SCOTTS CREEK
FLOOD STUDY

FINAL REPORT
March 2008

Floodwaters in lined section of channel upstream of Macquarie Street, 10 April 1998 Flood

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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 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	Determines the nature and extent of flooding.
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 Scotts Creek Flood Study is jointly funded by Willoughby City Council and Department of Environment and Climate Change (formerly known as Department of Natural Resources). The Flood Study constitutes the first stage of the Floodplain Management process for this area and has been prepared for Willoughby City Council to define flood behaviour under current conditions.

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NOTE ON FLOOD FREQUENCY

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having 5% AEP, there is a 5% probability that there will be floods of greater magnitude each year. As another example, for a flood having a 5 year ARI, there will be floods of equal or greater magnitude once in 5 years on average. The approximate correspondence between these two systems is:

ANNUAL EXCEEDENCE PROBABILITY (AEP) %	AVERAGE RECURRENCE INTERVAL (ARI) YEARS
0.5	200
1	100
5	20
20	5

The report also refers to the Probable Maximum Flood (PMF). This flood occurs as a result of the probable maximum precipitation (PMP). The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a model which simulates the conversion of rainfall to runoff. The PMF is defined as the limiting value of floods that could reasonably be expected to occur. In this report the term "Extreme Flood" is also used as a synonym for the PMF.

ABBREVIATIONS

AEP	Annual Exceedence Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff, 2001 Edition
BOM	Bureau of Meteorology
DECC	Department of Environment and Climate Change (formerly, the Department of Natural Resources, DNR)
WCC	Willoughby City Council

S1 SYNOPSIS

The study objective was to define flood behaviour in terms of flows, levels and flooding behaviour on Scotts Creek for floods ranging between 5 and 200 years average recurrence interval (ARI), as well as the Extreme Flood event. **Figure 1.2** shows the study area.

The flood study investigation involved:

- The hydrologic modelling of the catchment of Scotts Creek to determine flood flows.
- Hydraulic modelling of the overland flow path between Havilah Street and the commencement of the stormwater channel immediately downstream of the Temple Emanuel school to convert flows to peak water surface levels and flow velocities.
- Hydraulic modelling of the open channel between the Temple Emanuel school and the Eastern Valley Way. The concrete lined, rectangular shaped stormwater drain which extends to Penshurst Street is owned by Sydney Water. Downstream of Penshurst Street the creek is owned by Willoughby City Council and consists of semi-natural rock lined sections and improved sections lined by “pillow concrete”.

Flood behaviour was defined using a computer based hydrologic model of the catchment and a hydraulic model of the overland flow path, the channel and its overbanks.

The hydrologic modelling approach was based on the DRAINS rainfall-runoff software which was used to determine flood flows in the catchment. A one-dimensional model based on the HEC-RAS system was adopted for the hydraulic analysis to model flood levels on Scotts Creek.

There are two formal detention basins located on the Scotts Creek drainage system, together with the potential storage of overland flows traversing eastwards along Victoria Avenue in the basement car park of Chatswood Chase. These storages were incorporated in the DRAINS model. DRAINS gave estimates of the distribution of piped and overland flows along the line of the trunk drain. The resulting flows were applied to HEC-RAS to give estimates of peak water surface profiles and flow distributions across the waterway cross – sections comprising the model.

The models were tested for the major storm which occurred in the Chatswood area on 10 April 1998 for which the temporal distribution of rainfall, as recorded at the pluviometer at Chatswood Bowling Club was available, along with observations of flood behaviour through the Chatswood CBD and some recorded flood levels on the creek. The models reproduced observed flood behaviour. The derived flood levels and flows for the design flood events are consistent with expected results and historic flooding patterns. The impacts of a partial blockage of several bridge openings were also assessed.

The report contains exhibits showing the indicative extent of inundation for floods ranging between 5 year ARI and the PMF. Provisional flood hazard and hydraulic categorisation diagrams are also shown for the 20 and 100 year ARI floods.

1 INTRODUCTION

1.1 Study Background

This report presents the results of a detailed technical investigation of flooding in the Scotts Creek catchment and has been sponsored by Willoughby City Council (WCC) and Department of Environment and Climate Change. **Figure 1.1** shows the location of the catchment which drains the suburbs of Chatswood and Castle Cove before discharging to Sugarloaf Bay in Middle Harbour. The investigation defined flooding as far downstream as the Eastern Valley Way.

Mathematical models of the catchment and the floodplain were developed using detailed field surveys and interpreted to present a comprehensive picture of flooding under present day conditions. The study objective was to define flood behaviour in the stream in terms of flows, levels and flooding behaviour for floods ranging between 5 and 200 years average recurrence interval (ARI), as well as the PMF.

The investigation involved hydrologic modelling to assess flows in Scotts Creek between its headwaters in the Chatswood CBD area and the Eastern Valley Way. These flows were applied to a hydraulic model of the main arm of Scotts Creek to assess peak water levels and flow patterns. The hydraulic modelling extended from Havilah Street on the eastern side of Chatswood Chase to the Eastern Valley Way.

The trunk drainage system of Scotts Creek to Penshurst Street is denoted Stormwater Catchment 26 and is owned by Sydney Water. It comprises sections of piped drains, as well as covered and open concrete lined stormwater channels. The piped drainage system extends through the Chatswood CBD to the eastern side of Chatswood Chase in Havilah Street (**Figure 1.2**).

Between Havilah Street and Baldry Street, flows on the main arm of Scotts Creek are conveyed in Sydney Water's covered stormwater channel which follows the route of the original creek and extends as far as the Temple Emanuel School near Chatswood Avenue. An open concrete lined stormwater channel also owned by Sydney Water continues downstream and conveys flows to Penshurst Street. Willoughby City Council's channel continues downstream of Penshurst Street to the Eastern Valley Way, and comprises sections of rock lined and "pillow concrete" lined trapezoidal channel. The total catchment area at the Eastern Valley Way is 3 km^2.

The headwaters of the catchment are drained by separate piped trunk drainage systems which drain the northern and southern portions of the catchment. Overland flows from the southern trunk drain are diverted into Chatswood Oval, which functions as an off-line detention basin during periods of heavy rainfall.

Peak flows from the northern portion of the catchment will be influenced by a flood storage/ water harvesting basin which will be excavated adjacent to Ferguson Lane as part of the Chatswood Civic Place project, due for construction in 2009 and situated just upstream of the intersection of that street with Archer Street. The storage characteristics of both Chatswood Oval and the flood storage basin in Ferguson Lane have been included in the hydrologic model of Scotts Creek developed in this study for the estimation of design flows.

The trunk drainage systems meet at the intersection of Archer Street and Victoria Avenue and continue eastwards as separate piped systems along both the northern and southern sides of Victoria Avenue to Havilah Street. The drainage system is of limited hydraulic capacity and has been surcharged, most recently in April 1998, when flooding was experienced in several commercial properties bordering Victoria Avenue.

It was reported that overland flows heading eastwards along Victoria Avenue in the April 1998 flood were captured by the prevailing natural surface grade and flowed into the basement car park of Chatswood Chase via the driveway entrance near the intersection with Havilah Street. Overland flows heading eastwards down Mills Lane also entered Chatswood Chase. The car park then acted as a detention basin and had a local influence on downstream flows in the creek. To include the effect of this informal detention basin on downstream flows, the car park storage was also incorporated in the hydrologic model.

For the hydraulic modelling, which converted flows into flood levels and velocities, Willoughby City Council decided to focus on the section of the creek downstream of Havilah Street, where there is residential development bordering both sides of the creek and where flooding problems have been experienced in the past.

1.2 Approach to Flood Modelling

Flood behaviour was defined using a computer based hydrologic model of the catchment based on the DRAINS rainfall-runoff software and a hydraulic model of the overland flow path and channel sections downstream of Chatswood Chase based on the HEC-RAS system.

1.2.1. Hydrologic Modelling

For the hydrologic analysis of the Scotts Creek catchment, a model based on the ILSAX software had been developed by Rankine and Hill in 1987 and used to design the detention basin in Chatswood Oval. In 1989 the ILSAX model was extended to the Eastern Valley Way by K R Stubbs and Associates.

The ILSAX model of the portion of the catchment upstream of the intersection of Archer Street and Victoria Avenue was converted to DRAINS in a recent investigation associated the Chatswood Civic Place project (Lyall and Associates, 2006). The Civic Place project will require the deviation of Sydney Water's trunk stormwater system between Anderson Street and Victoria Avenue. The new trunk system will run along the northern side of Ferguson Lane and continue down Archer Street to Victoria Avenue. The DRAINS model was used to size the new drainage system, which will also include the dual purpose off-line flood storage – stormwater reuse basin excavated adjacent to Ferguson Lane.

The remaining portion of the ILSAX model downstream of Victoria Avenue was also converted to DRAINS for the present Flood Study and attached to the Civic Place DRAINS model. The resulting DRAINS model represents post-Civic Place conditions on Scotts Creek as far as the Eastern Valley Way and was adopted as representing present day conditions on the catchment.

The post - Civic Place DRAINS model was used for design flood estimation in this investigation. A second model with the drainage system in the Civic Place area configured as it existed at the time of the April 1998 storm was also constructed and used for model testing. WCC has instituted an on-site detention storage policy for the catchment, which has resulted in the implementation of storage tanks in individual developments in the CBD and downstream residential area. These storages are intended to mitigate the impacts of ongoing development in the catchment and may over time, result in a small reduction in downstream flood peaks. It was not practicable to include these many small storages in the DRAINS model. To the extent that they have not been incorporated in the investigation, the design peak flows may be on the high side. However, any effect on the results would be very small.

1.2.2. Hydraulic modelling

A one-dimensional model based on the HEC-RAS system was adopted for the hydraulic analysis to model flood levels and flow patterns in the channel of Scotts Creek. The model allowed for the interaction of flows between the channel and its overbanks, flow through culverts and flow over the decks of the local road bridges.

A HEC-2 model of the lower reaches of Scotts Creek had been prepared by Stubbs and Associates around 1987. The model extended upstream from Eastern Valley Way to Gibbes Street, a distance of about 500 m. The HEC-2 model was converted to HEC-RAS and extended about 2 km upstream to Havilah Street, using a creek survey undertaken for the present Flood Study. Gallagher Odell and Garey Consulting Surveyors provided cross-sections of the creek channel and overbanks, measured the bridge crossings between Gibbes Street and the commencement of the channel near Chatswood Avenue and also surveyed the overland flow path upstream to Havilah Street.

