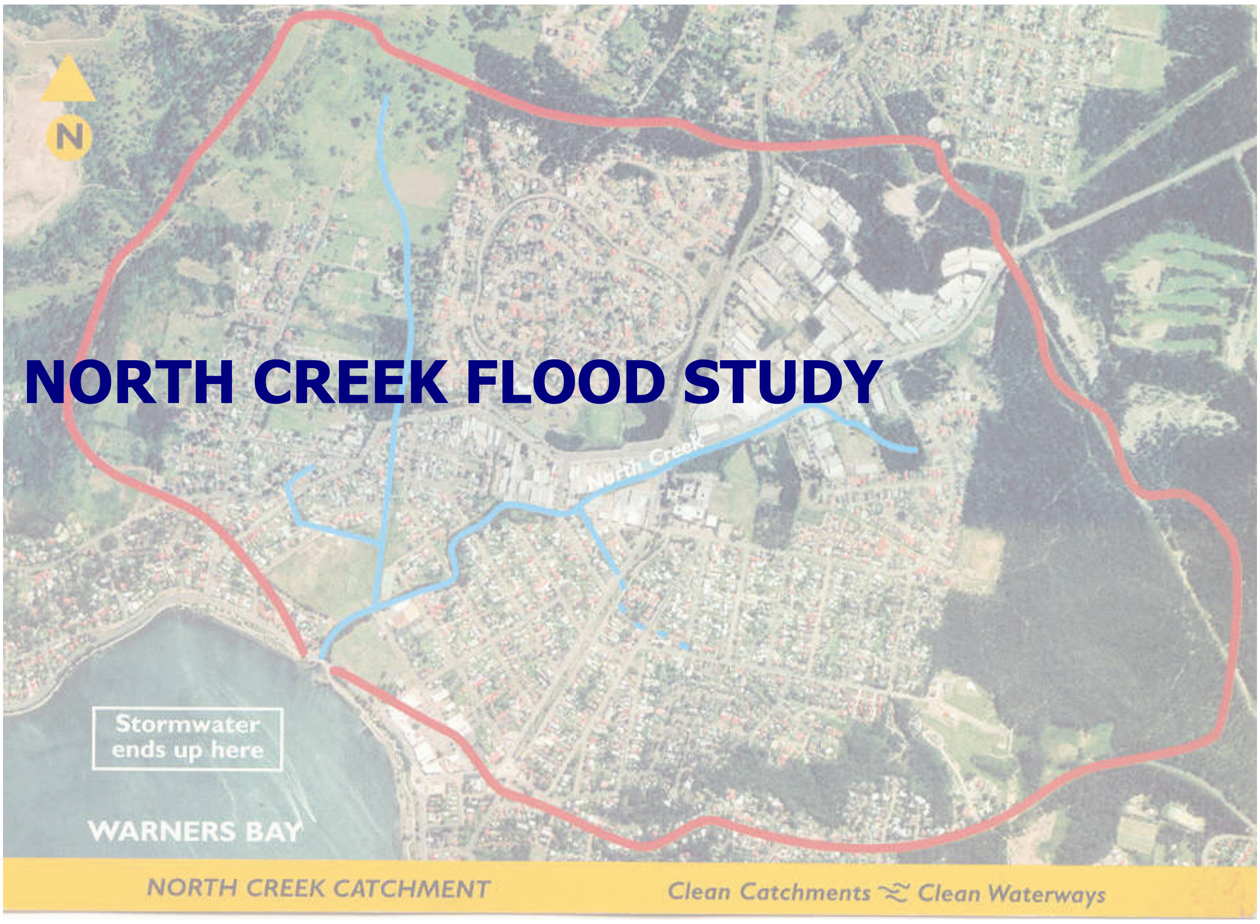
## CITY OF LAKE MACQUARIE

# NORTH CREEK FLOOD STUDY




## APRIL 2005

WEBB, McKEOWN & ASSOCIATES PTY LTD

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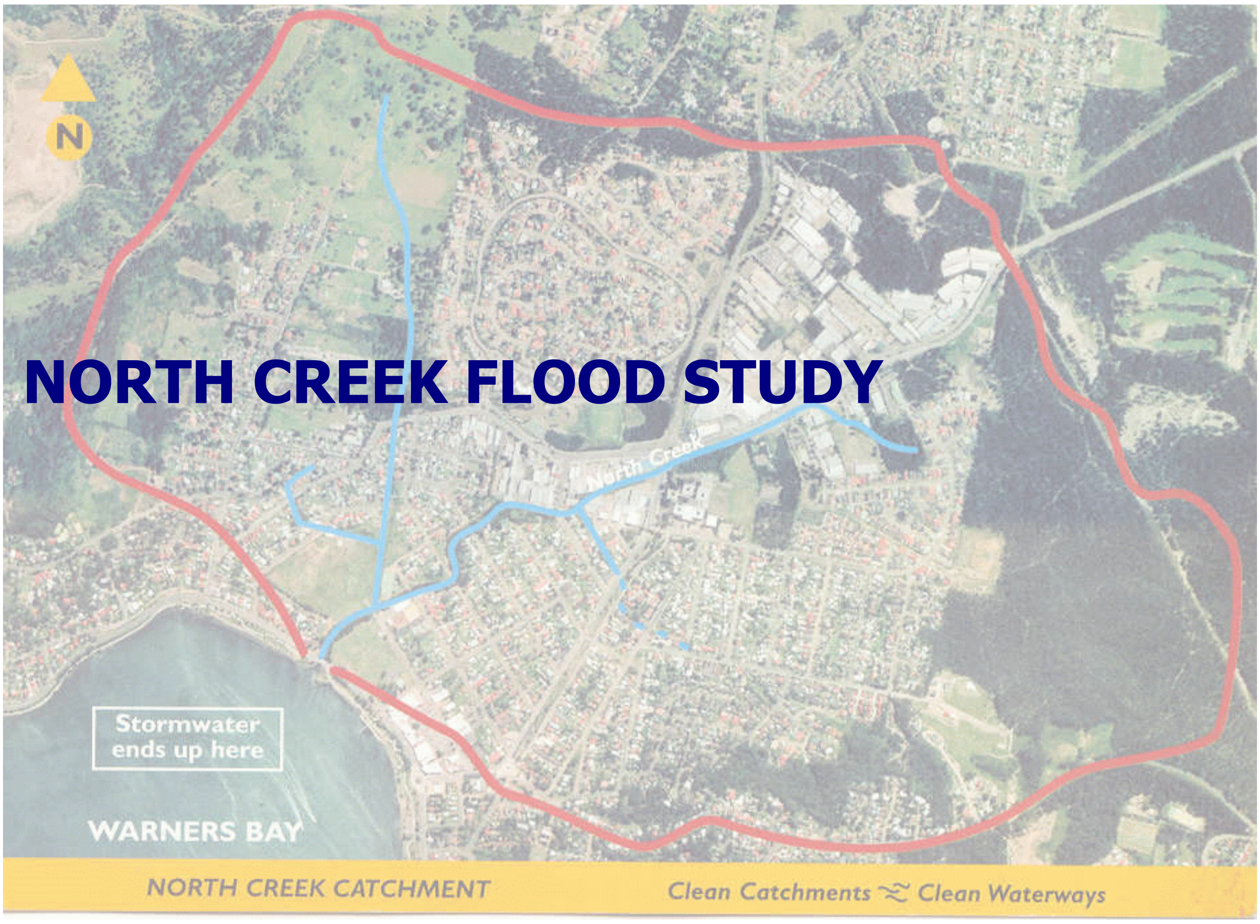


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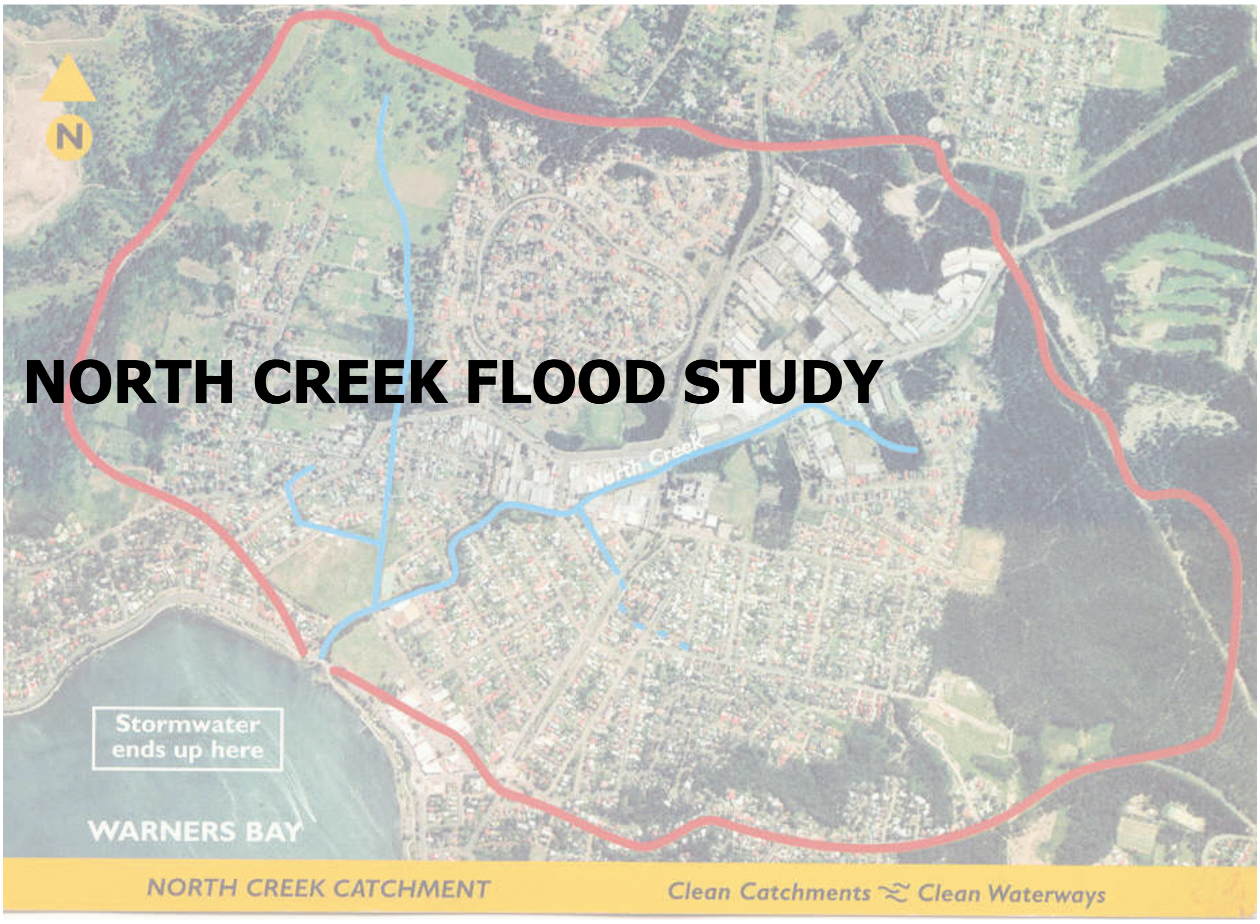


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## APRIL 2005

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# NORTH CREEK FLOOD STUDY

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# FOREWORD

The State Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through the following four sequential stages:

1. *Flood Study*
   - determine the nature and extent of the flood problem.
2. *Floodplain Risk Management Study*
   - evaluates management options for the floodplain in respect of both existing and proposed development.
3. *Floodplain Risk Management Plan*
   - involves formal adoption by Council of a plan of management for the floodplain.
4. *Implementation of the Plan*
   - construction of flood mitigation works to protect existing development,
   - use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The North Creek Flood Study constitutes the first stage of the management process for North Creek and its catchment area. It has been prepared for the Lake Macquarie Floodplain Risk Management Committee by Webb, McKeown & Associates to define flood behaviour under current conditions.

# SUMMARY


North Creek has a catchment area of approximately 5.3 square kilometres and lies within the boundaries of the City of Lake Macquarie Local Government Area. It drains into Lake Macquarie at Warners Bay. Flooding of roads and residential areas within the catchment has occurred on several occasions in living memory. The most notable being June 1949 and February 1990.

This report was prepared by Webb, McKeown & Associates on behalf of the City of Lake Macquarie Floodplain Risk Management Committee and details the hydrologic and hydraulic investigations carried out to determine the design flood behaviour (levels, flows and velocities). It represents the technical foundation in the process to provide a formal Floodplain Risk Management Plan for the catchment.

All available rainfall, flood and topographic data were collected and analysed as part of the study. Whilst there is a reasonably good flood record around the Lake itself, there is generally a poor record for the North Creek catchment. The quantity and quality of the available data has influenced the hydrologic and hydraulic modelling approach adopted.

A WBNM hydrologic model was set up to cover the entire catchment draining to the Lake at Warners Bay. A MIKE11 hydraulic model was structured to model the main creek channels and overbank areas within the designated study area. The downstream limit of the hydraulic model was Warners Bay.

Due to the limited amount of available historical data the hydrologic and hydraulic models could not be rigorously calibrated to ensure that they accurately simulated recorded flood events. For both models parameter values from established texts and those found to be applicable in previous studies were therefore used in determining appropriate values for the present study. The available historical flood level information was then compared to the design flood levels.

Design rainfall data were determined from Australian Rainfall & Runoff 1987 and input to the hydrologic model to derive flow inputs for the hydraulic model. Design flood levels were obtained by inputting the design flows and boundary conditions to the hydraulic model. Flood levels in the lower parts of the floodplain are influenced by a combination of:

- flows discharging from the North Creek catchment,
- elevated water levels in Lake Macquarie (investigated in Reference 1),
- wind wave activity within Warners Bay (investigated in Reference 2).

An "envelope" approach was used to determine design flood levels in these areas.

The accuracy of the design flood levels at any one location is largely dependent on the availability of suitable historical flood data, the survey data, and the reliability of the design rainfall intensities. The

relative accuracy of the design flood levels obtained from the Lake Macquarie Flood Studies are considered to be of the order of ±0.3. For the upper reaches of this North Creek study area the accuracy is more likely to be in the order of ±0.5 m due to the paucity of data available for model calibration and verification.

It is recommended that Council install maximum height recorders in the catchment in order to accurately record all future flood events. This would greatly assist in increasing the accuracy of any future flood studies.

The potential influence of wind wave effects on design flood levels near the mouth can be significant depending on the prevailing conditions. The results from previous studies suggest a wave runup value of 0.22 m should be added to the design 1% AEP "still" water lake flood levels to minimise the risk of inundation for new development affected by wave runup. Council's current Flood Planning Level for new floor levels is the 1% AEP flood level plus 0.5 m freeboard. As the wave runup value is within the 0.5 m freeboard there is no need to increase the Flood Planning Level to take account of wave runup. However wave runup may influence the structural design or location of any proposed structure adjacent to the foreshore.

Floor level data were collected as part of the present study and the number of buildings (residential and non-residential) inundated for the range of design events considered is summarised below along with the estimated tangible flood damages.

| Event | Number of Buildings Inundated above Floor Level | | Total Tangible Flood Damages ($) |
|---|---|---|---|
| | Residential | Non-Residential | |
| PMF | 157 | 27 | 10,300 000 |
| 0.5% AEP | 47 | 11 | 2,000,000 |
| 1% AEP | 42 | 11 | 1,630,000 |
| 2% AEP | 33 | 11 | 1,290,000 |
| 5% AEP | 24 | 9 | 960,000 |
| 10% AEP | 14 | 8 | 720,000 |
| 20% AEP | 7 | 8 | 610,000 |

The Average Annual Damages (AAD) based on the above values is estimated to be $440,000.

# 1. INTRODUCTION

North Creek is a 5.3 $km^2$ catchment (Figure 1) which enters Lake Macquarie at Warners Bay. The total catchment area of Lake Macquarie to the Ocean is 684 square kilometres of which 110 square kilometres (16%) is the lake itself. The lake extends approximately 22 kilometres in a north-south direction and varies from 2 kilometres to 6 kilometres in an east-west direction.

Lake Macquarie is the largest coastal lake in eastern Australia and has its outlet to the Pacific Ocean at Swansea. The water level in the lake is typically 0.1 mAHD but can rise to 0.4 mAHD following a period of high ocean levels.

The catchment area of North Creek is predominantly occupied by residential development (50%), non-residential development (10% - largely schools and commercial/light industrial), open space and forested areas (40%). The creek has two main tributaries, the western and eastern tributaries. Each of these has a sub-branch, the Seaman Avenue on the western tributary and the King Street and Lakelands branches on the eastern tributary. Since the late 1980's the main growth area is the Lakelands residential development situated between the western and eastern main tributaries.

In view of the increasing catchment development and the need to accurately define the flood problem, Lake Macquarie City Council engaged Webb, McKeown & Associates, to undertake a Flood Study. The primary objectives of this Flood Study are:

- to define the flood behaviour of the North Creek catchment by producing information on flood levels, velocities and flows for a range of design flood events under existing catchment and floodplain conditions,
- to assess the hydraulic categories and undertake provisional flood hazard mapping,
- to assess the extent of the flood problem by undertaking a damages assessment,
- to formulate suitable hydrologic/hydraulic models that can be used in a subsequent Floodplain Risk Management Study to assess various floodplain management measures, including the effects of further development.

This report details the results and findings of the Flood Study investigations. The key elements include:

- a summary of available data,
- reasons for the choice of hydrologic and hydraulic models,
- calibration of these models,
- establishment of design flood behaviour,
- flood damages assessment.

The Flood Study does not consider flooding from local drainage which may result from inadequate urban drainage provisions. A glossary of flood related terms used in this report is provided in Appendix A.

# 2. BACKGROUND

## 2.1 Study Limits

The study area for this investigation (Figure 1) was determined in consultation with Council and the Department of Infrastructure, Planning and Natural Resources (DIPNR). The upstream limits of each stream reach are:

- Eastern tributary, Main Branch - upstream extent of commercial development off Hillsborough Road,
- Eastern tributary, King Street Branch - to Queen Street,
- Eastern tributary, Lakelands Branch - to Lakelands basin upstream of Medcalf Street,
- Western tributary, Main Branch - 630 m upstream of Medcalf Street,
- Western tributary, Seaman Avenue Branch - 75 m downstream of Russwell Avenue.

## 2.2 Creek Description

As noted previously, the catchment has largely been developed for residential or commercial/light industrial purposes. The only remaining areas of natural bushland are in the south-east corner and a narrow band along the catchment divide in the north. The majority of the urban development has a road system with kerb and gutter and a piped drainage system. A number of road crossings are located throughout the study area as summarised in Table 1 and shown in the photographs included as Figure 2. At a number of locations in the creek system other informal structures (such as fences, bridges) have been constructed in the floodplain. These, as well as any other features that may have a significant impact on the hydraulic performance are also included in Table 1 (in sequential order along each reach from upstream to downstream) and in the photographs shown in Figure 2.

