB	Channel	Right OB
Vel Head (m)	0.02	Wt. n-Val.	0.065	0.060	
W.S. Elev (m)	8.09	Reach Len. (m)	124.00	150.00	170.00
Crit W.S. (m)		Flow Area (m2)	0.21	735.34	
E.G. Slope (m/m)	0.000209	Area (m2)	0.21	735.34	
Q Total (m3/s)	430.00	Flow (m3/s)	0.01	429.99	
Top Width (m)	198.35	Top Width (m)	4.52	193.83	
Vel Total (m/s)	0.58	Avg. Vel. (m/s)	0.03	0.58	
Max Chl Dpth (m)	7.09	Hydr. Depth (m)	0.05	3.79	
Conv. Total (m3/s)	29749.2	Conv. (m3/s)	0.4	29748.7	
Length Wtd. (m)	150.00	Wetted Per. (m)	4.52	194.44	
Min Ch El (m)	1.00	Shear (N/m2)	0.09	7.75	
Alpha	1.00	Stream Power (N/m s)	0.00	4.53	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)	2.98	1297.70	0.00
C & E Loss (m)	0.00	Cum SA (1000 m2)	6.42	388.72	0.01

CROSS SECTION OUTPUT Profile #ARI 25

E.G. Elev (m)	9.14	Element	Left OB	Channel	Right OB
Vel Head (m)	0.03	Wt. n-Val.	0.065	0.060	
W.S. Elev (m)	9.12	Reach Len. (m)	124.00	150.00	170.00
Crit W.S. (m)		Flow Area (m2)	30.94	938.63	
E.G. Slope (m/m)	0.000251	Area (m2)	30.94	938.63	
Q Total (m3/s)	690.00	Flow (m3/s)	4.76	685.24	
Top Width (m)	264.98	Top Width (m)	61.59	203.40	
Vel Total (m/s)	0.71	Avg. Vel. (m/s)	0.15	0.73	
Max Chl Dpth (m)	8.12	Hydr. Depth (m)	0.50	4.61	
Conv. Total (m3/s)	43568.8	Conv. (m3/s)	300.8	43267.9	
Length Wtd. (m)	149.79	Wetted Per. (m)	61.60	204.06	
Min Ch El (m)	1.00	Shear (N/m2)	1.24	11.31	
Alpha	1.05	Stream Power (N/m s)	0.19	8.26	
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	23.13	1637.51	7.22
C & E Loss (m)	0.00	Cum SA (1000 m2)	38.61	410.45	17.34

CROSS SECTION OUTPUT Profile #ARI 50

E.G. Elev (m)	9.93	Element	Left OB	Channel	Right OB
Vel Head (m)	0.04	Wt. n-Val.	0.065	0.060	
W.S. Elev (m)	9.90	Reach Len. (m)	124.00	150.00	170.00
Crit W.S. (m)		Flow Area (m2)	111.67	1100.69	
E.G. Slope (m/m)	0.000292	Area (m2)	111.67	1100.69	
Q Total (m3/s)	960.00	Flow (m3/s)	24.58	935.42	
Top Width (m)	358.47	Top Width (m)	145.72	212.75	

Vel Total (m/s)	0.79	Avg. Vel. (m/s)	0.22	0.85	
Max Chl Dpth (m)	8.90	Hydr. Depth (m)	0.77	5.17	
Conv. Total (m3/s)	56194.6	Conv. (m3/s)	1438.6	54756.0	
Length Wtd. (m)	149.26	Wetted Per. (m)	145.73	213.44	
Min Ch El (m)	1.00	Shear (N/m2)	2.19	14.76	
Alpha	1.12	Stream Power (N/m s)	0.48	12.54	
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	66.37	1906.15	34.93
C & E Loss (m)	0.00	Cum SA (1000 m2)	80.86	421.28	102.31

CROSS SECTION OUTPUT Profile #ARI 100

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	10.85	Wt. n-Val.	0.065	0.060	0.065
Vel Head (m)	0.05	Reach Len. (m)	124.00	150.00	170.00
W.S. Elev (m)	10.80	Flow Area (m2)	262.02	1294.53	16.03
Crit W.S. (m)		Area (m2)	262.02	1294.53	16.03
E.G. Slope (m/m)	0.000339	Flow (m3/s)	95.76	1315.42	3.82
Q Total (m3/s)	1415.00	Top Width (m)	178.65	214.00	20.00
Top Width (m)	412.64	Avg. Vel. (m/s)	0.37	1.02	0.24
Vel Total (m/s)	0.90	Hydr. Depth (m)	1.47	6.05	0.80
Max Chl Dpth (m)	9.80	Conv. (m3/s)	5203.2	71473.7	207.4
Conv. Total (m3/s)	76884.2	Wetted Per. (m)	178.67	214.70	20.80
Length Wtd. (m)	148.24	Shear (N/m2)	4.87	20.03	2.56
Min Ch El (m)	1.00	Stream Power (N/m s)	1.78	20.35	0.61
Alpha	1.20	Cum Volume (1000 m3)	165.05	2234.27	182.68
Frctn Loss (m)	0.05	Cum SA (1000 m2)	143.66	430.29	268.28
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 40

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.28	Wt. n-Val.	0.065	0.060	
Vel Head (m)	0.03	Reach Len. (m)	124.00	150.00	170.00
W.S. Elev (m)	9.25	Flow Area (m2)	39.93	965.35	
Crit W.S. (m)		Area (m2)	39.93	965.35	
E.G. Slope (m/m)	0.000258	Flow (m3/s)	6.44	724.56	
Q Total (m3/s)	731.00	Top Width (m)	75.72	204.97	
Top Width (m)	280.69	Avg. Vel. (m/s)	0.16	0.75	
Vel Total (m/s)	0.73	Hydr. Depth (m)	0.53	4.71	
Max Chl Dpth (m)	8.25	Conv. (m3/s)	400.9	45108.2	
Conv. Total (m3/s)	45509.0	Wetted Per. (m)	75.73	205.64	
Length Wtd. (m)	149.74	Shear (N/m2)	1.33	11.88	
Min Ch El (m)	1.00	Stream Power (N/m s)	0.22	8.91	
Alpha	1.06	Cum Volume (1000 m3)	28.32	1682.08	9.29
Frctn Loss (m)	0.04	Cum SA (1000 m2)	44.94	412.26	24.59
C & E Loss (m)	0.00				

CROSS SECTION

RS: 17

CROSS SECTION OUTPUT Profile #ARI 10

			Left OB	Channel	Right OB
E.G. Elev (m)	8.08	Element	Left OB	Channel	Right OB
Vel Head (m)	0.03	Wt. n-Val.	0.055	0.048	
W.S. Elev (m)	8.05	Reach Len. (m)	60.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	0.07	550.71	
E.G. Slope (m/m)	0.000187	Area (m2)	0.07	550.71	
Q Total (m3/s)	430.00	Flow (m3/s)	0.00	430.00	
Top Width (m)	123.04	Top Width (m)	2.85	120.19	
Vel Total (m/s)	0.78	Avg. Vel. (m/s)	0.02	0.78	
Max Chl Dpth (m)	6.05	Hydr. Depth (m)	0.02	4.58	
Conv. Total (m3/s)	31434.6	Conv. (m3/s)	0.1	31434.5	
Length Wtd. (m)	149.69	Wetted Per. (m)	2.85	121.43	
Min Ch El (m)	2.00	Shear (N/m2)	0.04	8.32	
Alpha	1.00	Stream Power (N/m s)	0.00	6.50	
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	2.96	1201.25	0.00
C & E Loss (m)	0.00	Cum SA (1000 m2)	5.96	365.17	0.01

CROSS SECTION OUTPUT Profile #ARI 25

E.G. Elev (m)	9.10	Element	Left OB	Channel	Right OB
Vel Head (m)	0.05	Wt. n-Val.	0.055	0.048	
W.S. Elev (m)	9.05	Reach Len. (m)	60.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	33.19	673.35	
E.G. Slope (m/m)	0.000253	Area (m2)	33.19	673.35	
Q Total (m3/s)	690.00	Flow (m3/s)	6.14	683.86	
Top Width (m)	189.06	Top Width (m)	64.86	124.20	
Vel Total (m/s)	0.98	Avg. Vel. (m/s)	0.19	1.02	
Max Chl Dpth (m)	7.05	Hydr. Depth (m)	0.51	5.42	
Conv. Total (m3/s)	43363.4	Conv. (m3/s)	386.1	42977.3	
Length Wtd. (m)	148.17	Wetted Per. (m)	64.87	125.57	
Min Ch El (m)	2.00	Shear (N/m2)	1.27	13.31	
Alpha	1.07	Stream Power (N/m s)	0.24	13.52	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)	19.15	1516.61	7.22
C & E Loss (m)	0.01	Cum SA (1000 m2)	30.77	385.88	17.34

CROSS SECTION OUTPUT Profile #ARI 50

E.G. Elev (m)	9.88	Element	Left OB	Channel	Right OB
Vel Head (m)	0.07	Wt. n-Val.	0.055	0.048	
W.S. Elev (m)	9.81	Reach Len. (m)	60.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	109.83	768.81	
E.G. Slope (m/m)	0.000311	Area (m2)	109.83	768.81	

Q Total (m3/s)	960.00	Flow (m3/s)	30.38	929.62	
Top Width (m)	264.25	Top Width (m)	137.01	127.24	
Vel Total (m/s)	1.09	Avg. Vel. (m/s)	0.28	1.21	
Max Chl Dpth (m)	7.81	Hydr. Depth (m)	0.80	6.04	
Conv. Total (m3/s)	54454.9	Conv. (m3/s)	1723.1	52731.7	
Length Wtd. (m)	145.72	Wetted Per. (m)	137.02	128.70	
Min Ch El (m)	2.00	Shear (N/m2)	2.44	18.21	
Alpha	1.19	Stream Power (N/m s)	0.68	22.01	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)	52.64	1765.94	34.93
C & E Loss (m)	0.01	Cum SA (1000 m2)	63.33	395.78	102.31

CROSS SECTION OUTPUT Profile #ARI 100

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	10.79	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.10	Reach Len. (m)	60.00	150.00	150.00
W.S. Elev (m)	10.69	Flow Area (m2)	252.39	881.90	69.47
Crit W.S. (m)		Area (m2)	252.39	881.90	69.47
E.G. Slope (m/m)	0.000377	Flow (m3/s)	113.42	1282.42	19.16
Q Total (m3/s)	1415.00	Top Width (m)	175.84	128.00	100.00
Top Width (m)	403.84	Avg. Vel. (m/s)	0.45	1.45	0.28
Vel Total (m/s)	1.18	Hydr. Depth (m)	1.44	6.89	0.69
Max Chl Dpth (m)	8.69	Conv. (m3/s)	5838.5	66015.9	986.2
Conv. Total (m3/s)	72840.6	Wetted Per. (m)	175.86	129.48	100.69
Length Wtd. (m)	141.42	Shear (N/m2)	5.31	25.21	2.55
Min Ch El (m)	2.00	Stream Power (N/m s)	2.39	36.65	0.70
Alpha	1.40	Cum Volume (1000 m3)	133.16	2071.04	175.41
Frctn Loss (m)	0.04	Cum SA (1000 m2)	121.68	404.64	258.08
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 40

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.23	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.06	Reach Len. (m)	60.00	150.00	150.00
W.S. Elev (m)	9.18	Flow Area (m2)	42.24	689.23	
Crit W.S. (m)		Area (m2)	42.24	689.23	
E.G. Slope (m/m)	0.000263	Flow (m3/s)	8.35	722.65	
Q Total (m3/s)	731.00	Top Width (m)	76.98	124.72	
Top Width (m)	201.70	Avg. Vel. (m/s)	0.20	1.05	
Vel Total (m/s)	1.00	Hydr. Depth (m)	0.55	5.53	
Max Chl Dpth (m)	7.18	Conv. (m3/s)	514.7	44555.7	
Conv. Total (m3/s)	45070.4	Wetted Per. (m)	76.99	126.10	
Length Wtd. (m)	147.83	Shear (N/m2)	1.42	14.10	
Min Ch El (m)	2.00	Stream Power (N/m s)	0.28	14.78	
Alpha	1.09	Cum Volume (1000 m3)	23.23	1557.99	9.29
Frctn Loss (m)	0.03	Cum SA (1000 m2)	35.47	387.53	24.59
C & E Loss (m)	0.01				

CROSS SECTION

RS: 16

CROSS SECTION OUTPUT Profile #ARI 10

E.G. Elev (m)	8.05	Element	Left OB	Channel	Right OB
Vel Head (m)	0.02	Wt. n-Val.	0.055	0.048	
W.S. Elev (m)	8.04	Reach Len. (m)	185.00	150.00	90.00
Crit W.S. (m)		Flow Area (m2)	24.15	730.07	
E.G. Slope (m/m)	0.000114	Area (m2)	24.15	730.07	
Q Total (m3/s)	430.00	Flow (m3/s)	2.98	427.02	
Top Width (m)	217.71	Top Width (m)	47.49	170.21	
Vel Total (m/s)	0.57	Avg. Vel. (m/s)	0.12	0.58	
Max Chl Dpth (m)	6.04	Hydr. Depth (m)	0.51	4.29	
Conv. Total (m3/s)	40340.1	Conv. (m3/s)	279.7	40060.4	
Length Wtd. (m)	150.12	Wetted Per. (m)	47.51	170.79	
Min Ch El (m)	2.00	Shear (N/m2)	0.57	4.76	
Alpha	1.05	Stream Power (N/m s)	0.07	2.79	
Frctn Loss (m)	0.01	Cum Volume (1000 m3)	2.23	1105.19	0.00
C & E Loss (m)	0.00	Cum SA (1000 m2)	4.45	343.39	0.01

CROSS SECTION OUTPUT Profile #ARI 25

E.G. Elev (m)	9.07	Element	Left OB	Channel	Right OB
Vel Head (m)	0.03	Wt. n-Val.	0.055	0.048	
W.S. Elev (m)	9.04	Reach Len. (m)	185.00	150.00	90.00
Crit W.S. (m)		Flow Area (m2)	107.27	904.24	
E.G. Slope (m/m)	0.000143	Area (m2)	107.27	904.24	
Q Total (m3/s)	690.00	Flow (m3/s)	21.97	668.03	
Top Width (m)	293.54	Top Width (m)	117.26	176.29	
Vel Total (m/s)	0.68	Avg. Vel. (m/s)	0.20	0.74	
Max Chl Dpth (m)	7.04	Hydr. Depth (m)	0.91	5.13	
Conv. Total (m3/s)	57727.4	Conv. (m3/s)	1837.8	55889.6	
Length Wtd. (m)	150.55	Wetted Per. (m)	117.28	176.95	
Min Ch El (m)	2.00	Shear (N/m2)	1.28	7.16	
Alpha	1.14	Stream Power (N/m s)	0.26	5.29	
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	14.94	1398.29	7.22
C & E Loss (m)	0.00	Cum SA (1000 m2)	25.30	363.34	17.34

CROSS SECTION OUTPUT Profile #ARI 50

E.G. Elev (m)	9.84	Element	Left OB	Channel	Right OB
Vel Head (m)	0.04	Wt. n-Val.	0.055	0.048	
W.S. Elev (m)	9.80	Reach Len. (m)	185.00	150.00	90.00
Crit W.S. (m)		Flow Area (m2)	212.62	1040.64	

E.G. Slope (m/m)	0.000169	Area (m2)	212.62	1040.64	
Q Total (m3/s)	960.00	Flow (m3/s)	60.88	899.12	
Top Width (m)	340.81	Top Width (m)	159.19	181.62	
Vel Total (m/s)	0.77	Avg. Vel. (m/s)	0.29	0.86	
Max Chl Dpth (m)	7.80	Hydr. Depth (m)	1.34	5.73	
Conv. Total (m3/s)	73924.8	Conv. (m3/s)	4688.1	69236.7	
Length Wtd. (m)	151.10	Wetted Per. (m)	159.21	182.34	
Min Ch El (m)	2.00	Shear (N/m2)	2.21	9.44	
Alpha	1.20	Stream Power (N/m s)	0.63	8.15	
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	42.97	1630.23	34.93
C & E Loss (m)	0.00	Cum SA (1000 m2)	54.45	372.62	102.31

CROSS SECTION OUTPUT Profile #ARI 100

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	10.74	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.05	Reach Len. (m)	185.00	150.00	90.00
W.S. Elev (m)	10.69	Flow Area (m2)	362.16	1202.62	
Crit W.S. (m)		Area (m2)	362.16	1202.62	
E.G. Slope (m/m)	0.000207	Flow (m3/s)	156.45	1258.55	
Q Total (m3/s)	1415.00	Top Width (m)	170.00	183.00	
Top Width (m)	353.00	Avg. Vel. (m/s)	0.43	1.05	
Vel Total (m/s)	0.90	Hydr. Depth (m)	2.13	6.57	
Max Chl Dpth (m)	8.69	Conv. (m3/s)	10871.3	87451.2	
Conv. Total (m3/s)	98322.5	Wetted Per. (m)	170.72	184.42	
Length Wtd. (m)	151.94	Shear (N/m2)	4.31	13.24	
Min Ch El (m)	2.00	Stream Power (N/m s)	1.86	13.86	
Alpha	1.22	Cum Volume (1000 m3)	114.72	1914.70	170.20
Frctn Loss (m)	0.03	Cum SA (1000 m2)	111.31	381.31	250.58
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 40

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.20	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.03	Reach Len. (m)	185.00	150.00	90.00
W.S. Elev (m)	9.17	Flow Area (m2)	122.73	926.87	
Crit W.S. (m)		Area (m2)	122.73	926.87	
E.G. Slope (m/m)	0.000147	Flow (m3/s)	26.84	704.16	
Q Total (m3/s)	731.00	Top Width (m)	124.30	177.18	
Top Width (m)	301.48	Avg. Vel. (m/s)	0.22	0.76	
Vel Total (m/s)	0.70	Hydr. Depth (m)	0.99	5.23	
Max Chl Dpth (m)	7.17	Conv. (m3/s)	2212.5	58042.2	
Conv. Total (m3/s)	60254.6	Wetted Per. (m)	124.32	177.86	
Length Wtd. (m)	150.64	Shear (N/m2)	1.42	7.52	
Min Ch El (m)	2.00	Stream Power (N/m s)	0.31	5.71	
Alpha	1.15	Cum Volume (1000 m3)	18.28	1436.78	9.29
Frctn Loss (m)	0.02	Cum SA (1000 m2)	29.44	364.89	24.59
C & E Loss (m)	0.00				

CROSS SECTION

RS: 15

CROSS SECTION OUTPUT Profile #ARI 10

E.G. Elev (m)	8.04	Element	Left OB	Channel	Right OB
Vel Head (m)	0.01	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	8.03	Reach Len. (m)	250.00	150.00	28.00
Crit W.S. (m)		Flow Area (m2)	0.00	956.58	0.00
E.G. Slope (m/m)	0.000077	Area (m2)	0.00	956.58	0.00
Q Total (m3/s)	430.00	Flow (m3/s)	0.00	430.00	0.00
Top Width (m)	247.45	Top Width (m)	0.27	247.00	0.19
Vel Total (m/s)	0.45	Avg. Vel. (m/s)	0.01	0.45	0.01
Max Chl Dpth (m)	6.03	Hydr. Depth (m)	0.01	3.87	0.01
Conv. Total (m3/s)	49075.9	Conv. (m3/s)	0.0	49075.9	0.0
Length Wtd. (m)	150.00	Wetted Per. (m)	0.27	247.54	0.19
Min Ch El (m)	2.00	Shear (N/m2)	0.01	2.91	0.01
Alpha	1.00	Stream Power (N/m s)	0.00	1.31	0.00
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	0.00	978.69	0.00
C & E Loss (m)	0.00	Cum SA (1000 m2)	0.04	312.10	0.00

CROSS SECTION OUTPUT Profile #ARI 25

E.G. Elev (m)	9.05	Element	Left OB	Channel	Right OB
Vel Head (m)	0.02	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	9.03	Reach Len. (m)	250.00	150.00	28.00
Crit W.S. (m)		Flow Area (m2)	5.32	1204.73	3.72
E.G. Slope (m/m)	0.000091	Area (m2)	5.32	1204.73	3.72
Q Total (m3/s)	690.00	Flow (m3/s)	0.58	689.01	0.41
Top Width (m)	264.84	Top Width (m)	10.56	247.00	7.28
Vel Total (m/s)	0.57	Avg. Vel. (m/s)	0.11	0.57	0.11
Max Chl Dpth (m)	7.03	Hydr. Depth (m)	0.50	4.88	0.51
Conv. Total (m3/s)	72183.7	Conv. (m3/s)	61.1	72079.6	43.0
Length Wtd. (m)	149.95	Wetted Per. (m)	10.61	247.54	7.35
Min Ch El (m)	2.00	Shear (N/m2)	0.45	4.36	0.45
Alpha	1.01	Stream Power (N/m s)	0.05	2.49	0.05
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	4.53	1240.12	7.05
C & E Loss (m)	0.00	Cum SA (1000 m2)	13.48	331.60	17.01

CROSS SECTION OUTPUT Profile #ARI 50

E.G. Elev (m)	9.82	Element	Left OB	Channel	Right OB
Vel Head (m)	0.02	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	9.79	Reach Len. (m)	250.00	150.00	28.00

Crit W.S. (m)		Flow Area (m2)	18.55	1392.50	11.86
E.G. Slope (m/m)	0.000108	Area (m2)	18.55	1392.50	11.86
Q Total (m3/s)	960.00	Flow (m3/s)	2.93	955.08	1.99
Top Width (m)	285.37	Top Width (m)	24.25	247.00	14.12
Vel Total (m/s)	0.67	Avg. Vel. (m/s)	0.16	0.69	0.17
Max Chl Dpth (m)	7.79	Hydr. Depth (m)	0.77	5.64	0.84
Conv. Total (m3/s)	92232.9	Conv. (m3/s)	281.6	91760.4	190.9
Length Wtd. (m)	149.81	Wetted Per. (m)	24.32	247.54	14.24
Min Ch El (m)	2.00	Shear (N/m2)	0.81	5.98	0.88
Alpha	1.03	Stream Power (N/m s)	0.13	4.10	0.15
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	21.58	1447.75	34.40
C & E Loss (m)	0.00	Cum SA (1000 m2)	37.48	340.47	101.68

CROSS SECTION OUTPUT Profile #ARI 100

E.G. Elev (m)	10.71	Element	Left OB	Channel	Right OB
Vel Head (m)	0.04	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	10.67	Reach Len. (m)	250.00	150.00	28.00
Crit W.S. (m)		Flow Area (m2)	56.28	1610.07	25.76
E.G. Slope (m/m)	0.000142	Area (m2)	56.28	1610.07	25.76
Q Total (m3/s)	1415.00	Flow (m3/s)	13.43	1394.14	7.43
Top Width (m)	311.00	Top Width (m)	48.00	247.00	16.00
Vel Total (m/s)	0.84	Avg. Vel. (m/s)	0.24	0.87	0.29
Max Chl Dpth (m)	8.67	Hydr. Depth (m)	1.17	6.52	1.61
Conv. Total (m3/s)	118628.3	Conv. (m3/s)	1126.0	116879.5	622.7
Length Wtd. (m)	149.34	Wetted Per. (m)	48.75	247.54	16.80
Min Ch El (m)	2.00	Shear (N/m2)	1.61	9.08	2.14
Alpha	1.06	Stream Power (N/m s)	0.38	7.86	0.62
Frctn Loss (m)	0.03	Cum Volume (1000 m3)	76.02	1703.75	169.04
C & E Loss (m)	0.00	Cum SA (1000 m2)	91.14	349.06	249.86

CROSS SECTION OUTPUT Profile #ARI 40

E.G. Elev (m)	9.18	Element	Left OB	Channel	Right OB
Vel Head (m)	0.02	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	9.16	Reach Len. (m)	250.00	150.00	28.00
Crit W.S. (m)		Flow Area (m2)	6.82	1236.29	4.73
E.G. Slope (m/m)	0.000094	Area (m2)	6.82	1236.29	4.73
Q Total (m3/s)	731.00	Flow (m3/s)	0.78	729.65	0.56
Top Width (m)	268.29	Top Width (m)	12.86	247.00	8.43
Vel Total (m/s)	0.59	Avg. Vel. (m/s)	0.12	0.59	0.12
Max Chl Dpth (m)	7.16	Hydr. Depth (m)	0.53	5.01	0.56
Conv. Total (m3/s)	75392.9	Conv. (m3/s)	81.0	75253.9	58.1
Length Wtd. (m)	149.94	Wetted Per. (m)	12.92	247.54	8.51
Min Ch El (m)	2.00	Shear (N/m2)	0.49	4.60	0.51
Alpha	1.01	Stream Power (N/m s)	0.06	2.72	0.06
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	6.30	1274.54	9.07

Murrayprofile

C & E Loss (m)	0.00	Cum SA (1000 m2)	16.75	333.07	24.21

CROSS SECTION
RS: 14

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.02	Wt. n-Val.		0.048	
Vel Head (m)	0.02	Reach Len. (m)	191.00	150.00	105.00
W.S. Elev (m)	8.00	Flow Area (m2)		703.24	
Crit W.S. (m)		Area (m2)	0.00	703.24	0.00
E.G. Slope (m/m)	0.000155	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)	0.01	193.00	0.02
Top Width (m)	193.02	Avg. Vel. (m/s)		0.61	
Vel Total (m/s)	0.61	Hydr. Depth (m)		3.64	
Max Chl Dpth (m)	6.00	Conv. (m3/s)		34547.1	
Conv. Total (m3/s)	34547.1	Wetted Per. (m)		194.22	
Length Wtd. (m)	150.00	Shear (N/m2)		5.50	
Min Ch El (m)	2.00	Stream Power (N/m s)		3.36	
Alpha	1.00	Cum Volume (1000 m3)	0.00	854.21	0.00
Frctn Loss (m)	0.01	Cum SA (1000 m2)	0.00	279.10	0.00
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.03	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.03	Reach Len. (m)	191.00	150.00	105.00
W.S. Elev (m)	9.00	Flow Area (m2)	3.49	895.63	6.97
Crit W.S. (m)		Area (m2)	3.49	895.63	6.97
E.G. Slope (m/m)	0.000177	Flow (m3/s)	0.53	688.41	1.06
Q Total (m3/s)	690.00	Top Width (m)	6.99	193.00	13.97
Top Width (m)	213.96	Avg. Vel. (m/s)	0.15	0.77	0.15
Vel Total (m/s)	0.76	Hydr. Depth (m)	0.50	4.64	0.50
Max Chl Dpth (m)	7.00	Conv. (m3/s)	39.6	51695.5	79.6
Conv. Total (m3/s)	51814.7	Wetted Per. (m)	7.06	194.22	14.01
Length Wtd. (m)	149.97	Shear (N/m2)	0.86	8.02	0.87
Min Ch El (m)	2.00	Stream Power (N/m s)	0.13	6.16	0.13
Alpha	1.02	Cum Volume (1000 m3)	3.42	1082.59	6.90
Frctn Loss (m)	0.01	Cum SA (1000 m2)	11.29	298.60	16.71
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 50

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.79	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.04	Reach Len. (m)	191.00	150.00	105.00
W.S. Elev (m)	9.75				

Crit W.S. (m)		Flow Area (m2)	9.87	1040.66	27.04
E.G. Slope (m/m)	0.000206	Area (m2)	9.87	1040.66	27.04
Q Total (m3/s)	960.00	Flow (m3/s)	2.52	952.00	5.47
Top Width (m)	242.48	Top Width (m)	10.00	193.00	39.49
Vel Total (m/s)	0.89	Avg. Vel. (m/s)	0.26	0.91	0.20
Max Chl Dpth (m)	7.75	Hydr. Depth (m)	0.99	5.39	0.68
Conv. Total (m3/s)	66944.7	Conv. (m3/s)	176.0	66387.0	381.7
Length Wtd. (m)	149.88	Wetted Per. (m)	10.16	194.22	39.53
Min Ch El (m)	2.00	Shear (N/m2)	1.96	10.81	1.38
Alpha	1.05	Stream Power (N/m s)	0.50	9.89	0.28
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	18.03	1265.26	33.86
C & E Loss (m)	0.01	Cum SA (1000 m2)	33.20	307.47	100.92

CROSS SECTION OUTPUT Profile #ARI 100

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	10.68	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.07	Reach Len. (m)	191.00	150.00	105.00
W.S. Elev (m)	10.61	Flow Area (m2)	20.76	1207.43	67.45
Crit W.S. (m)		Area (m2)	20.76	1207.43	67.45
E.G. Slope (m/m)	0.000264	Flow (m3/s)	7.26	1382.95	24.79
Q Total (m3/s)	1415.00	Top Width (m)	15.91	193.00	48.00
Top Width (m)	256.91	Avg. Vel. (m/s)	0.35	1.15	0.37
Vel Total (m/s)	1.09	Hydr. Depth (m)	1.30	6.26	1.41
Max Chl Dpth (m)	8.61	Conv. (m3/s)	446.2	85049.2	1524.5
Conv. Total (m3/s)	87019.9	Wetted Per. (m)	16.14	194.22	48.66
Length Wtd. (m)	149.61	Shear (N/m2)	3.33	16.12	3.59
Min Ch El (m)	2.00	Stream Power (N/m s)	1.17	18.46	1.32
Alpha	1.08	Cum Volume (1000 m3)	66.39	1492.44	167.74
Frctn Loss (m)	0.02	Cum SA (1000 m2)	83.15	316.06	248.96
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 40

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.16	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.03	Reach Len. (m)	191.00	150.00	105.00
W.S. Elev (m)	9.12	Flow Area (m2)	4.40	920.03	9.00
Crit W.S. (m)		Area (m2)	4.40	920.03	9.00
E.G. Slope (m/m)	0.000182	Flow (m3/s)	0.75	728.87	1.38
Q Total (m3/s)	731.00	Top Width (m)	7.50	193.00	18.23
Top Width (m)	218.73	Avg. Vel. (m/s)	0.17	0.79	0.15
Vel Total (m/s)	0.78	Hydr. Depth (m)	0.59	4.77	0.49
Max Chl Dpth (m)	7.12	Conv. (m3/s)	55.7	54063.6	102.2
Conv. Total (m3/s)	54221.4	Wetted Per. (m)	7.58	194.22	18.27
Length Wtd. (m)	149.96	Shear (N/m2)	1.03	8.44	0.88
Min Ch El (m)	2.00	Stream Power (N/m s)	0.18	6.69	0.13
Alpha	1.02	Cum Volume (1000 m3)	4.90	1112.82	8.88
Frctn Loss (m)	0.02				

C & E Loss (m)	0.01	Cum SA (1000 m2)	14.20	300.07	23.84

CROSS SECTION
RS: 13

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.00	Wt. n-Val.		0.048	
Vel Head (m)	0.01	Reach Len. (m)	167.00	150.00	53.00
W.S. Elev (m)	8.00	Flow Area (m2)		1120.34	
Crit W.S. (m)		Area (m2)		1120.34	
E.G. Slope (m/m)	0.000048	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		255.96	
Top Width (m)	255.96	Avg. Vel. (m/s)		0.38	
Vel Total (m/s)	0.38	Hydr. Depth (m)		4.38	
Max Chl Dpth (m)	6.00	Conv. (m3/s)		62344.0	
Conv. Total (m3/s)	62344.0	Wetted Per. (m)		256.64	
Length Wtd. (m)	150.00	Shear (N/m2)		2.04	
Min Ch El (m)	2.00	Stream Power (N/m s)		0.78	
Alpha	1.00	Cum Volume (1000 m3)		717.44	
Frctn Loss (m)	0.01	Cum SA (1000 m2)		245.43	
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.01	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.01	Reach Len. (m)	167.00	150.00	53.00
W.S. Elev (m)	9.00	Flow Area (m2)	3.96	1375.84	7.93
Crit W.S. (m)		Area (m2)	3.96	1375.84	7.93
E.G. Slope (m/m)	0.000062	Flow (m3/s)	0.35	688.94	0.71
Q Total (m3/s)	690.00	Top Width (m)	7.96	256.00	15.93
Top Width (m)	279.89	Avg. Vel. (m/s)	0.09	0.50	0.09
Vel Total (m/s)	0.50	Hydr. Depth (m)	0.50	5.37	0.50
Max Chl Dpth (m)	7.00	Conv. (m3/s)	45.0	87790.9	90.4
Conv. Total (m3/s)	87926.3	Wetted Per. (m)	8.03	256.68	15.96
Length Wtd. (m)	149.85	Shear (N/m2)	0.30	3.24	0.30
Min Ch El (m)	2.00	Stream Power (N/m s)	0.03	1.62	0.03
Alpha	1.01	Cum Volume (1000 m3)	2.71	912.23	6.12
Frctn Loss (m)	0.01	Cum SA (1000 m2)	9.86	264.92	15.14
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 50