1.3 Model Development and Testing

There are no stream flow data available on the Scotts Creek catchment. Several historic storms experienced in the Chatswood - Willoughby area had been identified during a previous flood investigation on the nearby Flat Rock Creek catchment (LACE, 2006).

Flood marks for the most recent major flood, which occurred on 10 April 1998, were identified as a result of the distribution of a Community Newsletter for this present investigation.

Rainfalls for the April 1998 storm which were recorded at the Chatswood Bowling Club pluviometer, located near the south-west boundary of the Scotts Creek catchment, were applied to the DRAINS model (conditions as at April 1998) to estimate flows.

The resulting flows were applied to the HEC-RAS model and the computed water surface profiles compared with the recorded flood marks. A reasonable fit was achieved between recorded and modelled flood levels which allowed the selection of model parameters for design purposes. Testing the models for the April 1998 storm is described in **Section 3** of **Appendix A**.

1.4 Design Flood Estimation

Design storms were derived from Australian Rainfall and Runoff (ARR), 2001 and then applied to the DRAINS model to generate discharge hydrographs within the study area. Peak flows from those hydrographs constituted the upstream boundary and tributary inflow inputs to the hydraulic model. The hydraulic model was then used to derive water surface profiles for the design flood flows, as well as provide an assessment of the flow distribution and average velocities of flow for the design events.

1.5 Summary of Study Tasks

The Flood Study had three main components:

(1) **Review of available hydrologic and hydraulic data and previous investigations.** A Brief was prepared for a cross sectional survey of the main arm of Scotts Creek. Historic flood marks identified by the Community Newsletter were also levelled during the creek survey. The Bureau of Meteorology and Sydney Water supplied rainfall data for the historic storm of 10 April 1998.

(2) The **hydrologic component,** which included refining and testing of the hydrologic model of the catchment, estimation of design storm rainfalls and their application to the model to assess flows.

(3) The **hydraulic component,** which comprised the testing of the hydraulic model and the definition of the water surface profiles, flows and velocities for the design floods.

1.6 Layout of Report

Section 2 contains background information including a description of the catchment, a brief review of the data base available for the study and a discussion on the history of flooding in the catchment.

Sections 3 and 4 deal with the hydrology of the Scotts Creek catchment and the results of the DRAINS modelling undertaken to assess flood flows on the catchment. These sections describe the set up and testing of the model, the determination of design storm rainfall depths over the catchments for a range of storm durations and conversion of the rainfall hyetographs to discharge hydrographs.

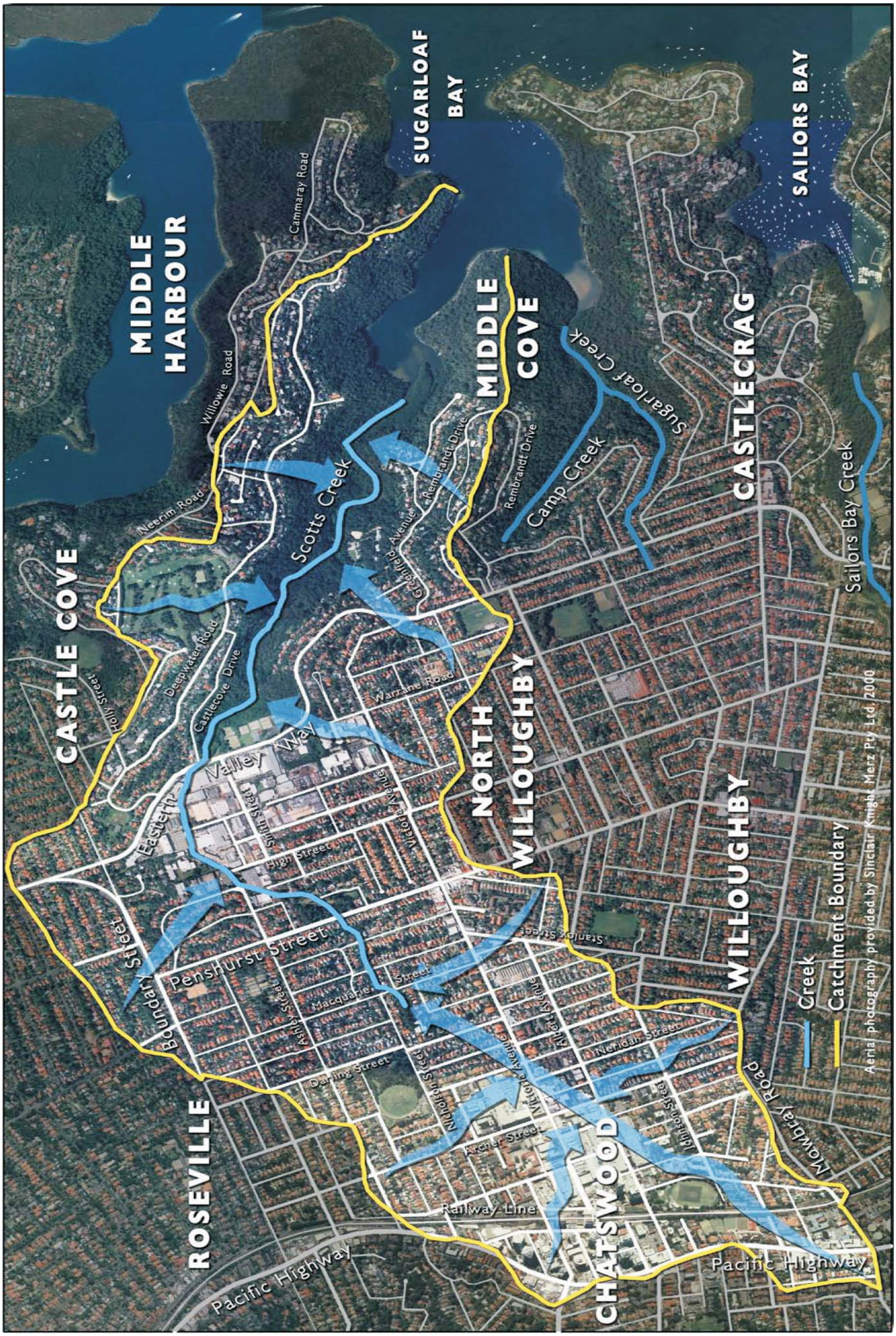
Section 5 deals with the development and testing of the HEC-RAS hydraulic model. This section also includes a detailed investigation of the hydraulics of the overland flow path, which controls flood levels in the upper reaches of the trunk drainage system where the flow is piped.

Section 6 details the results of the hydraulic modelling of the design floods using HEC-RAS. Results are presented as water surface profiles and plans showing indicative extents of inundation for each of the design flood events. A provisional assessment of flood hazard and hydraulic categorisation is also presented. (The assessment of flood hazard according to hydraulic criteria such as velocity and depth of floodwaters is necessarily “provisional”, pending a more detailed assessment of other flood related criteria which would be undertaken during a Floodplain Risk Management Study.) The flood study investigation also included an assessment of the hydraulic capacity of the culverts at the local road crossings in the event of their partial blockage by debris.

Section 7 contains a list of references.

Appendix A summarises responses of the Community Newsletter and describes testing of the hydrologic and hydraulic models

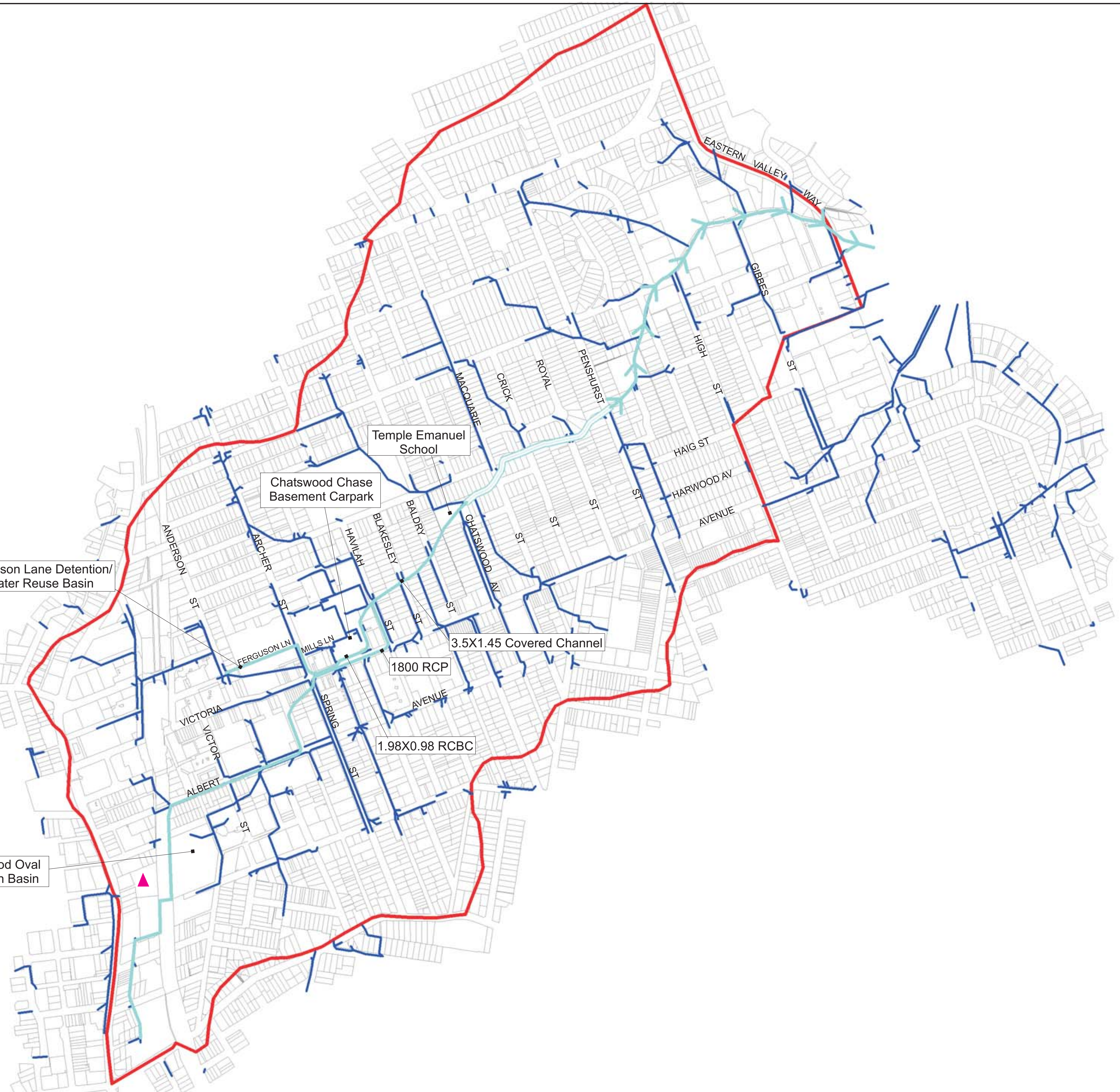
Appendix B contains tabulations of flood level, discharge and velocity data for design storm events between 5 and 200 years ARI, as well as for the PMF.