**Table 1:** Road Crossings and Floodplain Structures

| Location | Creek/ Branch | Type of Structure/ Feature | Invert Level (mAHD) | Waterway Area ($m^2$) | Road Level (mAHD) | Photo in Figure 2 | Included in MIKE11 | Blocked in MIKE11 |
|---|---|---|---|---|---|---|---|---|
| U/S Hillsborough Road, Driveway | North | 4 x 0.6m dia. pipes | 5.86 | 3.8 | 6.70 | 1 | Yes | Yes |
| Hillsborough Road | North | 3 x 1.05m dia. pipes | 5.65 | 2.6 | 5.30 | 2 | Yes | Yes |
| U/S King Street | North | Pedestrian bridge and sewer main | N/A | N/A | 4.80 | 3 | Yes* | No |
| King Street | North | 4 x 2.4m x 1.4m box culverts | 2.46 | 13.4 | 5.40 (refer Note 1) | 4 | Yes | Yes |
| D/S King Street | North | Two new road bridges | N/A | N/A | 5.40 | 5 | Yes*/No | No |
| King Street | North | Road widening and extension of existing culverts | N/A | N/A | N/A | 6 | Yes | No |

| Location | Creek/ Branch | Type of Structure/ Feature | Invert Level (mAHD) | Waterway Area ($m^2$) | Road Level (mAHD) | Photo in Figure 2 | Included in MIKE11 | Blocked in MIKE11 |
|---|---|---|---|---|---|---|---|---|
| U/S Walker Street | North | 0.35m dia. sewer main | N/A | N/A | N/A | 7 | No | No |
| U/S Walker Street | North | Road bridge | N/A | N/A | 3.75 | 8 | Yes | No |
| Walker Street | North | 3 x 2.55m x 2.0m box culverts | 0.72 | 15.3 | 2.80 | 9 | Yes | Yes |
| U/S Margaret Street | North | Sewer main | N/A | N/A | N/A | 10 | No | No |
| U/S Martin Street | North | Gabion weir 10m wide | 0.19 (crest) | N/A | N/A | 11 | Yes | No |
| Albert Street | North | Timber pedestrian bridge | N/A | N/A | 1.60 | 12 | Yes* | No |
| John Street | North | Concrete pedestrian bridge | N/A | N/A | 1.94 | 13 | Yes | No |
| The Esplanade | North | Concrete road bridge | N/A | N/A | 2.40 | 14 | Yes | No |
| D/S Medcalf Street | Seaman Avenue | Typical concrete lined channel of upper reaches | N/A | N/A | N/A | 15 | N/A | No |
| Medcalf Street | Seaman Avenue | 3 x 0.95m x 0.8m box culverts | 6.35 | 2.3 | 7.30 | 16 | Yes | Yes |
| U/S Seaman Avenue | Seaman Avenue | Typical concrete box channel of middle reaches | N/A | N/A | N/A | 17 | Yes | No |
| Seaman Avenue | Seaman Avenue | 3.25m x 0.8m box culvert | 2.98 | 2.6 | 4.10 | 18 | Yes | Yes |
| D/S Seaman Avenue | Seaman Avenue | Typical dense vegetation of lower reaches | N/A | N/A | N/A | 19 | N/A | No |
| Charles Street | Seaman Avenue | Steel truss pedestrian bridge | N/A | N/A | 2.30 | 20 | Yes* | No |
| D/S King Street | King Street | 2 x 1.8m x 1.17m box culverts (not in hydraulic model) | 6.64 | N/A | N/A | 21 | No | No |
| D/S King Street | King Street | Private boundary colourbond fence | N/A | N/A | N/A | 22 | Yes | Yes |
| D/S King Street | King Street | Private steel pedestrian bridge | N/A | N/A | N/A | 23 | No | No |
| D/S King Street | King Street | Private boundary metal fence | N/A | N/A | N/A | 24 | Yes | Yes |
| D/S King Street | King Street | Private steel and concrete pedestrian bridge | N/A | N/A | N/A | 25 | No | No |
| U/S Walker Street | King Street | 0.35m dia. sewer main | N/A | N/A | N/A | 26 | No | No |
| U/S Walker Street | King Street | Steel plank bridge | N/A | N/A | N/A | 27 | No | No |
| U/S Medcalf Street | Lakelands | Stormwater detention basin 2.7m x 0.75m box culvert at outlet | N/A 3.15 | 9800 (surface area) 2.0 | N/A | 28 | No | No |

| Location | Creek/ Branch | Type of Structure/ Feature | Invert Level (mAHD) | Waterway Area ($m^2$) | Road Level (mAHD) | Photo in Figure 2 | Included in MIKE11 | Blocked in MIKE11 |
|---|---|---|---|---|---|---|---|---|
| D/S Medcalf Street | Lakelands | 2.7m x 0.75m box culvert (not in hydraulic model) | 3.15 | 2.0 | 5.70 | 29 | No | No |
| U/S Junction with North Creek | Lakelands | Typical concrete lined channel section | N/A | N/A | N/A | 30 | N/A | No |
| Medcalf Street | Western Tributary | 2 x 1.05m dia. pipes | 6.58 | 0.9 | 8.30 | 31 | Yes | Yes |
| D/S Medcalf Street | Western Tributary | Typical grassed lined channel | N/A | N/A | N/A | 32 | N/A | No |
| Albert Street | Western Tributary | Pedestrian bridge | N/A | N/A | 4.15 | 33 | Yes | No |

**Note**: N/A - Data not applicable or not surveyed. * - Not modelled as a formal structure, however represented by cross section.
Note 1: This is the level of the bridge deck immediately downstream, the road level at Kings Street is 4.6m AHD.

Figure 3 provides the current land use zonings for the catchment. A short description of each branch is provided in the following sections.

### 2.2.1 Eastern Tributary - Main Branch

The lower parts of North Creek are estuarine in character and fringed by native vegetation. Downstream of the weir (located just upstream of Martin Street) the creek is approximately 10 m wide with an invert at -1 mAHD. This reach of the creek has fairly flat banks. Further upstream of the weir the creek narrows and is confined by steeper overbank areas. The first bridge crossing on North Creek is at The Esplanade and there are several other crossings as indicated in Table 1.

For its entire length from the Lake to where it verges east off Hillsborough Road, North Creek - Main branch is in a semi-natural state. Upstream of this point it becomes concrete lined in places.
From Walker Street to the start of this lined section, the creek is extremely heavily vegetated to the extent that the main channel is barely identifiable in places. In early 2003 Council cleared the channel upstream of King Street and clearing was also subsequently undertaken for the reach immediately downstream.

### 2.2.2 Eastern Tributary - King Street Branch

This branch extends eastwards from the Main Branch at a point approximately 40 m upstream of Walker Street. The branch is entirely within the yards of the surrounding properties and is crossed by fences and other structures. The creek is unlined but the channel has been significantly modified by the landowners. Upstream of King Street the branch continues along Queen Street but then largely disappears.

### 2.2.3 Eastern Tributary - Lakelands Branch

This branch joins the Eastern Tributary - Main Branch midway between Margaret and Martin Streets. It is concrete lined for its entire length to the Lakelands detention basin.

### 2.2.4 Western Tributary - Main Branch

This branch connects to the Eastern Tributary through Warner Park and is in a semi-natural state for its entire length. Upstream of Medcalf Street the channel is ill-defined as it passes across semi-rural lands.

### 2.2.5 Western Tributary - Seaman Avenue Branch

This branch joins the Western Tributary - Main Branch in the northern corner of Warner Park and becomes a lined channel upstream of Seaman Avenue. Thereafter the channel is situated within the yards of residential properties. It is crossed by Medcalf Street and becomes part of the urban drainage system downstream of Russwell Avenue.

## 2.3 Previous Studies

Previous investigations of the area are summarised in the following sections.

### 2.3.1 Lake Macquarie Flood Study

The Flood Study completed in January 1998 (References 1 and 2) was undertaken to determine flood behaviour for the 1%, 2% and 5% AEP events as well as an extreme flood. Inundation of land surrounding the lake results from a combination of factors, as shown in Table 2.

**Table 2:** Factors Affecting the Peak Lake Level

| Major Factors | Comment |
|---|---|
| Volume of Rainfall | Generally rainfall over a period of 3 to 7 days is required to produce an elevated lake level. |
| Size of the Entrance Channel at Swansea | The size (width and depth) of the channel controls how much water is released from the lake, as well as how much enters from the ocean. |
| Ocean Water Level | An elevated ocean level can result from a high tide, a storm surge and an ocean wave setup, or a combination thereof. |
| Local Wave Runup | The flood level may be raised in a local area as a result of wave runup. The amount of runup depends upon the local wind/wave climate and the foreshore profile. Little is known about this effect. |
| **Minor Factors** | **Comment** |
| Initial Water Level | There is little variation in the normal water level. |
| Antecedent Catchment Moisture Conditions | The "wetness" of the catchment prior to the rainfall event determines the volume of runoff. Generally if the catchment is "very dry" prior to the event it will "soak" up a lot of the rainfall and produce less runoff than from a "wet" catchment. |
| Volume of Temporary Floodplain Storage (includes the area of the lake) | As the surface area of the lake is very large (110 $km^2$), a minor reduction in the volume of temporary storage (filling of the floodplain) will have no significant impact upon the peak lake level. |
| Intensity of Rainfall | It is the volume of rainfall rather than the peak intensity of rainfall which is more important. |
| Level of Catchment Development | Sealing of pervious areas (with houses, roads, factories, etc.) will increase the volume of runoff. However it is considered that the present extent of development has had only a minor impact, as it represents only a small percentage of the total catchment area. |
| Catchment Deforestation or Other Agricultural Changes | These activities will tend to increase the volume of runoff. It is considered that these changes have had only a minor impact upon runoff volumes during floods. |
| Evapo-transpiration | Any change in the amount of evapo-transpiration will produce only a minor change in the total runoff volume. |
| Wind Setup within the Lake | The Flood Study concluded that in normal circumstances a maximum increase in level of only 0.04 m would occur. Consequently this factor was not included in the design flood analysis. |

The Flood Study determined design flood levels using two approaches:

- *Still Water Design Lake Levels (Reference 1):* These were obtained using a combination of hydrologic and hydraulic computer models. The hydrologic model converts rainfall over the catchment into streamflows. These are input into the hydraulic model which determines the design lake level. The hydraulic model takes account of:

- the bathymetry of the lake,
- the dimensions of the Swansea entrance channel,
- the complex interaction between ocean levels and outflow from the lake,
- wind setup across the lake.

The models were calibrated to historical data (November 1983 gauging and the floods of May 1974, February 1990 and March 1990) and the critical design storm duration was found to be 6 days (144 hours). The adopted design levels are shown in Table 3 and on Figure 4. These are referred to as Still Water Levels in the Lake as they exclude the effect of wind and wave set up in the lake itself. Although an ocean wave set up component is included in determination of the ocean tailwater level. The impact of wind and wave runup is discussed below.

**Table 3:** Peak Design Levels in Lake Macquarie

| Event | Still Water Level in the Lake (excludes wave runup in the lake) (mAHD) | Ocean Tailwater Level (includes ocean wave setup) (mAHD) |
|---|---|---|
| Extreme | 2.63 | 2.18 |
| 0.2% AEP | 1.75 * | n/c |
| 0.5% AEP | 1.55 * | n/c |
| 1% AEP | 1.38 | 1.80 |
| 2% AEP | 1.24 | 1.77 |
| 5% AEP | 0.97 | 1.63 |
| 10% AEP | 0.80 * | n/c |
| 20% AEP | 0.65 * | n/c |
| 50% AEP | 0.45 * | n/c |

**NOTES:** * Estimated as part of Reference 3.
n/c not calculated.
The peak levels at the lake and in the ocean are not coincident. For example the peak tailwater level occurs approximately four hours prior to the peak lake level.

One of the notable features of the above results is that for all design events, except the extreme flood, the ocean tailwater level (which includes ocean wave setup) is higher than the still water level in the lake. The difference is 0.42 m in a 1% AEP event and 0.66 m in a 5% AEP event.

- *Wave Runup:* The flood level at a particular location depends upon a combination of the still water design lake levels and the effects of local wind/wave action (wave runup). A separate study (Reference 2) was undertaken to examine the effects of wave runup at 48 locations. The results for Warners Bay indicate that wave runup may increase the 1% AEP still water design lake levels by approximately 0.22 m.

Sensitivity analyses were undertaken to determine the impacts of the following parameters:

- volume of rainfall runoff,
- ocean tailwater level,
- coincidence of rainfall and ocean high tide,
- bed friction in the Swansea Channel,
- bathymetry of the Swansea Channel,
- tide sequence,
- wind setup.

The results indicated that the critical factor is the ocean tailwater level. Changing this level results in a similar order of change in the lake level.

### 2.3.2 Lake Macquarie Floodplain Management Study

The Floodplain Management Study (Reference 3) firstly identified all the flood liable buildings surrounding the lake. It then examined various floodplain management measures (house raising, flood warning) for reducing flood damages. The effects of future development around the foreshore were also considered. A comprehensive community consultation program was implemented in order to ensure community input to the process.

### 2.3.3 Lake Macquarie Floodplain Management Plan

The Plan (Reference 4) provided a prioritised listing of management actions that should be implemented. No specific measures were proposed for the North Creek catchment or Warners Bay area.

## 2.4 Causes of Flooding

Flooding within the study area may occur as a result of a combination of the following factors:

- An elevated water level in Lake Macquarie due to intense rain over the entire catchment to Swansea. The water level rises when the rate of inflow to the Lake is greater than the outflow to the ocean. The Swansea Channel can act as a significant constriction to outflows.
- Elevated water levels within North Creek and its tributaries as a result of intense rain over the North Creek catchment. The levels in the creek may also be affected by an elevated water level in Lake Macquarie or by constrictions along their lengths (culverts, blockages, vegetation).
- Local runoff over a small area accumulating in low spots. Generally this occurs in areas which are relatively flat with little ground slope to facilitate drainage. The problem may be compounded by inadequate local drainage provisions and elevated Lake levels at the downstream outlet of the urban drainage (pipe, road drainage) system. Flooding as a result of this mechanism is not considered in this study.

- Elevated ocean levels. Generally elevated ocean levels occur as a result of storm surge (from a low pressure system) in combination with increased wave activity. This results in an elevated water level in the Lake and has been considered in Reference 1 in estimation of the design flood levels.
- Local wind conditions in Lake Macquarie generating waves and setup (wind wave action) across the fetch of Warners Bay.

These factors may occur in isolation or in combination with each other. Generally the peak water level in Lake Macquarie will occur several hours (or days) after the peak levels in North Creek. This is because the peak levels in the majority of the North Creek catchment are as a result of a short duration storm of say up to two hours duration. The peak level in Lake Macquarie results from a longer duration storm of say 48 hours or longer. For example in the event of 2-4 February 1990 the peak rainfall intensities for durations up to 6 hours occurred around 10:00am on 2$^{nd}$ February 1990. However the Lake rose in response to several days of rain and peaked around midday on 4$^{th}$ February 1990. The rainfall event causing the flooding of the creeks within the North Creek catchment may occur as part of a larger duration storm that causes flooding on Lake Macquarie (as happened in February 1990). Alternatively it may occur as an isolated thunder storm that is not part of a long duration event (as happened in April 2001).

# 3. DATA

## 3.1 Historical Flood Occurrences

A data search was carried out to identify the dates and magnitudes of historical floods. The search concentrated on the period since approximately 1970, as it was considered that data prior to this date would generally be of insufficient quality and quantity for model calibration. The following sources of data were investigated:

- Lake Macquarie City Council,
- Department of Infrastructure, Planning and Natural Resources,
- newspaper articles,
- previous reports,
- local residents.

Historical records (started in 1927) show that the level of the Lake has risen periodically in response to heavy rainfall over the catchment and/or elevated ocean levels. This has resulted in inundation of land and occasionally of buildings. The records show that the highest recorded Lake level was 1.25 mAHD in 1949 (observed at Marks Point) with the most recent major event occurring in February 1990 (1.0 mAHD observed at several locations on the eastern foreshore). Accurate recording of Lake levels has only been available since installation of the Marks Point and Belmont gauges in 1986 and Council's Speers Point gauge in 1989. The dates and approximate peak Lake levels of all known significant floods are shown in Table 4.

**Table 4:** Historical Flood Events in Lake Macquarie (in order of severity)

| Date | Approximate Peak Lake Level (mAHD) |
|---|---|
| 18 June 1949 | 1.25 |
| Easter 1946 | 1.2 |
| 11 June 1930 | 1.1 |
| 2 May 1964 | 1.0 |
| 4 February 1990 | 1.0 |
| 1953 | 0.9 |
| 1926/27 | 0.8 |
| 25 February 1981 | 0.8 |
| May 1974 | 0.8 |
| 4 March 1977 | 0.7 |

**Notes:**

1. Data obtained from Reference 1.
2. Levels are an average of several recorded heights.
3. It is likely that several floods prior to 1970 may not have been recorded.

Unfortunately there are no stream height gauges in the North Creek catchment or other means of determining the level of past flood events. Reliance must therefore be made on photographs, interviews with residents, Council records, newspaper articles or similar.

## 3.2 Data From Lake Macquarie City Council

Undoubtedly some flooding will have occurred in all of the above events, however the extent and magnitude cannot be accurately established. February 1990 is the only event for which Council has some reliable flood information (Table 5 and Figure 8). Peak levels are also available for the 1946, 1949 and 1951 events (also summarised in Table 5). The peak levels for these latter events were all 1.6 mAHD or less and located immediately upstream of The Esplanade. It is assumed that they were primarily influenced by Lake Macquarie flooding and consequently are considered of little value for North Creek calibration purposes. It is unclear why the 1951 event is not recorded as a high water level in the lake and thus shown in Table 4.

**Table 5:** Historical Flood Levels Recorded by Council

| Height (mAHD) | Date | Location | Comment | Modelled 1% AEP level (mAHD) |
|---|---|---|---|---|
| 7.70 | Feb 90 | Indoor Sports Centre, 314 Hillsborough Road | Inundated building by 0.05 m. It is unclear if the floor was inundated directly from floodwaters in the car park or by other means (other entrance or leakage). This site has undergone redevelopment in the last 20 years but it is not known if this was before or after the 1990 flood. | 7.5 |
| 6.63 | Feb 90 | 381 Hillsborough Road | Flooding is not a result of North Creek overtopping its banks along Hillsborough Road as the property is on the opposite side of the road to the creek. | N/A |
| 6.47 | Feb 90 | “The Willows”, 342 Hillsborough Road | Inundated property 0.48 m below floor level. This site has been redeveloped. This level would appear high as Hillsborough Road is at 6.0 mAHD. Possibly the level is as a result of inundation from local runoff rather than from the main creek. | 6.1 |
| 5.25 | Feb 90 | 7 King Street | This site has been redeveloped in 2003 which means a strict comparison of levels is not possible. This level appears high as the road level at King Street is at 4.6 mAHD and whilst there are reports of overtopping of the road the level appears high. | 5.7 |

| | | | | |
|---|---|---|---|---|
| 4.75 | Feb 90 | 14 Medcalf Street | No information available. | 5.4 |
| 3.21 | Feb 90 | 12 Walker Street | Inundated building by 0.45 m. This site has subsequently been redeveloped as a motor vehicle premise. There has also been a substantial amount of creek and channel works undertaken in the vicinity which will have affected flood levels. | 4.8 |
| 2.74 | Feb 90 | 5/7 Walker Street | Inundated building on 7 Walker Street by 0.3 m. This has been confirmed by local residents. There is a relatively steep flood gradient at this location as the bed of the creek falls rapidly from upstream of Walker Street. | approximately 3.0 |
| 2.37 | Feb 90 | 2 - 4 Margaret Street | Low lying land adjacent to the creek (refer Floodphoto 8). | 2.4 |
| 2.39 | Feb 90 | 3 Margaret Street | Inundated property 0.1 m below floor level. | 2.4 |
| 2.44 | Feb 90 | 24 Martin Street | Property inundated to top step of house. House floor not inundated. Level appears high compared to other levels in Martin Street. | 2.3 |
| 2.16 | Feb 90 | 26 Martin Street | No information available. | 2.3 |
| 2.15 | Feb 90 | 28 Martin Street | Property inundated to top step of house. House floor not inundated. | 2.3 |
| 2.18 | Feb 90 | 30 Martin Street | Property inundated up to fence line. House floor not inundated. | 2.3 |
| 2.29 | Feb 90 | 17 Martin Street | Property inundated to top step of house. House floor not inundated. Level appears high compared to other levels in Martin Street. | 2.3 |
| 2.12 | Feb 90 | 19 Martin Street | Property inundated up to house floor level. House floor not inundated. | 2.3 |
| 1.81 | Feb 90 | 45 Albert Street | Property inundated up to house floor level. House floor not inundated. | 2.1 |
| 1.81 | Feb 90 | 49 Albert Street | Property inundated up to house floor level. House floor not inundated. | 2.1 |
| 1.97 | Feb 90 | 53 Albert Street | No information available. | 2.1 |
| 1.94 | Feb 90 | 55 Albert Street | No information available. | 2.1 |
| 1.47 | Feb 90 | 11 Charles Street | No information available. | 2.1 |
| 1.79 | Feb 90 | 4 John Street | No information available. | 2.0 |
| 1.50 | Feb 90 | 6 John Street | No information available. | 2.0 |
| 1.60 | Feb 90 | 12 John Street | No information available. | 2.0 |
| 1.71 | Feb 90 | 20 Lake Street | No information available. | 2.0 |

| | | | | |
|---|---|---|---|---|
| 1.76 | Feb 90 | 436 The Esplanade | No information available. | 1.6 |
| 7.37* | Feb 90 | 82 Medcalf Street | Flooding not a result of main channel flooding | N/A |
| 7.30* | Feb 90 | 80 Medcalf Street | Flooding not a result of main channel flooding | N/A |
| 6.65* | Feb 90 | 76 Medcalf Street | Flooding not a result of main channel flooding | N/A |
| 7.22* | Feb 90 | 16 Albert Street | Flooding not a result of main channel flooding | N/A |
| 6.70* | Feb 90 | 2 Campbell Street | Flooding not a result of main channel flooding | N/A |
| 6.39* | Feb 90 | 6 Campbell Street | Flooding not a result of main channel flooding | N/A |
| 6.37* | Feb 90 | 14 Campbell Street | Flooding not a result of main channel flooding | N/A |
| 4.92* | Feb 90 | 20 Campbell Street | Flooding not a result of main channel flooding | N/A |
| 5.68 | Feb 90 | 22 Walker Street | On Kings Street Branch. There is a steep gradient within this reach and without knowing the precise location of the level it is not possible to accurately compare the actual versus modelled level. | N/A |
| 3.82 and 3.07 | Feb 90 | Downstream of 52 and 54 Medcalf Street | On Lakelands Branch. It is unclear if these levels relate to local runoff travelling east along the northern side of Medcalf Street and then heading south through the industrial properties, or from floodwaters overtopping the banks of the concrete lined channel. We believe the former explanation is more likely as the Lakelands basin was overtopped and the grade on Medcalf Street suggests that the majority of floodwaters did not cross the median strip immediately opposite the entrance to the channel. The exact locations of these levels within the properties is unknown. | N/A |
| 1.25* | 1946 | 48 Albert Street | No information available. | 2.1 |
| 1.20* | 1949 | The Esplanade | No information available. | 2.0 |
| 1.39* | 1949 | 10 Charles Street | No information available. | 2.0 |
| 1.62* | 1951 | 51 Albert Street | No information available. | 2.1 |
| 1.62* | 1951 | 26 Martin Street | No information available. | 2.3 |
| 1.20* | 1951 | The Esplanade | No information available. | 1.6 |

**Notes:** N/A - A direct comparison of levels it possible.

* - Levels not shown on Figure 8.