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.77	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.02				

W.S. Elev (m)	9.75	Reach Len. (m)	167.00	150.00	53.00
Crit W.S. (m)		Flow Area (m2)	14.18	1568.55	28.37
E.G. Slope (m/m)	0.000076	Area (m2)	14.18	1568.55	28.37
Q Total (m3/s)	960.00	Flow (m3/s)	1.83	954.49	3.68
Top Width (m)	313.67	Top Width (m)	19.22	256.00	38.45
Vel Total (m/s)	0.60	Avg. Vel. (m/s)	0.13	0.61	0.13
Max Chl Dpth (m)	7.75	Hydr. Depth (m)	0.74	6.13	0.74
Conv. Total (m3/s)	109857.8	Conv. (m3/s)	209.9	109227.0	420.8
Length Wtd. (m)	149.43	Wetted Per. (m)	19.31	256.68	38.49
Min Ch El (m)	2.00	Shear (N/m2)	0.55	4.58	0.55
Alpha	1.04	Stream Power (N/m s)	0.07	2.78	0.07
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	15.73	1069.57	30.95
C & E Loss (m)	0.00	Cum SA (1000 m2)	30.41	273.79	96.83

CROSS SECTION OUTPUT Profile #ARI 100

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	10.64	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.03	Reach Len. (m)	167.00	150.00	53.00
W.S. Elev (m)	10.61	Flow Area (m2)	61.31	1790.36	67.28
Crit W.S. (m)		Area (m2)	61.31	1790.36	67.28
E.G. Slope (m/m)	0.000104	Flow (m3/s)	10.53	1388.55	15.92
Q Total (m3/s)	1415.00	Top Width (m)	68.00	256.00	46.00
Top Width (m)	370.00	Avg. Vel. (m/s)	0.17	0.78	0.24
Vel Total (m/s)	0.74	Hydr. Depth (m)	0.90	6.99	1.46
Max Chl Dpth (m)	8.61	Conv. (m3/s)	1033.1	136166.3	1561.1
Conv. Total (m3/s)	138760.5	Wetted Per. (m)	68.71	256.68	46.66
Length Wtd. (m)	148.21	Shear (N/m2)	0.91	7.11	1.47
Min Ch El (m)	2.00	Stream Power (N/m s)	0.16	5.52	0.35
Alpha	1.09	Cum Volume (1000 m3)	58.55	1267.60	160.67
Frctn Loss (m)	0.02	Cum SA (1000 m2)	75.14	282.39	244.03
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 40

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.14	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.01	Reach Len. (m)	167.00	150.00	53.00
W.S. Elev (m)	9.12	Flow Area (m2)	5.09	1408.25	10.18
Crit W.S. (m)		Area (m2)	5.09	1408.25	10.18
E.G. Slope (m/m)	0.000064	Flow (m3/s)	0.47	729.57	0.95
Q Total (m3/s)	731.00	Top Width (m)	9.83	256.00	19.66
Top Width (m)	285.49	Avg. Vel. (m/s)	0.09	0.52	0.09
Vel Total (m/s)	0.51	Hydr. Depth (m)	0.52	5.50	0.52
Max Chl Dpth (m)	7.12	Conv. (m3/s)	59.4	91264.3	119.1
Conv. Total (m3/s)	91442.8	Wetted Per. (m)	9.90	256.68	19.69
Length Wtd. (m)	149.82	Shear (N/m2)	0.32	3.44	0.32
Min Ch El (m)	2.00	Stream Power (N/m s)	0.03	1.78	0.03
Alpha	1.02				

Frctn Loss (m)	0.01	Cum Volume (1000 m3)	3.99	938.20	7.87
C & E Loss (m)	0.00	Cum SA (1000 m2)	12.55	266.40	21.85

RS: 12

CROSS SECTION OUTPUT   Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.99	Wt. n-Val.		0.048	
Vel Head (m)	0.02	Reach Len. (m)	120.00	150.00	220.00
W.S. Elev (m)	7.98	Flow Area (m2)		784.56	
Crit W.S. (m)		Area (m2)		784.56	
E.G. Slope (m/m)	0.000102	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		185.68	
Top Width (m)	185.68	Avg. Vel. (m/s)		0.55	
Vel Total (m/s)	0.55	Hydr. Depth (m)		4.23	
Max Chl Dpth (m)	5.98	Conv. (m3/s)		42622.2	
Conv. Total (m3/s)	42622.2	Wetted Per. (m)		186.31	
Length Wtd. (m)	150.00	Shear (N/m2)		4.20	
Min Ch El (m)	2.00	Stream Power (N/m s)		2.30	
Alpha	1.00	Cum Volume (1000 m3)		574.57	
Frctn Loss (m)	0.02	Cum SA (1000 m2)		212.30	
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT   Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.99	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.03	Reach Len. (m)	120.00	150.00	220.00
W.S. Elev (m)	8.97	Flow Area (m2)	2.34	968.61	11.72
Crit W.S. (m)		Area (m2)	2.34	968.61	11.72
E.G. Slope (m/m)	0.000129	Flow (m3/s)	0.30	688.21	1.49
Q Total (m3/s)	690.00	Top Width (m)	4.84	186.00	24.21
Top Width (m)	215.05	Avg. Vel. (m/s)	0.13	0.71	0.13
Vel Total (m/s)	0.70	Hydr. Depth (m)	0.48	5.21	0.48
Max Chl Dpth (m)	6.97	Conv. (m3/s)	25.9	60489.6	131.3
Conv. Total (m3/s)	60646.8	Wetted Per. (m)	4.94	186.63	24.23
Length Wtd. (m)	150.09	Shear (N/m2)	0.60	6.59	0.61
Min Ch El (m)	2.00	Stream Power (N/m s)	0.08	4.68	0.08
Alpha	1.02	Cum Volume (1000 m3)	2.19	736.40	5.60
Frctn Loss (m)	0.03	Cum SA (1000 m2)	8.79	231.77	14.08
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT   Profile #ARI 50

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.75				

Vel Head (m)	0.04	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	9.71	Reach Len. (m)	120.00	150.00	220.00
Crit W.S. (m)		Flow Area (m2)	8.09	1106.94	47.29
E.G. Slope (m/m)	0.000158	Area (m2)	8.09	1106.94	47.29
Q Total (m3/s)	960.00	Flow (m3/s)	1.52	950.36	8.11
Top Width (m)	269.41	Top Width (m)	10.70	186.00	72.71
Vel Total (m/s)	0.83	Avg. Vel. (m/s)	0.19	0.86	0.17
Max Chl Dpth (m)	7.71	Hydr. Depth (m)	0.76	5.95	0.65
Conv. Total (m3/s)	76328.3	Conv. (m3/s)	121.0	75562.2	645.2
Length Wtd. (m)	150.51	Wetted Per. (m)	10.84	186.63	72.74
Min Ch El (m)	2.00	Shear (N/m2)	1.16	9.20	1.01
Alpha	1.07	Stream Power (N/m s)	0.22	7.90	0.17
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	13.87	868.91	28.94
C & E Loss (m)	0.01	Cum SA (1000 m2)	27.91	240.64	93.89

CROSS SECTION OUTPUT Profile #ARI 100

E.G. Elev (m)	10.62	Element	Left OB	Channel	Right OB
Vel Head (m)	0.06	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	10.56	Reach Len. (m)	120.00	150.00	220.00
Crit W.S. (m)		Flow Area (m2)	20.72	1265.17	122.77
E.G. Slope (m/m)	0.000211	Area (m2)	20.72	1265.17	122.77
Q Total (m3/s)	1415.00	Flow (m3/s)	5.61	1370.29	39.10
Top Width (m)	297.75	Top Width (m)	19.75	186.00	92.00
Vel Total (m/s)	1.00	Avg. Vel. (m/s)	0.27	1.08	0.32
Max Chl Dpth (m)	8.56	Hydr. Depth (m)	1.05	6.80	1.33
Conv. Total (m3/s)	97488.8	Conv. (m3/s)	386.4	94408.2	2694.2
Length Wtd. (m)	152.05	Wetted Per. (m)	19.94	186.63	92.59
Min Ch El (m)	2.00	Shear (N/m2)	2.15	14.00	2.74
Alpha	1.13	Stream Power (N/m s)	0.58	15.17	0.87
Frctn Loss (m)	0.05	Cum Volume (1000 m3)	51.70	1038.44	155.63
C & E Loss (m)	0.01	Cum SA (1000 m2)	67.81	249.24	240.37

CROSS SECTION OUTPUT Profile #ARI 40

E.G. Elev (m)	9.12	Element	Left OB	Channel	Right OB
Vel Head (m)	0.03	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	9.09	Reach Len. (m)	120.00	150.00	220.00
Crit W.S. (m)		Flow Area (m2)	3.00	991.89	15.13
E.G. Slope (m/m)	0.000134	Area (m2)	3.00	991.89	15.13
Q Total (m3/s)	731.00	Flow (m3/s)	0.40	728.63	1.96
Top Width (m)	223.01	Top Width (m)	5.75	186.00	31.26
Vel Total (m/s)	0.72	Avg. Vel. (m/s)	0.13	0.73	0.13
Max Chl Dpth (m)	7.09	Hydr. Depth (m)	0.52	5.33	0.48
Conv. Total (m3/s)	63136.7	Conv. (m3/s)	35.0	62932.3	169.5
Length Wtd. (m)	150.11	Wetted Per. (m)	5.85	186.63	31.28
Min Ch El (m)	2.00	Shear (N/m2)	0.67	6.99	0.64

Alpha	1.03	Stream Power (N/m s)	0.09	5.13	0.08
Frctn Loss (m)	0.03	Cum Volume (1000 m3)	3.31	758.18	7.20
C & E Loss (m)	0.00	Cum SA (1000 m2)	11.25	233.25	20.50

RS 11

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.97	Wt. n-Val.		0.048	
Vel Head (m)	0.04	Reach Len. (m)	72.00	150.00	243.00
W.S. Elev (m)	7.92	Flow Area (m2)		470.69	
Crit W.S. (m)		Area (m2)		470.69	
E.G. Slope (m/m)	0.000319	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		121.63	
Top Width (m)	121.63	Avg. Vel. (m/s)		0.91	
Vel Total (m/s)	0.91	Hydr. Depth (m)		3.87	
Max Chl Dpth (m)	5.92	Conv. (m3/s)		24061.4	
Conv. Total (m3/s)	24061.4	Wetted Per. (m)		122.46	
Length Wtd. (m)	150.00	Shear (N/m2)		12.04	
Min Ch El (m)	2.00	Stream Power (N/m s)		11.00	
Alpha	1.00	Cum Volume (1000 m3)		480.43	
Frctn Loss (m)	0.05	Cum SA (1000 m2)		189.25	
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.96	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.07	Reach Len. (m)	72.00	150.00	243.00
W.S. Elev (m)	8.89	Flow Area (m2)	2.76	589.32	2.76
Crit W.S. (m)		Area (m2)	2.76	589.32	2.76
E.G. Slope (m/m)	0.000393	Flow (m3/s)	0.58	688.85	0.58
Q Total (m3/s)	690.00	Top Width (m)	6.22	123.00	6.22
Top Width (m)	135.44	Avg. Vel. (m/s)	0.21	1.17	0.21
Vel Total (m/s)	1.16	Hydr. Depth (m)	0.44	4.79	0.44
Max Chl Dpth (m)	6.89	Conv. (m3/s)	29.1	34734.7	29.1
Conv. Total (m3/s)	34792.9	Wetted Per. (m)	6.28	123.84	6.28
Length Wtd. (m)	150.02	Shear (N/m2)	1.70	18.35	1.70
Min Ch El (m)	2.00	Stream Power (N/m s)	0.35	21.45	0.35
Alpha	1.01	Cum Volume (1000 m3)	1.88	619.55	4.00
Frctn Loss (m)	0.07	Cum SA (1000 m2)	8.13	208.60	10.73
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 50

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.71	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.10				

W.S. Elev (m)	9.61	Reach Len. (m)	72.00	150.00	243.00
Crit W.S. (m)		Flow Area (m2)	10.13	677.55	32.50
E.G. Slope (m/m)	0.000469	Area (m2)	10.13	677.55	32.50
Q Total (m3/s)	960.00	Flow (m3/s)	3.07	949.11	7.82
Top Width (m)	210.59	Top Width (m)	14.88	123.00	72.71
Vel Total (m/s)	1.33	Avg. Vel. (m/s)	0.30	1.40	0.24
Max Chl Dpth (m)	7.61	Hydr. Depth (m)	0.68	5.51	0.45
Conv. Total (m3/s)	44331.4	Conv. (m3/s)	141.9	43828.3	361.1
Length Wtd. (m)	150.33	Wetted Per. (m)	14.97	123.84	72.83
Min Ch El (m)	2.00	Shear (N/m2)	3.11	25.16	2.05
Alpha	1.09	Stream Power (N/m s)	0.94	35.24	0.49
Frctn Loss (m)	0.08	Cum Volume (1000 m3)	12.78	735.07	20.17
C & E Loss (m)	0.00	Cum SA (1000 m2)	26.38	217.47	77.89

CROSS SECTION OUTPUT Profile #ARI 100

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	10.56	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.15	Reach Len. (m)	72.00	150.00	243.00
W.S. Elev (m)	10.41	Flow Area (m2)	26.97	776.82	110.88
Crit W.S. (m)		Area (m2)	26.97	776.82	110.88
E.G. Slope (m/m)	0.000603	Flow (m3/s)	11.64	1352.18	51.17
Q Total (m3/s)	1415.00	Top Width (m)	28.27	123.00	105.00
Top Width (m)	256.27	Avg. Vel. (m/s)	0.43	1.74	0.46
Vel Total (m/s)	1.55	Hydr. Depth (m)	0.95	6.32	1.06
Max Chl Dpth (m)	8.41	Conv. (m3/s)	474.0	55044.8	2083.2
Conv. Total (m3/s)	57601.9	Wetted Per. (m)	28.39	123.84	105.57
Length Wtd. (m)	151.81	Shear (N/m2)	5.62	37.12	6.22
Min Ch El (m)	2.00	Stream Power (N/m s)	2.43	64.61	2.87
Alpha	1.21	Cum Volume (1000 m3)	48.84	885.29	129.93
Frctn Loss (m)	0.11	Cum SA (1000 m2)	64.93	226.06	218.70
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 40

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.08	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.07	Reach Len. (m)	72.00	150.00	243.00
W.S. Elev (m)	9.01	Flow Area (m2)	3.57	604.20	3.73
Crit W.S. (m)		Area (m2)	3.57	604.20	3.73
E.G. Slope (m/m)	0.000406	Flow (m3/s)	0.82	729.36	0.82
Q Total (m3/s)	731.00	Top Width (m)	7.13	123.00	23.79
Top Width (m)	153.92	Avg. Vel. (m/s)	0.23	1.21	0.22
Vel Total (m/s)	1.20	Hydr. Depth (m)	0.50	4.91	0.16
Max Chl Dpth (m)	7.01	Conv. (m3/s)	40.6	36208.8	40.9
Conv. Total (m3/s)	36290.3	Wetted Per. (m)	7.20	123.84	23.86
Length Wtd. (m)	150.03	Shear (N/m2)	1.97	19.41	0.62
Min Ch El (m)	2.00	Stream Power (N/m s)	0.45	23.43	0.14
Alpha	1.02				

Frctn Loss (m)	0.07	Cum Volume (1000 m3)	2.92	638.48	5.13
C & E Loss (m)	0.00	Cum SA (1000 m2)	10.48	210.07	14.44

CROSS SECTION
RS: 10

CROSS SECTION OUTPUT Profile #ARI 10

E.G. Elev (m)	7.91	Element	Left OB	Channel	Right OB
Vel Head (m)	0.05	Wt. n-Val.		0.048	
W.S. Elev (m)	7.86	Reach Len. (m)	43.00	150.00	230.00
Crit W.S. (m)		Flow Area (m2)		425.63	
E.G. Slope (m/m)	0.000401	Area (m2)		425.63	
Q Total (m3/s)	430.00	Flow (m3/s)		430.00	
Top Width (m)	111.71	Top Width (m)		111.71	
Vel Total (m/s)	1.01	Avg. Vel. (m/s)		1.01	
Max Chl Dpth (m)	6.86	Hydr. Depth (m)		3.81	
Conv. Total (m3/s)	21468.4	Conv. (m3/s)		21468.4	
Length Wtd. (m)	150.00	Wetted Per. (m)		112.98	
Min Ch El (m)	1.00	Shear (N/m2)		14.82	
Alpha	1.00	Stream Power (N/m s)		14.97	
Frctn Loss (m)	0.07	Cum Volume (1000 m3)		413.20	
C & E Loss (m)	0.00	Cum SA (1000 m2)		171.75	

CROSS SECTION OUTPUT Profile #ARI 25

E.G. Elev (m)	8.89	Element	Left OB	Channel	Right OB
Vel Head (m)	0.08	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	8.81	Reach Len. (m)	43.00	150.00	230.00
Crit W.S. (m)		Flow Area (m2)	3.25	534.19	3.90
E.G. Slope (m/m)	0.000501	Area (m2)	3.25	534.19	3.90
Q Total (m3/s)	690.00	Flow (m3/s)	0.72	688.42	0.86
Top Width (m)	132.73	Top Width (m)	8.06	115.00	9.67
Vel Total (m/s)	1.27	Avg. Vel. (m/s)	0.22	1.29	0.22
Max Chl Dpth (m)	7.81	Hydr. Depth (m)	0.40	4.65	0.40
Conv. Total (m3/s)	30822.8	Conv. (m3/s)	32.1	30752.1	38.6
Length Wtd. (m)	149.95	Wetted Per. (m)	8.10	116.30	9.70
Min Ch El (m)	1.00	Shear (N/m2)	1.97	22.57	1.97
Alpha	1.02	Stream Power (N/m s)	0.44	29.09	0.44
Frctn Loss (m)	0.08	Cum Volume (1000 m3)	1.66	535.29	3.20
C & E Loss (m)	0.00	Cum SA (1000 m2)	7.61	190.75	8.80

CROSS SECTION OUTPUT Profile #ARI 50

E.G. Elev (m)	9.62	Element	Left OB	Channel	Right OB
Vel Head (m)	0.12	Wt. n-Val.	0.055	0.048	0.055

			Left OB	Channel	Right OB
W.S. Elev (m)	9.50	Reach Len. (m)	43.00	150.00	230.00
Crit W.S. (m)		Flow Area (m2)	11.91	614.26	13.79
E.G. Slope (m/m)	0.000600	Area (m2)	11.91	614.26	13.79
Q Total (m3/s)	960.00	Flow (m3/s)	4.09	950.96	4.95
Top Width (m)	151.57	Top Width (m)	17.53	115.00	19.03
Vel Total (m/s)	1.50	Avg. Vel. (m/s)	0.34	1.55	0.36
Max Chl Dpth (m)	8.50	Hydr. Depth (m)	0.68	5.34	0.72
Conv. Total (m3/s)	39181.9	Conv. (m3/s)	167.0	38813.0	201.9
Length Wtd. (m)	149.79	Wetted Per. (m)	17.60	116.30	19.09
Min Ch El (m)	1.00	Shear (N/m2)	3.98	31.09	4.25
Alpha	1.06	Stream Power (N/m s)	1.37	48.14	1.53
Frctn Loss (m)	0.10	Cum Volume (1000 m3)	11.99	638.18	14.54
C & E Loss (m)	0.00	Cum SA (1000 m2)	25.21	199.62	66.74

CROSS SECTION OUTPUT Profile #ARI 100

E.G. Elev (m)	10.45	Element	Left OB	Channel	Right OB
Vel Head (m)	0.19	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	10.26	Reach Len. (m)	43.00	150.00	230.00
Crit W.S. (m)		Flow Area (m2)	30.22	701.54	101.04
E.G. Slope (m/m)	0.000806	Area (m2)	30.22	701.54	101.04
Q Total (m3/s)	1415.00	Flow (m3/s)	14.36	1374.90	25.74
Top Width (m)	440.15	Top Width (m)	34.15	115.00	291.00
Vel Total (m/s)	1.70	Avg. Vel. (m/s)	0.48	1.96	0.25
Max Chl Dpth (m)	9.26	Hydr. Depth (m)	0.89	6.10	0.35
Conv. Total (m3/s)	49844.9	Conv. (m3/s)	505.7	48432.3	906.9
Length Wtd. (m)	148.99	Wetted Per. (m)	34.23	116.30	291.34
Min Ch El (m)	1.00	Shear (N/m2)	6.98	47.67	2.74
Alpha	1.29	Stream Power (N/m s)	3.31	93.43	0.70
Frctn Loss (m)	0.13	Cum Volume (1000 m3)	46.78	774.41	104.18
C & E Loss (m)	0.00	Cum SA (1000 m2)	62.68	208.21	170.59

CROSS SECTION OUTPUT Profile #ARI 40

E.G. Elev (m)	9.01	Element	Left OB	Channel	Right OB
Vel Head (m)	0.09	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	8.92	Reach Len. (m)	43.00	150.00	230.00
Crit W.S. (m)		Flow Area (m2)	4.27	547.75	5.12
E.G. Slope (m/m)	0.000516	Area (m2)	4.27	547.75	5.12
Q Total (m3/s)	731.00	Flow (m3/s)	1.05	728.69	1.26
Top Width (m)	135.32	Top Width (m)	9.24	115.00	11.09
Vel Total (m/s)	1.31	Avg. Vel. (m/s)	0.25	1.33	0.25
Max Chl Dpth (m)	7.92	Hydr. Depth (m)	0.46	4.76	0.46
Conv. Total (m3/s)	32166.2	Conv. (m3/s)	46.2	32064.5	55.5
Length Wtd. (m)	149.93	Wetted Per. (m)	9.28	116.30	11.12
Min Ch El (m)	1.00	Shear (N/m2)	2.33	23.85	2.33
Alpha	1.02	Stream Power (N/m s)	0.57	31.73	0.57

Frctn Loss (m)	0.09	Cum Volume (1000 m3)	2.64	552.08	4.06
C & E Loss (m)	0.00	Cum SA (1000 m2)	9.89	192.22	10.20

RS: 9

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.84	Wt. n-Val.		0.048	
Vel Head (m)	0.06	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	7.78	Flow Area (m2)		388.73	
Crit W.S. (m)		Area (m2)		388.73	
E.G. Slope (m/m)	0.000529	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		109.93	
Top Width (m)	109.93	Avg. Vel. (m/s)		1.11	
Vel Total (m/s)	1.11	Hydr. Depth (m)		3.54	
Max Chl Dpth (m)	6.78	Conv. (m3/s)		18687.3	
Conv. Total (m3/s)	18687.3	Wetted Per. (m)		110.90	
Length Wtd. (m)	150.00	Shear (N/m2)		18.20	
Min Ch El (m)	1.00	Stream Power (N/m s)		20.13	
Alpha	1.00	Cum Volume (1000 m3)		352.13	
Frctn Loss (m)	0.14	Cum SA (1000 m2)		155.13	
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.80	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.10	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	8.71	Flow Area (m2)	4.98	494.67	3.49
Crit W.S. (m)		Area (m2)	4.98	494.67	3.49
E.G. Slope (m/m)	0.000645	Flow (m3/s)	1.15	688.05	0.80
Q Total (m3/s)	690.00	Top Width (m)	14.11	115.00	9.88
Top Width (m)	139.00	Avg. Vel. (m/s)	0.23	1.39	0.23
Vel Total (m/s)	1.37	Hydr. Depth (m)	0.35	4.30	0.35
Max Chl Dpth (m)	7.71	Conv. (m3/s)	45.2	27102.1	31.6
Conv. Total (m3/s)	27178.9	Wetted Per. (m)	14.13	115.99	9.91
Length Wtd. (m)	150.00	Shear (N/m2)	2.23	26.95	2.22
Min Ch El (m)	1.00	Stream Power (N/m s)	0.51	37.49	0.51
Alpha	1.03	Cum Volume (1000 m3)	1.49	458.13	2.35
Frctn Loss (m)	0.17	Cum SA (1000 m2)	7.13	173.50	6.55
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 50

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.52	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.14				

W.S. Elev (m)	9.38	Reach Len. (m)	150.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	26.12	572.60	17.07
E.G. Slope (m/m)	0.000751	Area (m2)	26.12	572.60	17.07
Q Total (m3/s)	960.00	Flow (m3/s)	7.15	947.91	4.94
Top Width (m)	217.63	Top Width (m)	64.09	115.00	38.54
Vel Total (m/s)	1.56	Avg. Vel. (m/s)	0.27	1.66	0.29
Max Chl Dpth (m)	8.38	Hydr. Depth (m)	0.41	4.98	0.44
Conv. Total (m3/s)	35026.2	Conv. (m3/s)	260.9	34585.1	180.2
Length Wtd. (m)	150.00	Wetted Per. (m)	64.12	115.99	38.58
Min Ch El (m)	1.00	Shear (N/m2)	3.00	36.37	3.26
Alpha	1.11	Stream Power (N/m s)	0.82	60.20	0.94
Frctn Loss (m)	0.18	Cum Volume (1000 m3)	11.17	549.17	10.99
C & E Loss (m)	0.01	Cum SA (1000 m2)	23.45	182.37	60.12

CROSS SECTION OUTPUT Profile #ARI 100

E.G. Elev (m)	10.32	Element	Left OB	Channel	Right OB
Vel Head (m)	0.20	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	10.12	Reach Len. (m)	150.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	103.28	656.94	75.46
E.G. Slope (m/m)	0.000955	Area (m2)	103.28	656.94	75.46
Q Total (m3/s)	1415.00	Flow (m3/s)	48.50	1343.76	22.73
Top Width (m)	442.00	Top Width (m)	135.00	115.00	192.00
Vel Total (m/s)	1.69	Avg. Vel. (m/s)	0.47	2.05	0.30
Max Chl Dpth (m)	9.12	Hydr. Depth (m)	0.77	5.71	0.39
Conv. Total (m3/s)	45791.7	Conv. (m3/s)	1569.6	43486.4	735.7
Length Wtd. (m)	150.00	Wetted Per. (m)	135.15	115.99	192.16
Min Ch El (m)	1.00	Shear (N/m2)	7.16	53.03	3.68
Alpha	1.39	Stream Power (N/m s)	3.36	108.48	1.11
Frctn Loss (m)	0.18	Cum Volume (1000 m3)	43.91	672.53	83.88
C & E Loss (m)	0.00	Cum SA (1000 m2)	59.05	190.96	115.04

CROSS SECTION OUTPUT Profile #ARI 40

E.G. Elev (m)	8.93	Element	Left OB	Channel	Right OB
Vel Head (m)	0.10	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	8.82	Reach Len. (m)	150.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	6.74	507.90	4.72
E.G. Slope (m/m)	0.000661	Area (m2)	6.74	507.90	4.72
Q Total (m3/s)	731.00	Flow (m3/s)	1.74	728.05	1.22
Top Width (m)	142.91	Top Width (m)	16.41	115.00	11.49
Vel Total (m/s)	1.41	Avg. Vel. (m/s)	0.26	1.43	0.26
Max Chl Dpth (m)	7.82	Hydr. Depth (m)	0.41	4.42	0.41
Conv. Total (m3/s)	28435.3	Conv. (m3/s)	67.6	28320.4	47.3
Length Wtd. (m)	150.00	Wetted Per. (m)	16.44	115.99	11.52
Min Ch El (m)	1.00	Shear (N/m2)	2.66	28.38	2.65
Alpha	1.03	Stream Power (N/m s)	0.69	40.68	0.68

Frctn Loss (m)	0.17	Cum Volume (1000 m3)	2.40	472.91	2.92
C & E Loss (m)	0.01	Cum SA (1000 m2)	9.33	174.97	7.61

CROSS SECTION
RS: 8

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.69	Wt. n-Val.		0.048	
Vel Head (m)	0.17	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	7.52	Flow Area (m2)		235.49	
Crit W.S. (m)		Area (m2)		235.49	
E.G. Slope (m/m)	0.002157	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		89.82	
Top Width (m)	89.82	Avg. Vel. (m/s)		1.83	
Vel Total (m/s)	1.83	Hydr. Depth (m)		2.62	
Max Chl Dpth (m)	5.52	Conv. (m3/s)		9258.0	
Conv. Total (m3/s)	9258.0	Wetted Per. (m)		90.84	
Length Wtd. (m)	150.00	Shear (N/m2)		54.84	
Min Ch El (m)	2.00	Stream Power (N/m s)		100.14	
Alpha	1.00	Cum Volume (1000 m3)		305.31	
Frctn Loss (m)	0.15	Cum SA (1000 m2)		140.15	
C & E Loss (m)	0.03				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.62	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.22	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	8.40	Flow Area (m2)	6.34	327.93	
Crit W.S. (m)		Area (m2)	6.34	327.93	
E.G. Slope (m/m)	0.002487	Flow (m3/s)	1.96	688.04	
Q Total (m3/s)	690.00	Top Width (m)	31.84	113.18	
Top Width (m)	145.03	Avg. Vel. (m/s)	0.31	2.10	
Vel Total (m/s)	2.06	Hydr. Depth (m)	0.20	2.90	
Max Chl Dpth (m)	6.40	Conv. (m3/s)	39.3	13796.2	
Conv. Total (m3/s)	13835.5	Wetted Per. (m)	31.85	114.27	
Length Wtd. (m)	150.00	Shear (N/m2)	4.85	69.99	
Min Ch El (m)	2.00	Stream Power (N/m s)	1.50	146.86	
Alpha	1.03	Cum Volume (1000 m3)	0.64	396.43	2.08
Frctn Loss (m)	0.19	Cum SA (1000 m2)	3.69	156.38	5.81
C & E Loss (m)	0.04				

CROSS SECTION OUTPUT Profile #ARI 50

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.32				

Vel Head (m)	0.26	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	9.06	Reach Len. (m)	150.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	45.10	404.81	17.68
E.G. Slope (m/m)	0.002387	Area (m2)	45.10	404.81	17.68
Q Total (m3/s)	960.00	Flow (m3/s)	26.27	931.28	2.46
Top Width (m)	488.95	Top Width (m)	84.95	118.00	286.00
Vel Total (m/s)	2.05	Avg. Vel. (m/s)	0.58	2.30	0.14
Max Chl Dpth (m)	7.06	Hydr. Depth (m)	0.53	3.43	0.06
Conv. Total (m3/s)	19649.9	Conv. (m3/s)	537.6	19062.0	50.3
Length Wtd. (m)	150.00	Wetted Per. (m)	84.95	119.13	286.06
Min Ch El (m)	2.00	Shear (N/m2)	12.43	79.54	1.45
Alpha	1.22	Stream Power (N/m s)	7.24	182.98	0.20
Frctn Loss (m)	0.19	Cum Volume (1000 m3)	5.83	475.86	8.39
C & E Loss (m)	0.05	Cum SA (1000 m2)	12.28	164.89	35.78

CROSSTION OUTPUT Profile #ARI 100

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	10.14	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.20	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	9.93	Flow Area (m2)	149.59	507.70	267.07
Crit W.S. (m)		Area (m2)	149.59	507.70	267.07
E.G. Slope (m/m)	0.001626	Flow (m3/s)	107.23	1121.12	186.65
Q Total (m3/s)	1415.00	Top Width (m)	154.72	118.00	286.00
Top Width (m)	558.72	Avg. Vel. (m/s)	0.72	2.21	0.70
Vel Total (m/s)	1.53	Hydr. Depth (m)	0.97	4.30	0.93
Max Chl Dpth (m)	7.93	Conv. (m3/s)	2659.3	27803.4	4628.9
Conv. Total (m3/s)	35091.7	Wetted Per. (m)	154.74	119.13	286.93
Length Wtd. (m)	150.00	Shear (N/m2)	15.41	67.95	14.84
Min Ch El (m)	2.00	Stream Power (N/m s)	11.05	150.06	10.37
Alpha	1.69	Cum Volume (1000 m3)	24.94	585.18	58.19
Frctn Loss (m)	0.18	Cum SA (1000 m2)	37.32	173.49	79.19
C & E Loss (m)	0.02				

CROSS SECTION OUTPUT Profile #ARI 40

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.74	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.23	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	8.51	Flow Area (m2)	10.35	340.50	
Crit W.S. (m)		Area (m2)	10.35	340.50	
E.G. Slope (m/m)	0.002477	Flow (m3/s)	3.76	727.24	
Q Total (m3/s)	731.00	Top Width (m)	40.70	114.07	
Top Width (m)	154.77	Avg. Vel. (m/s)	0.36	2.14	
Vel Total (m/s)	2.08	Hydr. Depth (m)	0.25	2.99	
Max Chl Dpth (m)	6.51	Conv. (m3/s)	75.6	14613.0	
Conv. Total (m3/s)	14688.6	Wetted Per. (m)	40.70	115.17	
Length Wtd. (m)	150.00	Shear (N/m2)	6.18	71.81	
Min Ch El (m)	2.00				