SCOTTS CREEK
FLOOD STUDY

Figure 1.1

LOCATION PLAN



LEGEND

- Catchment Boundary
- Minor Drainage Lines
- Chatswood Bowling Club Pluviometer
- Willoughby City Council's Unlined Stormwater Drain
- Sydney Water's Open Stormwater Channel
- Sydney Water's Piped and Covered Stormwater Channel

N

0 300 600 m
Scale

SCOTTS CREEK FLOOD STUDY

Figure 1.2

STORMWATER DRAINAGE SYSTEM

2 SCOTTS CREEK CATCHMENT AND ITS DRAINAGE SYSTEM

2.1 Catchment Description

The valley drained by Scotts Creek has a total catchment area of about 3 km^2 and extends eastwards in the suburb of Chatswood from the Pacific Highway to Eastern Valley Way, a distance of 4 km (**Figure 1.2**).

The catchment is completely urbanised. Its flooding characteristics have been altered by residential and commercial developments, which have displaced the natural drainage system and its flood storage characteristics. Features of the drainage system are illustrated by photographs in **Appendix C**.

2.1.1. Pacific Highway to Havilah Street

Within this section of the catchment, stormwater is conveyed in a piped system, with the streets acting as overland flow paths. The total catchment area at Havilah Street is 1.3 km^2. There are two formal detention basins at Ferguson Lane and Chatswood Oval and an informal storage in the Chatswood Chase basement car park, which becomes flooded during severe storm events as a result of ingress of overland flow from Victoria Avenue. The storage characteristics of these basins are shown in **Figure 2.1**. The storage characteristics of the Chatswood Oval basin were derived from Rankine and Hill, 1987. The potential storage in Chatswood Chase was estimated from working drawings of the project. Flood storage in the Fergusen Lane Basin was estimated from the Lyall and Associates, 2006 study.

The Ferguson Lane basin is located off-line to the piped stormwater system, has a total storage volume of about 5,000 m^3 and controls runoff from a catchment of 18 ha. The basin will store stormwater derived from the catchment for treatment and reuse to satisfy non-potable demand in nearby buildings. The maximum volume of "conservation storage" will be 3,000 m^3. It is proposed to provide pumps for the evacuation of the storage into the downstream piped stormwater system prior to the arrival of a flood (if required), to achieve a storage level of 1,000 m^3. At least 4,000 m^3 of "air space" would therefore be available to store overland flows which surcharge the capacity of the piped stormwater system. These pumps will achieve a speedy evacuation of the storage but will not tax the capacity of the stormwater system. Hydrologic analysis has shown that this method of operation would provide sufficient air space to store overland flows in Ferguson Lane from storms up to 100 year ARI. In addition, the proposed raising of road levels at the intersection with Mills Lane would prevent overland flows in Archer Street from entering the Chase via overland flows down that street.

The Chatswood Oval detention basin has a storage volume of 17,500 m^3 and stores runoff from a catchment of 25 ha. The Chatswood Oval basin is off-line to the piped drainage system. Runoff enters the oval as overland flow and would be stored to a maximum depth of 1.2 m.

In Victoria Avenue the piped drainage system consists of an 1800 mm diameter pipe on the southern side of the street and a box culvert of 1.98 m by 0.98 m dimensions on the northern side. As part of the Chatswood Chase development in the late 1980's, the culvert near the intersection with Havilah Street was replaced with a section of 2.5 m by 1.25 m RCBC. At the intersection the two lines join and continue northwards down Havilah Street as a single covered stormwater channel of 3.5 m by 1.45 m dimensions.

Overland flows which surcharge the piped system in Victoria Avenue travel in an easterly direction towards the entry ramp into the basement car park of Chatswood Chase. For medium storms, the flow would continue into Havilah Street. However when the depth in Victoria Avenue reaches a threshold of about 250 mm, flow into the car park would commence. The car park is capable of storing in excess of 6,000 m^3 before the pondage surcharges the earth landscaping mound which runs along the property boundary on the western side of Havilah Street (**Plate 1**).

The storage effects of water ponding in Victoria Avenue between Archer Street and Havilah Street have also been included in the DRAINS model by incorporating a stage-storage volume relationship derived using plans supplied by WCC.

2.1.2. Havilah Street to Penshurst Street

From Havilah Street to the commencement of the concrete stormwater channel on the eastern side of the Temple Emanuel School, flows are conveyed in a covered channel of dimensions 3.5 m by 1.45 m. The channel runs beneath the local north – south running streets between Havilah Street and Chatswood Avenue and through the residential allotments bordering those streets (**Plate 2**). Overland flow through the residential properties has been experienced when the covered channel surcharges, most recently in April 1998.

The open stormwater channel continues for a further 400 m to Penshurst Street, with three local road crossings at Macquarie, Crick and Royal Streets. During major flood events these crossings control upstream flood levels, and a significant proportion of the overall discharge is conveyed over the roadways as weir flow. The lowest crossing is at Crick Street. The typical dimensions of the channel are 4.5 m wide by 1.6 m deep and its average grade is about 0.6 per cent. Flow in the channel is in the mildly supercritical regime, with flow velocities around 4 to 5 m/s. Undular hydraulic jumps occur upstream of the bridges during major flood flows.

Residents reported that on 10 April 1998, floodwaters surcharged the channel and extended into adjacent residential allotments. Paling fences bordering the creek were brought down by the high velocity flow and conveyed downstream. Partial blockage of several of the bridge openings occurred, notably at Macquarie Street (**Plates 3** and **4**).

The Penshurst Street crossing is high set with the roadway about 5 m above the channel invert. The waterway opening is quite small amounting to 6.6 m^2 in area (**Plate 5**). The bridge controls flooding for about 100 m upstream and during major flooding low lying residential allotments on both sides of the creek would be inundated.

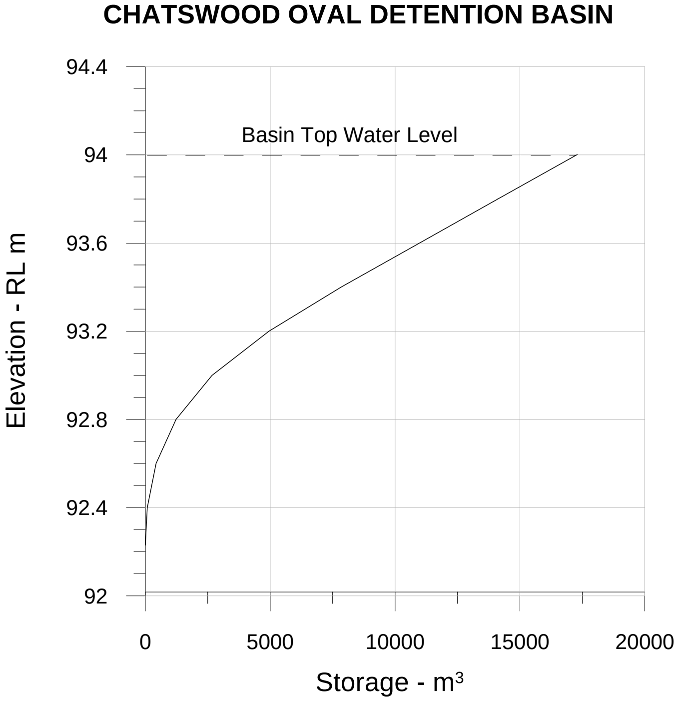
2.1.3. Penshurst Street to Eastern Valley Way

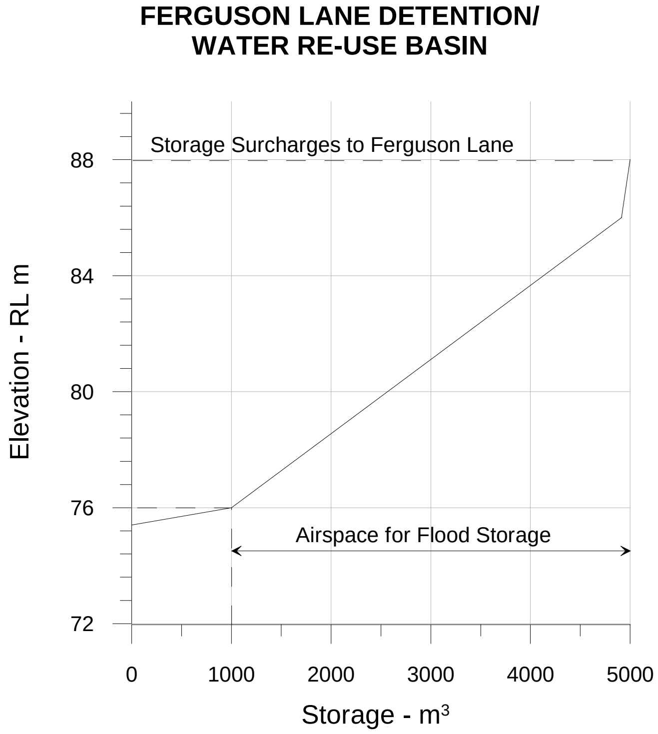
Sydney Water's lined channel ends at Penshurst Street. From that location to the downstream end of the study reach at the Eastern Valley Way, the channel is owned by Willoughby City Council. The stream over the 700 m reach to Gibbes Street is rock lined or in a semi natural state. Sections in Muston Park on the eastern side of Penshurst Street have been landscaped with pool and riffle zones constructed of sandstone blocks.