Council has a collection of photographs taken during flood events. A selection is provided below.

**Floodphoto 1:** Fairfax Road - February 1982

**Floodphoto 2:** Fairfax Road - February 1982

**Floodphoto 3:** Winterlake Street - February 1982

**Floodphoto 4:** Peachwood Close - February 1982

**Floodphoto 5:** Martin Street - May 1988

**Floodphoto 6:** The Esplanade Bridge - 4 Feb 1990

**Floodphoto 7:** Foreshore of Warners Bay - 4 Feb 1990


**Floodphoto 8:** 4 Margaret Street - 4 Feb 1990


**Floodphoto 9:** Medcalf/Albert Street - 2 Feb 1990

**Floodphoto 10:** Sweet Street - April 2001

**Floodphoto 11:** Sweet Street - April 2001

**Floodphoto 12:** Sweet Street - April 2001

Floodphoto 5 indicates a flood level of 2.0 to 2.1 mAHD in May 1988 (house floor at 2.2 mAHD) and Floodphotos 10, 11 and 12 a flood level of 4.7mAHD in April 2001. Floodphoto 8 is referred to in Table 5. None of the other floodphotos were able to provide data suitable for calibration purposes.

## 3.3 Questionnaire

Approximately 260 questionnaires were sent out to residents adjacent to the creek system. Some 25 responded and the results are summarised on Figures 5 and 6. Some 20 of the 25 respondents were subsequently contacted to see if they could provide additional information, particularly past flood levels. No further levels that would assist in the calibration were identified. The likely main reasons why no further levels were identified can be summarised as follows:

- many residents are new to the area and have therefore not experienced the historical flood events,
- many had levels in the lower parts of the floodplain but these areas were sufficiently covered by Council's flood level data,
- many residents did not record the peak level and were more interested in other water related issues (vegetation clearing, pollution),
- we were primarily interested in levels for the upper parts of the catchment where there are no records or data,
- many residents identified flooding as a result of local inundation (runoff from roads) rather than from creek flooding,
- it has been a long time since the last significant flood event in February 1990 and many residents will have forgotten about flooding.

One key point that was obtained from the resident feedback is that overtopping of Kings Street has occurred frequently in the past. Floodwaters have also inundated the car park at Warners Bay High School. Unfortunately there are no accurate records of the dates or the peak levels.

It is recommended that Council install maximum height recorders in the catchment in order to accurately record all future flood events. This would greatly assist with model calibration/verification and thus improving the confidence and accuracy of the design flood levels.

## 3.4 Rainfall

### 3.4.1 Historical Storms

Reference 1 indicates that there are nine daily read rainfall gauges in the Lake Macquarie catchment with the earliest recording taken at Wyee Post Office (Gauge No. 61082) in 1899. The nearest daily read gauge to the catchment is at Mt Hutton (Gauge No. 61359) which is just outside the North Creek catchment area. However, daily read rainfall gauges are of limited value for this study as the 24 hour rainfall totals provide no indication of the storm severity for the one to two hour duration peak storm bursts which generally cause flooding for this catchment.

Of much greater value are data from pluviometers which continuously record rainfalls in small (2 to 6 minute) time increments. Thus they can accurately define the critical intensities for the one to two hour events. There are three of these instruments within the catchment of Lake Macquarie with records for all of them commencing in the period 1987 to 1989. Two are located on Dora Creek and one on Cockle Creek.

The latter gauge (Barnsley) is the nearest pluviometer to the study catchment (approximately 6 kilometres to the west). Annual summaries have been obtained for this gauge and are provided in Table 6.

**Table 6:** Barnsley - Pluviometer Annual Maximum Rainfalls from 1989 to 2002

| **Duration (h)** | **Rainfall* (mm)** | **Date** | **Approximate ARI** |
|---|---|---|---|
| 0.5 | 47 (29) | 4 Nov 1990 | 1 in 50 |
| 1 | 66 (40) | 4 Nov 1990 | 1 in 50 |
| 2 | 76 (65) | 4 Nov 1990 | 1 in 20 |
| 3 | 82 | 2 Feb 1990 | 1 in 15 |
| 12 | 168 | 2 Feb 1990 | 1 in 40 |
| 24 | 241 | 2 Feb 1990 | Not Relevant |
| 48 | 392 | 2 Feb 1990 | Not Relevant |
| 72 | 423 | 2 Feb 1990 | Not Relevant |

**Note:** * the values in brackets indicate the maximum value on 2 February 1990

The above data clearly indicates that since 1989 the most intense period of rain recorded at Barnsley occurred in February and November 1990. From 1990 to 2001 the maximum 24 hour total barely exceeded the 3 hour total experienced on 2nd February 1990. The next most intense period occurred on 5th February 2002 and 28th March 2002. However these rainfalls were significantly less intense by between 20% (short duration) and 50% (24 hour duration).

Based upon the above rainfall data the only dates where flooding is likely to have been noticed on North Creek are 2nd February and 4th November 1990. No mention of the 4th November 1990 event has been made by either Council or residents. For this reason it is considered more likely that the storm event was very localised and did not produce flooding on North Creek.

No data are available to determine the rainfall intensities over the North Creek catchment for the other flood events listed in Table 4 or identified in the floodphotos.

### 3.4.2 Design Storms

Design rainfall intensities were obtained from Reference 5. These intensities and the total depths of rainfall for various storm durations and frequencies are summarised in Table 7.

**Table 7:** Design Rainfalls

| Duration | | Average Recurrence Interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1 in 5** | **1 in 10** | **1 in 20** | **1 in 50** | **1 in 100** | **1 in 200** | **1 in 500** |
| 30 minutes | intensity in mm/h | 65 | 73 | 84 | 98 | 109 | 120 | 135 |
| | depth in mm | 32 | 37 | 42 | 49 | 55 | 60 | 68 |
| 1 hour | intensity in mm/h | 44 | 50 | 58 | 68 | 75 | 83 | 93 |
| | depth in mm | 44 | 50 | 58 | 68 | 75 | 83 | 93 |
| 1.5 hours | intensity in mm/h | 35 | 39 | 45 | 53 | 59 | 65 | 74 |
| | depth in mm | 52 | 59 | 68 | 80 | 89 | 98 | 110 |
| 2 hours | intensity in mm/h | 29 | 33 | 38 | 45 | 50 | 55 | 62 |
| | depth in mm | 58 | 66 | 76 | 89 | 100 | 110 | 124 |
| 3 hours | intensity in mm/h | 23 | 26 | 30 | 35 | 39 | 43 | 49 |
| | depth in mm | 68 | 77 | 89 | 105 | 117 | 129 | 146 |
| 4.5 hours | intensity in mm/h | 18 | 20 | 23 | 27 | 30 | 34 | 38 |
| | depth in mm | 80 | 90 | 104 | 123 | 137 | 151 | 171 |
| 6 hours | intensity in mm/h | 15 | 17 | 20 | 23 | 26 | 28 | 32 |
| | depth in mm | 89 | 101 | 117 | 137 | 153 | 170 | 191 |
| 9 hours | intensity in mm/h | 12 | 13 | 15 | 18 | 20 | 22 | 25 |
| | depth in mm | 104 | 118 | 137 | 161 | 180 | 199 | 225 |
| 12 hours | intensity in mm/h | 10 | 11 | 13 | 15 | 17 | 19 | 221 |
| | depth in mm | 116 | 132 | 153 | 180 | 201 | 223 | 252 |

## 3.5 Survey

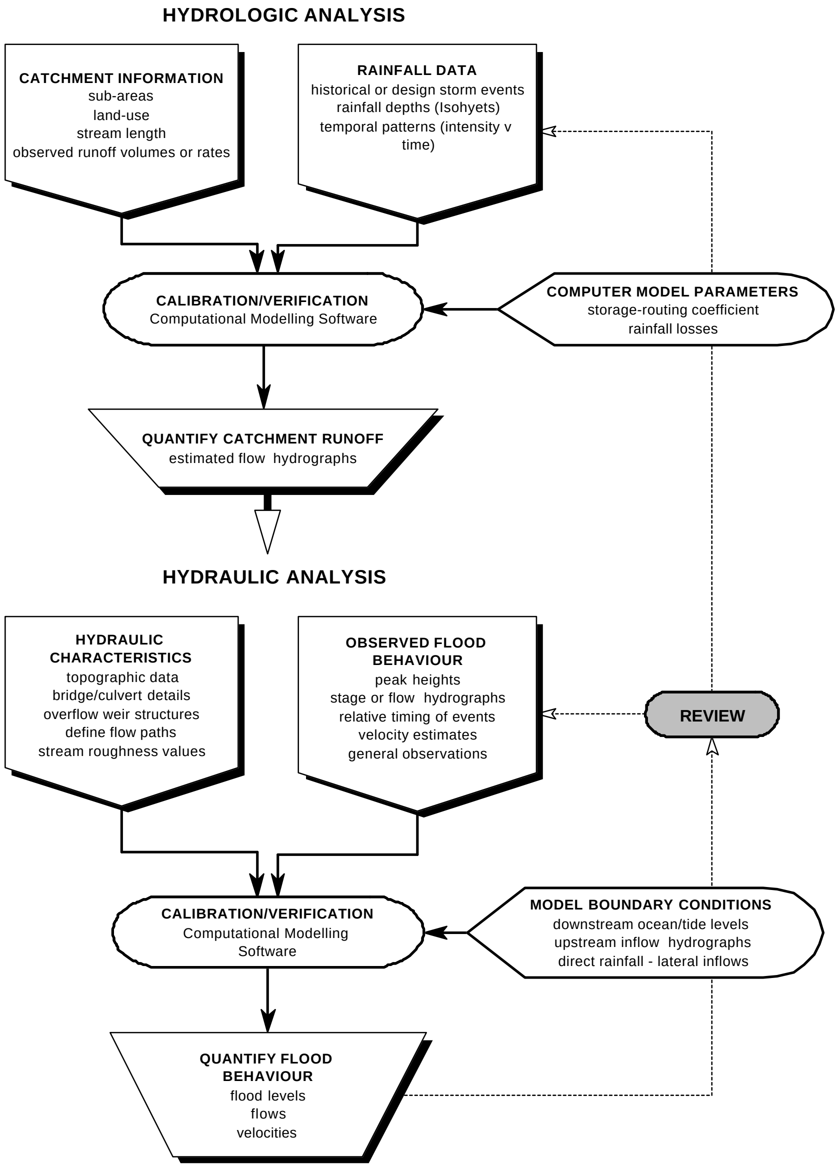
All of the survey data used in this study were provided by Lake Macquarie City Council and LMC$^2$ Consulting Surveyors. These include:

- a survey of the lake adjacent to the Lakelands residential area,
- a survey conducted by LMC$^2$ Consulting Surveyors in December 2003 to February 2004 specifically for this study. Approximately 70 cross-sections were surveyed as well as all the major structures (culverts, bridges, etc.). In addition the floor levels were obtained for approximately 160 buildings located on the floodplain. Council already had floor level data for approximately 100 other buildings in the floodplain. Following completion of the study it is noted that a limited amount of further floor level survey may still be required. This should be verified at the Floodplain Risk Management Study phase.

# 4. APPROACH ADOPTED

A diagrammatic representation of the Flood Study process is shown in Diagram 1. A hydrologic model (WBNM) was established for the entire catchment (Figure 7) and used to convert rainfall data into streamflow for input to a hydraulic (MIKE-11) model. The extents of the hydraulic model are indicated by the cross-sections shown on Figure 8. To ensure confidence in the results, both models require calibration and verification against observed historical events. However, with the limited amount of rainfall and flood data available and given the lack of any stream gaugings, the model calibration process relied upon comparing historical levels with design levels from the hydraulic model. The MIKE-11 model was used to quantify the design flood behaviour for a range of design storm events up to and including the Probable Maximum Flood (PMF).

**Diagram 1:** Flood Study Process



# 5. HYDROLOGIC MODELLING

## 5.1 General

Hydrologic models suitable for design flood estimation are described in AR&R 1987 (Reference 5). In current Australian engineering practice, examples of the more commonly used runoff routing models include RORB (Reference 6), RAFTS (Reference 7) and the Watershed Bounded Network Model (WBNM - Reference 8). These models allow the rainfall depth to vary both spatially and temporally over the catchment and readily lend themselves to calibration against recorded data.

A WBNM model was selected for the present study as it is widely used and the calibration parameters could be compared to studies undertaken using WBNM in other areas.

## 5.2 Model Configuration

The WBNM model simulates a catchment and its tributaries as a series of sub-catchment areas based on watershed boundaries linked together to replicate the rainfall/runoff process through the natural stream network. The adopted sub-catchment division is shown on Figure 7. The model input data includes definition of physical characteristics such as:

- surface-area,
- proportion urbanised or developed (imperviousness),
- stream shortening.

The model established for this study comprises a total of 35 sub-areas and included all tributaries upstream of the North Creek confluence with Lake Macquarie. The layout of the sub-areas was defined to provide a reasonable level of spatial detail within the catchment and to provide flow hydrographs at specific locations. For example, the model was structured to provide primary inflows at the upstream limits of the hydraulic model. Catchment areas for each sub-area were determined from 2 m topographic contours provided by Council in GIS format. Impervious areas were defined in the WBNM model based an analysis of existing development shown on Council's digital aerial photography.

The Lakelands stormwater detention basin was included as a "retarding basin" in the WBNM model. The outlet of the basin was simulated as a box culvert with weir flow across Medcalf Street and the initial water level in the basin was taken as the crest of the concrete weir surrounding the box culvert.

## 5.3 Calibration and Verification

### 5.3.1 Key Model Parameters

In calibrating the WBNM model, two main parameters can be varied to achieve a fit to observed data:

- *Rainfall losses:* Two values, initial loss and continuing loss, modify the amount of rainfall excess to be routed through the model storages.
- *Lag parameter:* The lag parameter ('C') affects the timing of the catchment response to the runoff process and is subject to catchment size, shape and slope.

### 5.3.2 WBNM Calibration

The WBNM model is calibrated by adjusting one or more of the model parameters in order to match observed streamflow hydrographs. However, as there were no observed flow data available within the North Creek catchment this process was not possible. Rather, the parameters adopted for this study were based on values recommended in AR&R and our own previous experience. A lag parameter value of C = 1.29 (recommended value for ungauged catchments), an initial loss of 0 mm and continuing loss of 2.5 mm/h were adopted. AR&R suggests values for initial loss ranging from 0 mm to 35 mm for eastern NSW catchments. Although it is a conservative assumption, the use of zero initial loss for the present study was considered justified in that prior to the flood producing rains, this relatively small catchment is likely to be wet from preceding rain. The adopted value of 2.5 mm/h for continuing loss has been found to be applicable over a wide range of catchments in Eastern Australia.

It is noted that a lag parameter C = value of 2.3, an initial loss of 80 mm and a continuing loss of 4 mm/h were adopted in Reference 1. These values were supported by a calibration to streamflow data on a tributary creek joining Dora Creek to the south-west of Lake Macquarie. These values were considered inappropriate for use on North Creek as the high initial loss means that for storms up to 3 hours duration there would be practically no runoff.

# 6. HYDRAULIC MODELLING

## 6.1 General Approach

Given the objectives of the study, the available data and in view of the nature of watercourses and potential flow paths within the study area, a one-dimensional (1D) flow representation provides the most efficient and effective assessment of flood behaviour. This is particularly so given that there are a number of concrete lined channels and structures, and the floodplain is relatively confined throughout much of the catchment.

The 1D hydraulic model of the floodplain was established using the MIKE-11 software package (Reference 9). The MIKE-11 model is widely used in flood engineering both within Australia and internationally. It is a proven tool for the dynamic modelling of branched networks comprising complex cross-sections and hydraulic control structures.

The extent of the MIKE-11 model layout for the North Creek floodplain is shown on Figure 8.

## 6.2 Model Calibration and Verification

The hydraulic efficiency of the creeks is mostly represented in the MIKE-11 model by the stream roughness or friction factor known as Manning's 'n'. This factor describes the net influence of:

- channel roughness,
- channel sinuosity,
- vegetation and other debris in the channel,
- bed forms and shapes.

The factors are generally adjusted along the length of the creek to obtain a calibration to historical flood height data. These same factors are then used for modelling the design flood events.

However, as indicated previously the questionnaire and search of Council records did not produce suitable historical flood data that could be used for model calibration. In the absence of a calibration process, the Manning's "n" values were derived from suitable references and experience. The adopted values are indicated in Table 8.

Three approaches are typically used in the MIKE-11 model to represent the hydraulic effects of structures in the floodplain. These are:

- the structure is represented by a culvert with an overflow weir at a higher level (generally for culverts),
- a closed cross section with an overflow weir at a higher level (generally for bridges),
- adjustment of the Manning's "n" value to represent increased friction or energy losses (generally for ill-defined structures or services bridges etc.).

**Table 8:** Adopted Manning's "n" Values

| Manning's "n" Value | Applied To |
|---|---|
| 0.015 | Concrete lined channel, clean of vegetation. |
| 0.03 | Concrete lined channel, with vegetation. Open water, clean of vegetation. |
| 0.04 | Open water, with vegetation. |
| 0.05 | Grassed areas. Channel with vegetation (not dense). |
| 0.07 | Overbank areas, with longer grass and sparse vegetation. |
| 0.08 | Overbank areas, with dense vegetation. Channel with reed type vegetation. |
| 0.12 | Main channel with dense vegetation. |
| 0.20 | Main channel with very dense vegetation. |

The adopted values were selected based upon an assessment of the vegetation density which existed within the floodplain at the time of the study. It should be noted that the extent of vegetation within the channel and floodplain can vary greatly from season to season and year to year. Maintenance (or the lack of it) can also have a significant impact on the adopted value.

# 7. DESIGN FLOOD RESULTS

## 7.1 Overview

There are two basic approaches to determining design flood levels, namely:

- *flood frequency analysis* - based upon a statistical analysis of the flood events, and
- *rainfall/runoff routing* - design rainfalls are processed by a suite of computer models to produce estimates of design flood behaviour.

A *rainfall/runoff routing* approach using the WBNM model was adopted for this study to derive design inflow hydrographs. These hydrographs then defined boundary conditions to produce corresponding design flood levels using the MIKE-11 hydraulic model. This approach reflects current engineering practice and is consistent with the quality and quantity of available data. The *flood frequency* approach requires a reasonably complete homogeneous record of flood levels/flows over a number of decades to give satisfactory results. No such records were available within the catchment.

## 7.2 Hydrologic Modelling

Design rainfall intensities and temporal patterns were derived from AR&R (Reference 5) and used as input for the WBNM model. Uniform depths of rainfall with zero areal-reduction factor were applied across the entire catchment.

Design inflow hydrographs for a range of durations (ranging from 30 minutes to 9 hours) for the 1% AEP event were input to the hydraulic model to determine the "critical storm duration" or the design storm that produces the highest peak flood levels along the creek. The 2 hour duration storm was found to be critical. This particular storm duration was then adopted for all other design event frequencies. In a similar manner, the 30 minute storm duration was found to be the critical duration for the PMF event.

For each design flood frequency, the WBNM model was used to define inflow hydrographs at appropriate locations throughout the catchment for input to the MIKE-11 model. The peak discharges obtained at the upstream limit of each branch are shown in Table 9 for various design events.