Alpha	1.05	Stream Power (N/m s)	2.24	153.37	
Frctn Loss (m)	0.19	Cum Volume (1000 m3)	1.12	409.28	2.57
C & E Loss (m)	0.05	Cum SA (1000 m2)	5.05	157.79	6.75

CROSS SECTION

RS: 7

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.50	Wt. n-Val.		0.048	
Vel Head (m)	0.05	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	7.45	Flow Area (m2)		419.74	
Crit W.S. (m)		Area (m2)		419.74	
E.G. Slope (m/m)	0.000602	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		147.30	
Top Width (m)	147.30	Avg. Vel. (m/s)		1.02	
Vel Total (m/s)	1.02	Hydr. Depth (m)		2.85	
Max Chl Dpth (m)	5.45	Conv. (m3/s)		17529.6	
Conv. Total (m3/s)	17529.6	Wetted Per. (m)		147.89	
Length Wtd. (m)	150.00	Shear (N/m2)		16.75	
Min Ch El (m)	2.00	Stream Power (N/m s)		17.16	
Alpha	1.00	Cum Volume (1000 m3)		256.17	
Frctn Loss (m)	0.08	Cum SA (1000 m2)		122.37	
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.39	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.08	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	8.31	Flow Area (m2)	0.74	564.56	
Crit W.S. (m)		Area (m2)	0.74	564.56	
E.G. Slope (m/m)	0.000743	Flow (m3/s)	0.11	689.89	
Q Total (m3/s)	690.00	Top Width (m)	4.72	178.15	
Top Width (m)	182.86	Avg. Vel. (m/s)	0.14	1.22	
Vel Total (m/s)	1.22	Hydr. Depth (m)	0.16	3.17	
Max Chl Dpth (m)	6.31	Conv. (m3/s)	3.9	25313.6	
Conv. Total (m3/s)	25317.6	Wetted Per. (m)	4.73	178.81	
Length Wtd. (m)	150.00	Shear (N/m2)	1.14	23.00	
Min Ch El (m)	2.00	Stream Power (N/m s)	0.16	28.10	
Alpha	1.00	Cum Volume (1000 m3)	0.11	329.49	2.08
Frctn Loss (m)	0.11	Cum SA (1000 m2)	0.95	134.53	5.81
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 50

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.09	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.10	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	8.99	Flow Area (m2)	7.29	686.41	
Crit W.S. (m)		Area (m2)	7.29	686.41	
E.G. Slope (m/m)	0.000784	Flow (m3/s)	2.31	957.69	
Q Total (m3/s)	960.00	Top Width (m)	14.79	184.86	
Top Width (m)	199.65	Avg. Vel. (m/s)	0.32	1.40	
Vel Total (m/s)	1.38	Hydr. Depth (m)	0.49	3.71	
Max Chl Dpth (m)	6.99	Conv. (m3/s)	82.6	34205.2	
Conv. Total (m3/s)	34287.8	Wetted Per. (m)	14.82	185.55	
Length Wtd. (m)	150.00	Shear (N/m2)	3.78	28.44	
Min Ch El (m)	2.00	Stream Power (N/m s)	1.20	39.68	
Alpha	1.01	Cum Volume (1000 m3)	1.90	394.02	7.06
Frctn Loss (m)	0.13	Cum SA (1000 m2)	4.80	142.18	14.33
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 100

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.94	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.14	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	9.80	Flow Area (m2)	35.58	840.50	26.02
Crit W.S. (m)		Area (m2)	35.58	840.50	26.02
E.G. Slope (m/m)	0.000894	Flow (m3/s)	14.45	1392.92	7.63
Q Total (m3/s)	1415.00	Top Width (m)	55.08	193.02	64.93
Top Width (m)	313.03	Avg. Vel. (m/s)	0.41	1.66	0.29
Vel Total (m/s)	1.57	Hydr. Depth (m)	0.65	4.35	0.40
Max Chl Dpth (m)	7.80	Conv. (m3/s)	483.2	46575.3	255.0
Conv. Total (m3/s)	47313.6	Wetted Per. (m)	55.12	193.75	65.74
Length Wtd. (m)	150.00	Shear (N/m2)	5.66	38.05	3.47
Min Ch El (m)	2.00	Stream Power (N/m s)	2.30	63.06	1.02
Alpha	1.10	Cum Volume (1000 m3)	11.06	484.06	36.21
Frctn Loss (m)	0.15	Cum SA (1000 m2)	21.58	150.16	52.87
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 40

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.51	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.08	Reach Len. (m)	150.00	150.00	150.00
W.S. Elev (m)	8.43	Flow Area (m2)	1.37	584.85	
Crit W.S. (m)		Area (m2)	1.37	584.85	
E.G. Slope (m/m)	0.000747	Flow (m3/s)	0.24	730.76	
Q Total (m3/s)	731.00	Top Width (m)	6.42	179.28	
Top Width (m)	185.70	Avg. Vel. (m/s)	0.18	1.25	
Vel Total (m/s)	1.25	Hydr. Depth (m)	0.21	3.26	
Max Chl Dpth (m)	6.43	Conv. (m3/s)	8.9	26734.5	
Conv. Total (m3/s)	26743.4	Wetted Per. (m)	6.44	179.95	
Length Wtd. (m)	150.00				

Min Ch El (m)	2.00	Shear (N/m2)	1.57	23.81	
Alpha	1.00	Stream Power (N/m s)	0.28	29.75	
Frctn Loss (m)	0.12	Cum Volume (1000 m3)	0.24	339.88	2.57
C & E Loss (m)	0.00	Cum SA (1000 m2)	1.52	135.79	6.75

CROSS SECTION

RS: 6

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.41	Wt. n-Val.		0.048	
Vel Head (m)	0.06	Reach Len. (m)	124.00	150.00	135.00
W.S. Elev (m)	7.35	Flow Area (m2)		390.39	
Crit W.S. (m)		Area (m2)		390.39	
E.G. Slope (m/m)	0.000529	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		111.05	
Top Width (m)	111.05	Avg. Vel. (m/s)		1.10	
Vel Total (m/s)	1.10	Hydr. Depth (m)		3.52	
Max Chl Dpth (m)	6.35	Conv. (m3/s)		18692.7	
Conv. Total (m3/s)	18692.7	Wetted Per. (m)		112.04	
Length Wtd. (m)	150.00	Shear (N/m2)		18.08	
Min Ch El (m)	1.00	Stream Power (N/m s)		19.92	
Alpha	1.00	Cum Volume (1000 m3)		195.41	
Frctn Loss (m)	0.10	Cum SA (1000 m2)		102.99	
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.27	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.10	Reach Len. (m)	124.00	150.00	135.00
W.S. Elev (m)	8.17	Flow Area (m2)	0.37	488.18	
Crit W.S. (m)		Area (m2)	0.37	488.18	
E.G. Slope (m/m)	0.000772	Flow (m3/s)	0.04	689.96	
Q Total (m3/s)	690.00	Top Width (m)	4.32	126.94	
Top Width (m)	131.26	Avg. Vel. (m/s)	0.10	1.41	
Vel Total (m/s)	1.41	Hydr. Depth (m)	0.09	3.85	
Max Chl Dpth (m)	7.17	Conv. (m3/s)	1.3	24827.1	
Conv. Total (m3/s)	24828.4	Wetted Per. (m)	4.32	128.00	
Length Wtd. (m)	150.00	Shear (N/m2)	0.65	28.89	
Min Ch El (m)	1.00	Stream Power (N/m s)	0.06	40.83	
Alpha	1.00	Cum Volume (1000 m3)	0.02	250.54	2.08
Frctn Loss (m)	0.15	Cum SA (1000 m2)	0.27	111.65	5.81
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 50

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.95	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.14	Reach Len. (m)	124.00	150.00	135.00
W.S. Elev (m)	8.81	Flow Area (m2)	8.15	572.17	
Crit W.S. (m)		Area (m2)	8.15	572.17	
E.G. Slope (m/m)	0.000976	Flow (m3/s)	2.53	957.47	
Q Total (m3/s)	960.00	Top Width (m)	20.19	137.73	
Top Width (m)	157.91	Avg. Vel. (m/s)	0.31	1.67	
Vel Total (m/s)	1.65	Hydr. Depth (m)	0.40	4.15	
Max Chl Dpth (m)	7.81	Conv. (m3/s)	80.9	30645.5	
Conv. Total (m3/s)	30726.4	Wetted Per. (m)	20.20	138.81	
Length Wtd. (m)	149.93	Shear (N/m2)	3.86	39.46	
Min Ch El (m)	1.00	Stream Power (N/m s)	1.20	66.03	
Alpha	1.02	Cum Volume (1000 m3)	0.74	299.63	7.06
Frctn Loss (m)	0.19	Cum SA (1000 m2)	2.17	117.99	14.33
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 100

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	9.78	Wt. n-Val.	0.055	0.048	0.055
Vel Head (m)	0.19	Reach Len. (m)	124.00	150.00	135.00
W.S. Elev (m)	9.59	Flow Area (m2)	50.58	681.96	84.72
Crit W.S. (m)		Area (m2)	50.58	681.96	84.72
E.G. Slope (m/m)	0.001131	Flow (m3/s)	19.07	1359.66	36.27
Q Total (m3/s)	1415.00	Top Width (m)	104.44	141.00	144.00
Top Width (m)	389.44	Avg. Vel. (m/s)	0.38	1.99	0.43
Vel Total (m/s)	1.73	Hydr. Depth (m)	0.48	4.84	0.59
Max Chl Dpth (m)	8.59	Conv. (m3/s)	567.0	40426.1	1078.5
Conv. Total (m3/s)	42071.6	Wetted Per. (m)	104.46	142.09	144.59
Length Wtd. (m)	149.39	Shear (N/m2)	5.37	53.24	6.50
Min Ch El (m)	1.00	Stream Power (N/m s)	2.02	106.15	2.78
Alpha	1.28	Cum Volume (1000 m3)	4.59	369.88	27.90
Frctn Loss (m)	0.22	Cum SA (1000 m2)	9.62	125.11	37.20
C & E Loss (m)	0.02				

CROSS SECTION OUTPUT Profile #ARI 40

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.39	Wt. n-Val.	0.055	0.048	
Vel Head (m)	0.11	Reach Len. (m)	124.00	150.00	135.00
W.S. Elev (m)	8.28	Flow Area (m2)	0.98	501.96	
Crit W.S. (m)		Area (m2)	0.98	501.96	
E.G. Slope (m/m)	0.000805	Flow (m3/s)	0.14	730.86	
Q Total (m3/s)	731.00	Top Width (m)	7.01	128.77	
Top Width (m)	135.78	Avg. Vel. (m/s)	0.14	1.46	
Vel Total (m/s)	1.45	Hydr. Depth (m)	0.14	3.90	
Max Chl Dpth (m)	7.28	Conv. (m3/s)	4.8	25760.6	
Conv. Total (m3/s)	25765.4				

Length Wtd. (m)	150.00	Wetted Per. (m)	7.02	129.83	
Min Ch El (m)	1.00	Shear (N/m2)	1.11	30.52	
Alpha	1.00	Stream Power (N/m s)	0.15	44.43	
Frctn Loss (m)	0.16	Cum Volume (1000 m3)	0.06	258.37	2.57
C & E Loss (m)	0.01	Cum SA (1000 m2)	0.51	112.69	6.75

CROSS SECTION
RS: 5

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.31	Wt. n-Val.		0.048	
Vel Head (m)	0.10	Reach Len. (m)	152.00	150.00	150.00
W.S. Elev (m)	7.20	Flow Area (m2)		304.75	
Crit W.S. (m)		Area (m2)		304.75	
E.G. Slope (m/m)	0.000965	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		93.88	
Top Width (m)	93.88	Avg. Vel. (m/s)		1.41	
Vel Total (m/s)	1.41	Hydr. Depth (m)		3.25	
Max Chl Dpth (m)	5.20	Conv. (m3/s)		13844.7	
Conv. Total (m3/s)	13844.7	Wetted Per. (m)		94.64	
Length Wtd. (m)	150.00	Shear (N/m2)		30.46	
Min Ch El (m)	2.00	Stream Power (N/m s)		42.98	
Alpha	1.00	Cum Volume (1000 m3)		143.27	
Frctn Loss (m)	0.22	Cum SA (1000 m2)		87.62	
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	8.11	Wt. n-Val.		0.048	
Vel Head (m)	0.17	Reach Len. (m)	152.00	150.00	150.00
W.S. Elev (m)	7.95	Flow Area (m2)		379.55	
Crit W.S. (m)		Area (m2)		379.55	
E.G. Slope (m/m)	0.001439	Flow (m3/s)		690.00	
Q Total (m3/s)	690.00	Top Width (m)		107.96	
Top Width (m)	107.96	Avg. Vel. (m/s)		1.82	
Vel Total (m/s)	1.82	Hydr. Depth (m)		3.52	
Max Chl Dpth (m)	5.95	Conv. (m3/s)		18187.9	
Conv. Total (m3/s)	18187.9	Wetted Per. (m)		108.80	
Length Wtd. (m)	150.00	Shear (N/m2)		49.24	
Min Ch El (m)	2.00	Stream Power (N/m s)		89.51	
Alpha	1.00	Cum Volume (1000 m3)		185.46	2.08
Frctn Loss (m)	0.32	Cum SA (1000 m2)		94.04	5.81
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 50

E.G. Elev (m)	8.75	Element	Left OB	Channel	Right OB
Vel Head (m)	0.24	Wt. n-Val.	0.055	0.048	0.048
W.S. Elev (m)	8.51	Reach Len. (m)	152.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	1.71	441.44	10.01
E.G. Slope (m/m)	0.001691	Area (m2)	1.71	441.44	10.01
Q Total (m3/s)	960.00	Flow (m3/s)	0.52	956.02	3.46
Top Width (m)	154.67	Top Width (m)	6.67	109.00	39.00
Vel Total (m/s)	2.12	Avg. Vel. (m/s)	0.30	2.17	0.35
Max Chl Dpth (m)	6.51	Hydr. Depth (m)	0.26	4.05	0.26
Conv. Total (m3/s)	23342.4	Conv. (m3/s)	12.5	23245.6	84.2
Length Wtd. (m)	150.00	Wetted Per. (m)	6.69	109.85	39.00
Min Ch El (m)	2.00	Shear (N/m2)	4.24	66.66	4.26
Alpha	1.04	Stream Power (N/m s)	1.28	144.35	1.47
Frctn Loss (m)	0.38	Cum Volume (1000 m3)	0.13	223.61	6.38
C & E Loss (m)	0.02	Cum SA (1000 m2)	0.51	99.48	11.70

CROSS SECTION OUTPUT Profile #ARI 100

E.G. Elev (m)	9.54	Element	Left OB	Channel	Right OB
Vel Head (m)	0.35	Wt. n-Val.	0.055	0.048	0.048
W.S. Elev (m)	9.19	Reach Len. (m)	152.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	9.65	515.57	53.32
E.G. Slope (m/m)	0.002077	Area (m2)	9.65	515.57	53.32
Q Total (m3/s)	1415.00	Flow (m3/s)	4.98	1372.20	37.82
Top Width (m)	211.14	Top Width (m)	19.57	109.00	82.57
Vel Total (m/s)	2.45	Avg. Vel. (m/s)	0.52	2.66	0.71
Max Chl Dpth (m)	7.19	Hydr. Depth (m)	0.49	4.73	0.65
Conv. Total (m3/s)	31048.1	Conv. (m3/s)	109.3	30109.0	829.8
Length Wtd. (m)	150.00	Wetted Per. (m)	19.61	109.85	82.58
Min Ch El (m)	2.00	Shear (N/m2)	10.02	95.60	13.15
Alpha	1.15	Stream Power (N/m s)	5.17	254.43	9.33
Frctn Loss (m)	0.44	Cum Volume (1000 m3)	0.86	280.06	18.59
C & E Loss (m)	0.02	Cum SA (1000 m2)	1.93	106.36	21.91

CROSS SECTION OUTPUT Profile #ARI 40

E.G. Elev (m)	8.22	Element	Left OB	Channel	Right OB
Vel Head (m)	0.18	Wt. n-Val.	0.055	0.048	0.048
W.S. Elev (m)	8.04	Reach Len. (m)	152.00	150.00	150.00
Crit W.S. (m)		Flow Area (m2)	0.01	390.08	0.07
E.G. Slope (m/m)	0.001494	Area (m2)	0.01	390.08	0.07
Q Total (m3/s)	731.00	Flow (m3/s)	0.00	731.00	0.00
Top Width (m)	112.73	Top Width (m)	0.55	109.00	3.19
Vel Total (m/s)	1.87	Avg. Vel. (m/s)	0.05	1.87	0.06
Max Chl Dpth (m)	6.04	Hydr. Depth (m)	0.02	3.58	0.02
Conv. Total (m3/s)	18915.1	Conv. (m3/s)	0.0	18914.9	0.1

			Left OB	Channel	Right OB
Length Wtd. (m)	150.00	Wetted Per. (m)	0.55	109.85	3.19
Min Ch El (m)	2.00	Shear (N/m2)	0.31	52.01	0.31
Alpha	1.00	Stream Power (N/m s)	0.02	97.46	0.02
Frctn Loss (m)	0.33	Cum Volume (1000 m3)	0.00	191.46	2.57
C & E Loss (m)	0.01	Cum SA (1000 m2)	0.04	94.85	6.53

CROSS SECTION

RS: 4

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.08	Wt. n-Val.		0.048	
Vel Head (m)	0.19	Reach Len. (m)	154.00	150.00	140.00
W.S. Elev (m)	6.89	Flow Area (m2)		224.81	
Crit W.S. (m)		Area (m2)		224.81	
E.G. Slope (m/m)	0.002375	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		86.42	
Top Width (m)	86.42	Avg. Vel. (m/s)		1.91	
Vel Total (m/s)	1.91	Hydr. Depth (m)		2.60	
Max Chl Dpth (m)	3.89	Conv. (m3/s)		8823.4	
Conv. Total (m3/s)	8823.4	Wetted Per. (m)		86.94	
Length Wtd. (m)	150.00	Shear (N/m2)		60.22	
Min Ch El (m)	3.00	Stream Power (N/m s)		115.19	
Alpha	1.00	Cum Volume (1000 m3)		103.55	
Frctn Loss (m)	0.46	Cum SA (1000 m2)		74.10	
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.78	Wt. n-Val.		0.048	0.055
Vel Head (m)	0.30	Reach Len. (m)	154.00	150.00	140.00
W.S. Elev (m)	7.48	Flow Area (m2)		278.51	14.38
Crit W.S. (m)		Area (m2)		278.51	14.38
E.G. Slope (m/m)	0.003464	Flow (m3/s)		682.24	7.76
Q Total (m3/s)	690.00	Top Width (m)		98.05	40.09
Top Width (m)	138.14	Avg. Vel. (m/s)		2.45	0.54
Vel Total (m/s)	2.36	Hydr. Depth (m)		2.84	0.36
Max Chl Dpth (m)	4.48	Conv. (m3/s)		11591.7	131.9
Conv. Total (m3/s)	11723.6	Wetted Per. (m)		98.63	40.12
Length Wtd. (m)	149.94	Shear (N/m2)		95.92	12.17
Min Ch El (m)	3.00	Stream Power (N/m s)		234.98	6.57
Alpha	1.07	Cum Volume (1000 m3)		136.10	1.01
Frctn Loss (m)	0.60	Cum SA (1000 m2)		78.59	2.81
C & E Loss (m)	0.02				

CROSS SECTION OUTPUT Profile #ARI 50

E.G. Elev (m)	8.36	Element	Left OB	Channel	Right OB
Vel Head (m)	0.39	Wt. n-Val.		0.048	0.055
W.S. Elev (m)	7.96	Reach Len. (m)	154.00	150.00	140.00
Crit W.S. (m)		Flow Area (m2)		328.69	38.85
E.G. Slope (m/m)	0.004192	Area (m2)		328.69	38.85
Q Total (m3/s)	960.00	Flow (m3/s)		925.99	34.01
Top Width (m)	168.79	Top Width (m)		108.26	60.52
Vel Total (m/s)	2.61	Avg. Vel. (m/s)		2.82	0.88
Max Chl Dpth (m)	4.96	Hydr. Depth (m)		3.04	0.64
Conv. Total (m3/s)	14827.4	Conv. (m3/s)		14302.1	525.3
Length Wtd. (m)	149.82	Wetted Per. (m)		108.89	60.57
Min Ch El (m)	3.00	Shear (N/m2)		124.08	26.37
Alpha	1.13	Stream Power (N/m s)		349.57	23.08
Frctn Loss (m)	0.69	Cum Volume (1000 m3)		165.85	2.72
C & E Loss (m)	0.03	Cum SA (1000 m2)		83.19	4.24

CROSS SECTION OUTPUT Profile #ARI 100

E.G. Elev (m)	9.09	Element	Left OB	Channel	Right OB
Vel Head (m)	0.51	Wt. n-Val.	0.055	0.048	0.055
W.S. Elev (m)	8.58	Reach Len. (m)	154.00	150.00	140.00
Crit W.S. (m)		Flow Area (m2)	0.83	395.47	100.61
E.G. Slope (m/m)	0.004487	Area (m2)	0.83	395.47	100.61
Q Total (m3/s)	1415.00	Flow (m3/s)	0.44	1298.01	116.55
Top Width (m)	220.29	Top Width (m)	2.89	109.00	108.40
Vel Total (m/s)	2.85	Avg. Vel. (m/s)	0.53	3.28	1.16
Max Chl Dpth (m)	5.58	Hydr. Depth (m)	0.29	3.63	0.93
Conv. Total (m3/s)	21124.9	Conv. (m3/s)	6.5	19378.4	1740.0
Length Wtd. (m)	149.59	Wetted Per. (m)	2.95	109.63	108.46
Min Ch El (m)	3.00	Shear (N/m2)	12.46	158.71	40.81
Alpha	1.23	Stream Power (N/m s)	6.54	520.93	47.28
Frctn Loss (m)	0.74	Cum Volume (1000 m3)	0.06	211.74	7.04
C & E Loss (m)	0.04	Cum SA (1000 m2)	0.22	90.01	7.59

CROSS SECTION OUTPUT Profile #ARI 40

E.G. Elev (m)	7.88	Element	Left OB	Channel	Right OB
Vel Head (m)	0.32	Wt. n-Val.		0.048	0.055
W.S. Elev (m)	7.56	Reach Len. (m)	154.00	150.00	140.00
Crit W.S. (m)		Flow Area (m2)		286.29	17.66
E.G. Slope (m/m)	0.003603	Area (m2)		286.29	17.66
Q Total (m3/s)	731.00	Flow (m3/s)		720.42	10.58
Top Width (m)	143.10	Top Width (m)		99.70	43.40
Vel Total (m/s)	2.41	Avg. Vel. (m/s)		2.52	0.60
Max Chl Dpth (m)	4.56	Hydr. Depth (m)		2.87	0.41

Conv. Total (m3/s)	12178.4	Conv. (m3/s)		12002.1	176.3
Length Wtd. (m)	149.93	Wetted Per. (m)		100.29	43.43
Min Ch El (m)	3.00	Shear (N/m2)		100.86	14.37
Alpha	1.08	Stream Power (N/m s)		253.81	8.61
Frctn Loss (m)	0.61	Cum Volume (1000 m3)		140.74	1.24
C & E Loss (m)	0.02	Cum SA (1000 m2)		79.20	3.04

CROSS SECTION
RS: 3

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	6.62	Wt. n-Val.		0.048	
Vel Head (m)	0.16	Reach Len. (m)	166.00	150.00	125.00
W.S. Elev (m)	6.46	Flow Area (m2)		244.07	
Crit W.S. (m)		Area (m2)		244.07	
E.G. Slope (m/m)	0.004014	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		157.73	
Top Width (m)	157.73	Avg. Vel. (m/s)		1.76	
Vel Total (m/s)	1.76	Hydr. Depth (m)		1.55	
Max Chl Dpth (m)	4.46	Conv. (m3/s)		6787.2	
Conv. Total (m3/s)	6787.2	Wetted Per. (m)		158.27	
Length Wtd. (m)	150.00	Shear (N/m2)		60.70	
Min Ch El (m)	2.00	Stream Power (N/m s)		106.94	
Alpha	1.00	Cum Volume (1000 m3)		68.39	
Frctn Loss (m)	0.64	Cum SA (1000 m2)		55.79	
C & E Loss (m)	0.00				

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	7.16	Wt. n-Val.		0.048	
Vel Head (m)	0.23	Reach Len. (m)	166.00	150.00	125.00
W.S. Elev (m)	6.93	Flow Area (m2)		321.89	
Crit W.S. (m)		Area (m2)		321.89	
E.G. Slope (m/m)	0.004607	Flow (m3/s)		690.00	
Q Total (m3/s)	690.00	Top Width (m)		171.90	
Top Width (m)	171.90	Avg. Vel. (m/s)		2.14	
Vel Total (m/s)	2.14	Hydr. Depth (m)		1.87	
Max Chl Dpth (m)	4.93	Conv. (m3/s)		10165.5	
Conv. Total (m3/s)	10165.5	Wetted Per. (m)		172.48	
Length Wtd. (m)	150.00	Shear (N/m2)		84.32	
Min Ch El (m)	2.00	Stream Power (N/m s)		180.75	
Alpha	1.00	Cum Volume (1000 m3)		91.07	
Frctn Loss (m)	0.70	Cum SA (1000 m2)		58.34	
C & E Loss (m)	0.01				

CROSS SECTION OUTPUT Profile #ARI 50

E.G. Elev (m)	7.64	Element	Left OB	Channel	Right OB
Vel Head (m)	0.30	Wt. n-Val.		0.048	
W.S. Elev (m)	7.34	Reach Len. (m)	166.00	150.00	125.00
Crit W.S. (m)		Flow Area (m2)		395.09	
E.G. Slope (m/m)	0.005116	Area (m2)		395.09	
Q Total (m3/s)	960.00	Flow (m3/s)		960.00	
Top Width (m)	189.14	Top Width (m)		189.14	
Vel Total (m/s)	2.43	Avg. Vel. (m/s)		2.43	
Max Chl Dpth (m)	5.34	Hydr. Depth (m)		2.09	
Conv. Total (m3/s)	13421.8	Conv. (m3/s)		13421.8	
Length Wtd. (m)	150.00	Wetted Per. (m)		189.74	
Min Ch El (m)	2.00	Shear (N/m2)		104.46	
Alpha	1.00	Stream Power (N/m s)		253.83	
Frctn Loss (m)	0.76	Cum Volume (1000 m3)		111.57	
C & E Loss (m)	0.01	Cum SA (1000 m2)		60.88	

CROSS SECTION OUTPUT Profile #ARI 100

E.G. Elev (m)	8.31	Element	Left OB	Channel	Right OB
Vel Head (m)	0.39	Wt. n-Val.		0.048	
W.S. Elev (m)	7.92	Reach Len. (m)	166.00	150.00	125.00
Crit W.S. (m)		Flow Area (m2)		513.08	
E.G. Slope (m/m)	0.005530	Area (m2)		513.08	
Q Total (m3/s)	1415.00	Flow (m3/s)		1415.00	
Top Width (m)	215.39	Top Width (m)		215.39	
Vel Total (m/s)	2.76	Avg. Vel. (m/s)		2.76	
Max Chl Dpth (m)	5.92	Hydr. Depth (m)		2.38	
Conv. Total (m3/s)	19028.0	Conv. (m3/s)		19028.0	
Length Wtd. (m)	150.00	Wetted Per. (m)		216.03	
Min Ch El (m)	2.00	Shear (N/m2)		128.80	
Alpha	1.00	Stream Power (N/m s)		355.21	
Frctn Loss (m)	0.82	Cum Volume (1000 m3)		143.60	
C & E Loss (m)	0.01	Cum SA (1000 m2)		65.68	

CROSS SECTION OUTPUT Profile #ARI 40

E.G. Elev (m)	7.24	Element	Left OB	Channel	Right OB
Vel Head (m)	0.25	Wt. n-Val.		0.048	
W.S. Elev (m)	6.99	Reach Len. (m)	166.00	150.00	125.00
Crit W.S. (m)		Flow Area (m2)		333.02	
E.G. Slope (m/m)	0.004687	Area (m2)		333.02	
Q Total (m3/s)	731.00	Flow (m3/s)		731.00	
Top Width (m)	173.83	Top Width (m)		173.83	
Vel Total (m/s)	2.20	Avg. Vel. (m/s)		2.20	
Max Chl Dpth (m)	4.99	Hydr. Depth (m)		1.92	

Conv. Total (m3/s)	10678.1	Conv. (m3/s)		10678.1	
Length Wtd. (m)	150.00	Wetted Per. (m)		174.41	
Min Ch El (m)	2.00	Shear (N/m2)		87.75	
Alpha	1.00	Stream Power (N/m s)		192.62	
Frctn Loss (m)	0.72	Cum Volume (1000 m3)		94.29	
C & E Loss (m)	0.01	Cum SA (1000 m2)		58.69	

CROSS SECTION
RS: 2

CROSS SECTION OUTPUT Profile #ARI 10

E.G. Elev (m)	5.97	Element	Left OB	Channel	Right OB
Vel Head (m)	0.14	Wt. n-Val.		0.048	
W.S. Elev (m)	5.83	Reach Len. (m)	133.00	150.00	133.00
Crit W.S. (m)	5.28	Flow Area (m2)		257.36	
E.G. Slope (m/m)	0.004571	Area (m2)		257.36	
Q Total (m3/s)	430.00	Flow (m3/s)		430.00	
Top Width (m)	198.89	Top Width (m)		198.89	
Vel Total (m/s)	1.67	Avg. Vel. (m/s)		1.67	
Max Chl Dpth (m)	2.83	Hydr. Depth (m)		1.29	
Conv. Total (m3/s)	6359.8	Conv. (m3/s)		6359.8	
Length Wtd. (m)	150.00	Wetted Per. (m)		199.21	
Min Ch El (m)	3.00	Shear (N/m2)		57.91	
Alpha	1.00	Stream Power (N/m s)		96.77	
Frctn Loss (m)	1.33	Cum Volume (1000 m3)		30.78	
C & E Loss (m)	0.03	Cum SA (1000 m2)		29.04	

CROSS SECTION OUTPUT Profile #ARI 25

E.G. Elev (m)	6.45	Element	Left OB	Channel	Right OB
Vel Head (m)	0.21	Wt. n-Val.		0.048	
W.S. Elev (m)	6.24	Reach Len. (m)	133.00	150.00	133.00
Crit W.S. (m)	5.59	Flow Area (m2)		341.72	
E.G. Slope (m/m)	0.004792	Area (m2)		341.72	
Q Total (m3/s)	690.00	Flow (m3/s)		690.00	
Top Width (m)	205.90	Top Width (m)		205.90	
Vel Total (m/s)	2.02	Avg. Vel. (m/s)		2.02	
Max Chl Dpth (m)	3.24	Hydr. Depth (m)		1.66	
Conv. Total (m3/s)	9967.5	Conv. (m3/s)		9967.5	
Length Wtd. (m)	150.00	Wetted Per. (m)		206.27	
Min Ch El (m)	3.00	Shear (N/m2)		77.85	
Alpha	1.00	Stream Power (N/m s)		157.20	
Frctn Loss (m)	1.35	Cum Volume (1000 m3)		41.30	
C & E Loss (m)	0.03	Cum SA (1000 m2)		30.00	

CROSS SECTION OUTPUT Profile #ARI 50

			Left OB	Channel	Right OB
E.G. Elev (m)	6.87	Element	Left OB	Channel	Right OB
Vel Head (m)	0.27	Wt. n-Val.		0.048	
W.S. Elev (m)	6.60	Reach Len. (m)	133.00	150.00	133.00
Crit W.S. (m)	5.87	Flow Area (m2)		415.22	
E.G. Slope (m/m)	0.005024	Area (m2)		415.22	
Q Total (m3/s)	960.00	Flow (m3/s)		960.00	
Top Width (m)	211.53	Top Width (m)		211.53	
Vel Total (m/s)	2.31	Avg. Vel. (m/s)		2.31	
Max Chl Dpth (m)	3.60	Hydr. Depth (m)		1.96	
Conv. Total (m3/s)	13543.7	Conv. (m3/s)		13543.7	
Length Wtd. (m)	150.00	Wetted Per. (m)		211.95	
Min Ch El (m)	3.00	Shear (N/m2)		96.52	
Alpha	1.00	Stream Power (N/m s)		223.16	
Frctn Loss (m)	1.37	Cum Volume (1000 m3)		50.79	
C & E Loss (m)	0.04	Cum SA (1000 m2)		30.83	