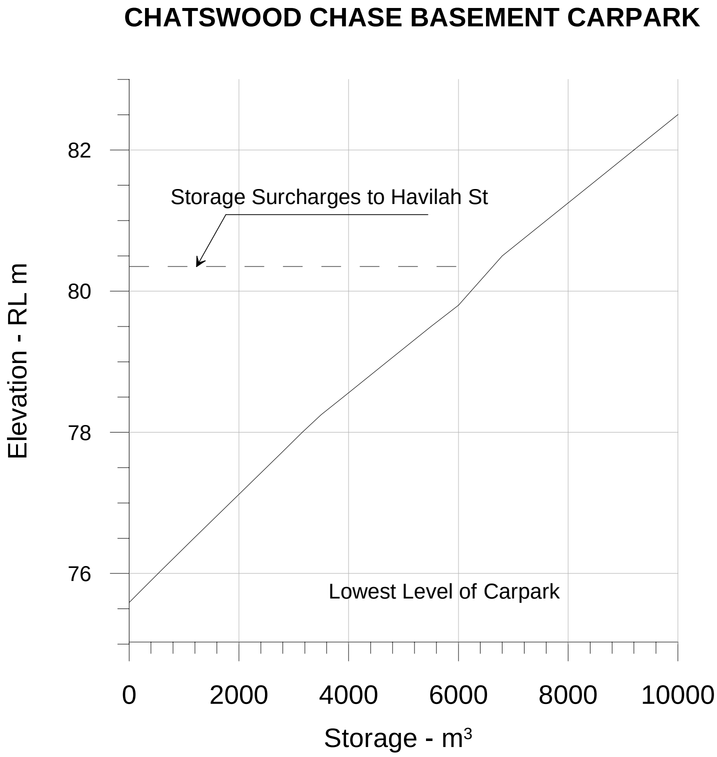
There are some isolated sections at the retirement village located downstream of Muston Park where the sides of the channel have been formed with "pillow concrete" to increase its hydraulic capacity (**Plates 6** and **7**). The entrance to the retirement village building on the northern side of the channel is connected to the southern bank by a walkway with its deck at the top of bank level.

Between the retirement village and Gibbes Street the creek comprises semi-natural rock lined and landscaped sections, (**Plates 8** to **10**).

Downstream of Gibbes Street the creek continues through an industrial area where the channel is of trapezoidal section formed of sections of pillow concrete and rock lined sections (**Plate 11**). This type of construction continues for 500 m to the culvert beneath the Eastern Valley Way. The channel in this reach was sized by K.R. Stubbs and Associates to contain the 100 year peak discharge.







SCOTTS CREEK
FLOOD STUDY

Figure 2.1

DETENTION BASINS STORAGE CHARACTERISTICS

3 HYDROLOGIC MODELLING OF SCOTTS CREEK CATCHMENT

3.1 Selection of Hydrologic Model

Consideration was given to the appropriate hydrologic modelling approach for the investigation.

The DRAINS rainfall-runoff modelling software adopted for the flood study is a more suitable approach to modelling an urbanised catchment such as Scotts Creek than other rainfall runoff approaches such as RAFTS and RORB, which do not explicitly model the piped component of the main drainage system.

DRAINS is specifically designed to model urban catchments drained by piped drainage systems. In DRAINS, rainfall on each sub-catchment is adjusted to allow for infiltration and other losses. The resulting sub-area rainfall-excess is converted into a hydrograph and assumed to enter the drainage system, subject to constraints imposed by the entrance and conveyance capacity of the system. There, it is added to any existing flow in the system and the combined flow is routed through the system to the outlet.

DRAINS allows for features which control the capacity of the piped system such as pit entry capacity and localised storage areas, assesses the capacity of the piped system using a Hydraulic Grade Line analysis, models gutter flows and routes overland flows along the street system to downstream areas via defined flow paths.

Overall, by accounting for the various elements of the constructed drainage system, including detention basins, DRAINS allowed a more realistic routing of flows through the drainage system than approaches which route flows through the model sub-catchments and do not specifically model piped systems.

The ability of the software to separately model both the piped flow and the overland flow surcharging the piped system was important in the study. On Scotts Creek, a considerable portion of the flow upstream of the commencement of the open channel near Macquarie Street is conveyed in Sydney Water's covered concrete stormwater drain, with the balance conveyed in the street system and across residential allotments as overland flow.

3.2 Model Setup and Layout

The model was developed from 1:2000 scale topographic maps of the Scotts Creek catchment and details of the existing drainage system supplied by Council. Percentages of impervious area were assessed using aerial photos and cadastral boundary data.

The sub-catchment areas, pits, conduits, overland flow paths, open channels and detention basin data were used to develop the two DRAINS models representing the drainage system under April 1998 and current conditions.

3.3 Model Testing Procedure and Results

The procedure adopted for testing the DRAINS model, in situations where historic flood data are available, involves the collection and analysis of rainfall data to ascertain the temporal and areal distribution of rainfall over the catchment. These rainfalls are input to the model to generate flows within the catchment.

In situations where there is a stream gauging station located on the catchment, the modelled discharge hydrograph is then compared with historic hydrographs and model parameters varied until a fit is achieved. Similarly, when sufficient data is available on historic flood levels along the channel, it is possible to use the known discharges and adjust the parameters of the hydraulic model to achieve a fit between recorded and modelled levels. Thus it is possible to achieve independent calibration of each of the models (hydrologic and hydraulic) in turn. However, in most situations the streams are not gauged and information is usually limited to some isolated flood marks along the stream, plus some recorded rainfall data.

Under those circumstances, independent "calibration" of the models cannot be achieved. The usual procedure adopted is to use "realistic" values of parameters for the hydrologic model. These values are estimated from experience and the engineering literature and used in conjunction with recorded rainfall data to estimate flows. Parameters of the hydraulic model are then varied to achieve a reasonable agreement with recorded flood levels. Sometimes the recorded flood marks or levels recorded at structures are used in conjunction with uniform flow or culvert formulae to estimate historic flood flows to assist with the selection of model parameters. However, in the absence of recorded stream flow data, the overall process as outlined above can at best be termed "model tuning" or "model testing" rather than calibration.

The major storm which occurred over the Scotts Creek catchment on 10 April 1998 was identified in responses by residents to the Community Questionnaire as resulting in flooding in residential allotments downstream of Havilah Street. Several flood marks were levelled in the area between Havilah Street and Penshurst Street.

Pluviographic data for the April 1998 storm were recorded at the Chatswood Bowling Club and Sydney Observatory, as well as a daily-read rain gauge at Northbridge. Rainfall intensities at the Chatswood pluviometer for the 1 hour to 90 minute durations likely to maximise peak flows on Scotts Creek were around the 50 to 100 year ARI.

Recorded rainfalls were applied to the DRAINS model to estimate flows, which were then applied to the HEC-RAS model of the Scotts Creek channel. The procedure and results are described in **Appendix A.** Model results were in agreement with observed flooding behaviour.

3.4 DRAINS Model Parameters

After consideration of the results of the DRAINS and HEC-RAS modelling testing described in **Appendix A**, the following parameters have been adopted for the design flood estimation described in **Section 4**.

Rainfall Losses

Soil Type = 2.5 (assessment of a soil's rate of infiltration).

AMC = 3.0 (Antecedent Moisture Condition – assessment of a catchment's wetness at the start of storm event).

Paved area depression storage = 2.0 mm.

Grassed area depression storage = 10.0 mm.

Pipe and Pit Data

In addition, the hydraulic roughness for the pipes was assumed to be 0.012, as recommended in ARR, 2001.

Values of pit loss coefficients were assigned in accordance with the Missouri Charts, the DRAINS manual, various technical papers and in accordance with observed behaviour during historic flooding. The minor drainage system was simplified to provide a reasonable definition of the various sub-catchments contributing to the trunk drainage system.

Travel Times

Information contained in ARR, 2001 suggests that for large commercial and industrial buildings, which are typical of the commercial areas in the Chatswood CBD, the response time of the allotments to rainfall would be in the range 5 to 15 minutes. For design purposes, DRAINS modelling was carried out with a minimum response time in the commercial and residential sub-catchments of 5 minutes.

In addition, the path of travel of overland flow was adjusted to follow the pattern of the street system. The resulting flow length and slope was then used by DRAINS to assess the travel time of the floodwave.

4 DESIGN FLOOD ESTIMATION

4.1 Rainfall intensity

The procedures used to obtain temporally and spatially accurate and consistent intensity-frequency-duration (IFD) design rainfall curves for the Scotts Creek catchment are presented in Chapter 2 of ARR, 2001. Design storms for frequencies of 5, 10, 20, 100 and 200 year ARI were derived for storm durations ranging between 1 hr and 6 hrs. The procedure adopted was to generate IFD data for each catchment by using the relevant charts in Volume 2 of ARR, 2001. These charts included design rainfall isopleths, regional skewness and geographical factors.

4.1.1. Areal Reduction Factors

The rainfalls derived using the processes outlined in ARR, 2001 are applicable strictly to a point. In the case of a large catchment of over tens of square kilometres, it is not realistic to assume that the same rainfall intensity can be maintained over a large area, an areal reduction factor is typically applied to obtain an intensity that is applicable over the entire area.

However, as the area of the Scotts Creek catchment is only 3 km^2, the reduction in rainfall intensities would be quite small. Accordingly, the conservative assumption of no reduction in point rainfalls was made for this study.

4.1.2. Temporal Patterns

Temporal patterns for various zones in Australia are presented in ARR, 2001. These patterns are used in the conversion of a design rainfall depth with a specific ARI into a design flood of the same frequency. Patterns of average variability are assumed to provide the desired conversion. The patterns may be used for ARIs up to 500 years where the design rainfall data is extrapolated to this ARI.

The derivation of temporal patterns for design storms is discussed in Chapter 3 of ARR, 2001 and separate patterns are presented in Volume 2 for ARI < 30 years and ARI > 30 years. The second pattern is intended for use for rainfalls with ARIs up to 100 years, and to 500 years in those cases where the design rainfall data in Chapter 2 of ARR, 2001 are extrapolated to this ARI.