**Table 9:** Peak Design Discharges at the upstream limit of each Branch

| WBNM (Sub-area) | Branch | Peak Discharge ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | PMF | 0.5% AEP | 1% AEP | 2% AEP | 10% AEP | 20% AEP |
| Sea02 | Seaman Ave | 15.9 | 4.0 | 3.7 | 3.4 | 2.9 | 2.7 |
| West01 | Western Trib | 32.1 | 8.0 | 7.5 | 7.0 | 6.0 | 5.7 |
| King04 | King St | 63.5 | 13.5 | 12.5 | 11.6 | 9.7 | 9.0 |
| Lake02 | Lakelands | 48.9 | 11.4 | 10.3 | 9.5 | 7.7 | 6.9 |
| North04 | North | 51.0 | 10.6 | 9.8 | 9.0 | 7.5 | 6.9 |
| North05 | North | 19.7 | 4.9 | 4.6 | 4.2 | 3.6 | 3.3 |

**Notes:** All discharges quoted for a 2 hour storm duration except PMF (30 minute duration)
Refer to Figure 7 for WBNM Sub-area locations

## 7.3 Hydraulic Modelling

### 7.3.1 Tailwater Conditions - Lake Macquarie

In addition to runoff from the catchment, the lower reaches of North Creek are influenced by backwater effects resulting from Lake Macquarie flooding. As noted previously, these two distinct flooding mechanisms may or may not result from the same storm. The North Creek catchment is much smaller in size (5.3 $km^2$) compared to the total area draining to Lake Macquarie (570 $km^2$). Hence, for a given flood event, it is more likely that the Lake level would peak after the corresponding flood peak occurs in North Creek. It is acknowledged however that this may not necessarily be the case. Consideration must therefore be given to accounting for the joint probability of coincident flooding from both catchment runoff and backwater effects from the Lake.

A full joint probability analysis is beyond the scope of the present study. Traditionally, it is common practice to estimate design flood levels in these situations using a 'peak envelope' approach that adopts the highest of the predicted levels from the two mechanisms. However, in view of the limited model calibration undertaken for the present study, a more conservative approach has been adopted where the flood peak in the Lake is assumed to coincide with the corresponding flood peak in the creek. Hence for each design event, the relevant design flows are used in conjunction with the corresponding design peak flood level for Lake Macquarie (see Table 3). This simplified conservative approach is considered appropriate given that there is a relatively short transitional zone/reach between the peak levels for the two mechanisms.

A sensitivity analysis of the relative impacts of assuming different tailwater conditions is presented in Section 7.5.

### 7.3.2 Calibration

As indicated previously a rigorous calibration of the hydrologic and hydraulic models was not possible. However a comparison was made between the historical flood levels recorded in February 1990 and the 1% AEP design levels (refer Table 3 and Figure 8). All these levels were obtained from Council records and were accurately surveyed at the time. One limitation of these data is that there is no record of the exact location within the property. For the lower floodplain downstream of Margaret Street this is not an issue as there is practically no flood gradient across the property. However for properties further upstream, particularly those with a long frontage to the creek there will be a strong gradient. This means that it is not possible to accurately compare the historical and design flood levels with any certainty as to the correct location for comparison.

It is recommended that a more rigorous procedure be adopted for collecting flood data along North Creek in future flood events. This could either involve installation of maximum height recorders or the photographing of all recorded flood levels the day after the event. Generally two photographs should be taken, one to show the wider view and a second to show more detail of the location. Hopefully this procedure will ensure that the quality and quantity of all future levels collected will be improved.

### 7.3.3 Blockage Assessment

Given the combination of urban development and natural bushland within the catchment, the potential blockage of culverts and stream crossings by debris can increase the flood levels experienced along all parts of the creek system. The role of blockages in exacerbating flood impacts during the August 1998 storm in North Wollongong highlights the importance of considering the implications for blockages in design flood assessment.

Based on numerous site inspections, and discussions with Council officers and local residents, the issue of culvert blockages is particularly relevant for North Creek. Field observations and related anecdotal evidence indicates that accumulated vegetative debris has been observed or experienced at several of the crossings.

Evidence from the August 1998 North Wollongong storm indicates that there is the potential for culvert openings less than 6 m width to be fully blocked during a flood. This observation would imply that the majority of the creek crossings within the catchment could be either partially or fully blocked. An exception to this would be the:

- road bridge at The Esplanade,
- pedestrian bridge at John Street,
- pedestrian bridge at Albert Street,
- road bridge at Walker Street.

To quantify the impacts of potential blockages on design flood behaviour, several different blockage scenarios (Table 10) based on the 1% AEP event were simulated using the MIKE-11 model.

**Table 10:** Blockage Assessment Modelling Scenarios - 1% AEP Event

| Scenario | Description |
|---|---|
| Base Case | No blockages |
| Scenario 1 | All culverts/bridges 50% blocked except those indicated in Table 1 as being excluded. |
| Scenario 2 | All culverts/bridges 100% blocked except those indicated as being excluded in Table 1. |

Figure 9 compares the resulting peak height flood profiles along selected reaches of North Creek for the different blockage scenarios.

As expected, the results indicate that the inclusion of 100% blockage at all culverts (Scenario 2) has significant impacts on flood levels in the vicinity of all stream crossings.

## 7.4 Design Events

Peak height profiles for the 20%, 10%, 5%, 2%, 1%, 0.5% AEP events and the PMF assuming blockage Scenario 2 conditions (refer Table 10) are provided on Figures 10a to 10e. A listing of the design flood results (peak flood levels and flows) at each model cross-section location is included as Appendix C.

For the purposes of floodplain risk management in NSW the floodplain is divided into one of three Hydraulic categories (floodway, flood storage or flood fringe) and two Hazard categories (Low or High). These terms are defined in Appendix A with further details of this process available in the NSW Government's Floodplain Management Manual (January 2001). A map of the hydraulic and hazard categorization for the North Creek floodplain in the 1% AEP event is presented as Figure 11.

The Hydraulic categorisation was determined qualitatively based upon the available hydraulic and survey information together with our knowledge of the North Creek catchment and experience.

The Hazard categorisation was determined based upon the available hydraulic and survey information. High Hazard was assumed where either the depth is 1m or greater, or the product of peak velocity and peak depth (V * D) is 1 or greater. It should be noted that only limited survey information is available and considerable interpretation has been required. As indicated in the NSW Government's Floodplain Management Manual this process of Hazard categorisation is **Provisional** and should be refined at a later date to reflect other factors that influence hazard (such as warning time available, flood readiness, rate of rise, duration of flooding, evacuation problems, effective flood access and the type of development).

Design flood contours for the PMF, 0.5%, 1% and 5% AEP events (all assume 100% blockage) are provided on Figures 12a to 12d respectively.

## 7.5 Results from Wind Wave Studies

Reference 2 examined the effects of wind wave action at 48 sites around the foreshore of Lake Macquarie. Appendix B provides a copy of the information at Site 48: Warners Bay North. The results indicate that the 1% AEP flood level from wind/wave action is 1.6 m AHD (0.22 m greater than the 1% AEP stillwater lake level). This level is within the 0.5m freeboard above the 1% AEP flood level for the Lake that is adopted by Council as the minimum floor level. As the 0.5m freeboard is generally included in order to take account of wind/wave action (amongst other factors) it is not recommended to increase the 1% AEP design flood level for properties fronting the foreshore. The impacts of the wind/wave action on structural requirements for buildings or other structures should be examined in accordance with those given in Reference 4.

## 7.6 Sensitivity Analyses

Given the lack of reliable historical flood level and streamflow data, a rigorous calibration of the MIKE-11 model was not possible. In view of this, sensitivity analyses were undertaken to determine the potential impacts of varying key model parameters on the simulated flood behaviour.

The following sensitivity analyses were carried out for the 1% AEP event (assuming no blockage):

- ±25% variation in Manning's 'n' value,
- ±10% variation in rainfall,
- ±20% variation in WBNM storage parameter,
- ±0.5 m change in tailwater level for Lake Macquarie.

A summary of results at key locations for the above sensitivity scenarios are provided in Table 11 and Figure 13.

**Table 11:** Sensitivity Analyses - 1% AEP Event - (assuming no blockage)

| MIKE-11 Chainage (m) | Change in Level (metres) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Manning's n | | Rainfall | | WBNM 'C' Value | | Tailwater | |
| | +25% | -25% | +10% | -10% | +20% | -20% | 1.88 mAHD | 0.88 mAHD |
| **King Street Branch** | | | | | | | | |
| 0 - 162 | 0.11 to 0.21 | -0.33 to -0.08 | 0.16 to 0.05 | -0.17 to -0.06 | 0.16 to 0.08 | -0.15 to 0.06 | 0.00 to 0.01 | 0.00 |
| 162 - 236 | <0.1 | <-0.1 | <0.1 | <-0.1 | <0.1 | <-0.1 | 0.00 | 0.00 |
| **Lakelands Branch** | | | | | | | | |
| 0 - 208 | <0.1 | -0.12 to -0.09 | <0.1 | <-0.1 | <0.05 | <-0.05 | 0.22 to 0.00 | -0.06 to 0.00 |
| 208 - 267 | 0.1 - 0.12 | -0.16 - -0.12 | <0.1 | <-0.1 | <0.05 | -0.02 | 0.00 | 0.00 |
| **North Creek Main** | | | | | | | | |
| 0 -866 | <0.1 | <-0.1 | 0.00 to 0.12 | 0.00 to -0.12 | <0.1 | <-0.1 | 0.20 to 0.50 | -0.50 to -0.05 |
| 866 - 1111 | 0.09 to 0.22 | -0.10 to -0.34 | 0.08 to 0.16 | -0.08 to -0.17 | 0.05 to 0.16 | -0.04 to -0.15 | 0.20 to 0.01 | -0.05 to -0.01 |
| 1111 - 1602 | 0.22 | -0.34 | 0.16 | -0.18 | 0.16 | -0.15 | 0.00 | 0.00 |

| MIKE-11 Chainage (m) | Change in Level (metres) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Manning's n | | Rainfall | | WBNM 'C' Value | | Tailwater | |
| | +25% | -25% | +10% | -10% | +20% | -20% | 1.88 mAHD | 0.88 mAHD |
| | to 0.11 | to -0.14 | to 0.09 | to -0.09 | to 0.1 | to -0.08 | | |
| 1602 - 2020 | 0.09 to 0.12 | -0.16 to 0.00 | <0.1 | <-0.1 | <0.1 | <-0.1 | 0.00 | 0.00 |
| **Seaman Avenue Branch** | | | | | | | | |
| 0 - 108 | <0.1 | -0.12 to -0.05 | 0.04 to 0.12 | -0.12 to -0.05 | <0.1 | <-0.1 | 0.01 to 0.31 | -0.14 to 0.00 |
| 108 - 420 | 0.00 to 0.11 | -0.12 to 0.00 | <0.1 | <-0.1 | <0.05 | <-0.05 | 0.00 | 0.00 |
| **Western Tributary Main** | | | | | | | | |
| 0 - 221 | 0.05 | <-0.1 | 0.12 to 0.04 | -0.12 to -0.05 | <0.1 | <-0.1 | 0.019 to 0.31 | -0.14 to -0.01 |
| 221 - 778 | <0.1 | -0.01 to -0.11 | <0.1 | <-0.1 | <0.1 | <-0.1 | 0.00 to 0.03 | 0.00 |
| 778 - 1171 | <0.1 | <-0.1 | <0.05 | <-0.05 | <0.05 | <-0.05 | 0.00 | 0.00 |

**Note:** Results are provided as a relative change in level (in metres) compared to the 1% AEP base case event with NO blockage.

### *Variation in Manning's 'n'*

In general, variations in Manning's 'n' roughness values of +/-25% did not result in significant variations in predicted peak flood levels. The middle reaches of North Creek near the King Street confluence was found to be the most sensitive area with predicted levels varying by as much as -0.34 m. These results reflect the potential uncertainty in the modelling (due to the lack of historical data available for calibration/verification) and highlight the relative impacts of assumed bed roughness on predicted flood levels. However, these results are still within the expected order of accuracy for the hydraulic modelling.

### *Variation in Design Rainfall*

Changes to the design rainfall produced minimal changes, generally less than 0.1 m, in the predicted flood peaks throughout the model.

### *Variation in WBNM 'C' Value*

The peak flood levels predicted by the hydraulic model were found to vary by <0.1 m with variations of ±20% in the WBNM lag parameter, except at the King Street confluence with North Creek (for similar reasons given above), where the variation was up to 0.16 m. In part, this is not unexpected as it reflects the fact that the local sub-area hydrographs from the WBNM model have been defined as lateral inflows distributed throughout the MIKE11 model. As the hydraulic model can better simulate in-channel flow routing effects compared to the WBNM model, the predicted levels are relatively insensitive to the adopted WBNM lag parameter.

### *Variation in Tailwater Level*

The results above demonstrate that for a significant flood event, the impacts of assumed tailwater conditions are confined to the very lower reaches of North Creek. Model results indicate that even with a relatively high tailwater (1.88 mAHD), the backwater effects did not extend beyond approximately 1km. For low tailwater conditions, the results also indicated that backwater effects do not extend upstream of approximately 1km upstream. This tailwater assessment also serves to highlight the potential impacts that may occur with a Greenhouse induced sea level rise.

# 8. FLOOD DAMAGES ASSESSMENT

## 8.1 Background

A flood damages assessment was also undertaken as part of this Flood Study based upon the following data sources:

- the floor and ground level data for 97 properties provided by Council from their database,
- a floor and ground level survey of 165 properties undertaken by LMC[2] in December 2003/January 2004 (at the same time as the cross-section survey).

Each of the 262 properties was "assigned" a MIKE11 model chainage which was then used to obtain a flood level for the full range of design flood events. This level was then used with the appropriate formulae and damages curve to determine the tangible property damages for each event. Some floors were subsequently omitted from the analysis as the buildings were considered to be too far from the main creek system and therefore not affected by mainstream flooding.

There are a number of issues with "assigning" a single flood level to a property to estimate flood damages. These include:

- no account is taken of the actual openings where floodwaters could enter a building relative to the applicable flood gradient. Thus a rear door may allow the water to enter rather than the front door,
- the level "assigned" is usually taken as the flood level midway across the property. For areas with low flood gradients this is appropriate, however in "long" factories or areas with strong flood gradients this may not necessarily be appropriate,
- the "assigned" flood level is only relevant for estimating flood damages and should not be used for development control purposes. These latter levels must be obtained from interpolation of the flood contour maps,
- at many localities floodwaters may enter properties as "local overland flow" rather than mainstream flooding and this has not been accounted for in this assessment.

## 8.2 Assessment of Tangible Flood Damages

Quantification of tangible flood damages is generally based upon data derived from post-flood damage surveys obtained following historical flood events. An alternative procedure is to undertake a self-assessment survey of the flood liable properties. This latter approach is more expensive and may not accurately reflect what actually occurs in a flood. Floods by their nature are unpredictable and conditions variable. It is therefore unlikely that a self-assessment survey would have predicted the scale or extent of the damages which occurred in Nyngan in 1990 or North Wollongong in August 1998. For this reason it was decided to use the post-flood damage approach in assessing flood damages for the North Creek study area.

The most comprehensive damage surveys are those carried out for Sydney (Georges River -1986), Nyngan (1990) and Inverell (1991). Some of the problems in applying data from these studies to other areas can be summarised as follows:

- varying building construction methods, e.g. slab on ground, pier, brick, timber,
- different average age of the buildings in the area,
- the quality of buildings may differ greatly,
- inflation must be taken into account,
- different fixtures within buildings, e.g. air-conditioning units, machinery, etc.,
- change in internal fit out of buildings over the years or in different areas, e.g. more carpets and less linoleum or change in kitchen/bathroom cupboard material,
- external (yard) damages can vary greatly. For example in some areas vehicles can be readily moved whilst in other areas it is not possible,
- different approaches in assessing flood damages. Are the damages assessed on a "replacement" or a "repair and reinstate where possible" basis? Some surveys include structural damage within internal damage whilst others do not,
- varying warning times between communities means that the potential versus actual damage ratio may change significantly,
- variations in flood awareness of the community.

## 8.3 Tangible Damages - Residential Properties

Tangible direct damages are generally calculated under the following components:

- Internal,
- Structural,
- External.

Tangible indirect damages can be subdivided into the following groups:

- accommodation and living expenses,
- loss of income,
- clean up activities.

Damages may be calculated as either estimated actual damages or estimated potential damages. If potential damages are calculated an Actual/Potential (A/P) ratio is assigned based upon (as well as other factors) the likely flood awareness of the community and the available warning time.

The flood awareness of the North Creek community is likely to be low and the available flood warning time short. However, there is generally relatively easy access to high ground for all residents. Based upon the limited data available it is considered that the A/P ratio for Lake Macquarie would most likely be similar to that applicable at Nyngan and Inverell.

The approach adopted for estimating flood damages was therefore based on that derived from the Nyngan and Inverell flood damages surveys with updating for inflation and the different type of buildings in the catchment.

### 8.3.1 Direct Internal Damages

Internal damages are based upon the following formulae:

$$\frac{D}{D_2} = 0.06 + 1.42H - 0.62H^2 \quad for\ H < 1.0m$$

$$\frac{D}{D_2} = 0.75 + 0.12H \quad for\ H > 1.0m$$

where,

| | | |
|---|---|---|
| H | = | height of flooding above floor level (m) |
| D | = | damage at height (H) above floor level |
| $D_2$ | = | damage at height of 2 m above floor level |

At Nyngan and Inverell $D_2$ was found to be $12,500 for small houses and $14,500 for medium/large houses. These values are in $1991's. The reference states that *"Damages to individual properties scatter widely around the relationship, which can only be used to reliably estimate the aggregated damage to a collection of flood prone dwellings and not the damage to a single dwelling."*. Structural damages were not included in the above figures.

Allowing for inflation and differences in the types of buildings and their contents, a $D_2$ value of $40,000 was adopted for this study.

### 8.3.2 Direct Structural Damages

Structural damages were assumed to be a linear relationship from $0 at 0 m to $10,000 at 0.5 m. Above this value it was considered that there would be no additional structural damages.

In floods larger than the 1% AEP event there is the possibility that some buildings may collapse or have to be destroyed. The cost of these damages have not been included in the analysis.

### 8.3.3 Direct External Damages

External damages (laundry/garage/yard/vehicle) were assumed to be a linear relationship from $0 at 0 m above ground level to $2,000 at 0.5 m. This assumes that the majority of vehicles are moved by residents.

### 8.3.4 Indirect Damages

Indirect damages were assumed to be a linear relationship from $0 at 0 m above floor level to a maximum of $4,000 at 0.5 m.

### 8.3.5 Summary

Table 12 provides a summary of the adopted residential depth/damage relationship.

**Table 12:** Adopted Residential Depth/Damage Relationship

| Depth over Floor/Yard (m) | Internal Damages ($) | Structural Damages ($) | External Damages ($) | Indirect Damages ($) | Total ($) |
|---|---|---|---|---|---|
| 0.1 | 7840 | 2000 | 400 | 800 | 11040 |
| 0.3 | 17280 | 6000 | 1200 | 2400 | 26880 |
| 0.5 | 24800 | 10000 | 2000 | 4000 | 40800 |
| 1.0 | 35200 | 10000 | 2000 | 4000 | 51200 |
| 1.5 | 37200 | 10000 | 2000 | 4000 | 53200 |
| 2.0 | 39600 | 10000 | 2000 | 4000 | 55600 |

## 8.4 Tangible Damages - Non-Residential Properties

Damages to commercial, industrial or public properties cannot be estimated as good as damages to residential properties for a number of reasons, including:

- less post-flood surveys have been undertaken in Australia,
- some properties are insured against flood loss, if this is the case the insurance premiums need to be considered in assessing flood damages,
- flood damages can vary greatly from building to building. For example an electrical retail shop may suffer more damages than say a sandwich shop, as the latter has less high value stock. On the other hand there is more opportunity to reduce this actual damage in the former as the items can be easily moved by staff if there is sufficient warning and awareness. In large premises the flood damages depends on the care taken in moving stock. Carpets are high value items and cannot be easily moved whilst the cars in a car showroom can generally be easily moved if there is warning,
- the damages can vary from year to year as the usage of a particular premises changes. Damages may also vary on a seasonal or weekly basis depending upon the nature of business,
- indirect damages (loss of trade) may be significant and these are difficult to properly quantify.

For this assessment the damage relationship was assumed to be the same as for residential, except that a multiplier factor was used to reflect the likely increase in damages.

## 8.5 Results

The number of buildings inundated above floor level along with the estimated flood damages are summarised for the range of design flood events in Table 13. Figure 14 shows the distribution of inundated buildings across the floodplain and also indicates the flood event in which the building is first inundated.

**Table 13:** Flood Damages

| Event | Number of Buildings Inundated above Floor Level | | Total Tangible Flood Damages ($) |
|---|---|---|---|
| | Residential | Non-Residential | |
| PMF | 157 | 27 | 10,300 000 |
| 0.5% AEP | 47 | 11 | 2,000,000 |
| 1% AEP | 42 | 11 | 1,630,000 |
| 2% AEP | 33 | 11 | 1,290,000 |
| 5% AEP | 24 | 9 | 960,000 |
| 10% AEP | 14 | 8 | 720,000 |
| 20% AEP | 7 | 8 | 610,000 |

The Average Annual Damages (AAD) based on the above values is estimated to be $440,000.

# 9. ACKNOWLEDGEMENTS

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- Department of Infrastructure, Planning and Natural Resources,
- Residents of the North Creek catchment.