CROSS SECTION OUTPUT Profile #ARI 100

E.G. Elev (m)	7.48	Element	Left OB	Channel	Right OB
Vel Head (m)	0.37	Wt. n-Val.		0.048	
W.S. Elev (m)	7.12	Reach Len. (m)	133.00	150.00	133.00
Crit W.S. (m)	6.27	Flow Area (m2)		528.20	
E.G. Slope (m/m)	0.005365	Area (m2)		528.20	
Q Total (m3/s)	1415.00	Flow (m3/s)		1415.00	
Top Width (m)	226.60	Top Width (m)		226.60	
Vel Total (m/s)	2.68	Avg. Vel. (m/s)		2.68	
Max Chl Dpth (m)	4.12	Hydr. Depth (m)		2.33	
Conv. Total (m3/s)	19318.6	Conv. (m3/s)		19318.6	
Length Wtd. (m)	150.00	Wetted Per. (m)		227.08	
Min Ch El (m)	3.00	Shear (N/m2)		122.38	
Alpha	1.00	Stream Power (N/m s)		327.84	
Frctn Loss (m)	1.39	Cum Volume (1000 m3)		65.50	
C & E Loss (m)	0.05	Cum SA (1000 m2)		32.53	

CROSS SECTION OUTPUT Profile #ARI 40

E.G. Elev (m)	6.51	Element	Left OB	Channel	Right OB
Vel Head (m)	0.22	Wt. n-Val.		0.048	
W.S. Elev (m)	6.30	Reach Len. (m)	133.00	150.00	133.00
Crit W.S. (m)	5.63	Flow Area (m2)		352.44	
E.G. Slope (m/m)	0.004879	Area (m2)		352.44	
Q Total (m3/s)	731.00	Flow (m3/s)		731.00	
Top Width (m)	206.73	Top Width (m)		206.73	
Vel Total (m/s)	2.07	Avg. Vel. (m/s)		2.07	
Max Chl Dpth (m)	3.30	Hydr. Depth (m)		1.70	

Conv. Total (m3/s)	10465.8	Conv. (m3/s)	10465.8
Length Wtd. (m)	150.00	Wetted Per. (m)	207.11
Min Ch El (m)	3.00	Shear (N/m2)	81.41
Alpha	1.00	Stream Power (N/m s)	168.86
Frctn Loss (m)	1.35	Cum Volume (1000 m3)	42.88
C & E Loss (m)	0.03	Cum SA (1000 m2)	30.15

CROSS SECTION
RS: 1

CROSS SECTION OUTPUT Profile #ARI 10

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	4.62	Wt. n-Val.		0.048	
Vel Head (m)	0.40	Reach Len. (m)			
W.S. Elev (m)	4.22	Flow Area (m2)		153.05	
Crit W.S. (m)	4.22	Area (m2)		153.05	
E.G. Slope (m/m)	0.024020	Flow (m3/s)		430.00	
Q Total (m3/s)	430.00	Top Width (m)		188.30	
Top Width (m)	188.30	Avg. Vel. (m/s)		2.81	
Vel Total (m/s)	2.81	Hydr. Depth (m)		0.81	
Max Chl Dpth (m)	2.22	Conv. (m3/s)		2774.5	
Conv. Total (m3/s)	2774.5	Wetted Per. (m)		188.56	
Length Wtd. (m)		Shear (N/m2)		191.19	
Min Ch El (m)	2.00	Stream Power (N/m s)		537.17	
Alpha	1.00	Cum Volume (1000 m3)			
Frctn Loss (m)		Cum SA (1000 m2)			
C & E Loss (m)					

CROSS SECTION OUTPUT Profile #ARI 25

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	5.06	Wt. n-Val.		0.048	
Vel Head (m)	0.56	Reach Len. (m)			
W.S. Elev (m)	4.51	Flow Area (m2)		208.99	
Crit W.S. (m)	4.51	Area (m2)		208.99	
E.G. Slope (m/m)	0.022813	Flow (m3/s)		690.00	
Q Total (m3/s)	690.00	Top Width (m)		194.15	
Top Width (m)	194.15	Avg. Vel. (m/s)		3.30	
Vel Total (m/s)	3.30	Hydr. Depth (m)		1.08	
Max Chl Dpth (m)	2.51	Conv. (m3/s)		4568.3	
Conv. Total (m3/s)	4568.3	Wetted Per. (m)		194.46	
Length Wtd. (m)		Shear (N/m2)		240.44	
Min Ch El (m)	2.00	Stream Power (N/m s)		793.82	
Alpha	1.00	Cum Volume (1000 m3)			
Frctn Loss (m)		Cum SA (1000 m2)			
C & E Loss (m)					

CROSS SECTION OUTPUT Profile #ARI 50

			Left OB	Channel	Right OB
E.G. Elev (m)	5.46	Element	Left OB	Channel	Right OB
Vel Head (m)	0.68	Wt. n-Val.		0.048	
W.S. Elev (m)	4.78	Reach Len. (m)			
Crit W.S. (m)	4.78	Flow Area (m2)		262.00	
E.G. Slope (m/m)	0.021564	Area (m2)		262.00	
Q Total (m3/s)	960.00	Flow (m3/s)		960.00	
Top Width (m)	199.54	Top Width (m)		199.54	
Vel Total (m/s)	3.66	Avg. Vel. (m/s)		3.66	
Max Chl Dpth (m)	2.78	Hydr. Depth (m)		1.31	
Conv. Total (m3/s)	6537.4	Conv. (m3/s)		6537.4	
Length Wtd. (m)		Wetted Per. (m)		199.88	
Min Ch El (m)	2.00	Shear (N/m2)		277.18	
Alpha	1.00	Stream Power (N/m s)		1015.63	
Frctn Loss (m)		Cum Volume (1000 m3)			
C & E Loss (m)		Cum SA (1000 m2)			

CROSS SECTION OUTPUT Profile #ARI 100

E.G. Elev (m)	6.04	Element	Left OB	Channel	Right OB
Vel Head (m)	0.86	Wt. n-Val.		0.048	
W.S. Elev (m)	5.19	Reach Len. (m)			
Crit W.S. (m)	5.19	Flow Area (m2)		345.13	
E.G. Slope (m/m)	0.019659	Area (m2)		345.13	
Q Total (m3/s)	1415.00	Flow (m3/s)		1415.00	
Top Width (m)	207.15	Top Width (m)		207.15	
Vel Total (m/s)	4.10	Avg. Vel. (m/s)		4.10	
Max Chl Dpth (m)	3.19	Hydr. Depth (m)		1.67	
Conv. Total (m3/s)	10091.9	Conv. (m3/s)		10091.9	
Length Wtd. (m)		Wetted Per. (m)		207.55	
Min Ch El (m)	2.00	Shear (N/m2)		320.57	
Alpha	1.00	Stream Power (N/m s)		1314.32	
Frctn Loss (m)		Cum Volume (1000 m3)			
C & E Loss (m)		Cum SA (1000 m2)			

CROSS SECTION OUTPUT Profile #ARI 40

E.G. Elev (m)	5.13	Element	Left OB	Channel	Right OB
Vel Head (m)	0.57	Wt. n-Val.		0.048	
W.S. Elev (m)	4.56	Reach Len. (m)			
Crit W.S. (m)	4.56	Flow Area (m2)		219.26	
E.G. Slope (m/m)	0.021979	Area (m2)		219.26	
Q Total (m3/s)	731.00	Flow (m3/s)		731.00	
Top Width (m)	195.21	Top Width (m)		195.21	
Vel Total (m/s)	3.33	Avg. Vel. (m/s)		3.33	

Max Chl Dpth (m)	2.56	Hydr. Depth (m)	1.12
Conv. Total (m3/s)	4930.7	Conv. (m3/s)	4930.7
Length Wtd. (m)		Wetted Per. (m)	195.52
Min Ch El (m)	2.00	Shear (N/m2)	241.71
Alpha	1.00	Stream Power (N/m s)	805.85
Frctn Loss (m)		Cum Volume (1000 m3)	
C & E Loss (m)		Cum SA (1000 m2)	

Profile Output Table - Standard Table 1

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
murray	18	ARI 10	430.00	1.00	8.09		8.11	0.000209	0.58	735.54	198.35	0.10
murray	18	ARI 25	690.00	1.00	9.12		9.14	0.000251	0.73	969.58	264.98	0.11
murray	18	ARI 50	960.00	1.00	9.90		9.93	0.000292	0.85	1212.35	358.47	0.12
murray	18	ARI 100	1415.00	1.00	10.80		10.85	0.000339	1.02	1572.59	412.64	0.13
murray	18	ARI 40	731.00	1.00	9.25		9.28	0.000258	0.75	1005.28	280.69	0.11
murray	17	ARI 10	430.00	2.00	8.05		8.08	0.000187	0.78	550.78	123.04	0.12
murray	17	ARI 25	690.00	2.00	9.05		9.10	0.000253	1.02	706.54	189.06	0.14
murray	17	ARI 50	960.00	2.00	9.81		9.88	0.000311	1.21	878.64	264.25	0.16
murray	17	ARI 100	1415.00	2.00	10.69		10.79	0.000377	1.45	1203.75	403.84	0.18
murray	17	ARI 40	731.00	2.00	9.18		9.23	0.000263	1.05	731.48	201.70	0.14
murray	16	ARI 10	430.00	2.00	8.04		8.05	0.000114	0.58	754.22	217.71	0.09
murray	16	ARI 25	690.00	2.00	9.04		9.07	0.000143	0.74	1011.51	293.54	0.10

Murrayprofile

murray	16		ARI 50		960.00	2.00	9.80	9.84	0.000169
0.86	1253.26	340.81		0.12					
murray	16		ARI 100		1415.00	2.00	10.69	10.74	0.000207
1.05	1564.78	353.00		0.13					
murray	16		ARI 40		731.00	2.00	9.17	9.20	0.000147
0.76	1049.60	301.48		0.11					
murray	15		ARI 10		430.00	2.00	8.03	8.04	0.000077
0.45	956.59	247.45		0.07					
murray	15		ARI 25		690.00	2.00	9.03	9.05	0.000091
0.57	1213.77	264.84		0.08					
murray	15		ARI 50		960.00	2.00	9.79	9.82	0.000108
0.69	1422.91	285.37		0.09					
murray	15		ARI 100		1415.00	2.00	10.67	10.71	0.000142
0.87	1692.11	311.00		0.11					
murray	15		ARI 40		731.00	2.00	9.16	9.18	0.000094
0.59	1247.83	268.29		0.08					
murray	14		ARI 10		430.00	2.00	8.00	8.02	0.000155
0.61	703.24	193.02		0.10					
murray	14		ARI 25		690.00	2.00	9.00	9.03	0.000177
0.77	906.09	213.96		0.11					
murray	14		ARI 50		960.00	2.00	9.75	9.79	0.000206
0.91	1077.57	242.48		0.13					
murray	14		ARI 100		1415.00	2.00	10.61	10.68	0.000264
1.15	1295.63	256.91		0.15					
murray	14		ARI 40		731.00	2.00	9.12	9.16	0.000182
0.79	933.43	218.73		0.12					
murray	13		ARI 10		430.00	2.00	8.00	8.00	0.000048
0.38	1120.34	255.96		0.06					
murray	13		ARI 25		690.00	2.00	9.00	9.01	0.000062
0.50	1387.73	279.89		0.07					
murray	13		ARI 50		960.00	2.00	9.75	9.77	0.000076
0.61	1611.10	313.67		0.08					
murray	13		ARI 100		1415.00	2.00	10.61	10.64	0.000104
0.78	1918.95	370.00		0.09					
murray	13		ARI 40		731.00	2.00	9.12	9.14	0.000064
0.52	1423.51	285.49		0.07					
murray	12		ARI 10		430.00	2.00	7.98	7.99	0.000102
0.55	784.56	185.68		0.09					
murray	12		ARI 25		690.00	2.00	8.97	8.99	0.000129
0.71	982.68	215.05		0.10					
murray	12		ARI 50		960.00	2.00	9.71	9.75	0.000158

0.86	1162.31	269.41		0.11					
murray	12		ARI 100		1415.00	2.00	10.56	10.62	0.000211
1.08	1408.65	297.75		0.13					
murray	12		ARI 40		731.00	2.00	9.09	9.12	0.000134
0.73	1010.03	223.01		0.10					
murray	11		ARI 10		430.00	2.00	7.92	7.97	0.000319
0.91	470.69	121.63		0.15					
murray	11		ARI 25		690.00	2.00	8.89	8.96	0.000393
1.17	594.84	135.44		0.17					
murray	11		ARI 50		960.00	2.00	9.61	9.71	0.000469
1.40	720.18	210.59		0.19					
murray	11		ARI 100		1415.00	2.00	10.41	10.56	0.000603
1.74	914.67	256.27		0.22					
murray	11		ARI 40		731.00	2.00	9.01	9.08	0.000406
1.21	611.49	153.92		0.17					
murray	10		ARI 10		430.00	1.00	7.86	7.91	0.000401
1.01	425.63	111.71		0.17					
murray	10		ARI 25		690.00	1.00	8.81	8.89	0.000501
1.29	541.33	132.73		0.19					
murray	10		ARI 50		960.00	1.00	9.50	9.62	0.000600
1.55	639.97	151.57		0.21					
murray	10		ARI 100		1415.00	1.00	10.26	10.45	0.000806
1.96	832.80	440.15		0.25					
murray	10		ARI 40		731.00	1.00	8.92	9.01	0.000516
1.33	557.14	135.32		0.19					
murray	9		ARI 10		430.00	1.00	7.78	7.84	0.000529
1.11	388.73	109.93		0.19					
murray	9		ARI 25		690.00	1.00	8.71	8.80	0.000645
1.39	503.14	139.00		0.21					
murray	9		ARI 50		960.00	1.00	9.38	9.52	0.000751
1.66	615.79	217.63		0.24					
murray	9		ARI 100		1415.00	1.00	10.12	10.32	0.000955
2.05	835.68	442.00		0.27					
murray	9		ARI 40		731.00	1.00	8.82	8.93	0.000661
1.43	519.35	142.91		0.22					
murray	8		ARI 10		430.00	2.00	7.52	7.69	0.002157
1.83	235.49	89.82		0.36					
murray	8		ARI 25		690.00	2.00	8.40	8.62	0.002487
2.10	334.27	145.03		0.39					
murray	8		ARI 50		960.00	2.00	9.06	9.32	0.002387
2.30	467.59	488.95		0.40					

Murrayprofile

murray	2.21	924.36	8	558.72	ARI 100	0.34	1415.00	2.00	9.93	10.14	0.001626
murray	2.14	350.85	8	154.77	ARI 40	0.39	731.00	2.00	8.51	8.74	0.002477
murray	1.02	419.74	7	147.30	ARI 10	0.19	430.00	2.00	7.45	7.50	0.000602
murray	1.22	565.30	7	182.86	ARI 25	0.22	690.00	2.00	8.31	8.39	0.000743
murray	1.40	693.71	7	199.65	ARI 50	0.23	960.00	2.00	8.99	9.09	0.000784
murray	1.66	902.10	7	313.03	ARI 100	0.25	1415.00	2.00	9.80	9.94	0.000894
murray	1.25	586.23	7	185.70	ARI 40	0.22	731.00	2.00	8.43	8.51	0.000747
murray	1.10	390.39	6	111.05	ARI 10	0.19	430.00	1.00	7.35	7.41	0.000529
murray	1.41	488.55	6	131.26	ARI 25	0.23	690.00	1.00	8.17	8.27	0.000772
murray	1.67	580.32	6	157.91	ARI 50	0.26	960.00	1.00	8.81	8.95	0.000976
murray	1.99	817.25	6	389.44	ARI 100	0.29	1415.00	1.00	9.59	9.78	0.001131
murray	1.46	502.95	6	135.78	ARI 40	0.24	731.00	1.00	8.28	8.39	0.000805
murray	1.41	304.75	5	93.88	ARI 10	0.25	430.00	2.00	7.20	7.31	0.000965
murray	1.82	379.55	5	107.96	ARI 25	0.31	690.00	2.00	7.95	8.11	0.001439
murray	2.17	453.16	5	154.67	ARI 50	0.34	960.00	2.00	8.51	8.75	0.001691
murray	2.66	578.53	5	211.14	ARI 100	0.39	1415.00	2.00	9.19	9.54	0.002077
murray	1.87	390.15	5	112.73	ARI 40	0.32	731.00	2.00	8.04	8.22	0.001494
murray	1.91	224.81	4	86.42	ARI 10	0.38	430.00	3.00	6.89	7.08	0.002375
murray	2.45	292.88	4	138.14	ARI 25	0.46	690.00	3.00	7.48	7.78	0.003464
murray	2.82	367.54	4	168.79	ARI 50	0.52	960.00	3.00	7.96	8.36	0.004192
murray			4		ARI 100		1415.00	3.00	8.58	9.09	0.004487

Murrayprofile

3.28	496.92		220.29		0.55						
murray		4		ARI 40		731.00	3.00	7.56		7.88	0.003603
2.52	303.95		143.10		0.47						
				ARI 10		430.00	2.00	6.46		6.62	0.004014
murray		3									
1.76	244.07		157.73		0.45						
murray		3		ARI 25		690.00	2.00	6.93		7.16	0.004607
2.14	321.89		171.90		0.50						
murray		3		ARI 50		960.00	2.00	7.34		7.64	0.005116
2.43	395.09		189.14		0.54						
murray		3		ARI 100		1415.00	2.00	7.92		8.31	0.005530
2.76	513.08		215.39		0.57						
murray		3		ARI 40		731.00	2.00	6.99		7.24	0.004687
2.20	333.02		173.83		0.51						
				ARI 10		430.00	3.00	5.83	5.28	5.97	0.004571
murray		2									
1.67	257.36		198.89		0.47						
murray		2		ARI 25		690.00	3.00	6.24	5.59	6.45	0.004792
2.02	341.72		205.90		0.50						
murray		2		ARI 50		960.00	3.00	6.60	5.87	6.87	0.005024
2.31	415.22		211.53		0.53						
murray		2		ARI 100		1415.00	3.00	7.12	6.27	7.48	0.005365
2.68	528.20		226.60		0.56						
murray		2		ARI 40		731.00	3.00	6.30	5.63	6.51	0.004879
2.07	352.44		206.73		0.51						
				ARI 10		430.00	2.00	4.22	4.22	4.62	0.024020
murray		1									
2.81	153.05		188.30		0.99						
murray		1		ARI 25		690.00	2.00	4.51	4.51	5.06	0.022813
3.30	208.99		194.15		1.02						
murray		1		ARI 50		960.00	2.00	4.78	4.78	5.46	0.021564
3.66	262.00		199.54		1.02						
murray		1		ARI 100		1415.00	2.00	5.19	5.19	6.04	0.019659
4.10	345.13		207.15		1.01						
murray		1		ARI 40		731.00	2.00	4.56	4.56	5.13	0.021979
3.33	219.26		195.21		1.00						

APPENDIX C

FLOOD DAMAGE ASSESSEMENT.

Appendix C: Flood Damage Assessment

C1 Introduction

In early February 2003, a site survey was carried out to evaluate properties affected by various extents of flooding. The obtained results are analysed using Rapid Appraisal Method (RAM) to evaluate the floodplain management measures. The ANUFLOOD program is used to assess the flood damage to determine the stage damage curve.

C2 Site Survey

Based on the floodplain maps supplied by Shire of Murray from Water River Commission regarding the extent of flooding for Town of Pinjarra, a car-based survey was conducted. Floor level for each residential and non-residential building is evaluated carefully based on the level of building to level of road.

C3 Rapid Appraisal METHOD (RAM)

The rapid appraisal method (RAM) is a methodology for evaluating floodplain management measures in a benefit cost analysis framework. It provides information about the benefits and costs of floodplain management in a timely and cost effective way.

The RAM is an eight step process which involves:

1. Define study areas.
2. Estimate damages for key flood events.
3. Calculate Average Annual Damage (AAD).
4. Evaluate tangible benefits and costs of floodplain management measures.
5. Evaluate intangible benefits and costs of floodplain management measures.
6. Summarise benefit cost analysis.
7. Develop project priorities.
8. Develop cost sharing arrangements.

The benefits of effective floodplain management are;

- Reductions in flood damage which includes social and environmental impacts;
- Enhancement of the natural values associated with floodplains; and
- Reductions in the operational costs of floodplain management.

The estimation of actual benefits will be imprecise because the growth in AAD with and without measures cannot be accurately predicted. However, it is believed that the RAM is a simple but robust analytical approach that can be implemented more efficient and conveniently than other approaches. *(RAM, 2000)*

C4 ANUFLOOD

ANUFLOOD uses stage damage curves, which define mean levels of damage per building for various depths of flooding, and for various classes of building. This program presents the data in a variety of forms, permits a preliminary assessment of the benefits of a number of flood mitigation schemes and allows property data and damages to be portrayed in the form of computer generated maps. *(Binnie & Partners, 1988)*

The steps involved in the ANUFLOOD approach are outlined in Figure C1. *(RAM, 2000)*

C5 Data Collection

The data collected from the car-based survey has been tabulated in table form. The estimated level obtained from the car-survey is added to the existing road level, which is obtained from the contour maps. Using the flood data given by Water and Rivers Commission the height inundated by floods for the various extents of floods for the site survey is calculated as shown in Table C1.

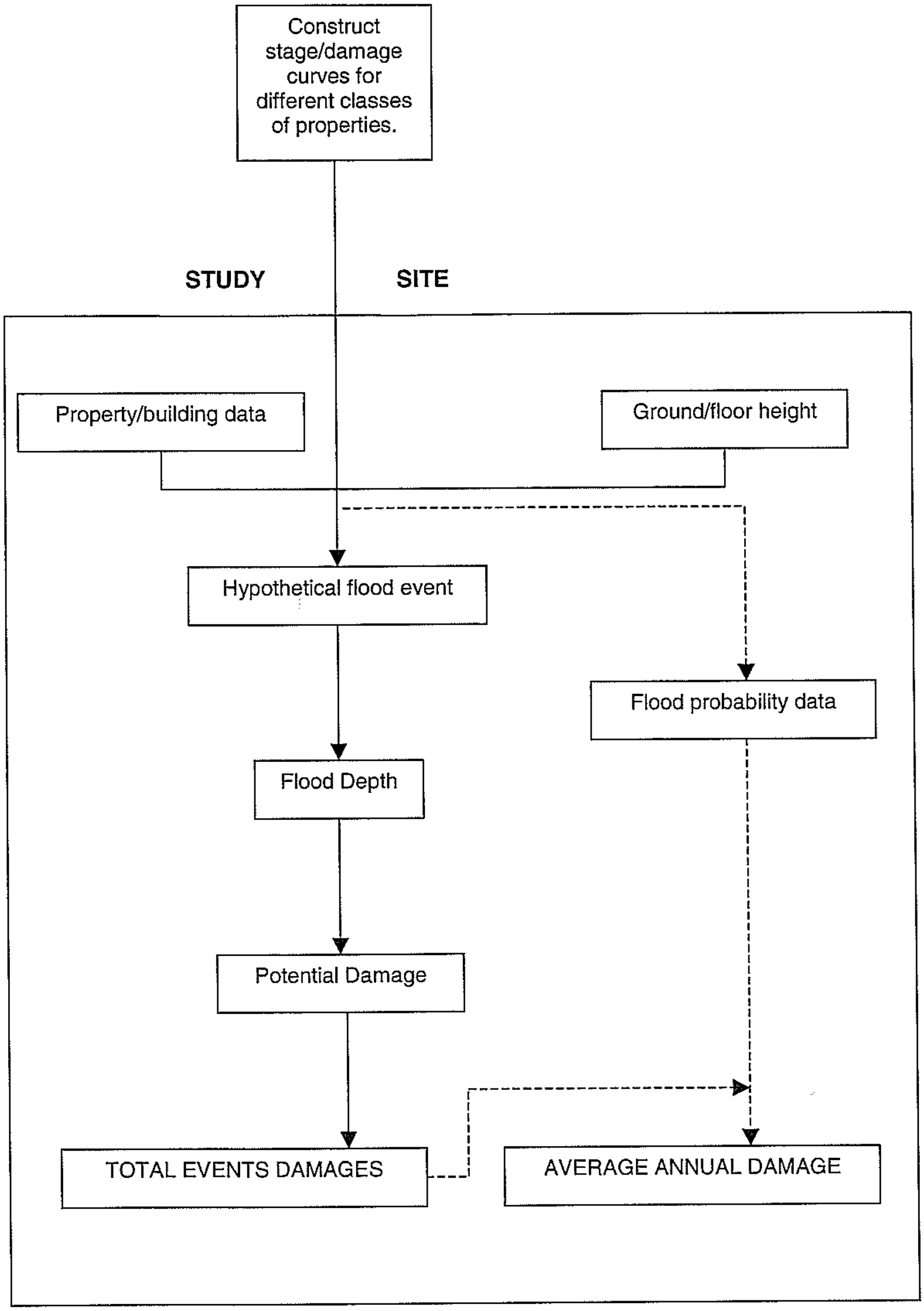


Figure C1 ANUFLOOD approach to assessment of flood damages to buildings

Table C1 Depths of Inundation for Various Magnitude of Floods

Street : Henry St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
201	1	Rose Garden	9.2	2.06	0.75	0.5	0.2
202	N/A	Church	7.5	0.25	-1.11	-1.37	-1.64
103	3	SS	8.5	1.51	0.24	0.05	-0.18
316	2	Tea House	9.5	2.25	0.89	0.63	0.36

Street : Murray St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
500	5	SS	8.7	1.59	0.3	0.05	-0.24
50	U1-11/7	SS	8.65	1.51	0.2	-0.05	-0.35
80	U1-3/9	SS	8.65	1.46	0.2	-0.05	-0.35
79	11	SS	8.65	1.44	0.1	-0.14	-0.43
78	13	Telstra	8.65	1.44	0.1	-0.14	-0.43
69-70--1	N/A	Murray House	8.85	1.6	0.24	-0.02	-0.29
227	N/A	Fire Station	8.65	1.32	-0.07	-0.38	-0.66
56	-	Empty land	-	0	0	0	0
55	29	SS	8.8	1.35	-0.03	-0.62	-0.71
54	31	SS	8.65	1.2	-0.18	-0.77	-0.86
53	33	SS	8.7	1.19	-0.2	-0.61	-0.88
52	35	SS	8.65	1.14	-0.25	-0.66	-0.93
51	37	SS	8.8	1.29	-0.1	-0.51	-0.78
37	36	SS	8.7	1.13	-0.27	-0.72	-1
38	34	SS	8.7	1.13	-0.27	-0.72	-1
39	-	Empty land	-	0	0	0	0
40	30	SS	9	1.45	0.07	-0.37	-0.61
41	28	SS	8.9	1.35	-0.03	-0.47	-0.71
42	-	Empty land	-	0	0	0	0
21	-	Empty land	-	0	0	0	0
20	N/A	St Vincent	8.65	1.2	-0.18	-0.59	-0.83

Street : Roe Avenue

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
1	N/A	SS	8.65	1.85	0.89	0.51	0.27
2	N/A	SS	8.65	1.85	0.89	0.51	0.27
207	-	Empty land	-	0	0	0	0
110	N/A	SS	8.85	1.96	0.85	0.57	0.33
114	-	Empty land	-	0	0	0	0

Street : James St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
119	49	SS	7.7	0.87	-0.11	-0.49	-0.72
118--1	47	SS	7.7	0.85	-0.18	-0.54	-0.77
118--2	45	SS	8.15	1.29	0.24	-0.09	-0.32
117--1	43	SS	8.15	1.27	0.2	-0.13	-0.34
117--2	41	SS	8.3	1.41	0.3	0.02	-0.19
116	-	Empty Land	-	0	0	0	0
115--1	-	Empty Land	-	0	0	0	0
115--2	37	SS	8.15	1.24	0.12	-0.17	-0.37
113	48	SS	9.15	2.27	1.15	0.87	0.66
112	46	SS	7.3	0.41	-0.7	-1.02	-1.25
98--16	42	SS	8.3	1.31	0.01	-0.1	-0.31
98--17	40	SS	8.3	1.31	0.01	-0.1	-0.31
97--18	38	SS	8.5	1.5	0.19	0.01	-0.13
97--13	36	SS	8.65	1.65	0.34	0.16	0.02
96--6	34	SS	8.6	1.58	0.24	0.09	-0.16
96--5	32	SS	8.6	1.57	0.23	0.08	-0.17
96--4	30	SS	8.75	1.7	0.38	0.22	-0.03
95--3	28	SS	8.85	1.78	0.47	0.23	0.05
95--2	26	SS	8.8	1.71	0.41	0.17	-0.1
95--1	24	SS	8.8	1.7	0.41	0.16	-0.12
106	-	Empty Land	-	0	0	0	0
105	-	Empty Land	-	0	0	0	0
104	-	Empty Land	-	0	0	0	0
102	35	SS	8.5	1.51	0.24	0.15	-0.07
101	33	SS	8.45	1.46	0.19	0.05	-0.18
100	U1-3/27	SS	8.9	1.91	0.63	0.41	0.22
99	25	SS	8.7	1.7	0.39	0.19	-0.06
71-1	-	Empty Land	-	0	0	0	0
71-2	19	SS	9	1.9	0.6	0.35	0.06
71-3	-	Empty Land	-	0	0	0	0
205	-	Empty Land	-	0	0	0	0
204	20	SS	9.05	1.91	0.6	0.35	0.05
203	18	SS	9	1.81	0.49	0.28	-0.04
3	16	SS	9	1.79	0.45	0.21	-0.08
2	14	SS	8.85	1.63	0.29	-0.02	-0.29
15--1	N/A	Shop	8.75	1.42	0.01	-0.29	-0.58
15--2	N/A	Shop	8.75	1.4	-0.01	-0.36	-0.61
15--3	N/A	Shop	8.75	1.38	-0.03	-0.39	-0.69
15--4	N/A	Shop	8.75	1.36	-0.05	-0.39	-0.69
15--5	N/A	Shop	8.75	1.36	-0.05	-0.39	-0.69
8--15	11	SS	8.75	1.47	0.1	-0.16	-0.44
8--16	9	SS	8.85	1.52	0.13	-0.18	-0.46
8--17	7	SS	9	1.65	0.26	-0.03	-0.31
8--18	-	Empty Land	-	0	0	0	0
7--19	-	Empty Land	-	0	0	0	0
7--20	-	Empty Land	-	0	0	0	0

Street : Carey St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
107	N/A	Empty land		0	0	0	0
111	2	SS	8.7	1.78	0.63	0.35	0.13
94--6	5	SS	8.85	1.83	0.49	0.34	0.09
14-15	3	SS	8.7	1.7	0.39	0.2	-0.05

Street : Forrest St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
208	-	Empty Land	-	0	0	0	0
209	-	Empty Land	-	0	0	0	0
46	32	SS	8.8	1.42	0.02	-0.34	-0.64
47	30	SS	8.8	1.43	0.04	-0.29	-0.59
48	28	SS	8.8	1.47	0.08	-0.23	-0.51
49	26	SS	8.8	1.47	0.15	-0.23	-0.51
327	27	Office	8.3	1.05	-0.25	-0.49	-0.78
57-59	N/A	Library	8.9	1.68	0.29	0.03	-0.24
60-61	N/A	Preschool Centre	8.8	1.61	0.35	0.1	-0.2
91	21	SS	8.6	1.41	0.15	-0.1	-0.4
91--1	19	DS	8.5	1.36	0.01	-0.15	-0.44
91--2	23	SS	8.4	1.26	-0.05	-0.3	-0.6
95--7	13	SS	8.7	1.6	0.3	0.05	-0.24
95--8	15	SS	8.7	1.6	0.3	0.05	-0.24
95--9	17	SS	8.6	1.49	0.2	-0.05	-0.34
99	11	SS	8.75	1.72	0.39	0.24	-0.01
501	9	SS	8.8	1.8	0.49	0.3	0.06
73	-	Empty Land	-	0	0	0	0
74	12	SS	8	0.93	-0.38	-0.66	-0.86
318	10	Sewere Pump Stn	8.2	1.15	-0.16	-0.31	-0.56

Street : Peel St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
229	11	SS	8.9	1.39	0	-0.42	-0.68
228	9	SS	8.9	1.35	-0.03	-0.46	-0.74
36--9	7	SS	8.8	1.23	-0.17	-0.69	-0.92
36--8	5	SS	8.85	1.27	-0.13	-0.65	-0.9
60	N/A	Shops	9.15	1.57	0.16	-0.38	-0.65
14	N/A	Shops	9.15	1.57	0.16	-0.32	-0.6
6	U6-8	SS	9.2	1.62	0.22	-0.27	-0.55