4.2 Design Discharges

The DRAINS model was run with the parameters given in **Section 3.4** to obtain design hydrographs for input to the hydraulic model. Discharge hydrographs for the critical 100 year ARI storm of 90 minutes duration are plotted on **Figure 4.1**. **Table 4.1** shows the distribution of peak flows downstream of Havilah Street for the range of flood events modelled.

The hydrographs in **Figure 4.1** show the "flash flooding" nature of the catchment. Flows derived from the upper portion of the catchment would reach a peak in the open channel about 40 minutes after the commencement of the storm. At the intersection with Havilah Street about 8.5 m^3/s of overland flow in Victoria Avenue would enter the Chatswood Chase car park. After the storage is filled to the level of the landscaping mound running along the eastern side of the property, overland flows would continue across Havilah Street and through the properties in the low points of the streets to the east, eventually reaching the stormwater channel east of the

Temple Emanuel school. Stored water in the car park which cannot drain by gravity to the stormwater system would need to be pumped out following the flood.

Near the upstream end of the channel at Macquarie Street, the peak 100 year ARI discharge would be about 50 m^3/s, increasing to 60 m^3/s at Penshurst Street and about 100 m^3/s at the Eastern Valley Way.

The basin in Chatswood Oval provides a considerable reduction in peak flows (**Figure 4.1**), but the effect is quite localised. The detention basin at Ferguson Lane stores overland flows in that street, which peak at 4 m^3/s for the 100 year ARI flood. The Ferguson Lane basin has an attenuating effect on flows as far as the intersection of Archer Street and Victoria Avenue. However the two basins do not have a significant effect on flows in the channel further to the east, due to both their relatively small storage volume and proportion of area of catchment controlled.

4.3 Extreme Flood Event

The magnitude of flows generated by applying Probable Maximum Precipitation (PMP) to the DRAINS model for Scotts Creek resulted in it only running for a storm of 60 minutes duration. By inspection of the model results, peak flows generated by this storm event were found to be only 2.5 times those of the 100 year ARI event. It was expected that storms of shorter duration would produce higher flood flows.

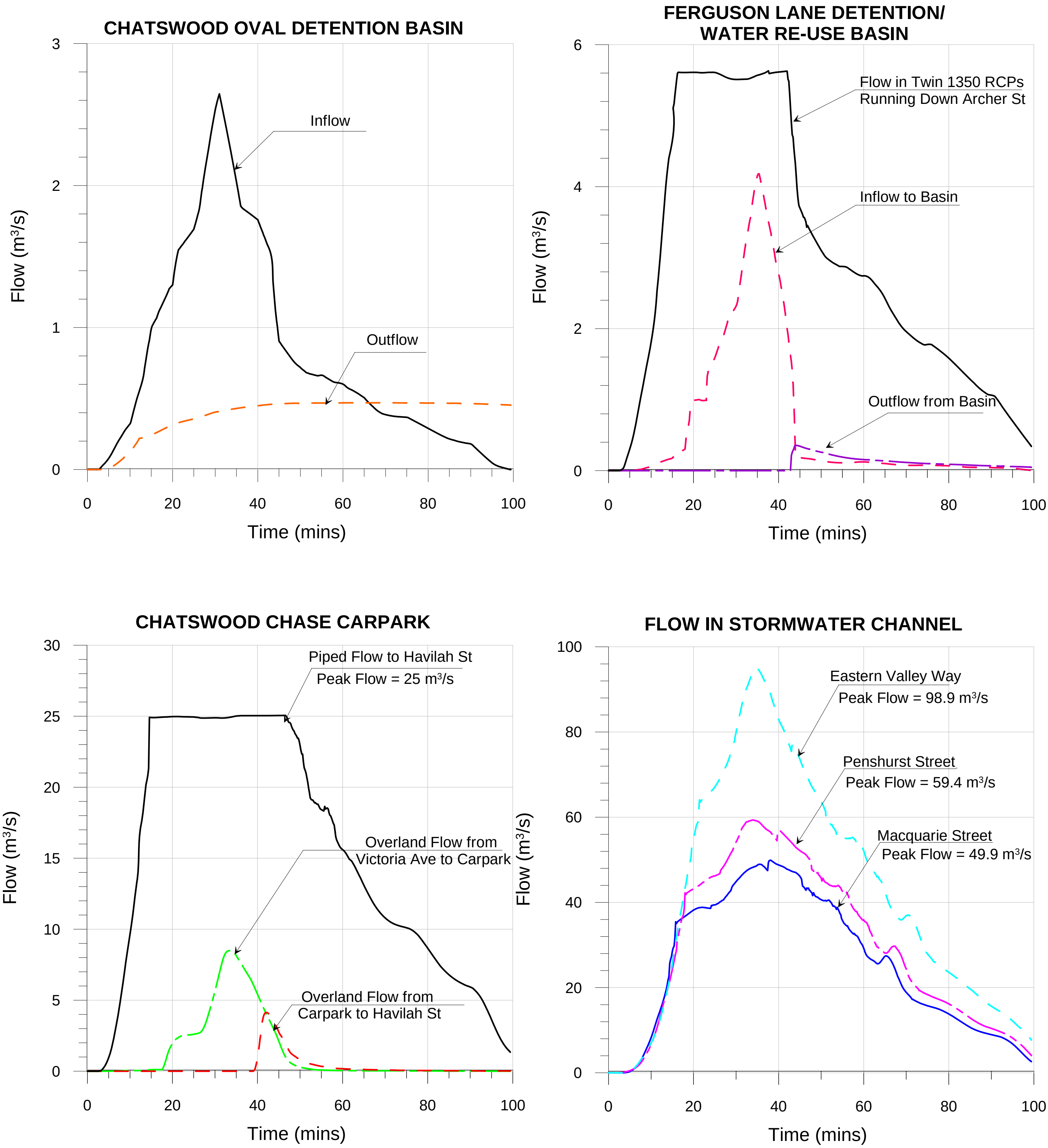
A recent flood study carried out on the nearby catchment of Flat Rock Creek (LACWE, 2006) showed that PMP rainfall of shorter duration than 60 minutes was critical for maximising flows in a catchment similar to Scotts Creek, with peak flows found to be around 4 times those of the 100 year ARI event.

Following discussions with DECC, an extreme flood type approach was adopted for the purpose of estimating a PMF event for this present study, with peak flows equal to 4 times those of the 100 year ARI event used as input to the HEC-RAS model for Scotts Creek. The adopted peak flows for the PMF/ Extreme Flood are shown in **Table 4.1**.

Table 4.1
PEAK FLOWS[1] ALONG SCOTTS CREEK
(m^3/s)

Location		10 April 1998 Storm[4]	Storm Frequency					
			5 Year ARI[2]	10 Year ARI[2]	20 Year ARI[2]	100 Year ARI[2]	200 Year ARI[2]	PMF/Extreme Flood[3]
Havilah Street	-Covered Channel	25	25	25	25	25	25.1	25
	-Overland	7.9	3.5	4.7	6.1	8.7	15.5	35
Blakesley Street	-Covered Channel	26	26	26	26	26	25.8	26
	-Overland	8.5	3.5	4.7	6.2	9	15.6	36
Baldry Street	- Covered Channel	28	28	28	28	28	28.3	28
	-Overland	10	3.3	4.6	6.1	10.4	16.3	42
Commencement of Open Section of Channel (d/s side of Temple Emanuel School)		44.1	32.9	34.4	36.6	43.5	47.2	174
Macquarie Street		50.9	36.9	39.1	42.8	49.9	54.2	200
Crick Street		52.5	37.7	40.1	44	51.5	56	206
Royal Street		53.9	38.5	41.1	45.1	52.9	57.7	212
Penshurst Street		61.3	42.3	45.4	49.5	59.4	65.1	238
Douglas Avenue		68.9	46.8	50.9	56.1	67	73.2	268
High Street		73.4	49.2	53.8	59.7	71.7	78.5	287
Gibbes Street		82.7	53.1	58.7	66	80.5	88.7	322
Eastern Valley Way		101	61.2	70	79.8	98.9	110	396

1. Peak flows are quoted at a location immediately downstream of each road crossing.
2. Critical storm of 90 minutes duration.
3. Adopted peak flows for the PMF/Extreme Flood are equal to 4 times the 100 year ARI event.
4. These flows were computed with catchment conditions applying at the time of the storm.



SCOTTS CREEK
FLOOD STUDY

Figure 4.1

DISCHARGE HYDROGRAPHS
100 YEAR ARI

5 HYDRAULIC MODELLING OF SCOTTS CREEK

5.1 Requirements for Hydraulic Model

A model was required which could produce flows, velocities and water surface elevations at nominated locations in the channels. The model was to be capable of analysing hydraulic conditions at culvert and bridge crossings, and capable of adjustment so that it could analyse the effects of possible modifications such as levees, channel enlargement, adjustments to bridge waterways or future land use changes on the floodplain, all of which could influence flooding behaviour.

Few commercially available hydrodynamic models contain all the features required for this present study. One however, HEC-RAS, has the required capabilities and is readily available to all potential model users at minimal cost.

On the technical side, HEC-RAS is capable of undertaking single model runs of "mixed flow" where the flow is a mix of the sub-critical and super-critical flow regimes, such as is the case in the Scotts Creek channel. Observations during historic flooding have shown that mixed flow occurs on Scotts Creek, with high velocity supercritical flow occurring in the channel and a hydraulic jump forming upstream of the local road crossings.

5.2 Brief Review of HEC-RAS Modelling Approach

HEC-RAS is a one-dimensional hydraulic modelling package developed by the Hydrologic Engineering Centre of the US Army Corps of Engineers and has seen widespread application in Australia in recent years.

The momentum equation of open channel flow is solved numerically between user defined grid arrangements (more typically, cross section locations) for given boundary conditions. Typically, a peak discharge comprises the upstream boundary and the downstream boundary is either a rating curve (stage versus discharge relationship) or the assumption of uniform flow (friction slope equals the bed slope of the stream).

In the present flood study, flows are confined to a relatively narrow extent in the close proximity to the channel and there are no significant floodplain storage effects which would require the complete discharge hydrograph to be applied to the model for resolution. Accordingly, the HEC-RAS software was used in its "steady state" mode, with only response to the peak discharge being modelled.