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# APPENDIX A: GLOSSARY OF TERMS

# APPENDIX A: GLOSSARY OF TERMS

| | |
|---|---|
| **acid sulfate soils** | Are sediments which contain sulfide mineral pyrite. These sediments may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual prepared by the Acid Sulfate Soil Management Advisory Committee (ASSMAC). |
| **Annual Exceedance Probability (AEP)** | The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 $m^3/s$ has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a peak flood discharge of 500 $m^3/s$ or larger occurring in any one year (see average recurrence interval). |
| **Australian Height Datum (AHD)** | A common national surface level datum approximately corresponding to mean sea level. |
| **Average Annual Damage (AAD)** | Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time. |
| **Average Recurrence Interval (ARI)** | The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. |
| **caravan and moveable home parks** | Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the Local Government Act, 1993. |
| **catchment** | The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location. |
| **consent authority** | The council, government agency or person having the function to determine a development application for land use under the Environmental Planning and Assessment Act (EP&A Act). The consent authority is most often the council, however there are instances where legislation or an environmental planning instrument (EPI) specifies a Minister or public authority (other than a council), or the Director General of Planning NSW, as having the function to determine an application. |
| **development** | Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act).<br><br>**infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.<br><br>**new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.<br><br>**redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services. |

| | |
|---|---|
| **disaster plan (DISPLAN)** | A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies. |
| **discharge** | The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second ($m^3/s$). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s). |
| **ecologically sustainable development (ESD)** | Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual are related to ESD. |
| **effective warning time** | The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions. |
| **emergency management** | A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding. |
| **flash flooding** | Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain. |
| **flood** | Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami. |
| **flood education, awareness and readiness** | **flood education** seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.<br><br>**flood awareness** is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.<br><br>**flood readiness** is an ability to react within the effective warning time. |
| **flood fringe areas** | The remaining area of flood prone land after floodway and flood storage areas have been defined. |
| **flood liable land** | Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land now covers the whole of the floodplain, not just that part below the flood planning level, as indicated in the 1986 Floodplain Development Manual (see flood planning area). |
| **flood mitigation standard** | The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding. |
| **floodplain** | Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land. |
| **floodplain risk management options** | The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options. |
| **floodplain risk management plan** | A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives. |

**flood plan (local)**
A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.

**flood planning area**
The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Floodplain Development Manual.

**Flood Planning Levels (FPLs)**
The combination of flood levels and freeboards selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans. The concept of flood planning levels supersedes the "standard flood event" of the first edition of this manual.

**flood proofing**
A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.

**flood prone land**
Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.

**flood risk**
Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.

**existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain.

**future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain.

**continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

**flood storage areas**
Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

**floodway areas**
Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.

**freeboard**
A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted flood planning level and the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change. Freeboard is included in the flood planning level.

**habitable room**
**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.

**in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

**hazard**
A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Floodplain Management Manual.

**hydraulics** — Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

**hydrograph** — A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

**hydrology** — Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

**local overland flooding** — Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

**local drainage** — Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

**mainstream flooding** — Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

**major drainage** — Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or

- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or

- the potential to affect a number of buildings along the major flow path.

**mathematical/computer models** — The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

**merit approach** — The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

**minor, moderate and major flooding** — Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

**minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

**moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

**major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

| | |
|---|---|
| **modification measures** | Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 and further discussion is given in Appendix J of the Floodplain Management Manual. |
| **peak discharge** | The maximum discharge occurring during a flood event. |
| **Probable Maximum Flood (PMF)** | The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event should be addressed in a Floodplain Risk Management study. |
| **Probable Maximum Precipitation (PMP)** | The greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to the estimation of the probable maximum flood. |
| **probability** | A statistical measure of the expected change of flooding (see annual exceedance probability). |
| **risk** | Change of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment. |
| **runoff** | The amount of rainfall which actually ends up as streamflow, also known as rainfall excess. |
| **stage** | Equivalent to “water level”. Both are measured with reference to a specified datum. |
| **stage hydrograph** | A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum. |
| **survey plan** | A plan prepared by a registered surveyor. |
| **water surface profile** | A graph showing the flood stage at any given location along a watercourse at a particular time. |
| **wind fetch** | The horizontal distance in the direction of wind over which wind waves are generated. |

# APPENDIX B: SECTIONS FROM LAKE MACQUARIE FLOOD STUDY

## 4.48 Warners Bay North

### Site Description

The site, shown in Figure 4.48, was characterised by a long grass embankment.

### Design Flood Levels

Estimated design flood levels are shown in Tables 4.48a and 4.48b for the cross-section observed at the site.

**Table 4.48a - 1% AEP Design Flood Level, Warners Bay North**

| Design Water Level (m AHD) | Design Wind Wave Climate | | Type of Cross-section | Flood Level (m AHD) | Recommended Design Flood Level) (m AHD) |
|---|---|---|---|---|---|
| | Hs (m) | Tp (sec) | | | |
| 1.38<br>0.4 | 0.4<br>1.1 | 2.0<br>3.1 | 4<br>1 | 1.6<br>1.0 | 1.6 |

**Table 4.48b - 5% AEP Design Flood Level, Warners Bay North**

| Design Water Level (m AHD) | Design Wind Wave Climate | | Type of Cross-section | Flood Level (m AHD) | Recommended Design Flood Level) (m AHD) |
|---|---|---|---|---|---|
| | Hs (m) | Tp (sec) | | | |
| 0.97<br>0.4 | 0.4<br>1.0 | 2.0<br>2.9 | 1<br>1 | 1.2<br>0.9 | 1.2 |

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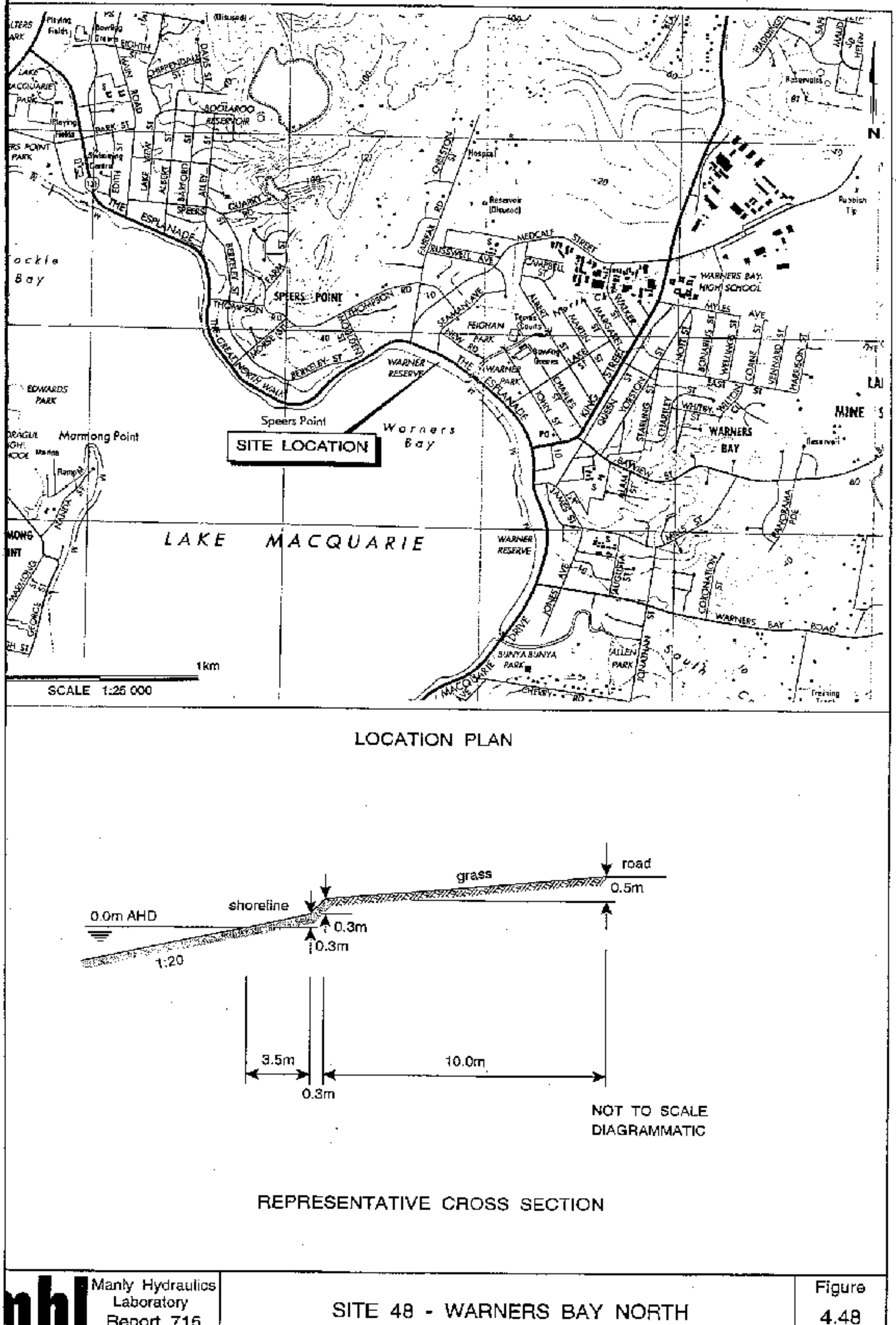


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SITE 48 - WARNERS BAY NORTH

Figure 4.48

# APPENDIX C: MIKE-11 RESULTS

| River Name | MIKE11 Chainage (m) | PMF (100% Blockage) | | | 0.5% AEP (100% Blockage) | | | 1% AEP (100% Blockage) | | | 2% AEP (100% Blockage) | | | 5% AEP (100% Blockage) | | | 10% AEP (100% Blockage) | | | 20% AEP (100% Blockage) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) |
| KING STREET | 0 | 7.24 | 0.94 | 66.15 | 5.09 | 0.3 | 13.9 | 5.03 | 0.3 | 12.9 | 4.94 | 0.3 | 11.9 | 4.86 | 0.3 | 11.1 | 4.71 | 0.3 | 9.8 | 4.63 | 0.3 | 9.1 |
| KING STREET | 19.16 | 7.25 | 0.89 | 65.82 | 5.09 | 0.3 | 13.9 | 5.03 | 0.3 | 12.9 | 4.95 | 0.3 | 11.9 | 4.86 | 0.3 | 11.0 | 4.71 | 0.3 | 9.8 | 4.63 | 0.3 | 9.2 |
| KING STREET | 32.62 | 7.28 | 1.00 | 65.87 | 5.09 | 0.4 | 13.9 | 5.03 | 0.4 | 12.9 | 4.94 | 0.4 | 11.8 | 4.86 | 0.4 | 11.0 | 4.71 | 0.4 | 9.9 | 4.63 | 0.4 | 9.2 |
| KING STREET | 46.07 | 7.28 | 1.34 | 66.05 | 5.10 | 0.6 | 13.9 | 5.04 | 0.6 | 12.9 | 4.96 | 0.6 | 11.8 | 4.87 | 0.6 | 11.0 | 4.73 | 0.7 | 9.9 | 4.65 | 0.7 | 9.2 |
| KING STREET | 59.53 | 7.26 | 1.52 | 66.30 | 5.17 | 0.9 | 13.9 | 5.11 | 0.9 | 12.9 | 5.03 | 0.9 | 11.9 | 4.95 | 0.9 | 11.1 | 4.82 | 0.9 | 10.0 | 4.74 | 0.9 | 9.3 |
| KING STREET | 78.49 | 7.27 | 1.39 | 65.76 | 5.26 | 1.0 | 14.0 | 5.20 | 1.0 | 12.9 | 5.13 | 1.0 | 11.9 | 5.06 | 1.0 | 11.1 | 4.95 | 1.0 | 10.0 | 4.87 | 0.9 | 9.3 |
| KING STREET | 97.44 | 7.28 | 1.47 | 66.01 | 5.32 | 1.1 | 14.0 | 5.27 | 1.1 | 13.0 | 5.20 | 1.1 | 12.0 | 5.14 | 1.1 | 11.2 | 5.04 | 1.0 | 10.1 | 4.97 | 1.0 | 9.4 |
| KING STREET | 116.39 | 7.27 | 1.64 | 66.00 | 5.38 | 1.2 | 14.0 | 5.33 | 1.2 | 13.0 | 5.27 | 1.2 | 12.0 | 5.21 | 1.2 | 11.2 | 5.12 | 1.2 | 10.1 | 5.06 | 1.2 | 9.4 |
| KING STREET | 135.35 | 7.28 | 1.69 | 64.16 | 5.45 | 1.3 | 13.7 | 5.40 | 1.3 | 12.7 | 5.34 | 1.3 | 11.7 | 5.29 | 1.3 | 10.9 | 5.21 | 1.3 | 9.8 | 5.15 | 1.3 | 9.2 |
| KING STREET | 147 | 8.20 | 2.02 | 62.68 | 7.53 | 0.3 | 13.4 | 7.49 | 0.3 | 12.5 | 7.44 | 0.3 | 11.5 | 7.39 | 0.2 | 10.7 | 7.33 | 0.2 | 9.7 | 7.30 | 0.2 | 9.0 |
| KING STREET | 162.16 | 8.20 | 2.68 | 62.73 | 7.53 | 0.4 | 13.4 | 7.49 | 0.3 | 12.5 | 7.44 | 0.3 | 11.5 | 7.39 | 0.3 | 10.8 | 7.33 | 0.3 | 9.7 | 7.30 | 0.3 | 9.0 |
| KING STREET | 177.33 | 8.18 | 3.28 | 62.94 | 7.53 | 0.5 | 13.5 | 7.49 | 0.5 | 12.5 | 7.44 | 0.4 | 11.5 | 7.39 | 0.4 | 10.8 | 7.33 | 0.4 | 9.7 | 7.29 | 0.4 | 9.0 |
| KING STREET | 192.49 | 8.18 | 3.78 | 63.14 | 7.53 | 0.8 | 13.5 | 7.48 | 0.8 | 12.5 | 7.43 | 0.8 | 11.5 | 7.39 | 0.8 | 10.8 | 7.33 | 0.8 | 9.7 | 7.29 | 0.7 | 9.0 |
| KING STREET | 200 | 8.21 | 2.81 | 63.24 | 7.53 | 0.8 | 13.5 | 7.49 | 0.8 | 12.5 | 7.44 | 0.8 | 11.6 | 7.39 | 0.8 | 10.8 | 7.33 | 0.7 | 9.7 | 7.29 | 0.7 | 9.0 |
| KING STREET | 211 | 8.20 | 3.41 | 63.31 | 7.52 | 1.7 | 13.5 | 7.47 | 1.7 | 12.5 | 7.42 | 1.7 | 11.6 | 7.38 | 1.7 | 10.8 | 7.31 | 1.7 | 9.7 | 7.28 | 1.7 | 9.0 |
| KING STREET | 229 | 9.92 | 1.36 | 63.40 | 8.74 | 0.3 | 13.5 | 8.71 | 0.3 | 12.5 | 8.67 | 0.3 | 11.6 | 8.63 | 0.3 | 10.8 | 8.58 | 0.3 | 9.7 | 8.55 | 0.3 | 9.0 |
| KING STREET | 236 | 9.91 | 2.25 | 63.40 | 8.74 | 0.4 | 13.5 | 8.70 | 0.4 | 12.5 | 8.66 | 0.4 | 11.6 | 8.63 | 0.4 | 10.8 | 8.58 | 0.3 | 9.7 | 8.55 | 0.3 | 9.0 |
| LAKELANDS | 0 | 4.36 | 0.49 | 65.38 | 2.43 | 0.2 | 15.3 | 2.38 | 0.2 | 13.5 | 2.33 | 0.2 | 12.1 | 2.27 | 0.2 | 10.9 | 2.20 | 0.2 | 9.6 | 2.15 | 0.2 | 8.7 |
| LAKELANDS | 14.85 | | | | 2.43 | 0.4 | 15.6 | 2.37 | 0.4 | 13.9 | 2.32 | 0.4 | 12.4 | 2.27 | 0.5 | 11.3 | 2.20 | 0.6 | 9.9 | 2.15 | 0.9 | 9.0 |
| LAKELANDS | 29.7 | | | | 2.42 | 1.1 | 15.9 | 2.36 | 1.3 | 14.2 | 2.31 | 1.4 | 12.7 | 2.26 | 1.7 | 11.5 | 2.19 | 1.9 | 10.2 | 2.14 | 1.9 | 9.3 |
| LAKELANDS | 44.54 | 4.33 | 2.28 | 66.50 | 2.54 | 2.6 | 16.1 | 2.50 | 2.8 | 14.4 | 2.46 | 2.8 | 12.9 | 2.42 | 2.8 | 11.6 | 2.36 | 2.8 | 10.3 | 2.33 | 2.7 | 9.3 |
| LAKELANDS | 60.12 | | 2.27 | | 2.72 | 2.1 | 16.1 | 2.69 | 2.1 | 14.5 | 2.66 | 2.1 | 12.9 | 2.63 | 2.1 | 11.6 | 2.59 | 2.0 | 10.3 | 2.56 | 2.0 | 9.4 |
| LAKELANDS | 75.7 | 4.35 | 2.25 | 67.23 | 2.90 | 1.9 | 16.2 | 2.87 | 1.9 | 14.5 | 2.84 | 1.8 | 12.9 | 2.81 | 1.8 | 11.6 | 2.78 | 1.8 | 10.3 | 2.76 | 1.7 | 9.4 |
| LAKELANDS | 91.27 | | 2.15 | | 3.08 | 1.7 | 16.2 | 3.05 | 1.7 | 14.5 | 3.02 | 1.7 | 12.9 | 2.99 | 1.7 | 11.6 | 2.96 | 1.7 | 10.3 | 2.94 | 1.7 | 9.4 |
| LAKELANDS | 106.85 | 4.39 | 1.97 | 65.73 | 3.26 | 1.7 | 15.8 | 3.22 | 1.7 | 14.2 | 3.19 | 1.7 | 12.6 | 3.17 | 1.7 | 11.4 | 3.14 | 1.7 | 10.1 | 3.12 | 1.7 | 9.2 |
| LAKELANDS | 123.83 | | 1.96 | | 3.42 | 1.6 | 15.0 | 3.38 | 1.5 | 13.4 | 3.35 | 1.5 | 12.0 | 3.32 | 1.5 | 10.9 | 3.29 | 1.5 | 9.7 | 3.27 | 1.5 | 8.8 |
| LAKELANDS | 140.82 | 4.45 | 1.91 | 60.48 | 3.56 | 1.7 | 14.2 | 3.52 | 1.6 | 12.7 | 3.49 | 1.6 | 11.4 | 3.46 | 1.6 | 10.4 | 3.43 | 1.6 | 9.2 | 3.40 | 1.5 | 8.4 |
| LAKELANDS | 157.8 | | 2.15 | | 3.70 | 1.8 | 13.3 | 3.66 | 1.8 | 11.9 | 3.62 | 1.8 | 10.8 | 3.60 | 1.7 | 9.9 | 3.56 | 1.7 | 8.8 | 3.53 | 1.6 | 7.9 |
| LAKELANDS | 174.78 | 4.54 | 2.53 | 53.88 | 3.84 | 1.9 | 12.5 | 3.79 | 1.9 | 11.2 | 3.76 | 1.9 | 10.3 | 3.73 | 1.8 | 9.4 | 3.69 | 1.8 | 8.3 | 3.65 | 1.7 | 7.5 |
| LAKELANDS | 191.71 | | | | 3.98 | 1.9 | 11.7 | 3.93 | 1.9 | 10.5 | 3.89 | 1.9 | 9.7 | 3.86 | 1.8 | 8.8 | 3.81 | 1.8 | 7.8 | 3.77 | 1.7 | 7.0 |
| LAKELANDS | 208.65 | | | | 4.10 | 2.0 | 11.2 | 4.05 | 2.0 | 10.2 | 4.01 | 2.0 | 9.4 | 3.97 | 1.9 | 8.6 | 3.91 | 1.9 | 7.6 | 3.87 | 1.8 | 6.8 |
| LAKELANDS | 225.58 | 5.07 | 3.20 | 48.89 | 4.22 | 2.2 | 11.2 | 4.17 | 2.1 | 10.2 | 4.12 | 2.1 | 9.4 | 4.08 | 2.2 | 8.6 | 4.02 | 2.1 | 7.6 | 3.97 | 2.0 | 6.8 |
| LAKELANDS | 239.38 | | | | 4.32 | 2.0 | 11.3 | 4.27 | 2.0 | 10.2 | 4.23 | 2.0 | 9.4 | 4.18 | 1.9 | 8.6 | 4.11 | 2.0 | 7.6 | 4.06 | 1.9 | 6.8 |
| LAKELANDS | 253.19 | | | | 4.41 | 1.8 | 11.3 | 4.36 | 1.8 | 10.3 | 4.31 | 1.8 | 9.5 | 4.27 | 1.8 | 8.6 | 4.20 | 1.8 | 7.6 | 4.14 | 1.8 | 6.8 |
| LAKELANDS | 267 | 5.40 | 2.80 | 48.92 | 4.48 | 1.8 | 11.3 | 4.43 | 1.8 | 10.3 | 4.39 | 1.8 | 9.5 | 4.34 | 1.8 | 8.7 | 4.28 | 1.8 | 7.7 | 4.22 | 1.8 | 6.9 |
| N'TH CK MAIN | 0 | 2.63 | 5.13 | 535.94 | 1.55 | 2.8 | 96.0 | 1.38 | 2.8 | 88.6 | 1.24 | 2.7 | 81.4 | 0.97 | 2.9 | 73.9 | 0.80 | 2.9 | 66.4 | 0.65 | 3.0 | 61.9 |
| N'TH CK MAIN | 26.66 | | | | 1.64 | 2.7 | 96.0 | 1.47 | 2.7 | 88.6 | 1.34 | 2.7 | 81.4 | 1.10 | 2.8 | 73.9 | 0.94 | 2.8 | 66.4 | 0.80 | 2.8 | 61.9 |
| N'TH CK MAIN | 53.31 | 3.38 | 3.21 | 535.92 | 1.72 | 2.7 | 96.0 | 1.56 | 2.7 | 88.6 | 1.43 | 2.6 | 81.4 | 1.21 | 2.7 | 73.9 | 1.06 | 2.6 | 66.4 | 0.94 | 2.7 | 61.9 |
| N'TH CK MAIN | 73 | 3.47 | 3.10 | 535.94 | 1.77 | 2.6 | 96.0 | 1.62 | 2.6 | 88.6 | 1.49 | 2.6 | 81.4 | 1.28 | 2.6 | 73.9 | 1.14 | 2.6 | 66.4 | 1.02 | 2.6 | 61.9 |
| N'TH CK MAIN | 109.4 | 3.64 | 1.57 | 535.97 | 1.95 | 1.8 | 96.0 | 1.78 | 2.1 | 88.6 | 1.62 | 2.3 | 81.4 | 1.42 | 2.5 | 73.9 | 1.27 | 2.4 | 66.4 | 1.17 | 2.4 | 61.9 |
| N'TH CK MAIN | 145.8 | 3.72 | 1.03 | 535.95 | 2.07 | 1.1 | 96.0 | 1.92 | 1.4 | 88.6 | 1.78 | 1.7 | 81.4 | 1.56 | 2.2 | 73.9 | 1.39 | 2.2 | 66.4 | 1.29 | 2.2 | 61.9 |
| N'TH CK MAIN | 182.2 | 3.75 | 0.76 | 536.23 | 2.12 | 0.7 | 96.1 | 1.99 | 0.9 | 88.7 | 1.86 | 1.2 | 81.4 | 1.70 | 1.8 | 74.0 | 1.55 | 1.9 | 66.5 | 1.42 | 2.0 | 61.9 |
| N'TH CK MAIN | 218.6 | 3.77 | 0.60 | 537.57 | 2.14 | 0.5 | 96.4 | 2.02 | 0.6 | 88.9 | 1.91 | 0.8 | 81.6 | 1.76 | 1.4 | 74.1 | 1.64 | 1.6 | 66.6 | 1.55 | 1.7 | 62.0 |
| N'TH CK MAIN | 255 | 3.78 | 0.49 | 539.26 | 2.16 | 0.4 | 97.1 | 2.04 | 0.4 | 89.5 | 1.93 | 0.5 | 82.2 | 1.80 | 1.1 | 74.6 | 1.69 | 1.4 | 66.9 | 1.61 | 1.5 | 62.4 |
| N'TH CK MAIN | 264.98 | 3.79 | 0.48 | 524.26 | 2.17 | 0.4 | 94.7 | 2.06 | 0.4 | 87.1 | 1.95 | 0.4 | 80.0 | 1.83 | 0.9 | 72.7 | 1.73 | 1.1 | 65.2 | 1.66 | 1.2 | 60.8 |
| N'TH CK MAIN | 274 | 3.79 | 0.47 | 510.69 | 2.17 | 0.3 | 92.6 | 2.06 | 0.4 | 85.0 | 1.96 | 0.4 | 78.1 | 1.84 | 0.9 | 71.0 | 1.74 | 1.0 | 63.6 | 1.67 | 1.1 | 59.3 |
| N'TH CK MAIN | 304.29 | 3.79 | 0.47 | 512.62 | 2.18 | 0.4 | 94.0 | 2.07 | 0.4 | 86.4 | 1.97 | 0.4 | 79.2 | 1.85 | 0.8 | 72.0 | 1.76 | 1.0 | 64.1 | 1.69 | 1.1 | 59.7 |
| N'TH CK MAIN | 304.29 | 3.79 | 0.47 | 512.62 | 2.18 | 0.4 | 76.3 | 2.07 | 0.4 | 70.3 | 1.97 | 0.4 | 64.9 | 1.85 | 0.8 | 59.0 | 1.76 | 1.0 | 52.6 | 1.69 | 1.1 | 48.8 |
| N'TH CK MAIN | 305.78 | 3.79 | 0.37 | 405.93 | 2.18 | 0.3 | 76.4 | 2.07 | 0.3 | 70.4 | 1.97 | 0.3 | 64.9 | 1.86 | 0.7 | 59.1 | 1.76 | 0.8 | 52.7 | 1.69 | 0.9 | 48.8 |
| N'TH CK MAIN | 341.54 | 3.79 | 0.51 | 395.22 | 2.19 | 0.3 | 76.4 | 2.08 | 0.3 | 70.7 | 1.99 | 0.3 | 64.9 | 1.87 | 0.5 | 58.7 | 1.78 | 0.7 | 52.3 | 1.71 | 0.8 | 48.2 |
| N'TH CK MAIN | 377.3 | 3.81 | 0.70 | 384.83 | 2.20 | 0.3 | 76.4 | 2.09 | 0.4 | 70.9 | 2.00 | 0.4 | 65.0 | 1.89 | 0.4 | 58.6 | 1.79 | 0.6 | 51.8 | 1.73 | 0.7 | 47.6 |
| N'TH CK MAIN | 413.06 | 3.85 | 0.80 | 377.57 | 2.21 | 0.4 | 77.2 | 2.11 | 0.4 | 71.7 | 2.01 | 0.4 | 65.5 | 1.91 | 0.4 | 58.9 | 1.82 | 0.5 | 51.9 | 1.76 | 0.6 | 47.6 |
| N'TH CK MAIN | 448.82 | 3.92 | 0.91 | 370.15 | 2.23 | 0.4 | 77.6 | 2.13 | 0.4 | 72.2 | 2.04 | 0.5 | 65.8 | 1.93 | 0.5 | 58.9 | 1.85 | 0.5 | 51.8 | 1.79 | 0.5 | 47.4 |
| N'TH CK MAIN | 484.58 | 4.02 | 1.06 | 371.84 | 2.26 | 0.5 | 79.3 | 2.16 | 0.5 | 73.7 | 2.08 | 0.5 | 67.2 | 1.98 | 0.6 | 60.0 | 1.90 | 0.6 | 52.5 | 1.85 | 0.6 | 48.0 |
| N'TH CK MAIN | 520.34 | 4.17 | 1.18 | 371.96 | 2.30 | 0.8 | 80.5 | 2.22 | 0.8 | 74.6 | 2.17 | 0.8 | 67.9 | 2.12 | 0.7 | 60.6 | 2.04 | 0.7 | 52.9 | 1.99 | 0.7 | 48.4 |
| N'TH CK MAIN | 557.69 | 4.25 | 1.29 | 373.26 | 2.34 | 0.8 | 81.1 | 2.28 | 0.8 | 75.1 | 2.23 | 0.7 | 68.1 | 2.18 | 0.7 | 61.0 | 2.11 | 0.6 | 53.3 | 2.06 | 0.6 | 48.7 |