Street : Pinjarra Road

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
109	-	Empty Land	-	0	0	0	0
108	-	Empty Land	-	0	0	0	0
107	-	Empty Land	-	0	0	0	0
94--5	-	Empty Land	-	0	0	0	0
93--4	-	Empty Land	-	0	0	0	0
93--3	-	Empty Land	-	0	0	0	0
315	N/A	Shire of Murray	8.65	1.32	-0.07	-0.38	-0.66
21--1	-	Empty Land	-	0	0	0	0
21--2	-	Empty Land	-	0	0	0	0
21--3	-	Empty Land	-	0	0	0	0
11	N/A	Tavern	9	1.45	0.07	-0.38	-0.64
29--3	N/A	Church	9	1.43	0.03	-0.42	-0.7
326	N/A	Ambulance	8.8	1.69	0.35	0.1	-0.2
321	N/A	Parkland	8.8	1.78	0.44	0.29	0.04

Street : MacLarty Road

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
59	3	SS	9.25	1.66	0.25	-0.28	-0.55
27	5	SS	9.65	2.06	0.65	0.08	-0.17
26	7	SS	9.8	2.2	0.8	0.22	-0.03
25	9	SS	9.55	1.95	0.54	-0.04	-0.31
24	11	SS	9.65	2.04	0.63	0.05	-0.22
23-22/3	15	SS	10.15	2.53	1.11	0.5	0.27
21-20/2	-	Empty Land	-	0	0	0	0
19	19	SS	10.15	2.48	1.06	0.41	0.13
18	21	DS	10.2	2.52	1.1	0.45	0.16
17	23	SS	10.4	2.71	1.28	0.63	0.35
16-15/1	25	SS	10.5	2.8	1.37	0.72	0.42
23	28	SS	10.8	3.04	1.63	0.89	0.6
22	N/A	Not Affected	-	0	0	0	0
21	N/A	Not Affected	-	0	0	0	0
20	N/A	Not Affected	-	0	0	0	0
19	N/A	Not Affected	-	0	0	0	0
19-17/1	N/A	Not Affected	-	0	0	0	0
16	46	SS	10.7	2.49	1	0.34	0
15	48	SS	10.7	2.46	0.98	0.3	-0.03
14	50	SS	10.75	2.49	1.02	0.32	0
13	52a	SS	10.65	2.36	0.9	0.18	-0.13
12	52	SS	10.7	2.41	0.93	0.22	-0.11
11	-	Empty Land	-	0	0	0	0

Street : George St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
223	N/A	Memorial Park	-	0	0	0	0
190	N/A	Cruise & Travel	8.65	1.24	-0.15	-0.49	-0.79
191	N/A	Park	-	0	0	0	0
89	N/A	Foodland	9.3	1.85	0.47	0.08	-0.21
88	N/A	Foodland	9.3	1.85	0.47	0.08	-0.21
87	N/A	Tavern	9.15	1.64	0.27	-0.14	-0.4
86	N/A	Exchange Hotel	9.2	1.69	0.3	-0.11	-0.38
85	N/A	Park	-	0	0	0	0
216	N/A	Post Office	9.5	1.95	0.57	0.14	-0.14
219	N/A	Court House	9.35	1.78	0.38	-0.07	-0.35
221	N/A	Police Station	9.5	1.93	0.53	0.08	-0.2
220	N/A	Challenge Bank	9.35	1.78	0.38	-0.07	-0.35
3	N/A	Crime Prevention	9.2	1.63	0.23	-0.26	-0.51
4	N/A	Fabric, Pizza	9.2	1.63	0.22	-0.26	-0.51
8	N/A	DD Fashion	9.25	1.68	0.27	-0.22	-0.47
7	N/A	Auto One	9.2	1.63	0.22	-0.27	-0.52
6	N/A	Church	9.15	1.57	0.16	-0.35	-0.59
Sub 1	N/A	Pre-primary	9.3	1.72	0.31	-0.31	-0.5
23	N/A	Liberty	9.15	1.56	0.16	-0.46	-0.65
24	N/A	Empty Land	0	0	0	0	0
13	N/A	Empty Land	0	0	0	0	0
35--12	N/A	Alliance Church	9.15	1.57	0.16	-0.38	-0.62
34	N/A	CWA	9.15	1.57	0.16	-0.37	-0.6
33	N/A	Chinese Rest.	9.3	1.72	0.31	-0.2	-0.44
32	N/A	Antique shop	9.2	1.63	0.22	-0.3	-0.54
31	N/A	Landmark Realty	9.2	1.63	0.22	-0.3	-0.54
30--2	N/A	Hardware	9.15	1.58	0.17	-0.32	-0.57
30--4	N/A	Shell	9.15	1.58	0.17	-0.27	-0.55
22	N/A	Church	9.15	1.58	0.18	-0.27	-0.55
23--7	N/A	Florist	9.2	1.63	0.23	-0.22	-0.5
23--14	N/A	SupaValue	9.25	1.7	0.28	-0.11	-0.39
26a	N/A	Pharmacy	9.2	1.65	0.27	-0.15	-0.42
26b	N/A	2nd Hand Shop	9.2	1.65	0.27	-0.15	-0.42
27	N/A	Video	9.15	1.64	0.25	-0.16	-0.43
28a	N/A	River Rooster	9.2	1.69	0.3	-0.11	-0.38
28b	N/A	Twigz Function	9.2	1.69	0.3	-0.11	-0.38
21	N/A	Mitre 10	9.3	1.85	0.47	0.05	-0.23
22	N/A	Deli	9.15	1.7	0.32	-0.1	-0.38
23	N/A	Real Estate	9.35	1.94	0.52	0.1	-0.18
5a	N/A	Newsagency	9.15	1.74	0.32	-0.1	-0.38
5b	N/A	Bendigo Bank	9.25	1.84	0.42	0	-0.28
4a	7a	Meat supplier	9.25	1.84	0.45	0.2	-0.14
4b	7	Sth Gate Realty	9.3	1.89	0.5	0.25	-0.09

Street : McKay St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
2	16	SS	11.4	3.01	1.55	0.84	0.47
3	14	SS	11.2	2.82	1.35	0.65	0.27
4	12	SS	10.95	2.57	1.11	0.41	0.03
5	10	SS	10.8	2.43	0.96	0.26	-0.11
6	8	SS	10.8	2.43	0.97	0.28	-0.09
7	6	Empty Land	-	0	0	0	0
8	4	Empty Land	-	0	0	0	0
9	2	SS	10.75	2.39	0.92	0.3	-0.12

Street : Jubilee St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
10a	1a	SS	10.7	2.35	0.87	0.21	-0.17
11a	3a	SS	10.7	2.34	0.87	0.2	-0.17
11b	3b	SS	10.7	2.34	0.87	0.2	-0.17
12	5	SS	10.8	2.44	0.97	0.3	-0.08
13	7	SS	10.85	2.48	1.02	0.34	-0.03
14	9	SS	10.95	2.58	1.12	0.43	0.06
15	11	SS	10.9	2.53	1.06	0.36	-0.01
16	13	SS	11	2.62	1.16	0.46	0.09
17	15	SS	10.8	2.42	0.95	0.24	-0.12
37	2	SS	10.8	2.48	1.02	0.36	-0.04
38	4	SS	10.75	2.41	0.95	0.29	-0.09
39	6	SS	11.1	2.75	1.28	0.64	0.24
40	8	SS	10.85	2.49	1.02	0.36	-0.02
41	10	SS	11.1	2.74	1.27	0.61	0.23
42	12	SS	10.8	2.44	0.97	0.31	-0.07
43	14	SS	10.8	2.43	0.97	0.29	-0.08

Street : Russell St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
48	1	SS	9.75	1.88	0.48	-0.22	-0.5
49	3	SS	9.75	1.86	0.44	-0.28	-0.63
50	5	SS	10.05	2.16	0.74	0.02	-0.33
51	7	SS	9.95	2.06	0.54	-0.08	-0.43
52	9	SS	9.95	1.99	0.48	-0.24	-0.54
53	11	SS	10.05	2.09	0.47	-0.14	-0.44
54	13	SS	10.2	2.17	0.6	0.01	-0.29
55	15	SS	10.3	2.18	0.66	0.07	-0.28

Street : Warr St

Lot No	House Numbe r	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
33	2	SS	10.7	2.44	0.98	0.36	-0.03
34	4	SS	10.6	2.33	0.87	0.24	-0.15
54	6	SS	10.8	2.51	1.05	0.4	0.02
53	8	SS	10.6	2.3	0.83	0.18	-0.2
52	10	SS	10.75	2.45	0.98	0.31	-0.05
51	12	SS	10.65	2.33	0.87	0.2	-0.19
50	14	SS	10.75	2.41	0.97	0.3	-0.09
49	16	SS	10.65	2.31	0.85	0.16	-0.22
48	18	SS	10.65	2.3	0.83	0.16	-0.22
78	7	SS	10.4	2.11	0.65	0.04	-0.35
79	-	Empty Land	-	0	0	0	0
118	13	SS	10.25	1.93	0.47	-0.19	-0.58
117	15	SS	10.25	1.91	0.45	-0.21	-0.59
116	-	Empty Land	-	0	0	0	0

Street : Clifton Crescent

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
24	1	SS	10.5	2.62	1.2	0.4	0.18
25	3	SS	10.65	2.69	1.18	0.54	0.16
26	5	SS	10.85	2.82	1.27	0.62	0.27
27	7	SS	10.75	2.63	1.11	0.48	0.09
28	9	SS	10.8	2.61	1.14	0.5	0.11
29	11	Empty Land	-	0	0	0	0
30	13	SS	10.6	2.36	0.9	0.26	-0.13
31	15	SS	10.65	2.39	0.93	0.29	-0.08
32	17	SS	10.6	2.33	0.86	0.2	-0.18
33a	19a	SS	10.65	2.36	0.89	0.21	-0.15
33b	19b	SS	10.65	2.36	0.89	0.21	-0.15
1	21	SS	10.75	2.43	0.97	0.29	-0.09
2	-	Empty Land	-	0	0	0	0
317	-	Recreational	-	0	0	0	0
298	-	Recreational	-	0	0	0	0
35	4	SS	10.7	2.43	0.97	0.3	-0.08
36	6	SS	10.7	2.4	0.93	0.26	-0.1
10b	10b	SS	10.6	2.25	0.77	0.11	-0.27

Street :Colin St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
68	1	SS	9.65	1.55	0.04	-0.58	-0.93
69	3	SS	9.8	1.7	0.19	-0.43	-0.78
70	5	SS	9.8	1.68	0.16	-0.47	-0.86
71	7	SS	10.2	2.08	0.56	-0.07	-0.46
72	9	SS	9.95	1.76	0.29	-0.35	-0.73
73	11	SS	10.05	1.84	0.38	-0.27	-0.64
74	13	SS	10	1.79	0.32	-0.32	-0.69
75	15	SS	10.15	1.91	0.45	-0.19	-0.58
76	17	SS	10.25	1.99	0.53	-0.09	-0.48
77	19	SS	10.2	1.93	0.47	-0.16	-0.55
62	14	SS	10.15	1.96	0.49	-0.12	-0.51
61	12	SS	10.05	1.86	0.4	-0.22	-0.61
60	10	SS	9.95	1.78	0.3	-0.28	-0.63
59	8	SS	9.9	1.78	0.26	-0.33	-0.68
58	6	SS	9.8	1.73	0.19	-0.4	-0.76
57	4	SS	9.9	1.87	0.32	-0.29	-0.59
56	2	SS	9.8	1.77	0.22	-0.39	-0.69

Street :Taylor Court

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
80	3	SS	10.3	2.02	0.56	-0.1	-0.48
81	5	SS	10.3	2.03	0.57	-0.06	-0.45
82	7	SS	10.3	2.04	0.58	-0.05	-0.44
83	9	SS	10.3	2.06	0.6	-0.04	-0.43
84	11	SS	10.2	1.99	0.52	-0.12	-0.49
85	13	SS	10.25	2.06	0.59	-0.05	-0.44
86	15	SS	10.2	2.03	0.55	-0.07	-0.46
87	-	Empty Land	-	0	0	0	0
105	-	Empty Land	-	0	0	0	0
126	-	Empty Land	-	0	0	0	0
125	16	SS	10.25	1.99	0.53	-0.09	-0.44
124	-	Empty Land	-	0	0	0	0
123	12	SS	10.8	2.52	1.06	0.44	0.05
122	10	SS	10.8	2.52	1.06	0.4	0.05
121	-	Empty Land	-	0	0	0	0
120	6	SS	10.35	2.06	0.6	-0.08	-0.43
119	-	Empty Land	-	0	0	0	0

Street :Bedingfield Road

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
Sub 20	N/A	Hospital	11.25	N/A	N/A	N/A	N/A
Sub 19	N/A	Hospital	11.25	N/A	N/A	N/A	N/A
Sub 18	N/A	Hospital	11.25	N/A	N/A	N/A	N/A
Sub 17	U16-20	SS	11.2	2.81	1.35	0.59	0.23
Sub 16	-	Empty Land	-	0	0	0	0
Sub 15	-	Empty Land	-	0	0	0	0
Sub 14	10	SS	10.75	2.38	0.92	0.23	-0.13
Sub 13	8	SS	10.7	2.34	0.87	0.27	-0.17
Sub 12	40	SS	10.5	2.16	0.7	0.04	-0.34
Sub 11	40	SS	10.5	2.21	0.75	0.1	-0.28
44	19	SS	10.9	2.53	1.06	0.38	0.01
45	11	SS	11	2.63	1.17	0.49	0.11
46	15	SS	10.7	2.33	0.87	0.19	-0.18
47	17	SS	10.8	2.44	0.97	0.3	-0.07
1	-	Empty Land	-	0	0	0	0
100	-	Empty Land	-	0	0	0	0

Street : Apricot St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
505	1	SS	10.2	2.01	0.54	-0.07	-0.46
506	3	SS	10.2	2.03	0.55	-0.03	-0.38
507	5	SS	10.3	2.15	0.66	0.07	-0.28
508	7	SS	10.25	2.13	0.64	0.03	-0.33
509	9	SS	10.25	2.13	0.64	0.05	-0.31
510	11	SS	9.2	1.13	-0.4	-1	-1.29
511	13	SS	8	-0.03	-1.58	-2.19	-2.49

Street : River Drive

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
512	32	SS	9.2	1.17	-0.38	-0.99	-1.29
513	30	SS	9.25	1.25	-0.3	-0.91	-1.22
514	28	SS	9.15	1.19	-0.32	-0.94	-1.28
515	26	SS	9.15	1.26	-0.16	-0.88	-1.23
516	24	SS	9.2	1.32	-0.1	-0.8	-1.09

Street : Orchard St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
517	14	SS	7.85	-0.04	-1.46	-2.18	-2.53
518	12	SS	8.25	0.36	-1.06	-1.84	-2.13
519	10	SS	8.7	0.74	-0.71	-1.39	-1.73
520	8	SS	9.2	1.24	-0.27	-0.96	-1.27
521	6	SS	9.85	1.89	0.3	-0.34	-0.62
522	4	SS	10.05	2.02	0.47	-0.14	-0.44
523	2	SS	9.95	1.88	0.35	-0.25	-0.54
30b	3	SS	9.7	1.81	0.29	-0.39	-0.73
35	5	SS	9.8	1.91	0.49	-0.2	-0.58
36	7	SS	9.7	1.82	0.4	-0.3	-0.55
37	9	SS	10	2.13	0.73	0.03	-0.25
38	11	SS	9.65	1.78	0.38	-0.32	-0.6

Street : Paterson Road

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
3	-	Empty Land	-	0	0	0	0
4	-	Empty Land	-	0	0	0	0
5	15	SS	8.85	1.62	0.28	0.02	-0.26
6	13	Empty Land	-	0	0	0	0
7	11	SS	8.7	1.49	0.15	-0.09	-0.38
8	9	SS	8.3	1.1	-0.21	-0.46	-0.75
9	7	SS	8.35	1.16	-0.16	-0.39	-0.68
10	5	SS	8.25	1.09	-0.23	-0.47	-0.77
11	3	SS	8.35	1.21	-0.1	-0.35	-0.65
17	4	SS	8.7	1.56	0.27	0.02	-0.3
16	6	SS	8.75	1.61	0.3	0.05	-0.25
15	8	Empty Land	-	0	0	0	0
14	10	SS	8.7	1.51	0.19	-0.04	-0.33
18	12	SS	8.25	1.04	-0.3	-0.54	-0.83
19	14	SS	8.25	1.03	-0.31	-0.56	-0.84
12	18	SS	8.2	0.97	-0.37	-0.63	-0.91

Street : Camp Road

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
Sub 10	38	SS	9.75	1.49	0.03	-0.59	-0.98
Sub 9	36	SS	10.2	1.96	0.5	-0.1	-0.46
504	34	SS	9.8	1.59	0.12	-0.49	-0.89
503	32	SS	9.65	1.46	-0.01	-0.62	-1.01
502	30	SS	9.8	1.63	0.15	-0.45	-0.78
501	28	SS	9.8	1.68	0.16	-0.43	-0.78
500	26	SS	9.9	1.83	0.29	-0.3	-0.65
30a	22	SS	9.3	1.27	-0.25	-0.79	-1.08
34	-	Empty Land	-	0	0	0	0
33	-	Empty Land	-	0	0	0	0
Sub 5	N/A	Deli, Grape Farm	9.7	1.97	0.55	-0.15	-0.43
Sub 5	N/A	SS	9.75	2.02	0.6	-0.1	-0.38
Sub 4	N/A	Community Centre	10.2	2.55	1.08	0.43	0.15
218	N/A	Community Centre	9.65	2.02	0.6	-0.13	-0.32
20	14	SS	9.8	2.17	0.75	0.08	-0.17
19	12	SS	9.85	2.23	0.81	0.17	-0.07
18	10	SS	9.6	1.98	0.57	-0.06	-0.3
17	8	SS	9.3	1.69	0.28	-0.31	-0.58
16	6	SS	9.3	1.63	0.29	-0.31	-0.58
22b	4b	SS	9.3	1.7	0.3	-0.29	-0.54
22a	4a	SS	9.3	1.7	0.3	-0.29	-0.54
21	2	SS	9.3	1.7	0.3	-0.28	-0.52
215	N/A	High School	9.85	2.21	0.81	0.24	-0.07
47	35	SS	9.9	2.02	0.6	-0.1	-0.39
46	37	SS	9.85	1.96	0.54	-0.18	-0.53
45	39	SS	9.75	1.79	0.34	-0.34	-0.68
67	41	SS	9.85	1.42	0.25	-0.34	-0.64
66	43	SS	10.2	2.13	0.59	-0.01	-0.38
65	45	SS	10.15	2.03	0.51	-0.09	-0.43
64	47	SS	10.1	1.91	0.44	-0.17	-0.56
104	49	SS	10.2	1.99	0.53	-0.07	-0.46
103	51	SS	10.2	1.99	0.52	-0.1	-0.49
102	53	SS	10.3	2.06	0.62	-0.02	-0.39
101	55	SS	10.3	2.06	0.6	-0.02	-0.43

Street : Pinjarra Williams Road

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
361	-	Empty Land	-	0	0	0	0
362	24	Scout HQ	9.15	1.58	0.18	0.05	-0.24
500	-	Empty Land	-	0	0	0	0
501	52	SS	9.25	1.38	-0.02	-0.72	-0.99
502	-	Empty Land	-	0	0	0	0
503	-	Empty Land	-	0	0	0	0
1	54	SS	9.6	1.72	0.31	-0.39	-0.67
2	56	SS	9.4	1.52	0.1	-0.61	-0.89
3	58	SS	9.4	1.51	0.1	-0.62	-0.94
4	60	SS	9.3	1.41	-0.01	-0.73	-1.08
5	62	DS	9.8	1.88	0.39	-0.23	-0.58
6	64	DS	9.3	1.34	-0.17	-0.8	-1.13
7	66	SS	9.25	1.29	-0.3	-0.9	-1.22
8	68	SS	9.15	1.12	-0.43	-1.04	-1.34
9	70	SS	9.35	1.28	-0.25	-0.85	-1.19
10	72	SS	9.15	1.07	-0.46	-1.07	-1.43
110	-	Empty Land	-	0	0	0	0
111	-	Empty Land	-	0	0	0	0
112	N/A	SS	10.2	1.96	0.52	-0.1	-0.49
113	N/A	SS	10.2	2.08	0.56	-0.05	-0.42
101	N/A	SS	9.7	1.67	0.1	-0.5	-0.84
96	57	SS	9.65	1.69	0.1	-0.48	-0.82
95	55	Empty Land	-	0	0	0	0
94	53	SS	9.6	1.7	0.19	-0.46	-0.81
93	51	SS	9.7	1.81	0.39	-0.33	-0.68
92	49	SS	9.7	1.81	0.4	-0.3	-0.64
85	47	SS	9.8	1.95	0.58	-0.11	-0.39
83	45	SS	9.85	2.02	0.34	-0.04	-0.32
81	43	SS	9.8	1.97	0.61	-0.07	-0.35
79	41	SS	9.55	1.79	0.37	-0.28	-0.58
77	39	Empty Land	-	0	0	0	0
75	37	Empty Land	-	0	0	0	0
73	35	SS	9.35	1.65	0.22	-0.42	-0.7
71	33	SS	9.4	1.71	0.28	-0.37	-0.65
11	31	SS	9.25	1.58	0.15	-0.41	-0.67
12	29	SS	9.2	1.58	0.11	-0.44	-0.7
13	27	SS	9.2	1.59	0.18	-0.41	-0.68
14	25	SS	9.2	1.59	0.2	-0.35	-0.6
15b	23	SS	9.25	1.67	0.26	-0.28	-0.55
7	21	SS	9.15	1.58	0.18	-0.16	-0.43
202	N/A	Empty Land	-	0	0	0	0
201	N/A	Empty Land	-	0	0	0	0
200	N/A	Tavern	9.2	1.87	0.46	0.17	-0.19

Street: South-Western Hwy

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
11	N/A	Shop	8.8	1.55	0.19	-0.07	-0.34
16	N/A	Shop	8.8	1.55	0.19	-0.07	-0.34
2	N/A	Shop	9.15	1.9	0.5	0.28	0.01
13	N/A	Shop	9.15	1.9	0.5	0.28	0.01
12	N/A	Shop	9.15	1.9	0.5	0.28	0.01
363	N/A	Railway Station	9.3	1.97	0.58	0.27	-0.01

Street : Birmingham Way

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
52	19	DS	9.5	1.86	0.45	-0.16	-0.42
49	17	DS	11	3.38	1.96	1.35	1.1
48	15	SS	8.8	1.19	-0.22	-0.81	-1.08
47	13	SS	8.75	1.16	-0.26	-0.83	-1.09
46	11	SS	8.75	1.17	-0.24	-0.78	-1.05
45	9	SS	9.3	1.73	0.33	-0.12	-0.4
34	7	SS	9.5	1.95	0.57	0.14	-0.12
33	5	SS	9.2	1.67	0.28	-0.15	-0.4
32	3	SS	9.5	1.99	0.6	0.19	-0.08
31	1	SS	11	3.49	2.12	1.73	1.53

Street : Kirkham St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
35	1	SS	9.3	1.73	0.33	-0.09	-0.37
36	3	SS	9.25	1.67	0.26	-0.17	-0.53
37	5	SS	9.2	1.61	0.2	-0.38	-0.62
38	7	SS	9.15	1.55	0.14	-0.46	-0.69
39	9	SS	9.2	1.59	0.17	-0.43	-0.69
40	11	SS	9.65	2.04	0.61	0	-0.26
41	8	DS	9.75	2.13	0.7	0.1	-0.15
42	6	SS	9.75	2.14	0.73	0.14	-0.05
43	4	SS	9.2	1.61	0.2	-0.38	-0.65
44	2	SS	9.25	1.67	0.26	-0.28	-0.55
53	10	SS	9.75	2.08	0.66	0.09	-0.17
54	12	Empty Land	-	0	0	0	0
55	16	DS	9.75	2.07	0.65	0.03	-0.26
56	14	SS	9.15	1.47	0.05	-0.57	-0.85
57-58/1	18	SS	9.3	1.61	0.17	-0.49	-0.78
59	21	SS	9.85	2.12	0.7	0	-0.27
63	19	SS	9.75	2.03	0.61	-0.07	-0.35
65	17	SS	9.75	2.05	0.62	-0.04	-0.34

67	15	SS	9.75	2.06	0.63	-0.02	-0.3
68	13	SS	9.8	2.13	0.71	0.05	-0.12

Street : Salter St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
3	1	SS	9.15	1.67	0.3	-0.06	-0.34
4	3	SS	9.3	1.82	0.45	0.09	-0.19
5	5	SS	9.2	1.72	0.35	-0.01	-0.29
6	7	SS	9.25	1.77	0.4	0.04	-0.24
10	9	SS	9.25	1.7	0.35	-0.06	-0.35
18	11	SS	9.4	1.83	0.43	-0.02	-0.3
19	13	SS	9.3	1.71	0.3	-0.28	-0.52
20	15	SS	9.25	1.64	0.23	-0.36	-0.63
21	17	SS	9.15	1.53	0.11	-0.5	-0.75
22	19	SS	9.15	1.53	0.1	-0.5	-0.76
23	16	SS	9.25	1.63	0.2	-0.4	-0.66
24	14	SS	9.3	1.68	0.26	-0.33	-0.59
25	12	SS	9.25	1.64	0.23	-0.36	-0.59
26/100	10	SS	9.3	1.71	0.3	-0.23	-0.52
27/101	8	SS	9.25	1.67	0.28	-0.17	-0.53
28	6	SS	9.4	1.83	0.43	0.01	-0.27
29	4	SS	9.35	1.8	0.42	-0.01	-0.27
30	2	SS	9.2	1.69	0.3	-0.11	-0.4
60	28	SS	9.85	2.05	0.67	-0.02	-0.3
61	26	SS	9.8	2.04	0.63	-0.06	-0.34
62	24	SS	9.35	1.62	0.2	-0.5	-0.78
64	22	SS	9.3	1.58	0.16	-0.52	-0.8
66	20	SS	9.2	1.5	0.07	-0.59	-0.88
69	18	SS	9.2	1.51	0.08	-0.57	-0.85
70	21	SS	9.45	1.76	0.33	-0.32	-0.53
72	23	SS	9.3	1.6	0.17	-0.49	-0.78
74	25	SS	9.2	1.48	0.06	-0.62	-0.9
76	27	SS	9.25	1.52	0.1	-0.6	-0.87
78	29	SS	9.2	1.44	0.03	-0.66	-0.94
80	31	SS	9.35	1.55	0.16	-0.52	-0.82
82	33	Empty Land	-	0	0	0	0
84	35	SS	9.65	1.8	0.43	-0.28	-0.53
86	37	SS	9.8	1.94	0.56	-0.13	-0.41
87	39	SS	9.8	1.93	0.53	-0.14	-0.42
88	41	SS	9.65	1.78	0.38	-0.3	-0.58
89	36	SS	9.65	1.77	0.36	-0.34	-0.63
90	38	SS	9.6	1.72	0.31	-0.39	-0.69
91	40	SS	9.65	1.77	0.36	-0.34	-0.65

Street : Sear St

Lot No	House Number	Residential (SS/DS) Commercial	Floor Level (m AHD)	Depth of Flooding (m)			
				10yr ARI	25yr ARI	50yr ARI	100yr ARI
8	2	SS	9.2	1.69	0.15	-0.11	-0.38
9	4	SS	9.25	1.74	0.23	-0.06	-0.33
15a	1	SS	9.3	1.73	0.31	-0.12	-0.4
16	3	SS	9.25	1.68	0.26	-0.17	-0.45
17	5	SS	9.2	1.63	0.21	-0.22	-0.5

Key:

SS Single storey

DS Double storey

N/A Not Available

Positive depth of flooding shows the save level above flood level.

Negative depth of flooding shows the level inundated above floor level.

C6 FLOOD DAMAGE ANALYSIS

The flood damage data is analysed based on the ANUFLOOD stage damage curves established by Rapid Appraisal Method for Floodplain Management in May 2000. According to the Shire of Murray, the Town of Pinjarra is classified as Class 1 for both residential and non-residential.

C6.1 Residential

The houses that form part of the Class 1 residential study area in the Town of Pinjarra are approximately 50 years old. A total of 412 dwellings (including empty land) were recorded. From Figure C2, the three stage equations derived for Class 1 Residential are as follows:

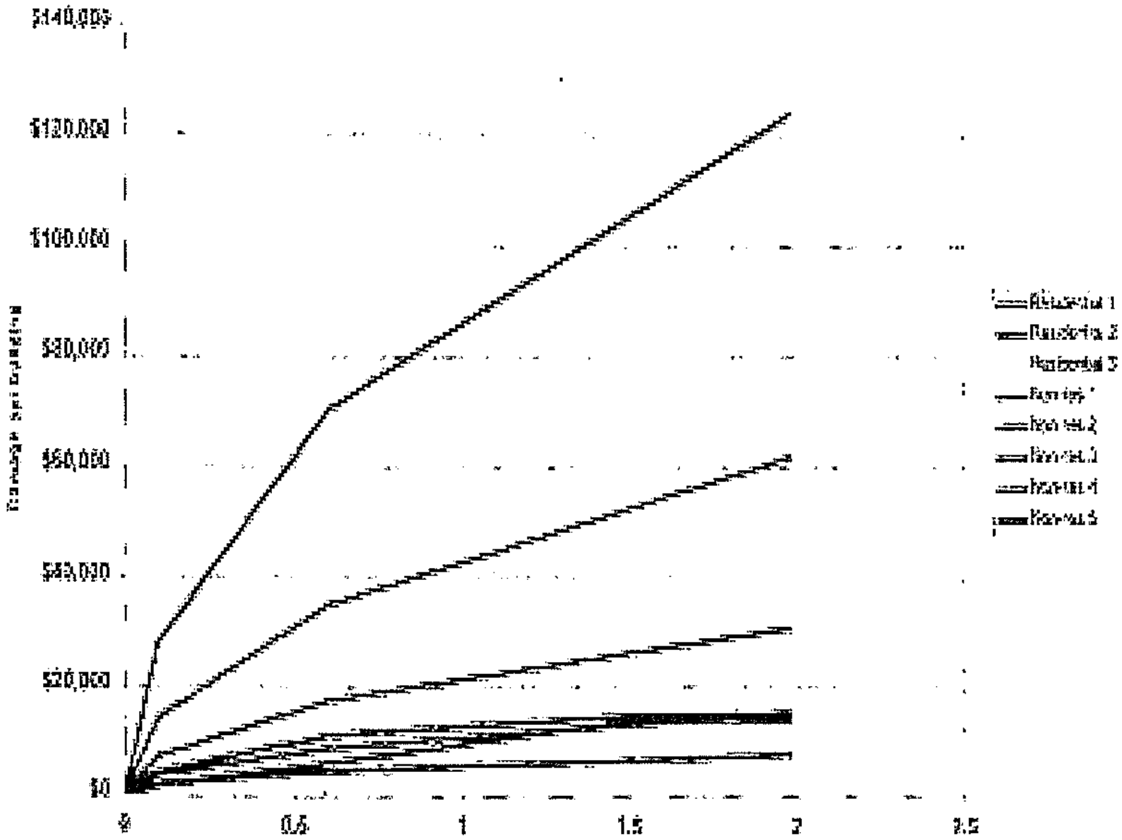


Figure C2: Guideline Using the RAM (Sturgess 2000)

ANUFLOOD Stage 1

For $0 \leq x \leq 0.09$m

$f(x) = 306666.67x$

ANUFLOOD Stage 2

For $0.091 \leq x \leq 0.586$m

$f(x) = 85068.56x + 20774.8$

ANUFLOOD Stage 3

For $x \geq 0.586$m

$f(x) = 37570.72x + 48608.56$

C6.1.1 ANUFLOOD stages for Residential Class 1

All residential houses were categorized according to three ANUFLOOD stages from the collected data (C5). Applying the derived equation, the cost damages for the stages 1, 2 and 3 are presented in Table C2 to C4. These tables are illustrated by graphs respectively by plotting the depth over floor flooding vs damage per building as shown in Figure C3 to C5.