5.2.1. Structure of Models

The **Scotts Creek** model consisted of cross sections derived from ground survey. Cross sections were taken in the street system and at the entrances to allotments along the overland flow path between the overflow from the Chatswood Chase car park and the head of the Sydney Water stormwater channel. Along this section flood levels are controlled by the levels of street centrelines, the widths of the openings in boundary fences and the space between residences in the allotments. The cross sections incorporated in the hydraulic model allowed for the effects of all of these features.

Over the extent of the concrete stormwater drain, channel dimensions do not vary greatly and essentially uniform flow conditions apply. Within their zones of influence, flood levels are controlled by the waterway areas of the bridges over the channel and the elevations of the road centrelines.

Below Penshurst Street, creek capacity is influenced by the crest levels of the numerous rock weirs across the channel.

Cross section locations of the model are shown on the indicative extents of inundation presented in **Section 6**. The spacing of the sections is quite dense and accurately represents features on the floodplain which influence hydraulic behaviour (e.g. bridge constrictions, changes in channel dimensions and the footprints of residential developments).

5.2.2. Boundary Conditions

Flows derived from DRAINS provided the boundary conditions at the upstream end of the model. DRAINS allows for the travel times of the piped and overland flows along their respective drainage paths, as well as the entry of flows from the lateral sub-catchments bordering the trunk drain. The peak flow in HEC-RAS was increased along the modelled reach to account for the effects of increased catchment area contributing to flow. The model was continued a sufficient distance downstream of the Eastern Valley Way to ensure that uncertainties introduced into the results by the assumption of uniform flow conditions at the downstream boundary did not extend upstream of this crossing.

5.3 Testing the Hydraulic Model

5.3.1. General

The main physical parameter for HEC-RAS is hydraulic roughness. There are other parameters such as contraction and expansion head loss coefficients which are of a hydraulic nature and need to be estimated.

There are limited historic flood level data available to assist with calibration of the model. Accordingly, roughness was estimated from site inspection, past experience and values contained in the engineering literature (Arcement and Schneider, 1984; Cowan, 1956; Barnes, 1967).

5.3.2. Roughness Values for Stream Channels

Although several factors affect the selection of an "n" value for the channel, the most important factors are the type and size of the materials that compose the bed and banks of the channel as well as its shape. Cowan, 1956 developed a procedure for estimating the effects of these factors.

In this procedure, the value of n may be computed by the following equation:

$$n = (nb + n1 + n2 + n3 + n4)\, m \quad \ldots\ldots\ldots \; 5.1$$

where	nb	=	a base value of n for a straight, uniform, smooth channel in natural materials
	n1	=	a value added to correct for the effects of surface irregularities
	n2	=	a value for variations in shape and size of the channel cross section
	n3	=	a value for obstructions to flow
	n4	=	a value for vegetation and flow conditions
	and m	=	a correction factor for meandering of the channel

Scotts Creek channel between the Temple Emanuel School and Penshurst Street runs along the rear of residential allotments, which are located on both sides of the stream and fenced. Most of these allotments are also separated by paling fences, which run normal to the creek centreline.

Experience with historic flooding on Scotts Creek showed that the hydrodynamic forces associated with overbank flows has resulted in overturning of the fences near the occurrence of the peak of the flood. Residents in their responses to the Community Questionnaire noted failure of the fences in the lower reaches of the creek in the April 1998 flood.

This effect would best be simulated in the hydraulic modelling by assuming that the overbanks within the fenced allotments were effective for the conveyance of flow, but with a relatively high value of hydraulic roughness.

For the major and Extreme Flood events, the extent of flooding would reach some of the buildings in the flooded allotments. To model this eventuality, the portion of the overbank occupied by the footprint of the buildings was excised from the effective waterway area.

The adopted hydraulic roughness values are summarised below:

Description	**Hydraulic Roughness**
➢ Overland flow in the street system and over paved areas	0.02
➢ Concrete lined SW stormwater channel between Temple Emanuel and Penshurst Street	0.012 – 0.015
➢ Grassed overbanks of SW channel between channel coping and allotment fence	0.035
➢ Flow within the allotments bordering the SW channel (i.e. behind the paling fences)	0.1
➢ Rock lined or "Pillow Concrete" WCC channel d/s Penshurst Street	0.02 – 0.045
➢ Overbanks of WCC channel d/s Penshurst Street	0.05 – 0.08

5.4 Hydraulics of Local Road Crossings

5.4.1. General

Initially, on the rising limb of the flood hydrograph, flows would be conveyed in the supercritical regime through the culverts**.** As flow increases, the water surface elevation would rise to the level of the soffit of the culvert. At this level it is likely that there would be some instability in the water surface, as levels alternate between orifice and free surface conditions. With further increases in flow, orifice conditions would stabilise and the hydraulic control would move upstream.

Under orifice flow conditions, there would be a backwater upstream of each road crossing which typically would extend upstream for a distance which would increase with increasing flow and would be generally around 50 to 100 m. Over this reach the flow would be in the subcritical mode. Further upstream flow would be mildly supercritical, with a hydraulic jump occurring at the junction of the two flow regimes. An example of the occurrence of a hydraulic jump in the channel is shown on the cover page of this report.

For major flood events, the water surface elevation within the bridge would surcharge the kerb at the top of the headwall of the culvert. The flow would therefore be conveyed as a combination of orifice flow through the low level culvert and weir flow over the headwall.

5.4.2. Assessment of Hydraulic Capacity

The hydraulic analysis was based on the culvert and weir equations and discharge coefficients given in Chapter 5 of the HEC-RAS manual. Contraction and expansion losses were quite small, as the dimensions of the concrete stormwater channel do not vary greatly along its length and the width of channel is maintained as it passes beneath the road crossings.

6 HYDRAULIC MODELLING OF DESIGN FLOODS

6.1 Presentation of Results – Scotts Creek Channel

Water surface profiles for the 5, 20 and 100 year ARI and the Extreme Flood/PMF along the channel of Scotts Creek are shown in **Figure 6.1**. The locations of the cross sections are shown at the bottom of the diagram. Each cross section is denoted as a River Station "RS" in the hydraulic model.

Figure 6.2 shows the indicative extents of inundation for the 5, 20, 100 year ARI and Extreme Floods. For the modelling of the Extreme Flood, consideration was given to the effect of buildings bordering the creek in blocking the passage of flows. In the commercial area downstream of Penshurst Street, buildings reduce the effective waterway area available for the conveyance of flow. This has an impact on the resulting peak water levels, which are up to 4 m higher than 100 year ARI levels. The extent of inundation of each flood event is necessarily indicative only. It is based on flood levels derived at the model cross sections, 2 m contour mapping provided by WCC and the locations of residences and commercial buildings bordering the channel as shown on Council's GIS system. Whilst the flood level and velocity data derived from the analyses are accurate at the sections comprising the model, the flood extent diagrams should not be used to give a precise determination of flood affectation in individual allotments.

In **Figures 6.3** and **6.4** the floodplain is divided into provisional "high" and "low" hazard zones for the 100 and 20 year ARI floods respectively. The significance of these terms in floodplain management planning is discussed later in **Section 6.5.**

Peak water surface elevations and the average flow and velocity distributions for the full range of flood events are tabulated in **Appendix B**.

Uncertainties associated with numerical hydraulic modelling are such that water levels are usually rounded off to the nearest 100 mm. However, in the present study water surface profiles along the steeper reaches of the creek do not show large differences in elevation for floods up to the 200 year ARI, indicating that large increases in flow result in relatively small increases in water level. Consequently, the results have generally been presented to two decimal places (i.e. to the nearest 10 mm), to highlight differences in the model results for the various floods.

6.2 Discussion of Results – Scotts Creek Channel

6.2.1. Flood Levels and Flow Patterns

For those larger events which exceed the capacity of the bridge crossings, some of the flow is conveyed across the roads, the high points of which act as broad crested weirs. The ponding levels upstream of the bridges rise and the hydraulic jumps become progressively more pronounced and move further upstream with increasing flow. For the 100 year flood, the locations of the jumps, whilst they vary for each road crossing, are typically about 50 to 100 m upstream of the bridges.

Flow velocities in the channel are in the range 5 to 6 m/s in the supercritical reach and reduce to about 2 - 3 m/s downstream of the hydraulic jump. On the grassed overbanks the flow velocity would be 0.5 to 1 m/s.

The effects of wave action, as shown in the photograph on the front cover of this report, are not incorporated in the numerical hydraulic modelling. These effects and also uncertainties in the precise location of the hydraulic jumps along the channel may be allowed for by increasing the freeboard allowance which is added to the computed flood level when fixing the floor levels of new development. It is usual practice to allow 500 mm for freeboard, but in the present case a larger allowance could be considered in the future *Floodplain Risk Management Study*. A larger than normal freeboard allowance may also be justified to account for possible partial blockages of the bridges, which is discussed in the following section.

6.2.2. Impacts on Existing Development Bordering Scotts Creek

By inspection of the area bordering the overland flow path which runs between Havilah Street and the open section of channel, several existing residences are at risk of experiencing above-floor inundation at the 100 year ARI level of flooding. (Floor levels of residences bordering the creek system would be surveyed for the *Floodplain Risk Management Study.)*

Similarly, several existing residences located in the zone of backwater influence upstream of the bridge crossings at Macquarie, Crick, Royal and Penshurst streets are also at risk of experiencing above-floor inundation at the 100 year ARI level of flooding. The floor level of the retirement village located on the left bank of Scotts Creek downstream of Muston Park approximates the peak 100 year ARI flood level in the adjacent lined section of channel.

Commercial development located downstream of Muston Park is generally located above 100 year ARI flood levels, with the exception of the property which fronts Eastern Valley Way on the right bank of Scotts Creek. Limited capacity in the two existing 3 m diameter pipes which cross the road corridor, result in flooding of this property during events greater than about 10 year ARI.

In the event of an Extreme Flood, depths of flow over the road crossings would generally exceed 2 m. A major constriction on flow is evident immediately downstream of Muston Park, where the close proximity of the retirement home buildings and adjacent commercial property, will restrict the passage of floodwaters during an Extreme Flood event. As a result, peak flood levels during an Extreme Flood would be up to 4 m higher than 100 year ARI levels.

Widths of flow are also constricted along the reach of Scotts Creek which runs between High Street and Eastern Valley Way. Peak flood levels during an extreme event will be up to 4 m higher than 100 year ARI levels along this reach of creek.