| River Name | MIKE11 Chainage (m) | PMF (100% Blockage) | | | 0.5% AEP (100% Blockage) | | | 1% AEP (100% Blockage) | | | 2% AEP (100% Blockage) | | | 5% AEP (100% Blockage) | | | 10% AEP (100% Blockage) | | | 20% AEP (100% Blockage) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) |
| N'TH CK MAIN | 595.03 | 4.29 | 1.43 | 374.11 | 2.37 | 0.8 | 81.6 | 2.30 | 0.8 | 75.5 | 2.26 | 0.7 | 68.4 | 2.21 | 0.7 | 61.4 | 2.14 | 0.6 | 53.6 | 2.09 | 0.6 | 49.1 |
| N'TH CK MAIN | 632.38 | 4.32 | 1.56 | 366.07 | 2.38 | 0.8 | 80.1 | 2.32 | 0.8 | 74.2 | 2.28 | 0.7 | 67.2 | 2.23 | 0.7 | 60.6 | 2.16 | 0.6 | 52.8 | 2.11 | 0.6 | 48.5 |
| N'TH CK MAIN | 662.95 | 4.35 | 1.59 | 358.49 | 2.39 | 0.9 | 78.9 | 2.33 | 0.8 | 73.1 | 2.29 | 0.8 | 66.3 | 2.24 | 0.7 | 59.9 | 2.17 | 0.7 | 52.2 | 2.12 | 0.7 | 48.0 |
| N'TH CK MAIN | 693.53 | 4.37 | 1.66 | 358.71 | 2.40 | 1.0 | 79.1 | 2.34 | 0.9 | 73.2 | 2.29 | 0.9 | 66.4 | 2.24 | 0.8 | 60.1 | 2.17 | 0.8 | 52.4 | 2.12 | 0.7 | 48.3 |
| N'TH CK MAIN | 724.11 | 4.39 | 1.75 | 359.67 | 2.41 | 1.0 | 79.4 | 2.35 | 1.0 | 73.4 | 2.30 | 0.9 | 66.5 | 2.25 | 0.9 | 60.4 | 2.18 | 0.8 | 52.7 | 2.13 | 0.8 | 48.6 |
| N'TH CK MAIN | 750 | 4.31 | 2.37 | 359.80 | 2.41 | 1.1 | 79.5 | 2.36 | 1.0 | 73.5 | 2.31 | 1.0 | 66.6 | 2.26 | 0.9 | 60.7 | 2.19 | 0.8 | 53.0 | 2.14 | 0.8 | 48.8 |
| N'TH CK MAIN | 770 | 4.33 | 2.48 | 360.49 | 2.42 | 1.2 | 79.6 | 2.37 | 1.1 | 73.6 | 2.32 | 1.1 | 66.6 | 2.27 | 1.0 | 60.7 | 2.19 | 1.0 | 53.2 | 2.14 | 0.9 | 48.9 |
| N'TH CK MAIN | 781.43 | 4.36 | 2.38 | 360.87 | 2.43 | 1.2 | 79.6 | 2.38 | 1.1 | 73.6 | 2.33 | 1.1 | 66.6 | 2.27 | 1.0 | 60.8 | 2.20 | 1.0 | 53.3 | 2.15 | 0.9 | 49.1 |
| N'TH CK MAIN | 781.43 | 4.36 | 2.38 | 360.87 | 2.43 | 1.2 | 65.8 | 2.38 | 1.1 | 61.0 | 2.33 | 1.1 | 55.6 | 2.27 | 1.0 | 50.7 | 2.20 | 1.0 | 44.6 | 2.15 | 0.9 | 41.2 |
| N'TH CK MAIN | 809.78 | 4.39 | 1.88 | 300.62 | 2.46 | 0.9 | 65.9 | 2.40 | 0.9 | 61.0 | 2.35 | 0.8 | 55.6 | 2.29 | 0.8 | 50.9 | 2.22 | 0.8 | 44.8 | 2.16 | 0.8 | 41.4 |
| N'TH CK MAIN | 838.11 | 4.44 | 1.80 | 299.77 | 2.48 | 0.9 | 66.0 | 2.42 | 0.9 | 61.1 | 2.37 | 0.9 | 55.7 | 2.31 | 0.8 | 51.1 | 2.23 | 0.8 | 45.0 | 2.18 | 0.8 | 41.6 |
| N'TH CK MAIN | 866.46 | 4.50 | 1.74 | 300.94 | 2.52 | 1.0 | 66.1 | 2.46 | 0.9 | 61.2 | 2.40 | 0.9 | 55.7 | 2.34 | 0.9 | 51.3 | 2.26 | 0.8 | 45.2 | 2.21 | 0.8 | 41.9 |
| N'TH CK MAIN | 905.97 | 4.56 | 2.15 | 296.49 | 2.58 | 1.2 | 65.1 | 2.51 | 1.1 | 60.2 | 2.46 | 1.1 | 54.9 | 2.39 | 1.1 | 50.7 | 2.31 | 1.0 | 44.8 | 2.25 | 1.0 | 41.6 |
| N'TH CK MAIN | 939.36 | 4.66 | 2.06 | 290.89 | 2.64 | 1.2 | 64.2 | 2.58 | 1.2 | 59.4 | 2.52 | 1.2 | 54.3 | 2.45 | 1.1 | 50.2 | 2.36 | 1.1 | 44.4 | 2.30 | 1.1 | 41.3 |
| N'TH CK MAIN | 972.75 | 4.76 | 1.99 | 290.81 | 2.71 | 1.3 | 64.3 | 2.64 | 1.3 | 59.5 | 2.58 | 1.2 | 54.4 | 2.51 | 1.2 | 50.4 | 2.41 | 1.2 | 44.6 | 2.35 | 1.2 | 41.5 |
| N'TH CK MAIN | 993.87 | 4.84 | 2.22 | 296.84 | 2.83 | 1.6 | 64.3 | 2.76 | 1.6 | 59.6 | 2.69 | 1.5 | 54.5 | 2.62 | 1.5 | 50.5 | 2.53 | 1.5 | 44.7 | 2.47 | 1.5 | 41.6 |
| N'TH CK MAIN | 1015 | 5.15 | 3.07 | 422.85 | 3.47 | 1.2 | 64.4 | 3.40 | 1.2 | 59.6 | 3.33 | 1.1 | 54.6 | 3.27 | 1.1 | 50.6 | 3.18 | 1.1 | 44.8 | 3.13 | 1.1 | 41.7 |
| N'TH CK MAIN | 1028 | 5.39 | 5.54 | 407.06 | 4.29 | 1.3 | 64.4 | 4.23 | 1.2 | 59.6 | 4.16 | 1.2 | 54.6 | 4.10 | 1.1 | 50.6 | 4.01 | 1.0 | 44.8 | 3.95 | 1.0 | 41.7 |
| N'TH CK MAIN | 1049 | 6.93 | 3.63 | 308.83 | 4.85 | 1.4 | 64.4 | 4.77 | 1.4 | 59.7 | 4.67 | 1.3 | 54.6 | 4.60 | 1.8 | 50.7 | 4.47 | 1.4 | 44.9 | 4.40 | 1.4 | 41.9 |
| N'TH CK MAIN | 1067 | 7.13 | 3.03 | 301.51 | 4.87 | 1.4 | 64.4 | 4.78 | 1.4 | 59.8 | 4.68 | 1.3 | 54.6 | 4.61 | 1.9 | 50.7 | 4.48 | 1.5 | 44.9 | 4.41 | 1.5 | 41.9 |
| N'TH CK MAIN | 1090.78 | 7.24 | 4.16 | 293.20 | 5.09 | 1.5 | 64.4 | 5.03 | 1.4 | 59.6 | 4.94 | 1.4 | 54.6 | 4.86 | 1.3 | 50.6 | 4.71 | 1.2 | 44.8 | 4.63 | 1.2 | 41.7 |
| N'TH CK MAIN | 1090.78 | 7.24 | 4.16 | 293.20 | 5.09 | 1.5 | 50.5 | 5.03 | 1.4 | 46.7 | 4.94 | 1.4 | 42.8 | 4.86 | 1.3 | 39.6 | 4.71 | 1.2 | 35.0 | 4.63 | 1.2 | 32.6 |
| N'TH CK MAIN | 1110.79 | 7.27 | 3.34 | 226.63 | 5.17 | 1.5 | 50.5 | 5.12 | 1.4 | 46.8 | 5.05 | 1.3 | 42.8 | 4.98 | 1.3 | 39.7 | 4.89 | 1.2 | 35.0 | 4.80 | 1.1 | 32.6 |
| N'TH CK MAIN | 1130.8 | 7.31 | 3.43 | 227.07 | 5.25 | 1.8 | 50.5 | 5.21 | 1.7 | 46.8 | 5.14 | 1.6 | 42.9 | 5.09 | 1.6 | 39.7 | 5.02 | 1.5 | 35.0 | 4.96 | 1.4 | 32.6 |
| N'TH CK MAIN | 1158.17 | 7.50 | 2.46 | 226.70 | 5.38 | 1.1 | 50.5 | 5.33 | 1.0 | 46.8 | 5.27 | 1.0 | 42.9 | 5.21 | 0.9 | 39.7 | 5.13 | 0.9 | 35.0 | 5.06 | 0.8 | 32.6 |
| N'TH CK MAIN | 1185.53 | 7.62 | 1.99 | 227.05 | 5.44 | 0.8 | 50.5 | 5.39 | 0.8 | 46.8 | 5.33 | 0.7 | 42.9 | 5.27 | 0.7 | 39.7 | 5.18 | 0.7 | 35.1 | 5.11 | 0.6 | 32.7 |
| N'TH CK MAIN | 1212.14 | 7.64 | 2.04 | 226.87 | 5.48 | 1.0 | 50.6 | 5.43 | 1.0 | 46.8 | 5.36 | 0.9 | 43.0 | 5.30 | 0.9 | 39.8 | 5.21 | 0.8 | 35.2 | 5.13 | 0.8 | 32.7 |
| N'TH CK MAIN | 1238.75 | 7.69 | 2.05 | 220.21 | 5.59 | 1.3 | 49.1 | 5.53 | 1.2 | 45.5 | 5.46 | 1.2 | 41.8 | 5.39 | 1.2 | 38.7 | 5.30 | 1.2 | 34.2 | 5.22 | 1.2 | 31.8 |
| N'TH CK MAIN | 1274 | 7.77 | 1.82 | 212.70 | 5.66 | 1.0 | 47.2 | 5.59 | 1.0 | 43.7 | 5.52 | 0.9 | 40.1 | 5.45 | 0.9 | 37.2 | 5.35 | 0.8 | 32.9 | 5.27 | 0.8 | 30.6 |
| N'TH CK MAIN | 1283.96 | 7.78 | 1.81 | 212.22 | 5.69 | 1.0 | 47.2 | 5.62 | 1.0 | 43.7 | 5.55 | 0.9 | 40.2 | 5.48 | 0.9 | 37.2 | 5.37 | 0.8 | 33.0 | 5.30 | 0.8 | 30.7 |
| N'TH CK MAIN | 1293 | 7.81 | 1.73 | 204.68 | 5.71 | 0.9 | 45.6 | 5.64 | 0.9 | 42.3 | 5.56 | 0.9 | 38.8 | 5.49 | 0.8 | 35.9 | 5.39 | 0.8 | 31.9 | 5.31 | 0.8 | 29.6 |
| N'TH CK MAIN | 1321.5 | 7.90 | 1.33 | 183.26 | 5.74 | 0.8 | 40.6 | 5.67 | 0.7 | 37.7 | 5.59 | 0.7 | 34.6 | 5.52 | 0.7 | 32.1 | 5.41 | 0.7 | 28.4 | 5.34 | 0.6 | 26.5 |
| N'TH CK MAIN | 1350 | 7.93 | 1.16 | 183.40 | 5.76 | 0.7 | 40.6 | 5.69 | 0.7 | 37.6 | 5.61 | 0.7 | 34.6 | 5.54 | 0.7 | 32.0 | 5.42 | 0.6 | 28.4 | 5.35 | 0.6 | 26.5 |
| N'TH CK MAIN | 1370 | 7.95 | 1.15 | 183.06 | 6.16 | 0.5 | 40.6 | 6.13 | 0.5 | 37.7 | 6.09 | 0.5 | 34.6 | 6.07 | 0.5 | 32.1 | 6.03 | 0.4 | 28.5 | 6.00 | 0.4 | 26.5 |
| N'TH CK MAIN | 1390.8 | 7.96 | 1.09 | 182.76 | 6.17 | 0.5 | 40.6 | 6.14 | 0.5 | 37.7 | 6.10 | 0.4 | 34.6 | 6.07 | 0.4 | 32.1 | 6.03 | 0.4 | 28.5 | 6.00 | 0.3 | 26.5 |
| N'TH CK MAIN | 1421.09 | 7.96 | 1.15 | 182.28 | 6.17 | 0.5 | 40.6 | 6.14 | 0.5 | 37.7 | 6.11 | 0.5 | 34.6 | 6.08 | 0.4 | 32.1 | 6.03 | 0.4 | 28.5 | 6.00 | 0.4 | 26.5 |
| N'TH CK MAIN | 1451.39 | 7.96 | 1.22 | 181.86 | 6.18 | 0.6 | 40.7 | 6.14 | 0.5 | 37.7 | 6.11 | 0.5 | 34.7 | 6.08 | 0.5 | 32.1 | 6.04 | 0.4 | 28.5 | 6.01 | 0.4 | 26.6 |
| N'TH CK MAIN | 1481.68 | 7.96 | 1.43 | 181.72 | 6.18 | 0.6 | 40.7 | 6.15 | 0.6 | 37.8 | 6.11 | 0.6 | 34.8 | 6.08 | 0.5 | 32.2 | 6.04 | 0.5 | 28.6 | 6.01 | 0.5 | 26.6 |
| N'TH CK MAIN | 1511.97 | 7.96 | 2.00 | 181.98 | 6.18 | 0.7 | 40.8 | 6.15 | 0.7 | 37.9 | 6.12 | 0.6 | 34.8 | 6.09 | 0.6 | 32.2 | 6.04 | 0.6 | 28.7 | 6.01 | 0.5 | 26.7 |
| N'TH CK MAIN | 1541.99 | 8.00 | 1.46 | 182.12 | 6.20 | 0.6 | 41.0 | 6.17 | 0.6 | 38.0 | 6.13 | 0.5 | 35.0 | 6.10 | 0.5 | 32.3 | 6.05 | 0.5 | 28.8 | 6.02 | 0.5 | 26.8 |
| N'TH CK MAIN | 1572 | 8.02 | 1.36 | 182.72 | 6.21 | 0.6 | 41.1 | 6.18 | 0.5 | 38.2 | 6.14 | 0.5 | 35.2 | 6.11 | 0.5 | 32.5 | 6.06 | 0.5 | 29.0 | 6.03 | 0.4 | 27.0 |
| N'TH CK MAIN | 1602.02 | 8.04 | 1.32 | 184.08 | 6.23 | 0.6 | 41.4 | 6.19 | 0.5 | 38.5 | 6.16 | 0.5 | 35.4 | 6.12 | 0.5 | 32.7 | 6.08 | 0.5 | 29.3 | 6.05 | 0.5 | 27.3 |
| N'TH CK MAIN | 1632.04 | 8.05 | 1.14 | 173.54 | 6.27 | 0.6 | 38.9 | 6.23 | 0.5 | 36.2 | 6.20 | 0.5 | 33.3 | 6.17 | 0.5 | 30.8 | 6.12 | 0.5 | 27.6 | 6.09 | 0.5 | 25.7 |
| N'TH CK MAIN | 1663.25 | 8.06 | 1.24 | 162.55 | 6.31 | 0.7 | 36.2 | 6.28 | 0.6 | 33.7 | 6.25 | 0.6 | 31.0 | 6.22 | 0.6 | 28.7 | 6.17 | 0.6 | 25.8 | 6.14 | 0.6 | 24.0 |
| N'TH CK MAIN | 1694.46 | 8.09 | 1.17 | 133.61 | 6.39 | 0.6 | 29.9 | 6.36 | 0.6 | 27.8 | 6.32 | 0.6 | 25.6 | 6.29 | 0.6 | 23.8 | 6.24 | 0.6 | 21.4 | 6.21 | 0.6 | 19.9 |
| N'TH CK MAIN | 1725.67 | 8.12 | 0.89 | 91.74 | 6.44 | 0.5 | 20.6 | 6.41 | 0.5 | 19.1 | 6.37 | 0.5 | 17.6 | 6.34 | 0.5 | 16.4 | 6.29 | 0.5 | 14.8 | 6.26 | 0.5 | 13.7 |
| N'TH CK MAIN | 1753.34 | 8.13 | 0.98 | 81.89 | 6.47 | 0.7 | 18.1 | 6.44 | 0.6 | 16.8 | 6.40 | 0.6 | 15.5 | 6.37 | 0.6 | 14.4 | 6.32 | 0.6 | 13.0 | 6.29 | 0.6 | 12.0 |
| N'TH CK MAIN | 1781 | 8.06 | 2.27 | 82.63 | 6.53 | 1.5 | 18.1 | 6.51 | 1.5 | 16.8 | 6.48 | 1.5 | 15.5 | 6.45 | 1.4 | 14.5 | 6.42 | 1.4 | 13.0 | 6.40 | 1.4 | 12.1 |
| N'TH CK MAIN | 1801 | 8.33 | 1.49 | 82.62 | 7.36 | 0.6 | 18.1 | 7.32 | 0.6 | 16.8 | 7.28 | 0.5 | 15.5 | 7.25 | 0.5 | 14.5 | 7.20 | 0.5 | 13.0 | 7.17 | 0.5 | 12.1 |
| N'TH CK MAIN | 1830 | 8.39 | 2.04 | 83.79 | 7.37 | 1.1 | 18.1 | 7.34 | 1.1 | 16.8 | 7.30 | 1.1 | 15.6 | 7.26 | 1.1 | 14.5 | 7.21 | 1.1 | 13.0 | 7.18 | 1.1 | 12.1 |
| N'TH CK MAIN | 1850 | 8.55 | 1.44 | 83.79 | 7.58 | 0.7 | 18.1 | 7.56 | 0.7 | 16.9 | 7.53 | 0.6 | 15.6 | 7.51 | 0.6 | 14.5 | 7.48 | 0.6 | 13.0 | 7.45 | 0.6 | 12.1 |
| N'TH CK MAIN | 1864.95 | 8.54 | 1.73 | 82.68 | 7.62 | 1.1 | 18.1 | 7.59 | 1.1 | 16.9 | 7.57 | 1.0 | 15.6 | 7.54 | 1.0 | 14.5 | 7.51 | 1.0 | 13.0 | 7.48 | 1.0 | 12.1 |
| N'TH CK MAIN | 1898.56 | 8.86 | 2.21 | 82.43 | 8.23 | 1.6 | 18.2 | 8.20 | 1.6 | 16.9 | 8.17 | 1.6 | 15.6 | 8.15 | 1.6 | 14.5 | 8.11 | 1.6 | 13.1 | 8.09 | 1.6 | 12.2 |
| N'TH CK MAIN | 1932.18 | 9.52 | 2.08 | 75.48 | 9.07 | 1.3 | 16.4 | 9.04 | 1.3 | 15.2 | 9.01 | 1.3 | 14.0 | 8.99 | 1.3 | 13.0 | 8.95 | 1.3 | 11.7 | 8.93 | 1.2 | 10.9 |
| N'TH CK MAIN | 1961.45 | 9.96 | 2.08 | 69.53 | 9.52 | 1.1 | 14.8 | 9.49 | 1.1 | 13.7 | 9.46 | 1.1 | 12.6 | 9.43 | 1.0 | 11.7 | 9.39 | 1.0 | 10.5 | 9.36 | 1.0 | 9.8 |
| N'TH CK MAIN | 1990.72 | 10.42 | 2.26 | 69.49 | 9.98 | 1.1 | 14.8 | 9.94 | 1.1 | 13.7 | 9.90 | 1.1 | 12.7 | 9.87 | 1.1 | 11.8 | 9.82 | 1.0 | 10.5 | 9.79 | 1.0 | 9.8 |