Table C2 ANUFLOOD Stage 1 Cost Damage for Class 1 Residential

$f(x) = 306666.67x$, for $0 \le x \le 0.09$m

		Lot No.	Depth of over-floor Flooding (m)	Damage ($)
10 ARI	**Apricot Street**	511	0.03	9,200.00
	Orchard Street	517	0.04	12,266.67
25 ARI	**Murray Street**	55	0.03	9,200.00
		41	0.03	9,200.00
	Forrest Street	91--2	0.05	15,333.33
	Peel Street	228	0.03	9,200.00
	Apricot Street	510	0.04	12,266.67
	Camp Road	503	0.01	3,066.67
	Pinjarra Williams Rd	501	0.02	6,133.33
		4	0.01	3,066.67
50 ARI	**Murray Street**	50	0.05	15,333.33
		80	0.05	15,333.33
	James Street	118--2	0.09	27,600.00
		2	0.02	6,133.33
		8--17	0.03	9,200.00
	Forrest Street	95--9	0.05	15,333.33
	MacLarty Road	25	0.04	12,266.67
	Russell Street	51	0.08	24,533.33
	Colin Street	71	0.07	21,466.67
		76	0.09	27,600.00
	Taylor Court	81	0.06	18,400.00
		82	0.05	15,333.33
		83	0.04	12,266.67
		85	0.05	15,333.33
		86	0.07	21,466.67
		125	0.09	27,600.00
		120	0.08	24,533.33

	Apricot Street	505	0.07	21,466.67
		506	0.03	9,200.00
	Camp Road	18	0.06	18,400.00
		66	0.01	3,066.67
		65	0.09	27,600.00
		104	0.07	21,466.67
		102	0.02	6,133.33
		101	0.02	6,133.33
	Paterson Road	7	0.09	27,600.00
		14	0.04	12,266.67
	South West Hwy	11	0.07	21,466.67
		16	0.07	21,466.67
	Pinjarra Williams Rd	113	0.05	15,333.33
		83	0.04	12,266.67
		81	0.07	21,466.67
	Sear Street	9	0.06	18,400.00
	Kirkham Street	35	0.09	27,600.00
		63	0.07	21,466.67
		65	0.04	12,266.67
		67	0.02	6,133.33
	Salter Street	3	0.06	18,400.00
		5	0.01	3,066.67
		10	0.06	18,400.00
		18	0.02	6,133.33
		29	0.01	3,066.67
		60	0.02	6,133.33
		61	0.06	18,400.00
100 ARI	Carey Avenue	14--15	0.05	15,333.33
	James Street	96--4	0.03	9,200.00
		102	0.07	21,466.67
		99	0.06	18,400.00
		203	0.04	12,266.67
		3	0.08	24,533.33
	Forrest Street	99	0.01	3,066.67
	MacLarty Road	26	0.03	9,200.00
		15	0.03	9,200.00
	McKay Street	6	0.09	27,600.00
	Jubilee St	12	0.08	24,533.33
		13	0.03	9,200.00
		15	0.01	3,066.67

		37	0.04	12,266.67
		38	0.05	15,333.33
		40	0.02	6,133.33
		42	0.07	21,466.67
		43	0.08	24,533.33
	Warr St	33	0.03	9,200.00
		52	0.05	15,333.33
		50	0.09	27,600.00
	Clifton Cresent	31	0.08	24,533.33
		1	0.09	27,600.00
		35	0.08	24,533.33
	Bedingfeld Road	47	0.07	21,466.67
	Orchard St	19	0.07	21,466.67
	Birmingham Way	32	0.08	24,533.33
	Kirkham St	42	0.05	15,333.33
			Total Damage	$ 1,281,866

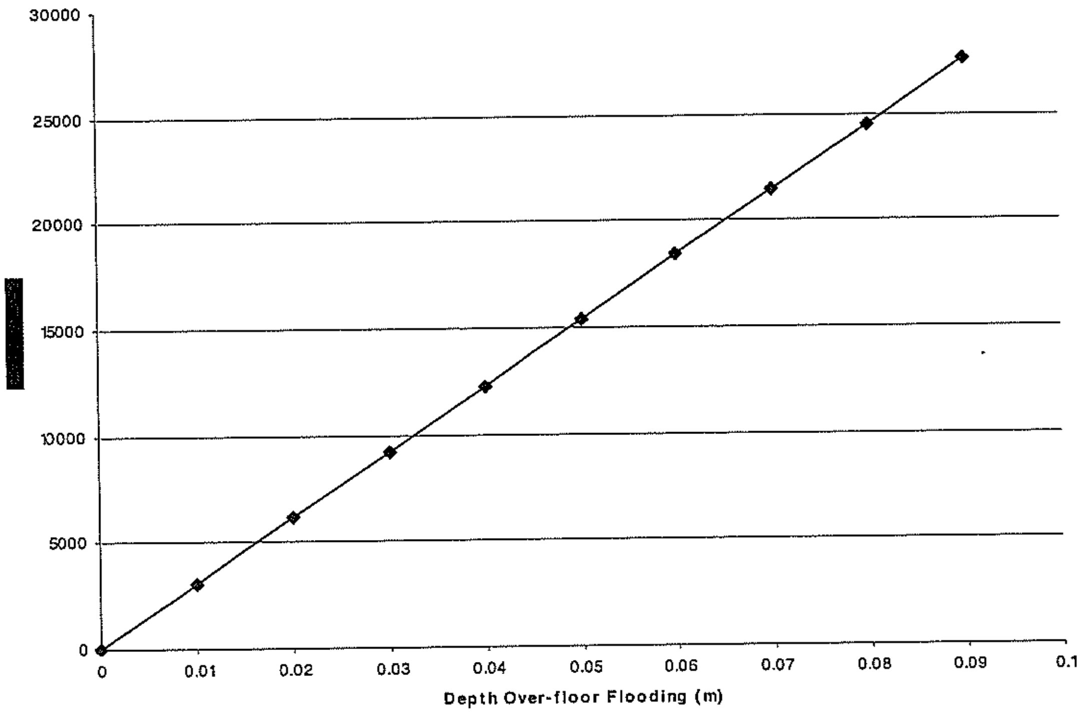


Figure C3: Stage 1 Residential Damage

Table C3 ANUFLOOD Stage 2 Cost Damage for Class 1 Residential

f(x) = 85068.56x + 20774.8, for $0.091 \leq x \leq 0.586$m

		Lot No.	Depth of over-floor Flooding (m)	Damage ($)
25 ARI	**Murray Street**	54	0.18	36,087.14
		53	0.2	37,788.51
		52	0.25	42,041.94
		51	0.1	29,281.66
		37	0.27	43,743.31
		38	0.27	43,743.31
	James Street	119	0.11	30,132.34
		118--1	0.18	36,087.14
	Forrest Street	74	0.38	53,100.85
	Peel Street	36--9	0.17	35,236.46
		36--8	0.13	31,833.71
	River Drive	512	0.38	53,100.85
		513	0.3	46,295.37
		514	0.32	47,996.74
		515	0.16	34,385.77
		516	0.1	29,281.66
	Orchard Street	520	0.27	43,743.31
	Camp Road	30a	0.25	42,041.94
	Paterson Road	8	0.21	38,639.20
		9	0.16	34,385.77
		10	0.23	40,340.57
		11	0.1	29,281.66
		18	0.3	46,295.37
		19	0.31	47,146.05
		12	0.37	52,250.17
	Pinjarra Williams Road	6	0.17	35,236.46
		7	0.3	46,295.37
		8	0.43	57,354.28
		9	0.25	42,041.94
		10	0.46	59,906.34
	Birmingham Way	48	0.22	39,489.88
		47	0.26	42,892.63
		46	0.24	41,191.25
50 ARI	**Murray Street**	79	0.14	32,684.40
		51	0.51	64,159.77
		40	0.37	52,250.17
		41	0.47	60,757.02
	James Street	117--1	0.13	31,833.71
		115--2	0.17	35,236.46
		119	0.49	62,458.39
		118--1	0.54	66,711.82

	98--16	0.1	29,281.66
	98--17	0.1	29,281.66
	8--15	0.16	34,385.77
	8--16	0.18	36,087.14
Forrest Street	46	0.34	49,698.11
	47	0.29	45,444.68
	48	0.23	40,340.57
	49	0.23	40,340.57
	91	0.1	29,281.66
	91--1	0.15	33,535.08
	91--2	0.3	46,295.37
Peel Street	229	0.42	56,503.60
	228	0.46	59,906.34
	6	0.27	43,743.31
MacLarty Road	59	0.28	44,594.00
Warr Street	118	0.19	36,937.83
	117	0.21	38,639.20
Russell Street	48	0.22	39,489.88
	49	0.28	44,594.00
	52	0.24	41,191.25
	53	0.14	32,684.40
Colin Street	68	0.58	70,114.56
	69	0.43	57,354.28
	70	0.47	60,757.02
	72	0.35	50,548.80
	73	0.27	43,743.31
	74	0.32	47,996.74
	75	0.19	36,937.83
	77	0.16	34,385.77
	62	0.12	30,983.03
	61	0.22	39,489.88
	60	0.28	44,594.00
	59	0.33	48,847.42
	58	0.4	54,802.22
	57	0.29	45,444.68
	56	0.39	53,951.54
Taylor Court	80	0.1	29,281.66
	84	0.12	30,983.03
Orchard Street	521	0.34	49,698.11
	522	0.14	32,684.40
	523	0.25	42,041.94
	30b	0.39	53,951.54
	35	0.2	37,788.51
	36	0.3	46,295.37
	38	0.32	47,996.74
Camp Road	Sub 9	0.1	29,281.66
	504	0.49	62,458.39
	502	0.45	59,055.65
	501	0.43	57,354.28

	500	0.3	46,295.37
	Sub 5	0.1	29,281.66
	17	0.31	47,146.05
	16	0.31	47,146.05
	22b	0.29	45,444.68
	22a	0.29	45,444.68
	21	0.28	44,594.00
	47	0.1	29,281.66
	46	0.18	36,087.14
	45	0.34	49,698.11
	67	0.34	49,698.11
	64	0.17	35,236.46
	103	0.1	29,281.66
Paterson Road	8	0.46	59,906.34
	9	0.39	53,951.54
	10	0.47	60,757.02
	11	0.35	50,548.80
	18	0.54	66,711.82
	19	0.56	68,413.19
Pinjarra Williams Road	1	0.39	53,951.54
	5	0.27	43,743.31
	112	0.1	29,281.66
	101	0.5	63,309.08
	96	0.48	61,607.71
	94	0.46	59,906.34
	93	0.33	48,847.42
	92	0.3	46,295.37
	85	0.11	30,132.34
	79	0.28	44,594.00
	73	0.42	56,503.60
	71	0.37	52,250.17
	11	0.41	55,652.91
	12	0.44	58,204.97
	13	0.41	55,652.91
	14	0.35	50,548.80
	15b	0.28	44,594.00
	7	0.16	34,385.77
Sear Street	8	0.11	30,132.34
	15a	0.12	30,983.03
	16	0.17	35,236.46
	17	0.22	39,489.88
Birmingham Way	52	0.16	34,385.77
	45	0.12	30,983.03
	33	0.15	33,535.08
Kirkham Street	36	0.17	35,236.46
	37	0.38	53,100.85
	38	0.46	59,906.34
	39	0.43	57,354.28
	43	0.38	53,100.85

		44	0.28	44,594.00
		56	0.57	69,263.88
		57--58/1	0.49	62,458.39
	Salter Street	19	0.28	44,594.00
		20	0.36	51,399.48
		21	0.5	63,309.08
		22	0.5	63,309.08
		23	0.4	54,802.22
		24	0.33	48,847.42
		25	0.36	51,399.48
		26/100	0.23	40,340.57
		27/101	0.17	35,236.46
		30	0.11	30,132.34
		62	0.5	63,309.08
		64	0.52	65,010.45
		69	0.57	69,263.88
		70	0.32	47,996.74
		72	0.49	62,458.39
		80	0.52	65,010.45
		84	0.28	44,594.00
		86	0.13	31,833.71
		87	0.14	32,684.40
		88	0.3	46,295.37
		89	0.34	49,698.11
		90	0.39	53,951.54
		91	0.34	49,698.11
100 ARI	**Henry Street**	103	0.18	36,087.14
	Murray Street	500	0.24	41,191.25
		50	0.35	50,548.80
		80	0.35	50,548.80
		79	0.43	57,354.28
	James Street	118--2	0.32	47,996.74
		117--1	0.34	49,698.11
		117--2	0.19	36,937.83
		115--2	0.37	52,250.17
		98--16	0.31	47,146.05
		98--17	0.31	47,146.05
		97--18	0.13	31,833.71
		96--6	0.16	34,385.77
		96--5	0.17	35,236.46
		95--2	0.1	29,281.66
		95--1	0.12	30,983.03
		101	0.18	36,087.14
		2	0.29	45,444.68
		8--15	0.44	58,204.97
		8--16	0.46	59,906.34
		8--17	0.31	47,146.05
	Forrest Street	91	0.4	54,802.22
		91--1	0.44	58,204.97
		48	0.51	64,159.77

		49	0.51	64,159.77
		95--7	0.24	41,191.25
		95--8	0.24	41,191.25
		95--9	0.34	49,698.11
	Peel Street	6	0.55	67,562.51
	MacLarty Road	59	0.55	67,562.51
		27	0.17	35,236.46
		25	0.31	47,146.05
		24	0.22	39,489.88
		13	0.13	31,833.71
		12	0.11	30,132.34
	McKay Street	5	0.11	30,132.34
		9	0.12	30,983.03
	Jubilee St	10a	0.17	35,236.46
		11a	0.17	35,236.46
		11b	0.17	35,236.46
		17	0.12	30,983.03
	Warr St	34	0.15	33,535.08
		53	0.2	37,788.51
		51	0.19	36,937.83
		49	0.22	39,489.88
		48	0.22	39,489.88
		78	0.35	50,548.80
		118	0.58	70,114.56
	Clifton Cresent	32	0.18	36,087.14
		33a	0.15	33,535.08
		33b	0.15	33,535.08
		30	0.13	31,833.71
		36	0.1	29,281.66
		10b	0.27	43,743.31
	Russell St	48	0.5	63,309.08
		50	0.33	48,847.42
		51	0.43	57,354.28
		52	0.54	66,711.82
		53	0.44	58,204.97
		54	0.29	45,444.68
		55	0.28	44,594.00
	Colin St	71	0.46	59,906.34
		75	0.58	70,114.56
		76	0.48	61,607.71
		77	0.55	67,562.51
		62	0.51	64,159.77
	Taylor Ct	80	0.48	61,607.71
		81	0.45	59,055.65
		82	0.44	58,204.97
		83	0.43	57,354.28
		84	0.49	62,458.39
		85	0.44	58,204.97
		86	0.46	59,906.34
		125	0.44	58,204.97
		120	0.43	57,354.28

Bedingfeld Road	Sub 14	0.13	31,833.71
	Sub 13	0.17	35,236.46
	Sub 12	0.34	49,698.11
	Sub 11	0.28	44,594.00
	46	0.18	36,087.14
Apricot St	505	0.46	59,906.34
	506	0.38	53,100.85
	507	0.28	44,594.00
	508	0.33	48,847.42
	509	0.31	47,146.05
Orchard St	522	0.44	58,204.97
	523	0.54	66,711.82
	35	0.58	70,114.56
	36	0.55	67,562.51
	37	0.25	42,041.94
	Sub 9	0.46	59,906.34
	Sub 5	0.38	53,100.85
	20	0.17	35,236.46
	18	0.3	46,295.37
	17	0.58	70,114.56
	16	0.58	70,114.56
	22b	0.54	66,711.82
	22a	0.54	66,711.82
	21	0.52	65,010.45
	47	0.39	53,951.54
	46	0.53	65,861.14
	66	0.38	53,100.85
	65	0.43	57,354.28
	64	0.56	68,413.19
	104	0.46	59,906.34
	103	0.49	62,458.39
	102	0.39	53,951.54
	101	0.43	57,354.28
Paterson Road	5	0.26	42,892.63
	7	0.38	53,100.85
	17	0.3	46,295.37
	16	0.25	42,041.94
	14	0.33	48,847.42
Pinjarra William Road	5	0.58	70,114.56
	112	0.49	62,458.39
	113	0.42	56,503.60
	85	0.39	53,951.54
	83	0.32	47,996.74
	81	0.35	50,548.80
	79	0.56	68,413.19
	15b	0.55	67,562.51
	7	0.43	57,354.28
Sear St	8	0.38	53,100.85
	9	0.33	48,847.42
	15a	0.4	54,802.22
	16	0.45	59,055.65

	17	0.5	63,309.08
Birmingham Way	52	0.42	56,503.60
	45	0.4	54,802.22
	34	0.12	30,983.03
	33	0.4	54,802.22
Kirkham St	35	0.37	52,250.17
	36	0.53	65,861.14
	40	0.26	42,892.63
	41	0.15	33,535.08
	44	0.55	67,562.51
	53	0.17	35,236.46
	55	0.26	42,892.63
	59	0.27	43,743.31
	63	0.35	50,548.80
	65	0.34	49,698.11
	67	0.3	46,295.37
	68	0.12	30,983.03
Salter St	3	0.34	49,698.11
	4	0.19	36,937.83
	5	0.29	45,444.68
	6	0.24	41,191.25
	10	0.35	50,548.80
	18	0.3	46,295.37
	19	0.52	65,010.45
	26/100	0.52	65,010.45
	27/101	0.53	65,861.14
	28	0.27	43,743.31
	29	0.27	43,743.31
	30	0.4	54,802.22
	60	0.3	46,295.37
	61	0.34	49,698.11
	70	0.53	65,861.14
	84	0.53	65,861.14
	86	0.41	55,652.91
	87	0.42	56,503.60
	88	0.58	70,114.56
		Total Damage	$ 15,762,137

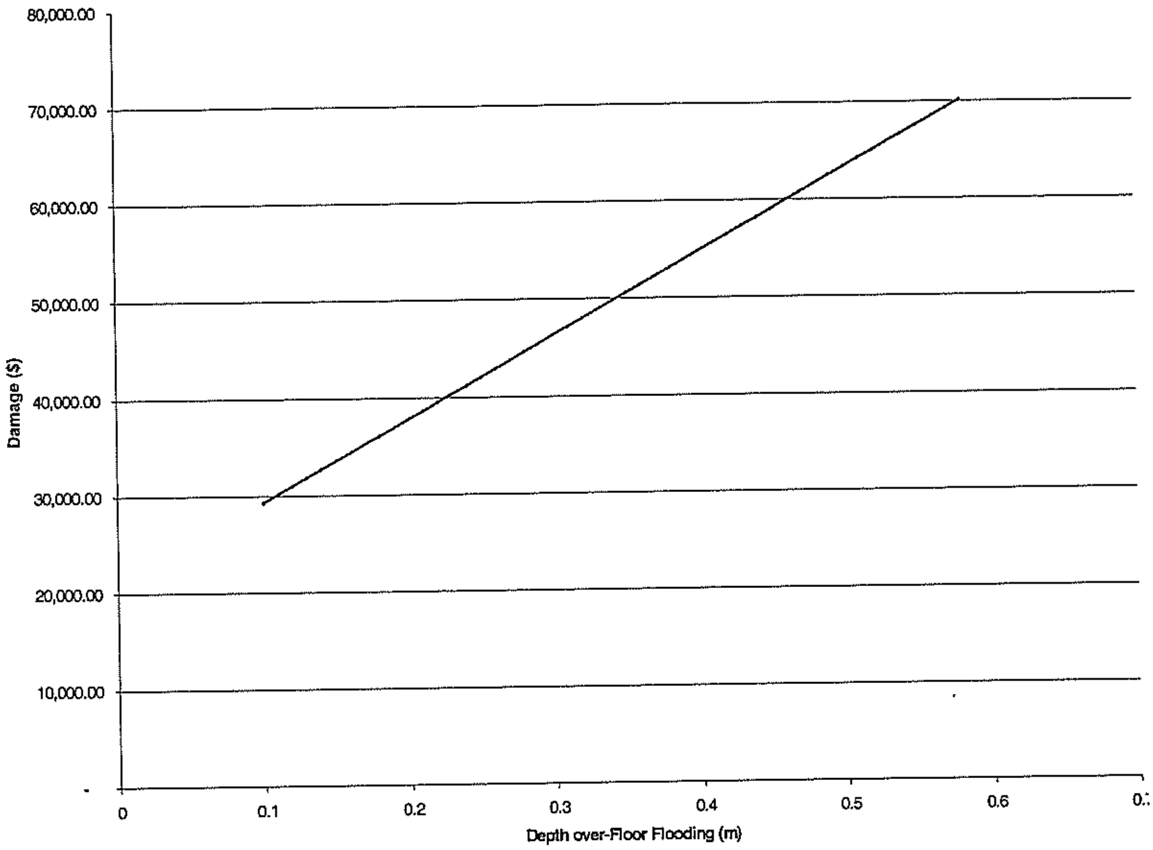


Figure C4: Stage 2 Residential Damage

Table C4 ANUFLOOD Stage 3 Cost Damage for Class 1 Residential

$f(x) = 37570.72x + 48608.56$, for $x \geq 0.586$m

		Lot No.	Depth of over-floor Flooding (m)	Damage ($)
25 ARI	James Street	112	0.7	74,908.06
	Apricot Street	511	1.58	107,970.30
	Orchard Street	519	0.71	75,283.77
		517	1.46	103,461.81
		518	1.06	88,433.52
50 ARI	Murray Street	55	0.62	71,902.41
		54	0.77	77,538.01
		53	0.61	71,526.70
		52	0.66	73,405.24
		37	0.72	75,659.48
		38	0.72	75,659.48
	James Street	112	1.02	86,930.69
	Forrest Street	74	0.66	73,405.24
	Peel Street	36--9	0.69	74,532.36

		36--8	0.65	73,029.53
	Apricot Street	510	1	86,179.28
		511	2.19	130,888.44
	River Drive	512	0.99	85,803.57
		513	0.91	82,797.92
		514	0.94	83,925.04
		515	0.88	81,670.79
		516	0.8	78,665.14
	Orchard Street	518	1.84	117,738.68
		519	1.39	100,831.86
		520	0.96	84,676.45
		517	2.18	130,512.73
	Camp Road	Sub 10	0.59	70,775.28
		503	0.62	71,902.41
		30a	0.79	78,289.43
	Paterson Road	12	0.63	72,278.11
	Pinjarra Williams Rd	501	0.72	75,659.48
		2	0.61	71,526.70
		3	0.62	71,902.41
		4	0.73	76,035.19
		6	0.8	78,665.14
		7	0.9	82,422.21
		8	1.04	87,682.11
		9	0.85	80,543.67
		10	1.07	88,809.23
	Birmingham Way	48	0.81	79,040.84
		47	0.83	79,792.26
		46	0.78	77,913.72
	Salter Street	66	0.59	70,775.28
		74	0.62	71,902.41
		76	0.6	71,150.99
		78	0.66	73,405.24
100 ARI	Murray Street	55	0.71	75,283.77
		54	0.86	80,919.38
		53	0.88	81,670.79
		52	0.93	83,549.33
		51	0.78	77,913.72
		37	1	86,179.28
		38	1	86,179.28
		40	0.61	71,526.70
		41	0.71	75,283.77
	James Street	119	0.72	75,659.48
		118--1	0.77	77,538.01
		112	1.25	95,571.96
	Forrest Street	46	0.64	72,653.82
		47	0.59	70,775.28
		91--2	0.6	71,150.99
		74	0.86	80,919.38
	Peel Street	229	0.68	74,156.65
		228	0.74	76,410.89
		36--9	0.92	83,173.62

	36--8	0.9	82,422.21
Warr St	117	0.59	70,775.28
Russell St	49	0.63	72,278.11
Colin St	68	0.93	83,549.33
	69	0.78	77,913.72
	70	0.86	80,919.38
	72	0.73	76,035.19
	73	0.64	72,653.82
	74	0.69	74,532.36
	61	0.61	71,526.70
	60	0.63	72,278.11
	59	0.68	74,156.65
	58	0.76	77,162.31
	56	0.69	74,532.36
	57	0.59	70,775.28
Apricot St	510	1.29	97,074.79
	511	2.49	142,159.65
River Drive	512	1.29	97,074.79
	513	1.22	94,444.84
	514	1.28	96,699.08
	515	1.23	94,820.55
	516	1.09	89,560.64
Orchard St	517	2.52	143,286.77
	518	2.13	128,634.19
	519	1.73	113,605.91
	520	1.27	96,323.37
	521	0.62	71,902.41
	30b	0.73	76,035.19
	38	0.6	71,150.99
	Sub 10	0.98	85,427.87
	504	0.89	82,046.50
	503	1.01	86,554.99
	502	0.78	77,913.72
	501	0.78	77,913.72
	500	0.65	73,029.53
	30a	1.08	89,184.94
	45	0.68	74,156.65
	67	0.64	72,653.82
Paterson Road	8	0.75	76,786.60
	9	0.68	74,156.65
	10	0.77	77,538.01
	11	0.65	73,029.53
	18	0.83	79,792.26
	19	0.84	80,167.96
	12	0.91	82,797.92
Pinjarra William Road	501	0.99	85,803.57
	1	0.67	73,780.94
	2	0.89	82,046.50
	3	0.94	83,925.04
	4	1.08	89,184.94
	6	1.13	91,063.47

		7	1.22	94,444.84
		8	1.34	98,953.32
		9	1.19	93,317.72
		10	1.43	102,334.69
		101	0.84	80,167.96
		96	0.82	79,416.55
		94	0.81	79,040.84
		93	0.68	74,156.65
		92	0.64	72,653.82
		73	0.7	74,908.06
		71	0.65	73,029.53
		11	0.67	73,780.94
		12	0.7	74,908.06
		13	0.68	74,156.65
		14	0.6	71,150.99
	Birmingham Way	48	1.08	89,184.94
		47	1.09	89,560.64
		46	1.05	88,057.82
	Kirkham St	37	0.62	71,902.41
		38	0.69	74,532.36
		39	0.69	74,532.36
		43	0.65	73,029.53
		56	0.85	80,543.67
		57-58/1	0.78	77,913.72
	Salter St	20	0.63	72,278.11
		21	0.75	76,786.60
		22	0.76	77,162.31
		23	0.66	73,405.24
		24	0.59	70,775.28
		25	0.59	70,775.28
		62	0.78	77,913.72
		64	0.8	78,665.14
		66	0.88	81,670.79
		69	0.85	80,543.67
		72	0.78	77,913.72
		74	0.9	82,422.21
		76	0.87	81,295.09
		78	0.94	83,925.04
		80	0.82	79,416.55
		89	0.63	72,278.11
		90	0.69	74,532.36
		91	0.65	73,029.53
			Total Damage	$ 12,928,030

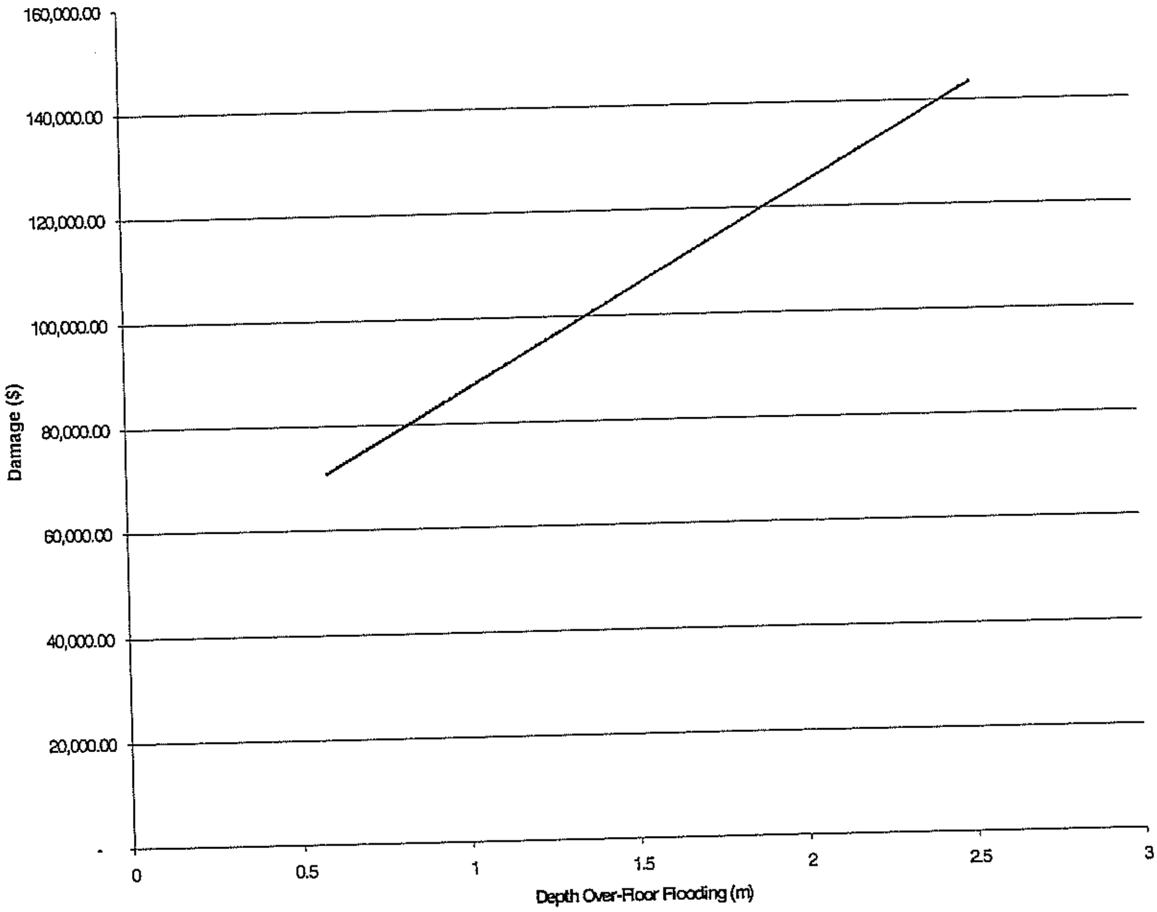


Figure C5: Stage 3 Residential Damage

C6.1.1.1 Conclusion for ANUFLOOD Stage Damage Curve for Residential Class 1

The results show that ANUFLOOD stage 2 has the highest flood damages with 326 households affected. This shows that the range flooding between 0.09m AHD to 0.586 m AHD are the most common depth of over-floor flooding for the various extents of floods. Figure C6 shows the overall damage cost for all of the 3 ANUFLOOD stages.

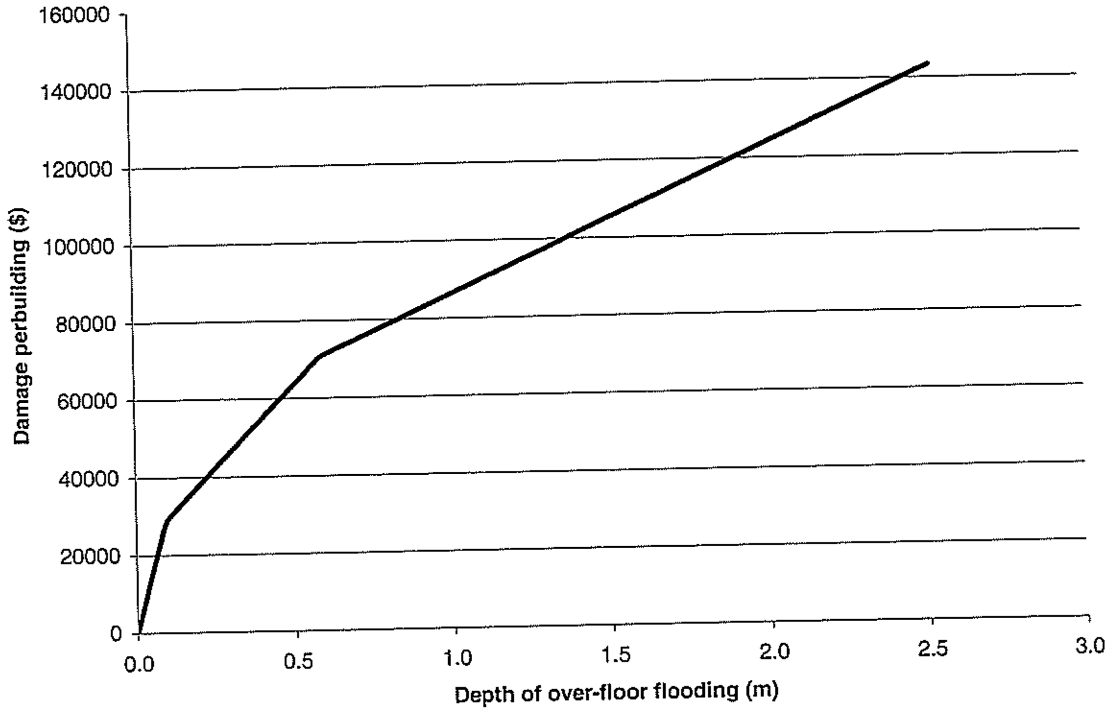


Figure C6: ANUFLOOD Stage Damage Curve for Residential in Pinjarra

C6.1.2 Damage Cost of Flood Event for Class 1 Residential

In this section the results data is rearranged and presented in Tables C5 to C8 that shows the damage for each period of flooding which are the 10 year ARI, 25 year ARI, 50 year ARI as well as the 100 year ARI. Also, Figure C7 to Figure C10 for graphs of the cost damages for each flooding period.