In the *Floodplain Risk Management Study* it will be necessary to quantify the economic impacts of flooding over the full range of flood events.

6.3 Sensitivity Studies – Flooding in Chatswood CBD Area

Hydrologic and hydraulic modelling using the DRAINS software was carried out to test the sensitivity of peak flows and flood levels to changes in:

i). pipe roughness; the adopted value of 0.012 was doubled to 0.024;

ii). rainfall losses; initial loss values for paved and grassed surfaces were reduced to 1 and 5 mm respectively. The soil type was also set equal to 3, which corresponds with a soil of comparatively high runoff potential;

iii). pit losses; adopted pit loss coefficients were increased by 25%; and

iv). pit blockage factors; blockage factors of 20% and 50% were applied to all sag and on-grade inlet pits respectively.

The findings of the sensitivity analysis are summarised in **Table 6.1**.

The doubling of pipe roughness in both Sydney Water and Council's drainage network will result in a significant increase in the magnitude of overland flow in the street system of the CBD. The increase in the magnitude of overland flow would result in a surcharging of the Ferguson Lane storage basin.

Depths of ponding in both Victoria Avenue and the Chatswood Chase carpark would also increase as a result of a doubling in pipe roughness.

The characteristics of major flooding in the CBD area of Chatswood are not particularly sensitive to increases in pit losses, partial blockages of the pit inlet system or reductions in rainfall losses.

6.4 Sensitivity Studies – Flooding in Property Upstream of Scotts Creek Channel

Hydraulic modelling showed that the results are not sensitive to variations in hydraulic roughness of the overland flow path between Havilah Street and the commencement of the channel. The main factor influencing flows and resulting flood levels in this zone is the hydraulic capacity of Sydney Water's covered section of channel. Accordingly, consideration was given to the impacts of increased pipe roughness and pit losses on its hydraulic capacity.

A doubling of the pipe roughness values from 0.012 to 0.024 results in an increase of up to 200 mm in peak flood levels in the local road reserves downstream of the CBD area, in Havilah, Blakesley and Baldry streets. This increase persists along the line of the low point which follows the covered section of Sydney Water channel where it runs through residential property.

6.5 Sensitivity Studies – Flooding in Scotts Creek Channel

6.5.1. Variation in Hydraulic Roughness

Hydraulic modelling showed that the results are not sensitive to variations in hydraulic roughness. The main factor influencing flood levels in the channel zone is the hydraulic capacity of the bridge waterways. Accordingly, consideration is given in **Section 6.5.2** below to the impacts of blockage on hydraulic capacity.

TABLE 6.1
SUMMARY OF SENSITIVITY ANALYSES
CHATSWOOD CBD AREA
100 YEAR ARI EVENT

Modelled Case	Maximum Storage in Ferguson Lane Storage Basin (m^3)	Peak Flow Surcharging Ferguson Lane Storage Basin (m^3/s)	Maximum Depth of Ponding in Victoria Avenue (m)	Peak Overland Flow Discharging to Chatswood Chase Carpark (m^3/s)	Peak Flow Surcharging Chatswood Chase Carpark (m^3/s)	Maximum Depth of Inundation in Chatswood Chase Carpark (m)
Base Case Conditions	3570	0	0.64	8.5	4.1	4.66
100% Increase in Pipe Roughness	4078	5.2	0.78	13.1	13.0	4.87
25% Increase in Pit Loss Coefficients	3675	0	0.68	9.8	7.6	4.76
Partial Blockage of Inlet Pits	3649	0	0.64	8.5	3.6	4.33
Reduction in Initial Rainfall Losses	3620	0	0.67	9.4	6.8	4.74

6.5.2. Potential Blockage of Bridges/Culverts

The width of flow through the bridge crossings in the Sydney Water's section of the creek is about 4 m on the average. The crossings are vulnerable to the build up of "debris rafts" which could comprise a mix of shopping trolleys, garden refuse and collapsed fences from the residential allotments bordering the creek system.

The mechanism and geometrical characteristics of the blockage are difficult to quantify and would no doubt be different for each flood event. For the purposes of this study analyses were carried out with the waterway openings reduced by 25 per cent to 75% of their unobstructed areas. That area was achieved by a reduction in the effective height of the various waterway openings.

Table 6.2 shows the increase in peak flood levels in the pool which would form upstream of the bridges compared with the unblocked case. Increases of between 200 – 400 mm would generally be experienced at each of the bridge/culvert crossings in the case of a partial blockage.

The exception is Crick Street, where a large percentage of flood flows were found to surcharge the road crossing under unblocked conditions. The increase in flow over the roadway resulting from a partial blockage of the bridge waterway, in combination with the efficient nature of the overland flow path, would result in an insignificant increase in upstream flood levels.

TABLE 6.2
COMPARISON OF PEAK FLOOD LEVELS
BRIDGE/CULVERT BLOCKAGE ANALYSIS
100 YEAR ARI EVENT

Bridge/Culvert Crossing	Peak 100 year ARI Flood Level (m AHD)		Difference (m)
	Unblocked	25% Blocked	
Macquarie Street	73.92	74.19	0.27
Crick Street	71.26	71.24	Neg.
Royal Street	70.36	70.68	0.32
Penshurst Street	68.33	68.51	0.18
Eastern Valley Way	55.01	55.41	0.40

Note: differences shown represent the increase in peak flood levels occurring as a result of blockage.

6.6 Use of Model Data to Assess Flood Levels

Consideration was given to presenting the model results as contours of peak water surface levels for the various floods. However, this approach was not appropriate due to the variations in water levels in the mixed flow regime due to the impacts of channel bed slope, structures in and across the channel and the impacts of building footprints for the major flood events.

Accordingly, the following approach is suggested for using the flood data when assessing peak flood levels within the study area.

- Mark the location for which flood information is required on **Figure 6.2**. This diagram will give an initial (but not necessarily final) estimate on whether or not that particular location is flood prone. Note whether the site is upstream or downstream of any adjacent bridge crossing. This is important because of the considerable water level drop across most of the bridges.

- Consult the appropriate water surface profile (i.e. **Figure 6.1**), locate the position of the site on the reach and obtain a first estimate of peak flood level for the various frequencies by scaling.
- Consult the tabulations of flood data in **Appendix B** to refine the estimate of flood levels and obtain further information on the local distribution of flows and velocities.
- In the zones where supercritical flow occurs (mainly upstream of bridges) consideration should be given to the increase in water level which could potentially occur if the flow reverted to the subcritical regime at that location. The level of the Energy Grade Line (also shown in the tabulation) represents a conservative upper limit to the subcritical water level. It could be used in setting floor levels of future developments, possibly in conjunction with a reduced freeboard, in lieu of the 500 mm of freeboard on flood levels which is commonly adopted. (The suitability of this approach should be reviewed during the future *Floodplain Risk Management Study*).

Note that as mentioned previously, the above procedure will only yield the flood level at the cross section adjacent to the point of interest. Interpolation is required to provide estimates of flood levels at locations between cross sections. A detailed site survey would also be required to confirm the extent of flood affectation in individual allotments.

6.7 Flood Hazard Areas and Floodways

6.7.1. Provisional Flood Hazard

Flood hazard categories may be assigned to flood affected areas in accordance with the procedures outlined in the Floodplain Development Manual, 2005.

Flood prone areas may be provisionally categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity. Flood depths as high as 1.2 m, in the absence of any significant flow velocity, could be considered to represent Low Hazard conditions. Similarly, areas of flow velocities up to 2.0 m/s, but with minimal flood depth could also represent Low Hazard conditions.

Following a review of the modelled distribution of flows and velocities at the various model cross sections, depths between 0.8 and 1.2 m were adopted, depending on the velocity in the overbank areas, as the boundary between the *Low* and *High Hazard* zones. Provisional Hazard diagrams for the 100 and 20 year ARI floods on Scotts Creek are presented in **Figures 6.3** and **6.4** respectively.

The Flood Hazard assessment presented herein is based on considerations of depth and velocity of flow and is *provisional* only. As noted in the Floodplain Development Manual, 2005 other considerations such as rate of rise of floodwaters and access to high ground for evacuation from the floodplain should also be taken into consideration before a final determination of Flood Hazard can be made. These factors are normally taken into account in the *Floodplain Risk Management Study* for the catchment, which is the next stage in the flood management process for the area.

6.7.2. Floodways

According to the Floodplain Development Manual, 2005, the floodplain may be subdivided into the following:

- Floodways;
- Flood storage; and
- Flood fringe

Floodways are those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with obvious naturally defined channels. Floodways are the areas that, even if only partially blocked, would cause a significant redistribution of flow, or a significant increase in flood level which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow of areas where higher velocities occur.

Flood Storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood Fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Flood storage effects are not significant on Scotts Creek as the discharge is conveyed as fast moving flow within the close proximity to the creek channel. There is very little storage in the overbank areas. Therefore for the hydraulic categorisation of the floodplain is only necessary to define **Floodways** and **Flood Fringe** areas.