| River Name | MIKE11 Chainage (m) | PMF (100% Blockage) | | | 0.5% AEP (100% Blockage) | | | 1% AEP (100% Blockage) | | | 2% AEP (100% Blockage) | | | 5% AEP (100% Blockage) | | | 10% AEP (100% Blockage) | | | 20% AEP (100% Blockage) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) |
| N'TH CK MAIN | 2020 | 10.90 | 1.86 | 51.00 | 10.46 | 0.9 | 10.6 | 10.42 | 0.8 | 9.8 | 10.37 | 0.8 | 9.0 | 10.33 | 0.8 | 8.4 | 10.27 | 0.8 | 7.5 | 10.23 | 0.8 | 6.9 |
| SEAMAN AV | 0 | 3.80 | 0.38 | 41.83 | 2.19 | 0.3 | 11.2 | 2.09 | 0.3 | 10.4 | 1.99 | 0.3 | 9.6 | 1.89 | 0.3 | 9.1 | 1.80 | 0.3 | 8.3 | 1.74 | 0.3 | 7.7 |
| SEAMAN AV | 15 | 3.79 | 1.28 | 42.37 | 2.19 | 1.8 | 11.3 | 2.10 | 1.9 | 10.6 | 2.04 | 1.9 | 9.7 | 1.99 | 1.9 | 9.2 | 1.94 | 1.8 | 8.3 | 1.90 | 1.7 | 7.8 |
| SEAMAN AV | 24.08 | 3.81 | 1.10 | 42.50 | 2.34 | 1.3 | 11.3 | 2.31 | 1.3 | 10.5 | 2.30 | 1.2 | 9.7 | 2.26 | 1.3 | 9.2 | 2.20 | 1.2 | 8.3 | 2.16 | 1.2 | 7.8 |
| SEAMAN AV | 29.1 | 3.81 | 0.94 | 42.46 | 2.35 | 0.7 | 11.2 | 2.33 | 0.7 | 10.5 | 2.31 | 0.7 | 9.7 | 2.27 | 0.7 | 9.1 | 2.21 | 0.7 | 8.3 | 2.18 | 0.6 | 7.7 |
| SEAMAN AV | 48.94 | 3.82 | 1.01 | 42.75 | 2.42 | 0.8 | 11.2 | 2.40 | 0.8 | 10.4 | 2.37 | 0.8 | 9.6 | 2.33 | 0.8 | 9.1 | 2.28 | 0.8 | 8.2 | 2.24 | 0.8 | 7.7 |
| SEAMAN AV | 68.78 | 3.82 | 1.06 | 42.91 | 2.52 | 0.9 | 11.1 | 2.49 | 0.9 | 10.4 | 2.46 | 0.9 | 9.6 | 2.43 | 0.9 | 9.0 | 2.37 | 0.9 | 8.2 | 2.34 | 0.9 | 7.6 |
| SEAMAN AV | 88.62 | 3.83 | 1.10 | 43.02 | 2.65 | 1.0 | 11.0 | 2.61 | 1.0 | 10.3 | 2.58 | 1.0 | 9.5 | 2.55 | 1.0 | 9.0 | 2.50 | 1.0 | 8.1 | 2.46 | 1.0 | 7.6 |
| SEAMAN AV | 108.46 | 3.84 | 1.13 | 43.05 | 2.79 | 1.0 | 10.9 | 2.77 | 1.0 | 10.2 | 2.73 | 1.0 | 9.4 | 2.70 | 1.0 | 8.9 | 2.66 | 1.0 | 8.0 | 2.62 | 1.0 | 7.5 |
| SEAMAN AV | 125.23 | 3.86 | 1.36 | 43.05 | 2.93 | 1.2 | 10.8 | 2.90 | 1.1 | 10.1 | 2.87 | 1.1 | 9.4 | 2.84 | 1.1 | 8.8 | 2.80 | 1.1 | 8.0 | 2.77 | 1.0 | 7.5 |
| SEAMAN AV | 142 | 3.89 | 1.58 | 42.95 | 3.10 | 1.2 | 10.7 | 3.07 | 1.2 | 10.0 | 3.03 | 1.1 | 9.3 | 3.00 | 1.1 | 8.8 | 2.96 | 1.1 | 7.9 | 2.93 | 1.1 | 7.4 |
| SEAMAN AV | 158.77 | 3.98 | 1.80 | 42.73 | 3.28 | 1.2 | 10.6 | 3.26 | 1.2 | 9.9 | 3.22 | 1.2 | 9.2 | 3.20 | 1.2 | 8.7 | 3.16 | 1.2 | 7.9 | 3.13 | 1.2 | 7.3 |
| SEAMAN AV | 175.54 | 4.19 | 2.12 | 42.45 | 3.50 | 1.3 | 10.6 | 3.48 | 1.3 | 9.9 | 3.45 | 1.4 | 9.1 | 3.43 | 1.4 | 8.6 | 3.39 | 1.4 | 7.8 | 3.37 | 1.4 | 7.3 |
| SEAMAN AV | 187.77 | 4.26 | 2.50 | 42.19 | 3.53 | 1.6 | 10.5 | 3.50 | 1.6 | 9.8 | 3.47 | 1.6 | 9.1 | 3.45 | 1.5 | 8.6 | 3.42 | 1.6 | 7.7 | 3.39 | 1.5 | 7.2 |
| SEAMAN AV | 200 | 4.29 | 3.49 | 41.99 | 3.43 | 3.4 | 10.4 | 3.40 | 3.3 | 9.8 | 3.37 | 3.1 | 9.1 | 3.35 | 3.0 | 8.5 | 3.32 | 3.0 | 7.7 | 3.30 | 2.9 | 7.2 |
| SEAMAN AV | 220 | 4.96 | 3.05 | 41.92 | 4.61 | 1.0 | 10.4 | 4.59 | 0.9 | 9.7 | 4.57 | 0.9 | 9.0 | 4.55 | 0.8 | 8.5 | 4.53 | 0.7 | 7.7 | 4.51 | 0.7 | 7.2 |
| SEAMAN AV | 240 | 5.09 | 4.58 | 41.93 | 4.49 | 2.2 | 10.4 | 4.48 | 2.1 | 9.8 | 4.49 | 2.0 | 9.0 | 4.50 | 1.9 | 8.5 | 4.50 | 1.7 | 7.7 | 4.49 | 1.6 | 7.2 |
| SEAMAN AV | 250.76 | 5.18 | 4.82 | 41.88 | 4.51 | 2.2 | 10.4 | 4.50 | 2.0 | 9.7 | 4.49 | 1.9 | 9.0 | 4.48 | 1.8 | 8.5 | 4.47 | 1.7 | 7.7 | 4.45 | 1.6 | 7.2 |
| SEAMAN AV | 261.53 | 5.27 | 5.04 | 41.87 | 4.47 | 3.6 | 10.4 | 4.44 | 3.4 | 9.7 | 4.44 | 3.3 | 9.0 | 4.44 | 3.2 | 8.5 | 4.44 | 3.0 | 7.7 | 4.44 | 2.9 | 7.2 |
| SEAMAN AV | 278.61 | 5.53 | 6.58 | 41.91 | 4.75 | 4.5 | 10.4 | 4.73 | 4.5 | 9.7 | 4.70 | 4.4 | 9.0 | 4.68 | 4.4 | 8.5 | 4.66 | 4.3 | 7.7 | 4.64 | 4.2 | 7.2 |
| SEAMAN AV | 295.69 | 5.91 | 8.44 | 41.94 | 5.22 | 6.2 | 10.4 | 5.20 | 6.0 | 9.7 | 5.18 | 5.9 | 9.0 | 5.16 | 5.7 | 8.5 | 5.13 | 5.5 | 7.7 | 5.11 | 5.4 | 7.2 |
| SEAMAN AV | 311.7 | 6.37 | 7.94 | 41.95 | 5.72 | 5.8 | 10.4 | 5.70 | 5.6 | 9.7 | 5.68 | 5.5 | 9.0 | 5.66 | 5.4 | 8.5 | 5.63 | 5.2 | 7.7 | 5.61 | 5.1 | 7.2 |
| SEAMAN AV | 327.7 | 6.87 | 7.47 | 41.96 | 6.24 | 5.1 | 10.4 | 6.21 | 5.0 | 9.7 | 6.19 | 4.9 | 9.0 | 6.17 | 4.8 | 8.5 | 6.14 | 4.6 | 7.7 | 6.13 | 4.5 | 7.2 |
| SEAMAN AV | 340 | 7.20 | 4.66 | 41.92 | 6.49 | 3.3 | 10.4 | 6.46 | 3.2 | 9.7 | 6.44 | 3.1 | 9.0 | 6.42 | 3.0 | 8.5 | 6.38 | 2.9 | 7.7 | 6.36 | 2.8 | 7.2 |
| SEAMAN AV | 360 | 7.57 | 5.42 | 41.93 | 7.98 | 0.6 | 10.4 | 7.95 | 0.6 | 9.7 | 7.93 | 0.6 | 9.0 | 7.91 | 0.5 | 8.5 | 7.88 | 0.5 | 7.7 | 7.86 | 0.5 | 7.2 |
| SEAMAN AV | 380 | 8.44 | 5.39 | 33.21 | 8.04 | 2.6 | 8.3 | 8.00 | 2.5 | 7.7 | 7.97 | 2.4 | 7.2 | 7.94 | 2.3 | 6.7 | 7.90 | 2.2 | 6.1 | 7.87 | 2.1 | 5.7 |
| SEAMAN AV | 399.82 | 8.87 | 4.76 | 18.77 | 8.28 | 1.9 | 4.7 | 8.25 | 1.9 | 4.4 | 8.21 | 1.8 | 4.1 | 8.19 | 1.8 | 3.8 | 8.15 | 1.7 | 3.5 | 8.12 | 1.6 | 3.2 |
| SEAMAN AV | 409.91 | 8.95 | 3.37 | 15.79 | 8.38 | 1.5 | 3.9 | 8.34 | 1.5 | 3.7 | 8.31 | 1.4 | 3.4 | 8.28 | 1.4 | 3.2 | 8.23 | 1.4 | 2.9 | 8.20 | 1.4 | 2.7 |
| SEAMAN AV | 420 | 9.03 | 3.16 | 15.89 | 8.41 | 1.8 | 4.0 | 8.38 | 1.8 | 3.7 | 8.34 | 1.8 | 3.4 | 8.31 | 1.8 | 3.2 | 8.27 | 1.7 | 2.9 | 8.24 | 1.7 | 2.7 |
| WEST'N TRIB | 0 | 3.79 | 0.11 | 108.95 | 2.18 | 0.1 | 19.4 | 2.07 | 0.1 | 18.3 | 1.97 | 0.1 | 17.2 | 1.85 | 0.3 | 16.5 | 1.76 | 0.3 | 15.3 | 1.69 | 0.4 | 14.7 |
| WEST'N TRIB | 16.75 | 3.79 | 0.15 | 111.66 | 2.18 | 0.1 | 21.9 | 2.07 | 0.1 | 20.7 | 1.97 | 0.2 | 19.3 | 1.86 | 0.3 | 18.4 | 1.76 | 0.4 | 17.0 | 1.69 | 0.4 | 16.1 |
| WEST'N TRIB | 33.49 | 3.79 | 0.20 | 115.77 | 2.19 | 0.1 | 24.1 | 2.07 | 0.2 | 22.7 | 1.97 | 0.2 | 21.1 | 1.86 | 0.4 | 20.1 | 1.76 | 0.4 | 18.5 | 1.69 | 0.5 | 17.4 |
| WEST'N TRIB | 50.24 | 3.79 | 0.27 | 119.42 | 2.19 | 0.2 | 26.0 | 2.07 | 0.2 | 24.4 | 1.97 | 0.2 | 22.7 | 1.86 | 0.4 | 21.6 | 1.76 | 0.5 | 19.8 | 1.69 | 0.6 | 18.6 |
| WEST'N TRIB | 66.98 | 3.79 | 0.38 | 122.57 | 2.19 | 0.2 | 27.5 | 2.07 | 0.2 | 25.7 | 1.98 | 0.3 | 23.9 | 1.86 | 0.5 | 22.8 | 1.76 | 0.7 | 20.8 | 1.70 | 0.7 | 19.5 |
| WEST'N TRIB | 83.73 | 3.79 | 0.57 | 124.69 | 2.19 | 0.2 | 28.7 | 2.07 | 0.3 | 26.8 | 1.98 | 0.4 | 24.8 | 1.86 | 0.6 | 23.6 | 1.76 | 0.8 | 21.5 | 1.70 | 0.9 | 20.1 |
| WEST'N TRIB | 100.47 | 3.78 | 1.05 | 124.57 | 2.18 | 0.7 | 29.1 | 2.07 | 0.8 | 27.1 | 1.97 | 0.8 | 25.1 | 1.86 | 0.9 | 23.9 | 1.76 | 0.9 | 21.7 | 1.70 | 1.0 | 20.2 |
| WEST'N TRIB | 117.98 | 3.79 | 1.03 | 123.95 | 2.19 | 0.7 | 29.1 | 2.08 | 0.7 | 27.2 | 1.98 | 0.7 | 25.1 | 1.87 | 0.8 | 23.8 | 1.78 | 0.8 | 21.6 | 1.71 | 0.8 | 20.1 |
| WEST'N TRIB | 135.49 | 3.79 | 1.03 | 124.69 | 2.19 | 0.6 | 29.4 | 2.08 | 0.7 | 27.4 | 1.99 | 0.7 | 25.4 | 1.88 | 0.7 | 24.0 | 1.79 | 0.7 | 21.7 | 1.73 | 0.7 | 20.2 |
| WEST'N TRIB | 153 | 3.80 | 1.03 | 125.39 | 2.19 | 0.6 | 29.7 | 2.09 | 0.6 | 27.7 | 1.99 | 0.7 | 25.6 | 1.89 | 0.7 | 24.1 | 1.80 | 0.7 | 21.8 | 1.74 | 0.6 | 20.2 |
| WEST'N TRIB | 153 | 3.80 | 1.03 | 125.39 | 2.19 | 0.6 | 19.5 | 2.09 | 0.6 | 18.3 | 1.99 | 0.7 | 17.0 | 1.89 | 0.7 | 16.1 | 1.80 | 0.7 | 14.6 | 1.74 | 0.6 | 13.6 |
| WEST'N TRIB | 170.32 | 3.80 | 0.78 | 85.09 | 2.19 | 0.5 | 19.7 | 2.09 | 0.6 | 18.5 | 2.00 | 0.6 | 17.1 | 1.89 | 0.6 | 16.1 | 1.81 | 0.6 | 14.6 | 1.77 | 0.6 | 13.6 |
| WEST'N TRIB | 187.63 | 3.80 | 0.93 | 85.67 | 2.20 | 0.7 | 19.9 | 2.09 | 0.7 | 18.6 | 2.01 | 0.8 | 17.2 | 1.92 | 0.8 | 16.2 | 1.88 | 0.8 | 14.6 | 1.85 | 0.8 | 13.6 |
| WEST'N TRIB | 204.95 | 3.80 | 1.15 | 86.20 | 2.21 | 0.9 | 20.0 | 2.14 | 0.9 | 18.7 | 2.10 | 0.9 | 17.2 | 2.07 | 0.9 | 16.2 | 2.03 | 0.9 | 14.6 | 2.01 | 0.9 | 13.6 |
| WEST'N TRIB | 221.06 | 3.81 | 1.37 | 86.65 | 2.38 | 1.2 | 20.1 | 2.35 | 1.2 | 18.7 | 2.32 | 1.2 | 17.2 | 2.29 | 1.2 | 16.2 | 2.26 | 1.1 | 14.6 | 2.23 | 1.1 | 13.6 |
| WEST'N TRIB | 237.18 | 3.82 | 1.64 | 86.99 | 2.66 | 1.4 | 20.1 | 2.63 | 1.4 | 18.7 | 2.60 | 1.3 | 17.3 | 2.57 | 1.3 | 16.2 | 2.53 | 1.3 | 14.6 | 2.51 | 1.2 | 13.6 |
| WEST'N TRIB | 253.3 | 3.86 | 1.97 | 87.22 | 2.98 | 1.5 | 20.1 | 2.95 | 1.5 | 18.7 | 2.92 | 1.5 | 17.3 | 2.89 | 1.5 | 16.2 | 2.85 | 1.4 | 14.6 | 2.81 | 1.4 | 13.6 |
| WEST'N TRIB | 269.41 | 3.98 | 2.41 | 87.37 | 3.30 | 1.8 | 20.1 | 3.29 | 1.7 | 18.7 | 3.27 | 1.6 | 17.3 | 3.25 | 1.6 | 16.2 | 3.20 | 1.6 | 14.6 | 3.17 | 1.5 | 13.6 |
| WEST'N TRIB | 285.53 | 4.24 | 4.28 | 87.44 | 3.64 | 2.1 | 20.1 | 3.62 | 2.0 | 18.7 | 3.60 | 1.9 | 17.3 | 3.59 | 1.9 | 16.2 | 3.56 | 1.8 | 14.6 | 3.54 | 1.7 | 13.7 |
| WEST'N TRIB | 305 | 4.74 | 6.15 | 87.48 | 3.95 | 3.7 | 20.1 | 3.92 | 3.6 | 18.7 | 3.89 | 3.4 | 17.3 | 3.86 | 3.3 | 16.2 | 3.82 | 3.1 | 14.6 | 3.79 | 3.0 | 13.7 |
| WEST'N TRIB | 324 | 6.89 | 2.40 | 87.49 | 4.98 | 1.5 | 20.1 | 4.92 | 1.5 | 18.7 | 4.86 | 1.4 | 17.3 | 4.82 | 1.4 | 16.2 | 4.75 | 1.4 | 14.6 | 4.73 | 1.3 | 13.7 |
| WEST'N TRIB | 338.14 | 6.89 | 2.56 | 87.49 | 4.97 | 1.8 | 20.1 | 4.92 | 1.7 | 18.7 | 4.86 | 1.7 | 17.3 | 4.82 | 1.7 | 16.2 | 4.75 | 1.6 | 14.6 | 4.73 | 1.6 | 13.7 |
| WEST'N TRIB | 352.28 | 6.85 | 2.95 | 87.49 | 5.01 | 2.0 | 20.1 | 4.96 | 2.0 | 18.7 | 4.91 | 2.0 | 17.3 | 4.87 | 1.9 | 16.2 | 4.81 | 1.8 | 14.6 | 4.79 | 1.8 | 13.7 |
| WEST'N TRIB | 366.43 | 6.80 | 3.79 | 87.49 | 5.13 | 2.2 | 20.1 | 5.09 | 2.1 | 18.7 | 5.05 | 2.0 | 17.3 | 5.01 | 2.0 | 16.2 | 4.96 | 1.9 | 14.6 | 4.94 | 1.8 | 13.7 |
| WEST'N TRIB | 383.53 | 6.89 | 4.27 | 87.50 | 5.37 | 2.5 | 20.1 | 5.33 | 2.4 | 18.7 | 5.30 | 2.3 | 17.3 | 5.27 | 2.2 | 16.2 | 5.23 | 2.1 | 14.6 | 5.21 | 2.0 | 13.7 |
| WEST'N TRIB | 400.63 | 7.04 | 4.75 | 87.50 | 5.66 | 2.7 | 20.1 | 5.62 | 2.6 | 18.7 | 5.59 | 2.5 | 17.3 | 5.57 | 2.4 | 16.2 | 5.53 | 2.3 | 14.6 | 5.51 | 2.2 | 13.7 |
| WEST'N TRIB | 417.72 | 7.23 | 5.23 | 87.50 | 5.97 | 2.9 | 20.1 | 5.94 | 2.8 | 18.7 | 5.91 | 2.7 | 17.3 | 5.88 | 2.6 | 16.2 | 5.85 | 2.4 | 14.6 | 5.83 | 2.3 | 13.7 |