Table C5 Cost of Damage for 10 year ARI flood event for Class 1 Residential

	Lot No.	Depth of over-floor Flooding (m)	Damage ($)
Apricot Street			
Stage 1	511	0.03	9,200.00
Orchard Street			
Stage 1	517	0.04	12,266.67
		Total Damage	$ 21,466.67

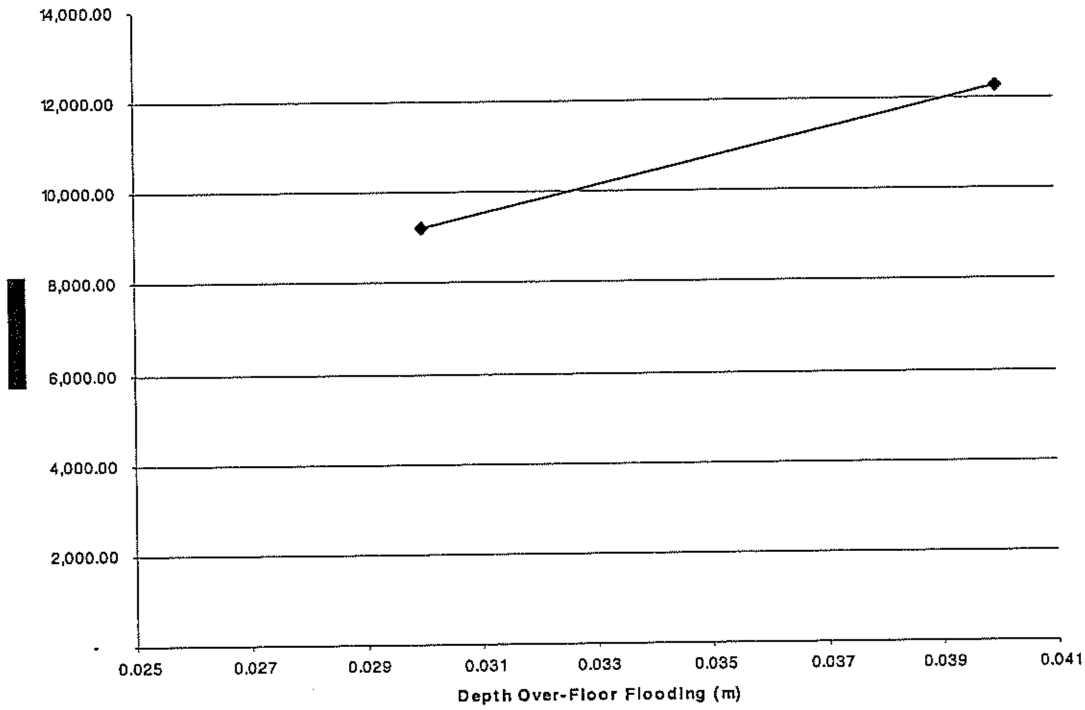


Figure C7: 10 Year ARI Flood Damage for Residential

Table C6 Cost of Damage for 25 year ARI flood event for Class 1 Residential

	Lot No.	Depth of over-floor Flooding (m)	Damage ($)
Murray Street			
Stage 1	55	0.03	9,200.00
	41	0.03	9,200.00
Stage 2	54	0.18	36,087.14
	53	0.2	37,788.51
	52	0.25	42,041.94
	51	0.1	29,281.66
	37	0.27	43,743.31
	38	0.27	43,743.31
James Street			
Stage 2	119	0.11	30,132.34
	118--1	0.18	36,087.14
Stage 3	112	0.7	74,908.06
Forrest Street			
Stage 1	91--2	0.05	15,333.33
Stage 2	74	0.38	53,100.85
Peel Street			
Stage 1	228	0.03	9,200.00
Stage 2	36--9	0.17	35,236.46
	36--8	0.13	31,833.71

Apricot Street			
Stage 1	510	0.04	12,266.67
Stage 3	511	1.58	107,970.30
River Drive			
Stage 2	512	0.38	53,100.85
	513	0.3	46,295.37
	514	0.32	47,996.74
	515	0.16	34,385.77
	516	0.1	29,281.66
Orchard Street			
Stage 2	520	0.27	43,743.31
Stage 3	519	0.71	75,283.77
	517	1.46	103,461.81
	518	1.06	88,433.52
Camp Road			
Stage 1	503	0.01	3,066.67
Stage 2	30a	0.25	42,041.94
Paterson Road			
Stage 2	8	0.21	38,639.20
	9	0.16	34,385.77
	10	0.23	40,340.57
	11	0.1	29,281.66
	18	0.3	46,295.37
	19	0.31	47,146.05
	12	0.37	52,250.17
Pinjarra Williams Road			
Stage 1	501	0.02	6,133.33
	4	0.01	3,066.67
Stage 2	6	0.17	35,236.46
	7	0.3	46,295.37
	8	0.43	57,354.28
	9	0.25	42,041.94
	10	0.46	59,906.34
Birmingham Way			
Stage 2	48	0.22	39,489.88
	47	0.26	42,892.63
	46	0.24	41,191.25
		Total Damage	$ 1,886,193.07

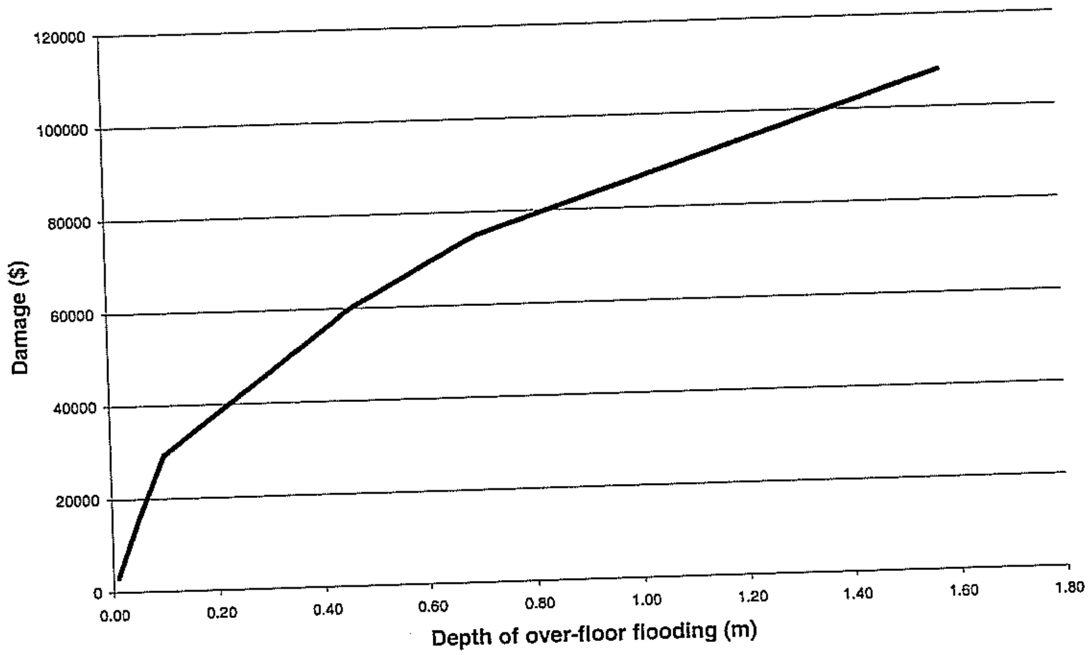


Figure C8: 25 Year ARI Flood Damage for Residential

Table C7 Cost of Damage for 50 year ARI flood event for Class 1 Residential

	Lot No.	Depth of over-floor Flooding (m)	Damage ($)
Murray Street			
Stage 1	50	0.05	15,333.33
	80	0.05	15,333.33
Stage 2	79	0.14	32,684.40
	51	0.51	64,159.77
	40	0.37	52,250.17
	41	0.47	60,757.02
Stage 3	55	0.62	71,902.41
	54	0.77	77,538.01
	53	0.61	71,526.70
	52	0.66	73,405.24
	37	0.72	75,659.48
	38	0.72	75,659.48
James Street			
Stage 1	118--2	0.09	27,600.00
	2	0.02	6,133.33
	8--17	0.03	9,200.00
Stage 2	117--1	0.13	31,833.71
	115--2	0.17	35,236.46
	119	0.49	62,458.39
	118--1	0.54	66,711.82

	98--16	0.1	29,281.66
	98--17	0.1	29,281.66
	8--15	0.16	34,385.77
	8--16	0.18	36,087.14
Stage 3	112	1.02	86,930.69
Forrest Street			
Stage 1	95--9	0.05	15,333.33
Stage 2	46	0.34	49,698.11
	47	0.29	45,444.68
	48	0.23	40,340.57
	49	0.23	40,340.57
	91	0.1	29,281.66
	91--1	0.15	33,535.08
	91--2	0.3	46,295.37
Stage 3	74	0.66	73,405.24
Peel Street			
Stage 2	229	0.42	56,503.60
	228	0.46	59,906.34
	6	0.27	43,743.31
Stage 3	36--9	0.69	74,532.36
	36--8	0.65	73,029.53
MacLarty Road			
Stage 1	25	0.04	12,266.67
Stage 2	59	0.28	44,594.00
Warr Street			
Stage 2	118	0.19	36,937.83
	117	0.21	38,639.20
Russell Street			
Stage 1	51	0.08	24,533.33
Stage 2	48	0.22	39,489.88
	49	0.28	44,594.00
	52	0.24	41,191.25
	53	0.14	32,684.40
Colin Street			
Stage 1	71	0.07	21,466.67
	76	0.09	27,600.00
Stage 2	68	0.58	70,114.56
	69	0.43	57,354.28
	70	0.47	60,757.02
	72	0.35	50,548.80
	73	0.27	43,743.31
	74	0.32	47,996.74
	75	0.19	36,937.83
	77	0.16	34,385.77
	62	0.12	30,983.03
	61	0.22	39,489.88
	60	0.28	44,594.00
	59	0.33	48,847.42
	58	0.4	54,802.22
	57	0.29	45,444.68

	56	0.39	53,951.54
Taylor Court			
Stage 1	81	0.06	18,400.00
	82	0.05	15,333.33
	83	0.04	12,266.67
	85	0.05	15,333.33
	86	0.07	21,466.67
	125	0.09	27,600.00
	120	0.08	24,533.33
Stage 2	80	0.1	29,281.66
	84	0.12	30,983.03
Apricot Street			
Stage 1	505	0.07	21,466.67
	506	0.03	9,200.00
Stage 3	510	1	86,179.28
	511	2.19	130,888.44
River Drive			
Stage 3	512	0.99	85,803.57
	513	0.91	82,797.92
	514	0.94	83,925.04
	515	0.88	81,670.79
	516	0.8	78,665.14
Orchard Street			
Stage 2	521	0.34	49,698.11
	522	0.14	32,684.40
	523	0.25	42,041.94
	30b	0.39	53,951.54
	35	0.2	37,788.51
	36	0.3	46,295.37
	38	0.32	47,996.74
Stage 3	518	1.84	117,738.68
	519	1.39	100,831.86
	520	0.96	84,676.45
	517	2.18	130,512.73
Camp Road			
Stage 1	18	0.06	18,400.00
	66	0.01	3,066.67
	65	0.09	27,600.00
	104	0.07	21,466.67
	102	0.02	6,133.33
	101	0.02	6,133.33
Stage 2	Sub 9	0.1	29,281.66
	504	0.49	62,458.39
	502	0.45	59,055.65
	501	0.43	57,354.28
	500	0.3	46,295.37
	Sub 5	0.1	29,281.66
	17	0.31	47,146.05
	16	0.31	47,146.05
	22b	0.29	45,444.68

	22a	0.29	45,444.68
	21	0.28	44,594.00
	47	0.1	29,281.66
	46	0.18	36,087.14
	45	0.34	49,698.11
	67	0.34	49,698.11
	64	0.17	35,236.46
	103	0.1	29,281.66
Stage 3	Sub 10	0.59	70,775.28
	503	0.62	71,902.41
	30a	0.79	78,289.43
Paterson Road			
Stage 1	7	0.09	27,600.00
	14	0.04	12,266.67
Stage 2	8	0.46	59,906.34
	9	0.39	53,951.54
	10	0.47	60,757.02
	11	0.35	50,548.80
	18	0.54	66,711.82
	19	0.56	68,413.19
Stage 3	12	0.63	72,278.11
South West Hwy			
Stage 1	11	0.07	21,466.67
	16	0.07	21,466.67
Pinjarra Williams Road			
Stage 1	113	0.05	15,333.33
	83	0.04	12,266.67
	81	0.07	21,466.67
Stage 2	1	0.39	53,951.54
	5	0.27	43,743.31
	112	0.1	29,281.66
	101	0.5	63,309.08
	96	0.48	61,607.71
	94	0.46	59,906.34
	93	0.33	48,847.42
	92	0.3	46,295.37
	85	0.11	30,132.34
	79	0.28	44,594.00
	73	0.42	56,503.60
	71	0.37	52,250.17
	11	0.41	55,652.91
	12	0.44	58,204.97
	13	0.41	55,652.91
	14	0.35	50,548.80
	15b	0.28	44,594.00
	7	0.16	34,385.77
Stage 3	501	0.72	75,659.48
	2	0.61	71,526.70
	3	0.62	71,902.41
	4	0.73	76,035.19

	6	0.8	78,665.14
	7	0.9	82,422.21
	8	1.04	87,682.11
	9	0.85	80,543.67
	10	1.07	88,809.23
Sear Street			
Stage 1	9	0.06	18,400.00
Stage 2	8	0.11	30,132.34
	15a	0.12	30,983.03
	16	0.17	35,236.46
	17	0.22	39,489.88
Birmingham Way			
Stage 2	52	0.16	34,385.77
	45	0.12	30,983.03
	33	0.15	33,535.08
Stage 3	48	0.81	79,040.84
	47	0.83	79,792.26
	46	0.78	77,913.72
Kirkham Street			
Stage 1	35	0.09	27,600.00
	63	0.07	21,466.67
	65	0.04	12,266.67
	67	0.02	6,133.33
Stage 2	36	0.17	35,236.46
	37	0.38	53,100.85
	38	0.46	59,906.34
	39	0.43	57,354.28
	43	0.38	53,100.85
	44	0.28	44,594.00
	56	0.57	69,263.88
	57--58/1	0.49	62,458.39
Salter Street			
Stage 1	3	0.06	18,400.00
	5	0.01	3,066.67
	10	0.06	18,400.00
	18	0.02	6,133.33
	29	0.01	3,066.67
	60	0.02	6,133.33
	61	0.06	18,400.00
Stage 2	19	0.28	44,594.00
	20	0.36	51,399.48
	21	0.5	63,309.08
	22	0.5	63,309.08
	23	0.4	54,802.22
	24	0.33	48,847.42
	25	0.36	51,399.48
	26/100	0.23	40,340.57
	27/101	0.17	35,236.46
	30	0.11	30,132.34
	62	0.5	63,309.08

Stage 3	64	0.52	65,010.45
	69	0.57	69,263.88
	70	0.32	47,996.74
	72	0.49	62,458.39
	80	0.52	65,010.45
	84	0.28	44,594.00
	86	0.13	31,833.71
	87	0.14	32,684.40
	88	0.3	46,295.37
	89	0.34	49,698.11
	90	0.39	53,951.54
	91	0.34	49,698.11
	66	0.59	70,775.28
	74	0.62	71,902.41
	76	0.6	71,150.99
	78	0.66	73,405.24
		Total Damage	$ 10,238,775.83

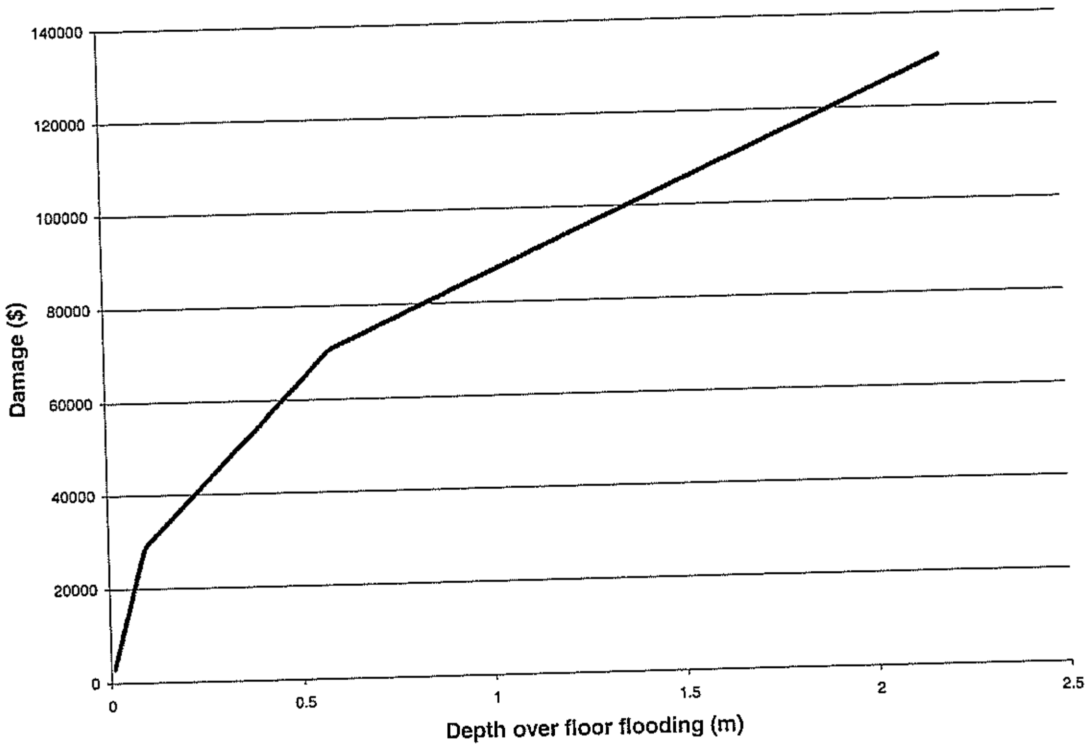


Figure C9: 50 Year ARI Residential Damage

Table C8 Cost of Damage for 100 year ARI flood event for Class 1 Residential

	Lot No.	Depth of over-floor Flooding (m)	Damage ($)
Henry Street			
Stage2	103	0.18	36,087.14
Murray Street			
Stage 2	500	0.24	41,191.25
	50	0.35	50,548.80
	80	0.35	50,548.80
	79	0.43	57,354.28
Stage 3	55	0.71	75,283.77
	54	0.86	80,919.38
	53	0.88	81,670.79
	52	0.93	83,549.33
	51	0.78	77,913.72
	37	1	86,179.28
	38	1	86,179.28
	40	0.61	71,526.70
	41	0.71	75,283.77
Carey Avenue			
Stage 1	14--15	0.05	15,333.33
James Street			
Stage1	96--4	0.03	9,200.00
	102	0.07	21,466.67
	99	0.06	18,400.00
	203	0.04	12,266.67
	3	0.08	24,533.33
Stage 2	118--2	0.32	47,996.74
	117--1	0.34	49,698.11
	117--2	0.19	36,937.83
	115--2	0.37	52,250.17
	98--16	0.31	47,146.05
	98--17	0.31	47,146.05
	97--18	0.13	31,833.71
	96--6	0.16	34,385.77
	96--5	0.17	35,236.46
	95--2	0.1	29,281.66
	95--1	0.12	30,983.03
	101	0.18	36,087.14
	2	0.29	45,444.68
	8--15	0.44	58,204.97
	8--16	0.46	59,906.34
	8--17	0.31	47,146.05
Stage 3	119	0.72	75,659.48
	118--1	0.77	77,538.01
	112	1.25	95,571.96
Forrest Street			
Stage 1	99	0.01	3,066.67
Stage 2	91	0.4	54,802.22

	91--1	0.44	58,204.97
	48	0.51	64,159.77
	49	0.51	64,159.77
	95--7	0.24	41,191.25
	95--8	0.24	41,191.25
	95--9	0.34	49,698.11
Stage 3	46	0.64	72,653.82
	47	0.59	70,775.28
	91--2	0.6	71,150.99
	74	0.86	80,919.38
Peel Street			
Stage 2	6	0.55	67,562.51
Stage3	229	0.68	74,156.65
	228	0.74	76,410.89
	36--9	0.92	83,173.62
	36--8	0.9	82,422.21
MacLarty Road			
Stage 1	26	0.03	9,200.00
	15	0.03	9,200.00
Stage 2	59	0.55	67,562.51
	27	0.17	35,236.46
	25	0.31	47,146.05
	24	0.22	39,489.88
	13	0.13	31,833.71
	12	0.11	30,132.34
McKay Street			
Stage 1	6	0.09	27,600.00
Stage 2	5	0.11	30,132.34
	9	0.12	30,983.03
Jubilee St			
Stage 1	12	0.08	24,533.33
	13	0.03	9,200.00
	15	0.01	3,066.67
	37	0.04	12,266.67
	38	0.05	15,333.33
	40	0.02	6,133.33
	42	0.07	21,466.67
	43	0.08	24,533.33
Stage 2	10a	0.17	35,236.46
	11a	0.17	35,236.46
	11b	0.17	35,236.46
	17	0.12	30,983.03
Warr St			
Stage 1	33	0.03	9,200.00
	52	0.05	15,333.33
	50	0.09	27,600.00
Stage 2	34	0.15	33,535.08
	53	0.2	37,788.51
	51	0.19	36,937.83
	49	0.22	39,489.88

	48	0.22	39,489.88
	78	0.35	50,548.80
	118	0.58	70,114.56
Stage 3	117	0.59	70,775.28
Clifton Cresent			
Stage 1	31	0.08	24,533.33
	1	0.09	27,600.00
	35	0.08	24,533.33
Stage 2	32	0.18	36,087.14
	33a	0.15	33,535.08
	33b	0.15	33,535.08
	30	0.13	31,833.71
	36	0.1	29,281.66
	10b	0.27	43,743.31
Russell St			
Stage 2	48	0.5	63,309.08
	50	0.33	48,847.42
	51	0.43	57,354.28
	52	0.54	66,711.82
	53	0.44	58,204.97
	54	0.29	45,444.68
	55	0.28	44,594.00
Stage 3	49	0.63	72,278.11
Colin St			
Stage 2	71	0.46	59,906.34
	75	0.58	70,114.56
	76	0.48	61,607.71
	77	0.55	67,562.51
	62	0.51	64,159.77
Stage 3	68	0.93	83,549.33
	69	0.78	77,913.72
	70	0.86	80,919.38
	72	0.73	76,035.19
	73	0.64	72,653.82
	74	0.69	74,532.36
	61	0.61	71,526.70
	60	0.63	72,278.11
	59	0.68	74,156.65
	58	0.76	77,162.31
	56	0.69	74,532.36
	57	0.59	70,775.28
Taylor Ct			
Stage 2	80	0.48	61,607.71
	81	0.45	59,055.65
	82	0.44	58,204.97
	83	0.43	57,354.28
	84	0.49	62,458.39
	85	0.44	58,204.97
	86	0.46	59,906.34
	125	0.44	58,204.97

	120	0.43	57,354.28
Bedingfeld Road			
Stage 1	47	0.07	21,466.67
Stage 2	Sub 14	0.13	31,833.71
	Sub 13	0.17	35,236.46
	Sub 12	0.34	49,698.11
	Sub 11	0.28	44,594.00
	46	0.18	36,087.14
Apricot St			
Stage 2	505	0.46	59,906.34
	506	0.38	53,100.85
	507	0.28	44,594.00
	508	0.33	48,847.42
	509	0.31	47,146.05
Stage 3	510	1.29	97,074.79
	511	2.49	142,159.65
River Drive			
Stage 3	512	1.29	97,074.79
	513	1.22	94,444.84
	514	1.28	96,699.08
	515	1.23	94,820.55
	516	1.09	89,560.64
Orchard St			
Stage 1	19	0.07	21,466.67
Stage 2	522	0.44	58,204.97
	523	0.54	66,711.82
	35	0.58	70,114.56
	36	0.55	67,562.51
	37	0.25	42,041.94
	Sub 9	0.46	59,906.34
	Sub 5	0.38	53,100.85
	20	0.17	35,236.46
	18	0.3	46,295.37
	17	0.58	70,114.56
	16	0.58	70,114.56
	22b	0.54	66,711.82
	22a	0.54	66,711.82
	21	0.52	65,010.45
	47	0.39	53,951.54
	46	0.53	65,861.14
	66	0.38	53,100.85
	65	0.43	57,354.28
	64	0.56	68,413.19
	104	0.46	59,906.34
	103	0.49	62,458.39
	102	0.39	53,951.54
	101	0.43	57,354.28
Stage 3	517	2.52	143,286.77
	518	2.13	128,634.19
	519	1.73	113,605.91

	520	1.27	96,323.37
	521	0.62	71,902.41
	30b	0.73	76,035.19
	38	0.6	71,150.99
	Sub 10	0.98	85,427.87
	504	0.89	82,046.50
	503	1.01	86,554.99
	502	0.78	77,913.72
	501	0.78	77,913.72
	500	0.65	73,029.53
	30a	1.08	89,184.94
	45	0.68	74,156.65
	67	0.64	72,653.82
Paterson Road			
Stage 2	5	0.26	42,892.63
	7	0.38	53,100.85
	17	0.3	46,295.37
	16	0.25	42,041.94
	14	0.33	48,847.42
Stage 3	8	0.75	76,786.60
	9	0.68	74,156.65
	10	0.77	77,538.01
	11	0.65	73,029.53
	18	0.83	79,792.26
	19	0.84	80,167.96
	12	0.91	82,797.92
Pinjarra William Road			
Stage 2	5	0.58	70,114.56
	112	0.49	62,458.39
	113	0.42	56,503.60
	85	0.39	53,951.54
	83	0.32	47,996.74
	81	0.35	50,548.80
	79	0.56	68,413.19
	15b	0.55	67,562.51
	7	0.43	57,354.28
Stage 3	501	0.99	85,803.57
	1	0.67	73,780.94
	2	0.89	82,046.50
	3	0.94	83,925.04
	4	1.08	89,184.94
	6	1.13	91,063.47
	7	1.22	94,444.84
	8	1.34	98,953.32
	9	1.19	93,317.72
	10	1.43	102,334.69
	101	0.84	80,167.96
	96	0.82	79,416.55
	94	0.81	79,040.84
	93	0.68	74,156.65

	92	0.64	72,653.82
	73	0.7	74,908.06
	71	0.65	73,029.53
	11	0.67	73,780.94
	12	0.7	74,908.06
	13	0.68	74,156.65
	14	0.6	71,150.99
Sear St			
Stage 2	8	0.38	53,100.85
	9	0.33	48,847.42
	15a	0.4	54,802.22
	16	0.45	59,055.65
	17	0.5	63,309.08
Birmingham Way			
Stage 1	32	0.08	24,533.33
Stage 2	52	0.42	56,503.60
	45	0.4	54,802.22
	34	0.12	30,983.03
	33	0.4	54,802.22
Stage 3	48	1.08	89,184.94
	47	1.09	89,560.64
	46	1.05	88,057.82
Kirkham St			
Stage 1	42	0.05	15,333.33
Stage 2	35	0.37	52,250.17
	36	0.53	65,861.14
	40	0.26	42,892.63
	41	0.15	33,535.08
	44	0.55	67,562.51
	53	0.17	35,236.46
	55	0.26	42,892.63
	59	0.27	43,743.31
	63	0.35	50,548.80
	65	0.34	49,698.11
	67	0.3	46,295.37
	68	0.12	30,983.03
Stage 3	37	0.62	71,902.41
	38	0.69	74,532.36
	39	0.69	74,532.36
	43	0.65	73,029.53
	56	0.85	80,543.67
	57-58/1	0.78	77,913.72
Salter St			
Stage 2	3	0.34	49,698.11
	4	0.19	36,937.83
	5	0.29	45,444.68
	6	0.24	41,191.25
	10	0.35	50,548.80
	18	0.3	46,295.37
	19	0.52	65,010.45

Stage 3	26/100	0.52	65,010.45
	27/101	0.53	65,861.14
	28	0.27	43,743.31
	29	0.27	43,743.31
	30	0.4	54,802.22
	60	0.3	46,295.37
	61	0.34	49,698.11
	70	0.53	65,861.14
	84	0.53	65,861.14
	86	0.41	55,652.91
	87	0.42	56,503.60
	88	0.58	70,114.56
	20	0.63	72,278.11
	21	0.75	76,786.60
	22	0.76	77,162.31
	23	0.66	73,405.24
	24	0.59	70,775.28
	25	0.59	70,775.28
	62	0.78	77,913.72
	64	0.8	78,665.14
	66	0.88	81,670.79
	69	0.85	80,543.67
	72	0.78	77,913.72
	74	0.9	82,422.21
	76	0.87	81,295.09
	78	0.94	83,925.04
	80	0.82	79,416.55
	89	0.63	72,278.11
	90	0.69	74,532.36
	91	0.65	73,029.53
		Total Damage	$ 17,825,599.64

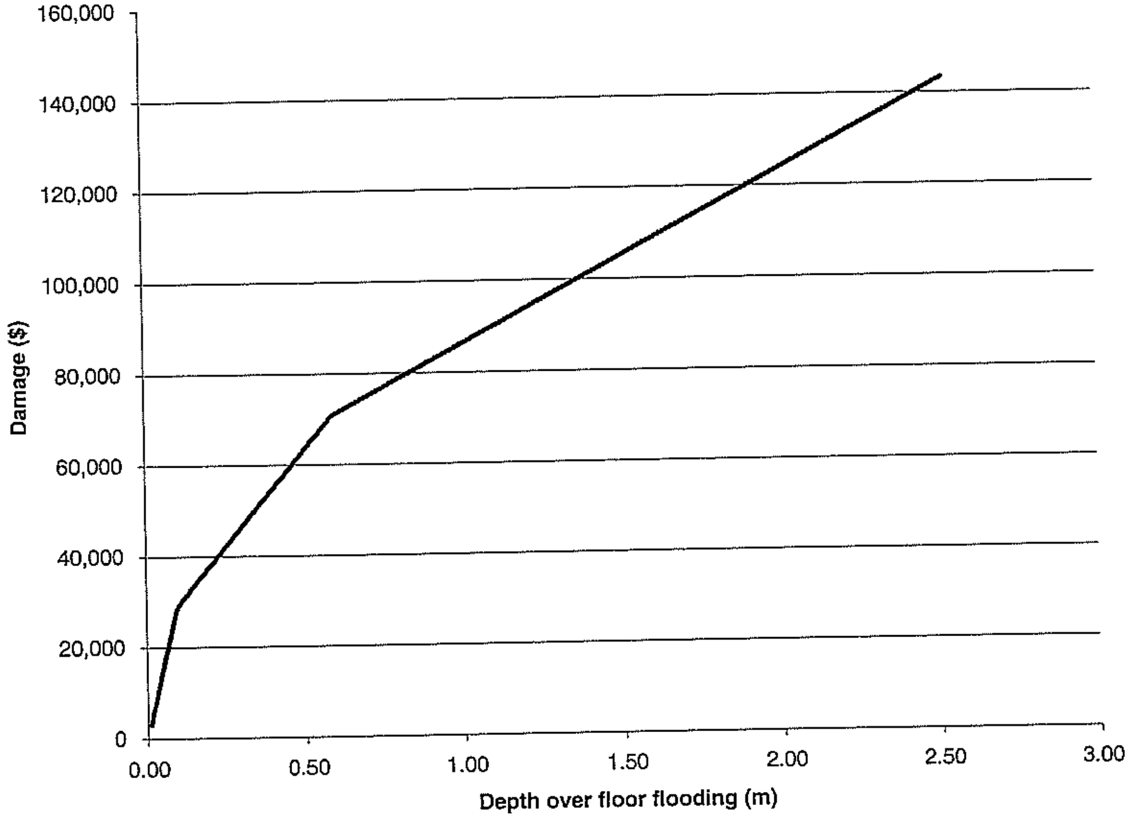


Figure C10: 100 Year ARI Flood Damage for Residential

C6.1.2.1 Conclusion

Out of the 343 dwellings that were recorded, 302 dwellings (not including empty land) appear to be affected by the 1 in 100 year flood. This also shows that more than half the Pinjarra Townsite will be flooded above floor level in the event of 1 in 100 year flood. Lot 503 in Camp Road has been recorded to have the lowest flooding with a depth of over-floor flooding of 0.01m for the 1 in 50 year ARI. The highest flood depth over-floor level is 2.49m recorded at Apricot Street for lot 511 for the 1 in 100 year ARI.