| River Name | MIKE11 Chainage (m) | PMF (100% Blockage) | | | 0.5% AEP (100% Blockage) | | | 1% AEP (100% Blockage) | | | 2% AEP (100% Blockage) | | | 5% AEP (100% Blockage) | | | 10% AEP (100% Blockage) | | | 20% AEP (100% Blockage) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) | Flood Peak (mAHD) | Peak Velocity (m/s) | Peak Discharge (m3/s) |
| WEST'N TRIB | 434.82 | 7.47 | 4.84 | 74.73 | 6.29 | 2.7 | 17.5 | 6.26 | 2.6 | 16.3 | 6.23 | 2.5 | 15.1 | 6.21 | 2.4 | 14.2 | 6.17 | 2.3 | 12.8 | 6.15 | 2.2 | 11.9 |
| WEST'N TRIB | 450.11 | 7.59 | 4.21 | 63.36 | 6.49 | 2.3 | 15.3 | 6.46 | 2.3 | 14.3 | 6.43 | 2.2 | 13.2 | 6.41 | 2.1 | 12.4 | 6.38 | 2.0 | 11.2 | 6.36 | 1.9 | 10.5 |
| WEST'N TRIB | 465.4 | 7.74 | 4.24 | 63.34 | 6.71 | 2.3 | 15.3 | 6.69 | 2.2 | 14.3 | 6.66 | 2.1 | 13.2 | 6.64 | 2.1 | 12.4 | 6.60 | 2.0 | 11.2 | 6.58 | 1.9 | 10.5 |
| WEST'N TRIB | 480.68 | 7.90 | 4.26 | 63.33 | 6.95 | 2.2 | 15.3 | 6.93 | 2.2 | 14.3 | 6.90 | 2.1 | 13.2 | 6.87 | 2.0 | 12.4 | 6.83 | 1.9 | 11.2 | 6.80 | 1.9 | 10.5 |
| WEST'N TRIB | 497.12 | 8.06 | 4.00 | 63.32 | 7.12 | 2.0 | 15.3 | 7.09 | 1.9 | 14.3 | 7.07 | 1.8 | 13.2 | 7.04 | 1.7 | 12.4 | 7.00 | 1.6 | 11.2 | 6.98 | 1.6 | 10.5 |
| WEST'N TRIB | 513.56 | 8.19 | 3.82 | 63.32 | 7.25 | 1.8 | 15.3 | 7.23 | 1.7 | 14.3 | 7.20 | 1.6 | 13.2 | 7.18 | 1.6 | 12.4 | 7.14 | 1.5 | 11.2 | 7.11 | 1.4 | 10.5 |
| WEST'N TRIB | 530 | 8.32 | 3.67 | 63.32 | 7.37 | 1.7 | 15.3 | 7.34 | 1.6 | 14.3 | 7.31 | 1.5 | 13.2 | 7.29 | 1.5 | 12.4 | 7.25 | 1.4 | 11.2 | 7.23 | 1.3 | 10.5 |
| WEST'N TRIB | 550 | 9.24 | 2.61 | 63.32 | 9.05 | 0.7 | 15.3 | 9.02 | 0.6 | 14.3 | 8.99 | 0.6 | 13.2 | 8.97 | 0.6 | 12.4 | 8.93 | 0.5 | 11.2 | 8.90 | 0.5 | 10.5 |
| WEST'N TRIB | 567.48 | 9.38 | 0.70 | 63.32 | 9.07 | 0.2 | 15.3 | 9.04 | 0.2 | 14.3 | 9.00 | 0.2 | 13.2 | 8.98 | 0.2 | 12.4 | 8.94 | 0.1 | 11.2 | 8.91 | 0.1 | 10.5 |
| WEST'N TRIB | 584.97 | 9.39 | 0.81 | 63.33 | 9.07 | 0.1 | 15.3 | 9.04 | 0.1 | 14.3 | 9.01 | 0.1 | 13.2 | 8.98 | 0.1 | 12.4 | 8.94 | 0.1 | 11.2 | 8.91 | 0.1 | 10.5 |
| WEST'N TRIB | 602.45 | 9.40 | 1.04 | 63.33 | 9.07 | 0.2 | 15.4 | 9.04 | 0.2 | 14.4 | 9.01 | 0.2 | 13.3 | 8.98 | 0.2 | 12.5 | 8.94 | 0.2 | 11.3 | 8.91 | 0.1 | 10.6 |
| WEST'N TRIB | 619.93 | 9.43 | 1.11 | 63.36 | 9.07 | 0.3 | 15.6 | 9.04 | 0.3 | 14.5 | 9.01 | 0.3 | 13.5 | 8.99 | 0.3 | 12.6 | 8.94 | 0.3 | 11.4 | 8.92 | 0.3 | 10.7 |
| WEST'N TRIB | 637.42 | 9.63 | 1.23 | 63.39 | 9.19 | 0.8 | 15.7 | 9.16 | 0.8 | 14.6 | 9.14 | 0.8 | 13.6 | 9.12 | 0.8 | 12.8 | 9.08 | 0.7 | 11.6 | 9.05 | 0.7 | 10.8 |
| WEST'N TRIB | 654.9 | 10.04 | 1.37 | 63.40 | 9.61 | 1.0 | 15.7 | 9.59 | 0.9 | 14.7 | 9.58 | 0.9 | 13.6 | 9.56 | 0.9 | 12.8 | 9.54 | 0.9 | 11.6 | 9.52 | 0.9 | 10.9 |
| WEST'N TRIB | 672.39 | 10.56 | 1.40 | 63.42 | 10.14 | 1.0 | 15.7 | 10.13 | 1.0 | 14.7 | 10.11 | 1.0 | 13.6 | 10.10 | 1.0 | 12.9 | 10.08 | 1.0 | 11.6 | 10.07 | 0.9 | 10.9 |
| WEST'N TRIB | 689.48 | 11.10 | 1.58 | 63.42 | 10.72 | 1.1 | 15.7 | 10.70 | 1.1 | 14.7 | 10.68 | 1.1 | 13.6 | 10.67 | 1.0 | 12.9 | 10.65 | 1.0 | 11.6 | 10.64 | 1.0 | 10.9 |
| WEST'N TRIB | 706.58 | 11.66 | 1.78 | 63.42 | 11.31 | 1.2 | 15.8 | 11.29 | 1.2 | 14.7 | 11.27 | 1.1 | 13.6 | 11.26 | 1.1 | 12.9 | 11.24 | 1.1 | 11.6 | 11.22 | 1.1 | 10.9 |
| WEST'N TRIB | 723.68 | 12.23 | 2.04 | 63.43 | 11.91 | 1.4 | 15.8 | 11.89 | 1.3 | 14.7 | 11.87 | 1.3 | 13.6 | 11.86 | 1.3 | 12.9 | 11.84 | 1.2 | 11.6 | 11.83 | 1.2 | 10.9 |
| WEST'N TRIB | 740.77 | 12.84 | 2.54 | 63.43 | 12.51 | 1.6 | 15.8 | 12.50 | 1.5 | 14.7 | 12.48 | 1.5 | 13.7 | 12.47 | 1.5 | 12.9 | 12.45 | 1.4 | 11.6 | 12.44 | 1.4 | 10.9 |
| WEST'N TRIB | 759.54 | 13.35 | 2.26 | 63.43 | 13.00 | 1.4 | 15.8 | 12.99 | 1.4 | 14.7 | 12.97 | 1.3 | 13.7 | 12.96 | 1.3 | 12.9 | 12.94 | 1.3 | 11.6 | 12.93 | 1.3 | 10.9 |
| WEST'N TRIB | 778.3 | 13.82 | 2.18 | 63.43 | 13.47 | 1.4 | 15.8 | 13.45 | 1.4 | 14.7 | 13.44 | 1.3 | 13.7 | 13.43 | 1.3 | 12.9 | 13.41 | 1.3 | 11.6 | 13.39 | 1.3 | 10.9 |
| WEST'N TRIB | 797.07 | 14.28 | 2.14 | 63.44 | 13.93 | 1.4 | 15.8 | 13.92 | 1.4 | 14.7 | 13.90 | 1.3 | 13.7 | 13.89 | 1.3 | 12.9 | 13.87 | 1.3 | 11.6 | 13.85 | 1.3 | 10.9 |
| WEST'N TRIB | 815.83 | 14.73 | 2.11 | 63.44 | 14.39 | 1.4 | 15.8 | 14.38 | 1.4 | 14.7 | 14.36 | 1.4 | 13.7 | 14.35 | 1.3 | 12.9 | 14.33 | 1.3 | 11.7 | 14.31 | 1.3 | 10.9 |
| WEST'N TRIB | 834.59 | 15.19 | 2.08 | 63.44 | 14.85 | 1.4 | 15.8 | 14.84 | 1.4 | 14.7 | 14.82 | 1.4 | 13.7 | 14.81 | 1.3 | 12.9 | 14.79 | 1.3 | 11.7 | 14.77 | 1.3 | 10.9 |
| WEST'N TRIB | 853.36 | 15.65 | 2.05 | 63.45 | 15.31 | 1.4 | 15.8 | 15.30 | 1.4 | 14.7 | 15.28 | 1.4 | 13.7 | 15.27 | 1.4 | 12.9 | 15.24 | 1.3 | 11.7 | 15.23 | 1.3 | 10.9 |
| WEST'N TRIB | 872.12 | 16.11 | 2.02 | 63.45 | 15.78 | 1.4 | 15.8 | 15.76 | 1.4 | 14.7 | 15.74 | 1.4 | 13.7 | 15.73 | 1.4 | 12.9 | 15.70 | 1.3 | 11.7 | 15.69 | 1.3 | 10.9 |
| WEST'N TRIB | 890.89 | 16.56 | 1.99 | 63.45 | 16.24 | 1.4 | 15.8 | 16.22 | 1.4 | 14.8 | 16.20 | 1.4 | 13.7 | 16.19 | 1.4 | 12.9 | 16.16 | 1.3 | 11.7 | 16.15 | 1.3 | 10.9 |
| WEST'N TRIB | 909.65 | 17.02 | 1.96 | 63.46 | 16.70 | 1.4 | 15.8 | 16.68 | 1.4 | 14.8 | 16.66 | 1.4 | 13.7 | 16.65 | 1.4 | 12.9 | 16.62 | 1.4 | 11.7 | 16.61 | 1.3 | 10.9 |
| WEST'N TRIB | 928.41 | 17.48 | 1.93 | 63.46 | 17.16 | 1.5 | 15.8 | 17.14 | 1.4 | 14.8 | 17.12 | 1.4 | 13.7 | 17.11 | 1.4 | 12.9 | 17.08 | 1.4 | 11.7 | 17.07 | 1.3 | 10.9 |
| WEST'N TRIB | 947.18 | 17.94 | 1.91 | 63.46 | 17.62 | 1.5 | 15.8 | 17.60 | 1.5 | 14.8 | 17.58 | 1.4 | 13.7 | 17.57 | 1.4 | 12.9 | 17.54 | 1.4 | 11.7 | 17.53 | 1.4 | 10.9 |
| WEST'N TRIB | 965.94 | 18.40 | 1.41 | 47.45 | 18.08 | 1.1 | 11.9 | 18.06 | 1.1 | 11.1 | 18.04 | 1.1 | 10.3 | 18.03 | 1.1 | 9.8 | 18.00 | 1.1 | 8.8 | 17.99 | 1.0 | 8.3 |
| WEST'N TRIB | 984.46 | 18.81 | 1.53 | 31.73 | 18.50 | 1.4 | 8.1 | 18.49 | 1.4 | 7.5 | 18.47 | 1.4 | 7.0 | 18.46 | 1.4 | 6.6 | 18.44 | 1.3 | 6.0 | 18.42 | 1.3 | 5.6 |
| WEST'N TRIB | 1002.98 | 19.36 | 1.64 | 31.73 | 19.07 | 1.6 | 8.1 | 19.06 | 1.6 | 7.5 | 19.04 | 1.5 | 7.0 | 19.03 | 1.5 | 6.6 | 19.01 | 1.5 | 6.0 | 18.99 | 1.5 | 5.6 |
| WEST'N TRIB | 1021.5 | 19.94 | 1.71 | 31.76 | 19.66 | 1.7 | 8.1 | 19.64 | 1.6 | 7.5 | 19.63 | 1.6 | 7.0 | 19.61 | 1.6 | 6.6 | 19.59 | 1.6 | 6.0 | 19.58 | 1.6 | 5.7 |
| WEST'N TRIB | 1040.03 | 20.51 | 1.78 | 31.77 | 20.25 | 1.7 | 8.1 | 20.23 | 1.7 | 7.5 | 20.22 | 1.7 | 7.0 | 20.20 | 1.7 | 6.6 | 20.18 | 1.7 | 6.0 | 20.16 | 1.6 | 5.7 |
| WEST'N TRIB | 1058.55 | 21.09 | 1.86 | 31.80 | 20.84 | 1.8 | 8.1 | 20.82 | 1.8 | 7.5 | 20.80 | 1.8 | 7.0 | 20.79 | 1.8 | 6.7 | 20.76 | 1.7 | 6.0 | 20.75 | 1.7 | 5.7 |
| WEST'N TRIB | 1077.29 | 21.65 | 1.76 | 31.82 | 21.39 | 1.7 | 8.1 | 21.37 | 1.7 | 7.5 | 21.36 | 1.7 | 7.0 | 21.34 | 1.7 | 6.7 | 21.32 | 1.6 | 6.0 | 21.30 | 1.6 | 5.7 |
| WEST'N TRIB | 1096.03 | 22.20 | 1.84 | 31.85 | 21.92 | 1.6 | 8.1 | 21.91 | 1.6 | 7.5 | 21.90 | 1.6 | 7.0 | 21.89 | 1.6 | 6.7 | 21.86 | 1.6 | 6.0 | 21.84 | 1.6 | 5.7 |
| WEST'N TRIB | 1114.77 | 22.74 | 1.90 | 31.88 | 22.46 | 1.5 | 8.1 | 22.44 | 1.5 | 7.5 | 22.43 | 1.5 | 7.0 | 22.42 | 1.5 | 6.7 | 22.41 | 1.5 | 6.0 | 22.39 | 1.5 | 5.7 |
| WEST'N TRIB | 1133.52 | 23.29 | 1.93 | 31.92 | 22.99 | 1.5 | 8.1 | 22.98 | 1.5 | 7.5 | 22.97 | 1.5 | 7.0 | 22.96 | 1.4 | 6.7 | 22.95 | 1.4 | 6.0 | 22.94 | 1.4 | 5.7 |
| WEST'N TRIB | 1152.26 | 23.83 | 1.95 | 31.97 | 23.53 | 1.4 | 8.1 | 23.52 | 1.4 | 7.5 | 23.50 | 1.4 | 7.0 | 23.50 | 1.4 | 6.7 | 23.48 | 1.4 | 6.0 | 23.47 | 1.4 | 5.7 |
| WEST'N TRIB | 1171 | 24.37 | 1.97 | 31.95 | 24.06 | 1.4 | 8.1 | 24.05 | 1.3 | 7.5 | 24.04 | 1.3 | 7.0 | 24.03 | 1.3 | 6.7 | 24.02 | 1.3 | 6.0 | 24.01 | 1.3 | 5.7 |