C6.3 Commercial / Non-Residential

A total of 81 commercial dwellings were recorded that form part of the Class 1 non-residential area in the Town of Pinjarra. From Figure C2, the three stage equations derived for Class 1 non-residential are as follows:

ANUFLOOD Stage 1
For $0 \le x \le 0.09$m
$f(x) = 143750x$

ANUFLOOD Stage 2
For $0.091 \le x \le 0.586$m
$f(x) = 42500x + 10125$

ANUFLOOD Stage 3
For $x \ge 0.586$m
$f(x) = 18750x + 24375$

C6.3.1 Results for Non-Residential Class 1

All non-residential dwellings were categorized according to three ANUFLOOD stages from the collected data (C5). Applying the derived equation, the cost damages for the stages 1, 2 and 3 are presented in Tables C9 to C11. These tables are illustrated by graphs respectively by plotting the depth over floor flooding vs. damage per building as shown in Figure C11 to C13.

Table C9 ANUFLOOD Stage 1 Cost Damage for Class 1 Non-Residential

$f(x) = 143750x$, for $0 \le x \le 0.09$m

		Lot No.	Depth of over-floor Flooding (m)	Damage ($)
25 ARI	**Murray Street**	227	0.07	10,062.50
	James Street	15--2	0.01	1,437.50
		15--3	0.03	4,312.50
		15--4	0.05	7,187.50

		15--5	0.05	7,187.50
	Pinjarra Road	315	0.07	10,062.50
50 ARI	Murray Street	69--70--1	0.02	2,875.00
	George Street	219	0.07	10,062.50
		220	0.07	10,062.50
100 ARI	George Street	4b	0.09	12,937.50
	Orchard St	215	0.07	10,062.50
	SouthWest Hwy	363	0.01	1,437.50
			Total Damage	$87,687.50

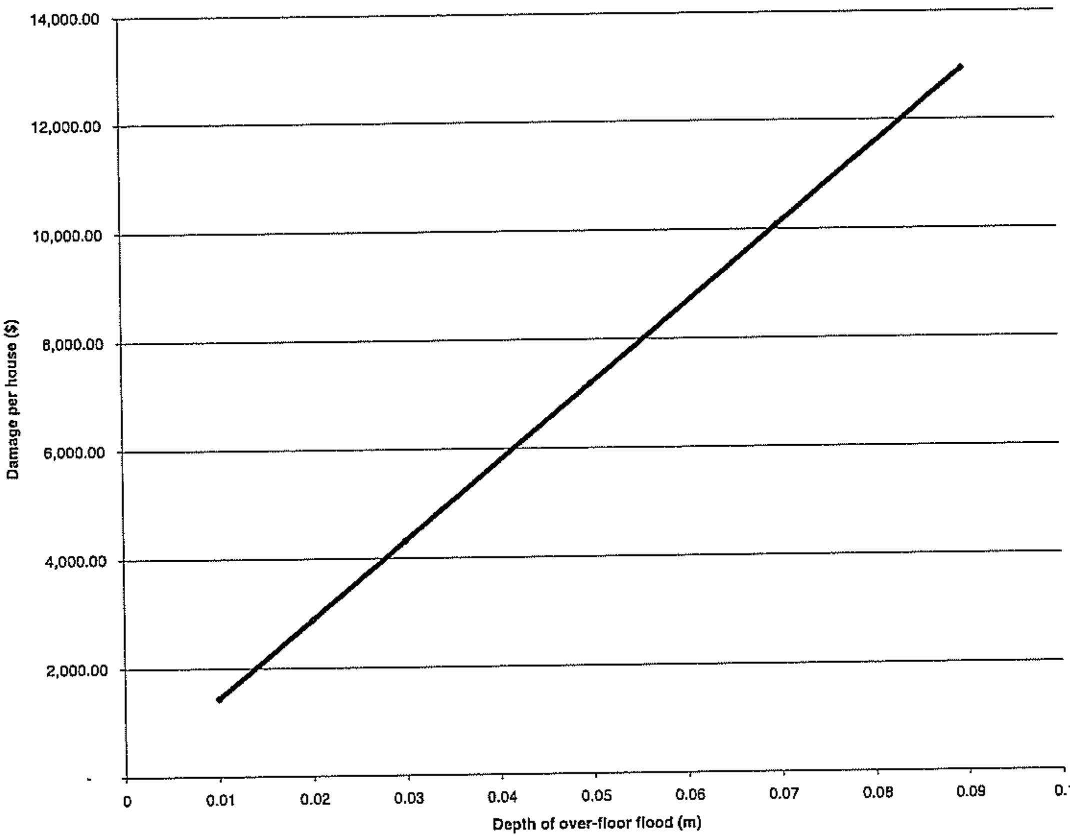


Figure C11: Stage 1 Commercial Damage

Table C10 ANUFLOOD Stage 2 Cost Damage for Class 1 Non-Residential

$f(x) = 42500x + 10125$, for $0.091 \leq x \leq 0.586$m

		Lot No.	Depth of over-floor Flooding (m)	Damage ($)
25 ARI	Murray Street	20	0.18	17,775.00
	Forrest Street	327	0.25	20,750.00
		318	0.16	16,925.00
	George Street	190	0.15	16,500.00
50 ARI	Murray Street	78	0.14	16,075.00
		227	0.38	26,275.00
	James Street	15--1	0.29	22,450.00
		15--2	0.36	25,425.00
		15--3	0.39	26,700.00
		15--4	0.39	26,700.00
		15--5	0.39	26,700.00
	Forrest Street	327	0.49	30,950.00
		318	0.31	23,300.00
	Peel Street	60	0.38	26,275.00
		14	0.32	23,725.00
	Pinjarra Road	315	0.38	26,275.00
		11	0.38	26,275.00
		29--3	0.42	27,975.00
	George Street	190	0.49	30,950.00
		87	0.14	16,075.00
		86	0.11	14,800.00
		3	0.26	21,175.00
		4	0.26	21,175.00
		8	0.22	19,475.00
		7	0.27	21,600.00
		6	0.35	25,000.00
		Sub 1	0.31	23,300.00
		23	0.46	29,675.00
		35--12	0.38	26,275.00
		34	0.37	25,850.00
		33	0.2	18,625.00
		32	0.3	22,875.00
		31	0.3	22,875.00
		30--2	0.32	23,725.00
		30--4	0.27	21,600.00
		22	0.27	21,600.00
		23--7	0.22	19,475.00
		23--14	0.11	14,800.00
		26a	0.15	16,500.00
		26b	0.15	16,500.00
		27	0.16	16,925.00
		28a	0.11	14,800.00
		28b	0.11	14,800.00

		22	0.1	14,375.00
		5a	0.1	14,375.00
	Camp Road	Sub 5	0.15	16,500.00
		218	0.13	15,650.00
100 ARI	Murray Street	78	0.43	28,400.00
		69--70--1	0.29	22,450.00
	James Street	15--1	0.58	34,775.00
	Forrest Street	318	0.56	33,925.00
		57--59	0.24	20,325.00
		60--61	0.2	18,625.00
	Pinjarra Road	326	0.2	18,625.00
	George Street	89	0.21	19,050.00
		88	0.21	19,050.00
		87	0.4	27,125.00
		86	0.38	26,275.00
		216	0.14	16,075.00
		219	0.35	25,000.00
		221	0.2	18,625.00
		220	0.35	25,000.00
		3	0.51	31,800.00
		4	0.51	31,800.00
		8	0.47	30,100.00
		7	0.52	32,225.00
		Sub1	0.5	31,375.00
		33	0.44	28,825.00
		32	0.54	33,075.00
		31	0.54	33,075.00
		30--2	0.57	34,350.00
		30--4	0.55	33,500.00
		22	0.55	33,500.00
		23--7	0.5	31,375.00
		23--14	0.39	26,700.00
		26a	0.42	27,975.00
		26b	0.42	27,975.00
		27	0.43	28,400.00
		28a	0.38	26,275.00
		28b	0.38	26,275.00
		21	0.23	19,900.00
		22	0.38	26,275.00
		23	0.18	17,775.00
		5a	0.38	26,275.00
		5b	0.28	22,025.00
		4a	0.14	16,075.00
	Orchard St	Sub 5	0.43	28,400.00
		218	0.32	23,725.00
	SouthWest Hwy	11	0.34	24,575.00
		16	0.34	24,575.00
	Pinjarra William Road	200	0.19	18,200.00
		362	0.24	20,325.00
			Total Damage	$2,178,450.00

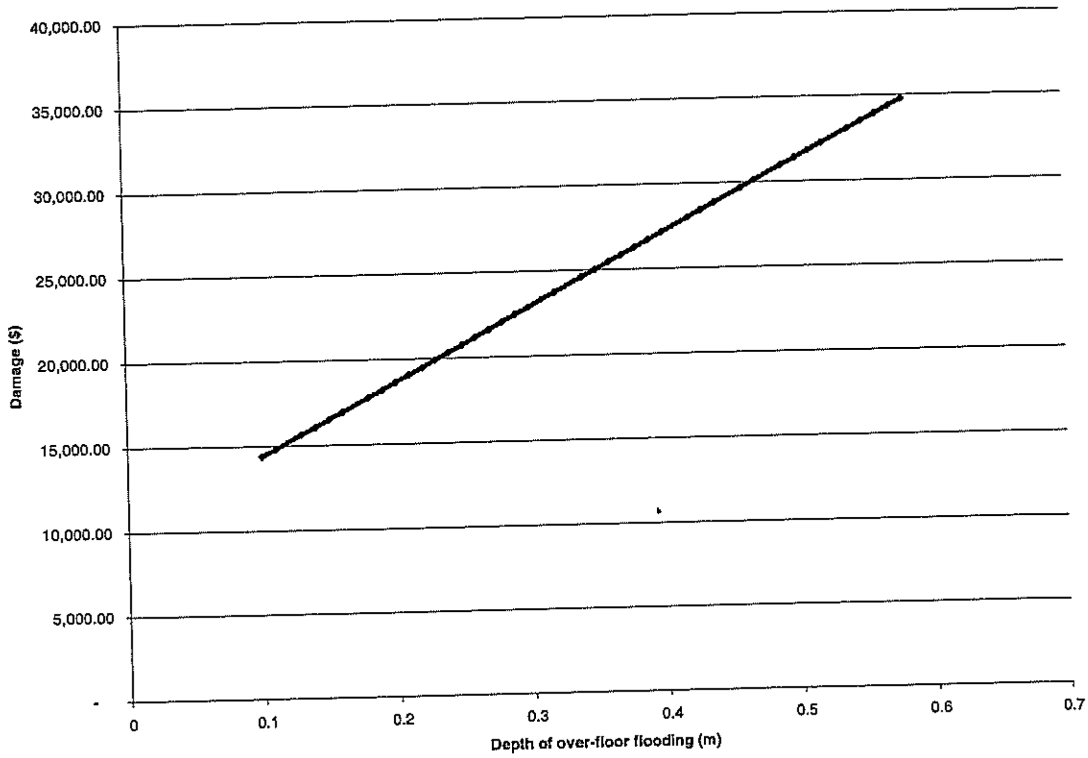


Figure C12: Stage 2 Commercial Damage

Table C10 ANUFLOOD Stage 3 Cost Damage for Class 1 Non-Residential

$f(x) = 18750x + 24375$, for $x \geq 0.586$m

		Lot No.	Depth of over-floor Flooding (m)	Damage ($)
25 ARI	Henry Street	202	1.11	45,187.50
50 ARI	Henry Street	202	1.37	50,062.50
	Murray Street	20	0.59	35,437.50
100 ARI	Henry Street	202	1.64	55,125.00
	Murray Street	227	0.66	36,750.00
		20	0.83	39,937.50
	James Street	15—2	0.61	35,812.50
		15—3	0.69	37,312.50
		15—4	0.69	37,312.50
		15—5	0.69	37,312.50
	Forrest Street	327	0.78	39,000.00
	Peel Street	60	0.65	36,562.50
		14	0.6	35,625.00
	Pinjarra Road	315	0.66	36,750.00
		11	0.64	36,375.00
		29—3	0.7	37,500.00

	George Street	190	0.79	39,187.50
		6	0.59	35,437.50
		23	0.65	36,562.50
		35--12	0.62	36,000.00
		34	0.6	35,625.00
			Total Damage	$769,687.50

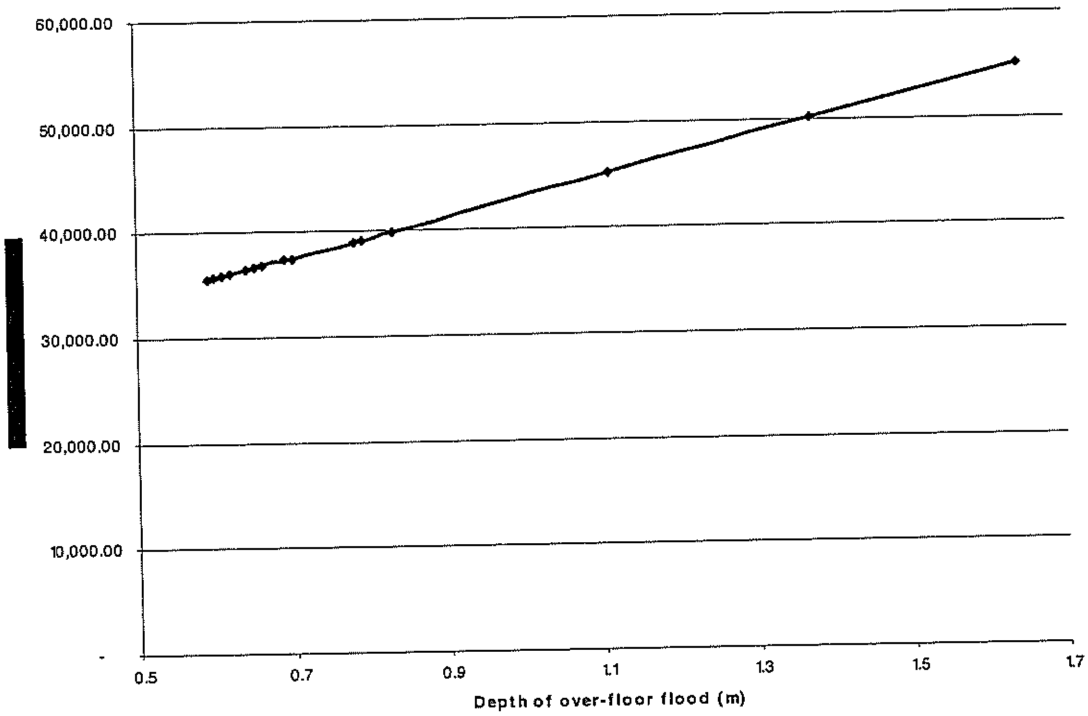


Figure C13: Stage 3 Commercial Damage

C6.3.1.1 Conclusion for ANUFLOOD Stage Damage Curve for Non-Residential Class 1

The result again shows that ANUFLOOD stage 2 has the highest flood damages affecting 69 non-residential dwellings. Refer to Figure C14 for the overall damage cost for all of the 3 ANUFLOOD stages.

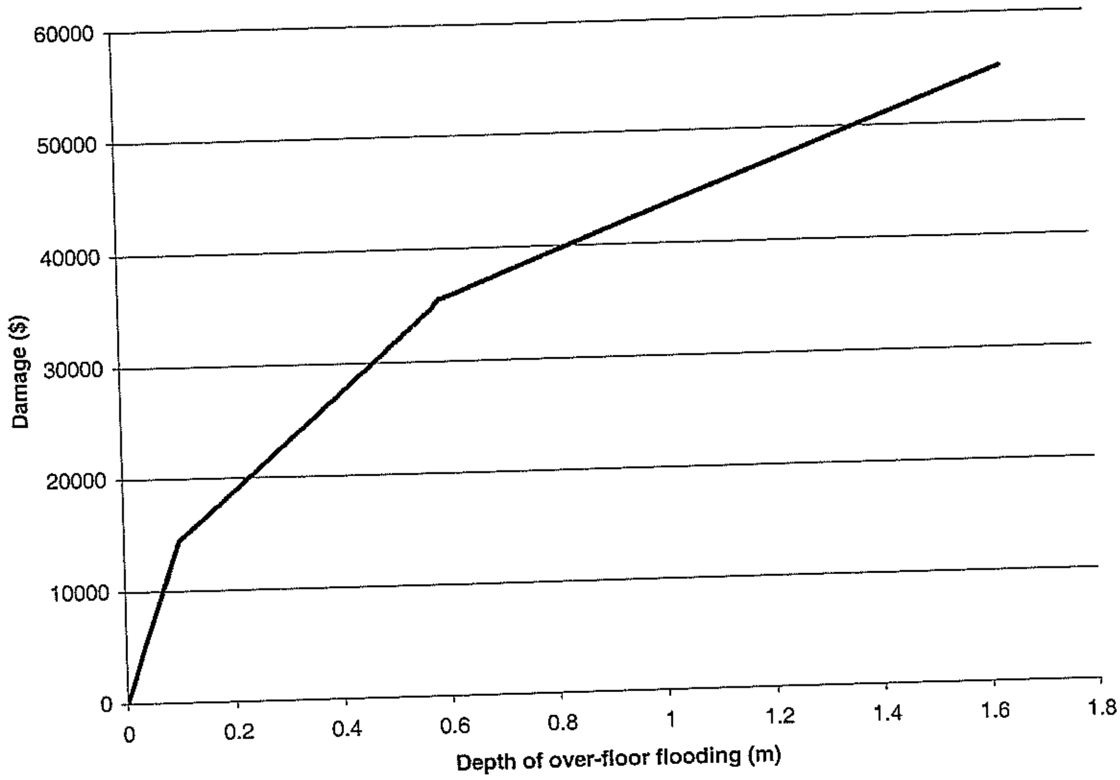


Figure C14: Combine Stage Damage Curve for Non-Residential in Pinjarra

C6.3.2 Damage Cost of Flood Event for Class 1 Non-Residential

Once again same as Residential, the results data is rearranged and presented in Tables C11 to C13 that shows the damage for each period of flooding which are the 25 year ARI, 50 year ARI and the 100 year ARI. Figure C15 to Figure C17 graphs the cost damages for each flooding period against the depth of flooding.

Table C11 Cost of Damage for 25 year ARI flood event for Class 1 Non-Residential

	Lot No.	Depth of over-floor Flooding (m)	Damage ($)
Henry Street			
Stage 2	202	1.11	57,300.00
Murray Street			
Stage 1	227	0.07	10,062.50
Stage 2	20	0.18	17,775.00
James Street			

Stage 1	15--2	0.01	1,437.50
	15--3	0.03	4,312.50
	15--4	0.05	7,187.50
	15--5	0.05	7,187.50
Forrest Street			
Stage 2	327	0.25	20,750.00
	318	0.16	16,925.00
Pinjarra Road			
Stage 1	315	0.07	10,062.50
George Street			
Stage 2	190	0.15	16,500.00
		Total Damage	$169,500.00

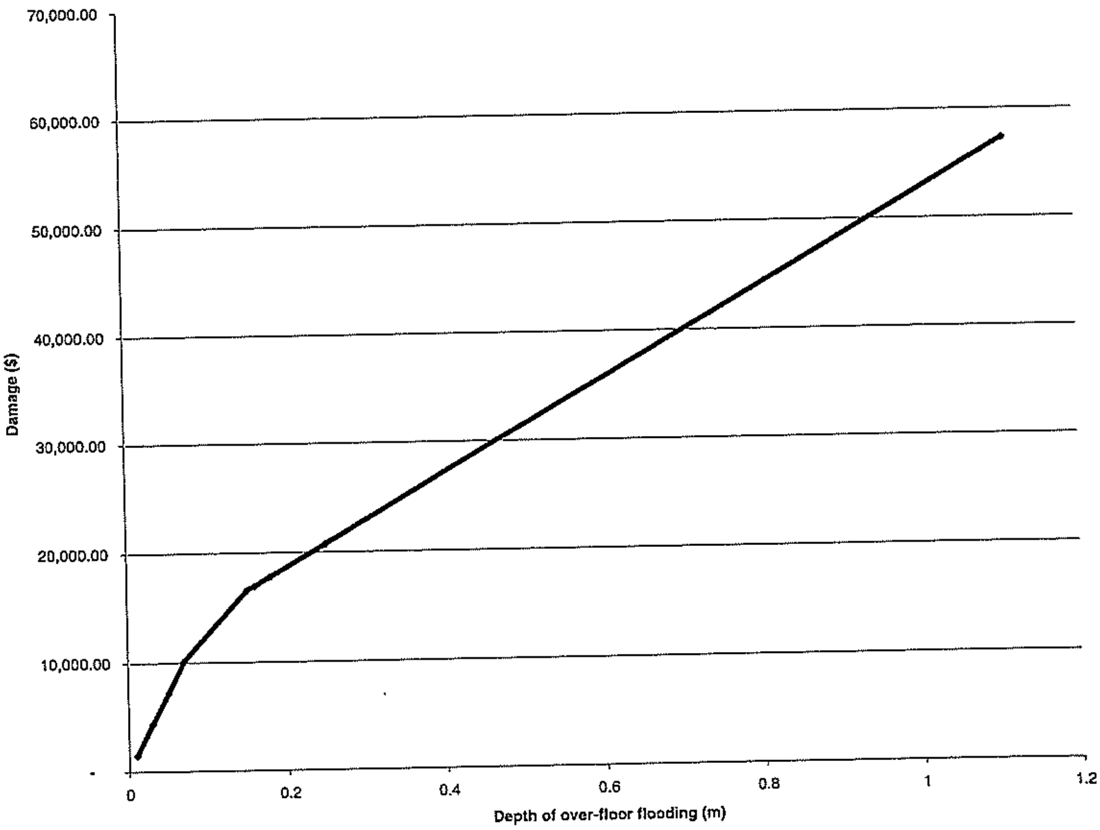


Figure C15: 25 year ARI Commercial Damage

Table C12 Cost of Damage for 50 year ARI flood event for Class 1 Non-Residential

	Lot No.	Depth of over-floor Flooding (m)	Damage ($)
Henry Street			
Stage 3	202	1.37	50,062.50
Murray Street			
Stage 1	69-70-1	0.02	2,875.00
Stage 2	78	0.14	16,075.00
	227	0.38	26,275.00
Stage 3	20	0.59	35,437.50
James Street			
Stage 2	15--1	0.29	22,450.00
	15--2	0.36	25,425.00
	15--3	0.39	26,700.00
	15--4	0.39	26,700.00
	15--5	0.39	26,700.00
Forrest Street			
Stage 2	327	0.49	30,950.00
	318	0.31	23,300.00
Peel Street			
Stage 2	60	0.38	26,275.00
	14	0.32	23,725.00
Pinjarra Road			
Stage 2	315	0.38	26,275.00
	11	0.38	26,275.00
	29--3	0.42	27,975.00
George Street			
Stage 1	219	0.07	10,062.50
	220	0.07	10,062.50
Stage 2	190	0.49	30,950.00
	87	0.14	16,075.00
	86	0.11	14,800.00

	3	0.26	21,175.00
	4	0.26	21,175.00
	8	0.22	19,475.00
	7	0.27	21,600.00
	6	0.35	25,000.00
	Sub 1	0.31	23,300.00
	23	0.46	29,675.00
	35--12	0.38	26,275.00
	34	0.37	25,850.00
	33	0.2	18,625.00
	32	0.3	22,875.00
	31	0.3	22,875.00
	30--2	0.32	23,725.00
	30--4	0.27	21,600.00
	22	0.27	21,600.00
	23--7	0.22	19,475.00
	23--14	0.11	14,800.00
	26a	0.15	16,500.00
	26b	0.15	16,500.00
	27	0.16	16,925.00
	28a	0.11	14,800.00
	28b	0.11	14,800.00
	22	0.1	14,375.00
	5a	0.1	14,375.00
Camp Road			
Stage 2	Sub 5	0.15	16,500.00
	218	0.13	15,650.00
		Total Damage	$1,044,950.00

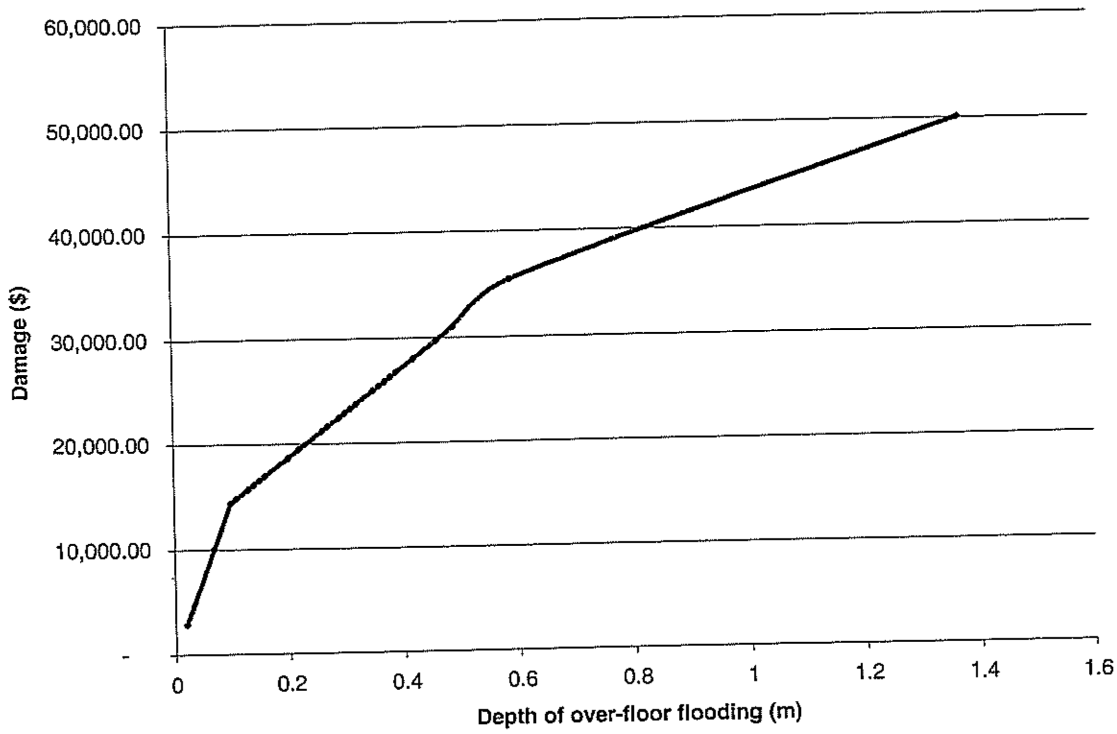


Figure C16: 50 year ARI Commercial Damage

Table C13 Cost of Damage for 100 year ARI flood event for Class 1 Non-Residential

	Lot No.	Depth of over-floor Flooding (m)	Damage ($)
Henry Street			
Stage3	202	1.64	55,125.00
Murray Street			
Stage 2	78	0.43	28,400.00
	69--70--1	0.29	22,450.00
Stage 3	227	0.66	36,750.00
	20	0.83	39,937.50
James Street			
Stage 2	15--1	0.58	34,775.00
Stage 3	15--2	0.61	35,812.50
	15--3	0.69	37,312.50
	15--4	0.69	37,312.50
	15--5	0.69	37,312.50
Forrest Street			
Stage 2	318	0.56	33,925.00
	57--59	0.24	20,325.00
	60--61	0.2	18,625.00
Stage 3	327	0.78	39,000.00

Peel Street			24,375.00
Stage3	60	0.65	36,562.50
	14	0.6	35,625.00
Pinjarra Road			
Stage 2	326	0.2	18,625.00
Stage 3	315	0.66	36,750.00
	11	0.64	36,375.00
	29--3	0.7	37,500.00
George Street			
Stage 1	4b	0.09	12,937.50
Stage 2	89	0.21	19,050.00
	88	0.21	19,050.00
	87	0.4	27,125.00
	86	0.38	26,275.00
	216	0.14	16,075.00
	219	0.35	25,000.00
	221	0.2	18,625.00
	220	0.35	25,000.00
	3	0.51	31,800.00
	4	0.51	31,800.00
	8	0.47	30,100.00
	7	0.52	32,225.00
	Sub1	0.5	31,375.00
	33	0.44	28,825.00
	32	0.54	33,075.00
	31	0.54	33,075.00
	30--2	0.57	34,350.00
	30--4	0.55	33,500.00
	22	0.55	33,500.00
	23--7	0.5	31,375.00
	23--14	0.39	26,700.00
	26a	0.42	27,975.00
	26b	0.42	27,975.00
	27	0.43	28,400.00
	28a	0.38	26,275.00
	28b	0.38	26,275.00
	21	0.23	19,900.00
	22	0.38	26,275.00
	23	0.18	17,775.00
	5a	0.38	26,275.00
	5b	0.28	22,025.00
	4a	0.14	16,075.00
Stage 3	190	0.79	39,187.50
	6	0.59	35,437.50
	23	0.65	36,562.50
	35--12	0.62	36,000.00
	34	0.6	35,625.00
Orchard St			
Stage 1	215	0.07	10,062.50
Stage 2	Sub 5	0.43	28,400.00
	218	0.32	23,725.00
SouthWest Hwy			

Stage 1	363	0.01	1,437.50
Stage2	11	0.34	24,575.00
	16	0.34	24,575.00
Pinjarra William Road			
Stage 2	200	0.19	18,200.00
	362	0.24	20,325.00
		Total Damage	$1,903,050.00

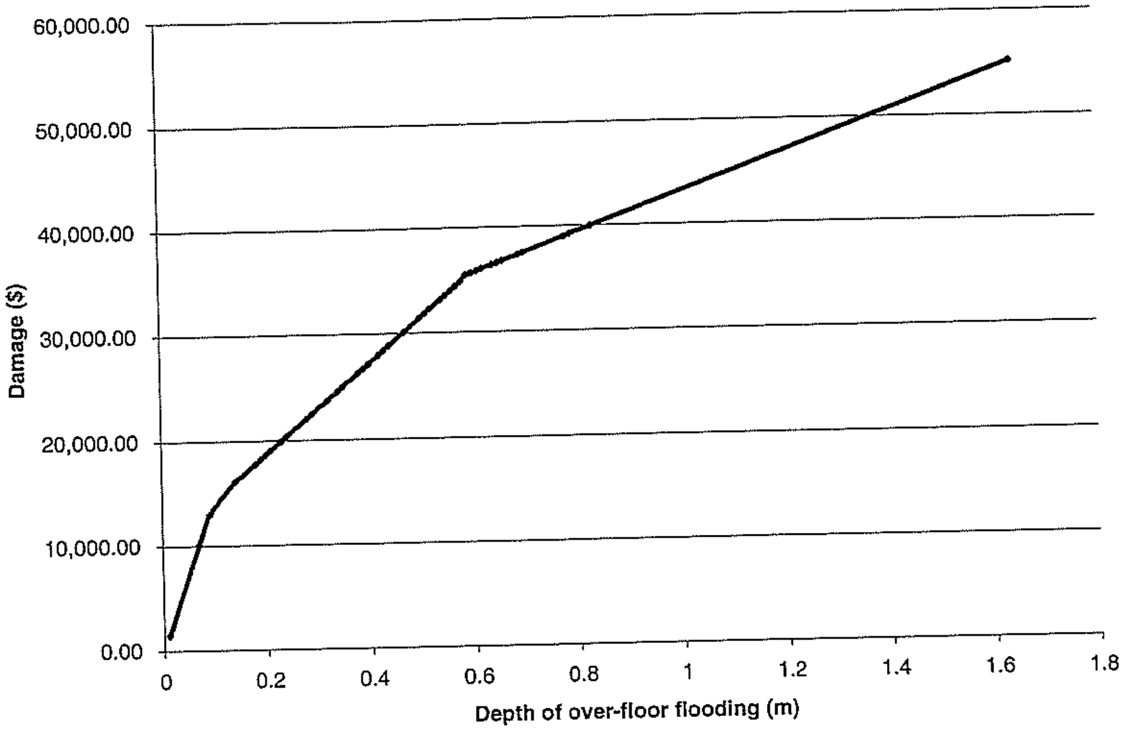


Figure C17: 100 year ARI Commercial Damage

C6.3.2.1 Conclusion

No commercials are affected by the 1 in 10 year ARI flood. Out of the total 76 commercial properties that are covered in the study area, 67 of the premises will be inundated by the 1 in 100 year ARI flood. Lot 202 on Henry Street, which is the St. John's Church has the highest above floor-flooding level of 1.64 m for the 1 in 100 year flood. 1 in 50 year ARI flood will inundate 48 premises majority being located in George Street where as 1 in 10 year ARI will inundate only 11 premises.