Floodplain Risk Management Guideline No 2 Floodway Definition, offers guidance in relation to two alternative procedures for identifying floodways. They are:

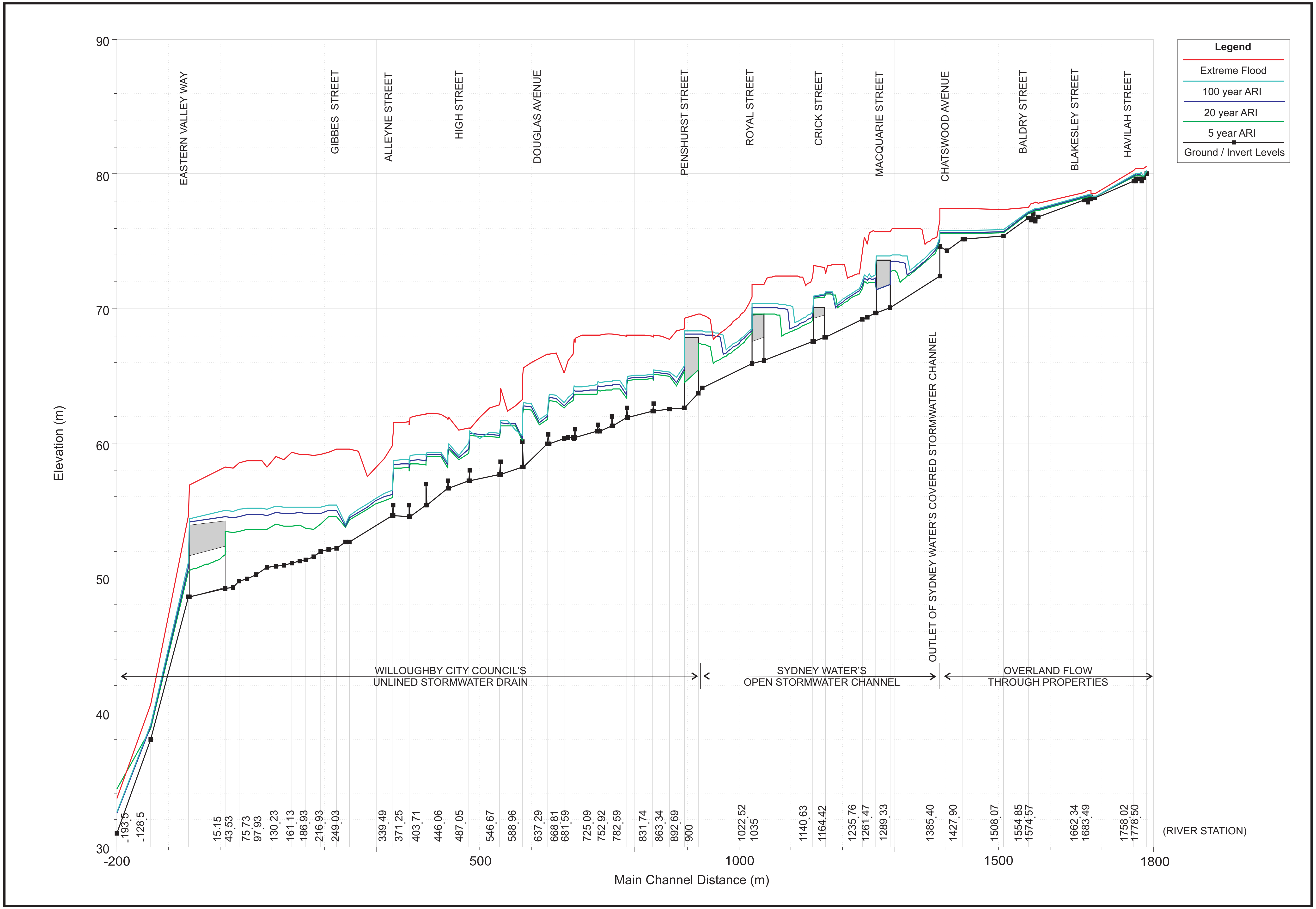
- **Approach A**. Using a *qualitative approach* which is based on the judgement of an experienced hydraulic engineer. In assessing whether or not the area under consideration was a floodway, the qualitative approach would need to consider; whether obstruction would divert water to other existing flow paths; or would have a significant impact on upstream flood levels during major flood events; or would adversely re-direct flows towards existing development.
- **Approach B**. Using the hydraulic model, in this case HEC-RAS, to define the floodway based on *quantitative experiments* where flows are restricted or the conveyance capacity of the flow path reduced, until there was a significant effect on upstream flood levels and/or a diversion of flows to existing or new flow paths.

One quantitative experimental procedure commonly used is to progressively encroach across either floodplain towards the channel until the designated flood level has increased by a significant amount (for example 0.1 m) above the existing (un-encroached) flood levels. This indicates the limits of the hydraulic floodway since any further encroachment will intrude into that part of the floodplain necessary for the free flow of flood waters – that is, into the floodway.

The HEC-RAS software has the capability to determine the stations at each cross section which define the hydraulic floodway. It computes the encroachment stations so that the conveyance within the encroachment cross section (at some higher level) is equal to the conveyance of the natural cross section at the natural water level. This higher water level is specified as a fixed amount above the un-encroached flood profile (e.g. 100 mm).

Discharges in the open channel section of Scotts Creek are conveyed in both the sub- critical and super-critical flow regimes, with intervening hydraulic jumps. Under those flow conditions, the *quantitative assessment* associated with **Approach B** is technically difficult to implement. Restricting the flow to achieve the 0.1 m increase in flood levels can result in movements in the location of hydraulic jumps and contradictory results, with the restriction actually causing reductions in computed levels in some areas. Accordingly the *qualitative approach* associated with **Approach A** was adopted.

The extents of the 100 and 20 year ARI floodways are shown on **Figures 6.5** and **6.6** respectively. As a minimum, the full extent of the channel was assumed to act as a floodway. When overtopped, the grass verges between the channel banks and the fences defining the boundaries of the residential allotments bordering the creek were also assumed to act as floodways. However, within the allotments on the leeward sides of the fences, the flows and velocities were quite small and these areas were generally considered to comprise the flood fringe.



SCOTTS CREEK
FLOOD STUDY

Figure 6.1

DESIGN WATER SURFACE PROFILES
5, 20, 100 YEAR ARI AND EXTREME FLOOD EVENTS

N

0 50 100 m
Scale

NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

LEGEND

- PMF
- 100 YEAR ARI
- 20 YEAR ARI
- 5 YEAR ARI
- 1261.47 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK FLOOD STUDY

Figure 6.2a

INDICATIVE EXTENTS OF INUNDATION
5, 20, 100 YEAR ARI AND EXTREME FLOOD EVENTS
HAVILAH STREET TO PENSHURST STREET

N
0 50 100 m
Scale

NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

LEGEND

- PMF
- 100 YEAR ARI
- 20 YEAR ARI
- 5 YEAR ARI
- 831.74 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK
FLOOD STUDY

Figure 6.2b

INDICATIVE EXTENTS OF INUNDATION
5, 20, 100 YEAR ARI AND EXTREME FLOOD EVENTS
PENSHURST STREET TO EASTERN VALLEY WAY

N

0 50 100 m
Scale

NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

LEGEND

HIGH HAZARD

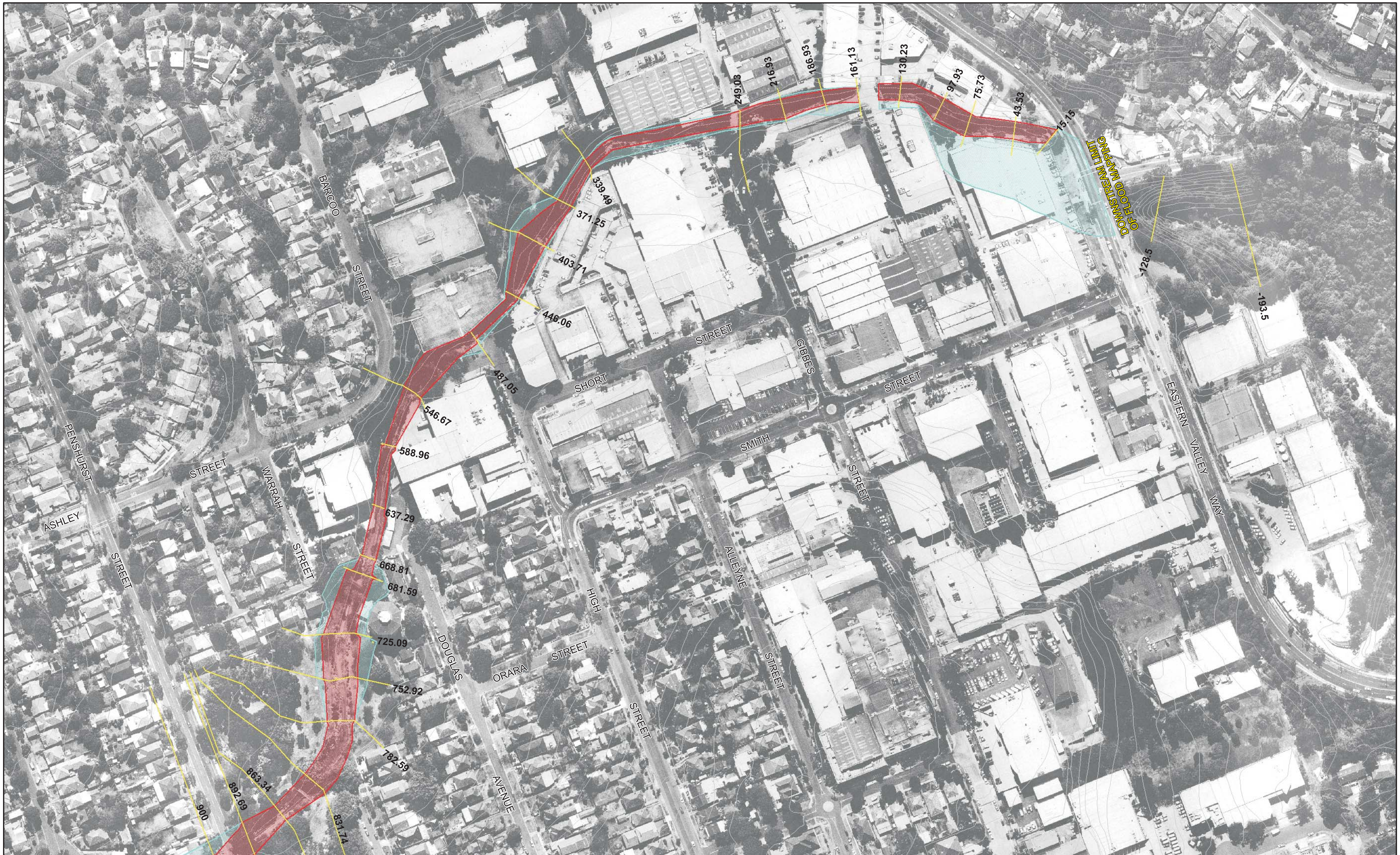
LOW HAZARD

1261.47 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK
FLOOD STUDY

Figure 6.3a

PROVISIONAL FLOOD HAZARD DIAGRAM
100 YEAR ARI
HAVILAH STREET TO PENSHURST STREET



NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

LEGEND

HIGH HAZARD

LOW HAZARD

831.74 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK FLOOD STUDY

Figure 6.3b

PROVISIONAL FLOOD HAZARD DIAGRAM
100 YEAR ARI
PENSHURST STREET TO EASTERN VALLEY WAY

NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

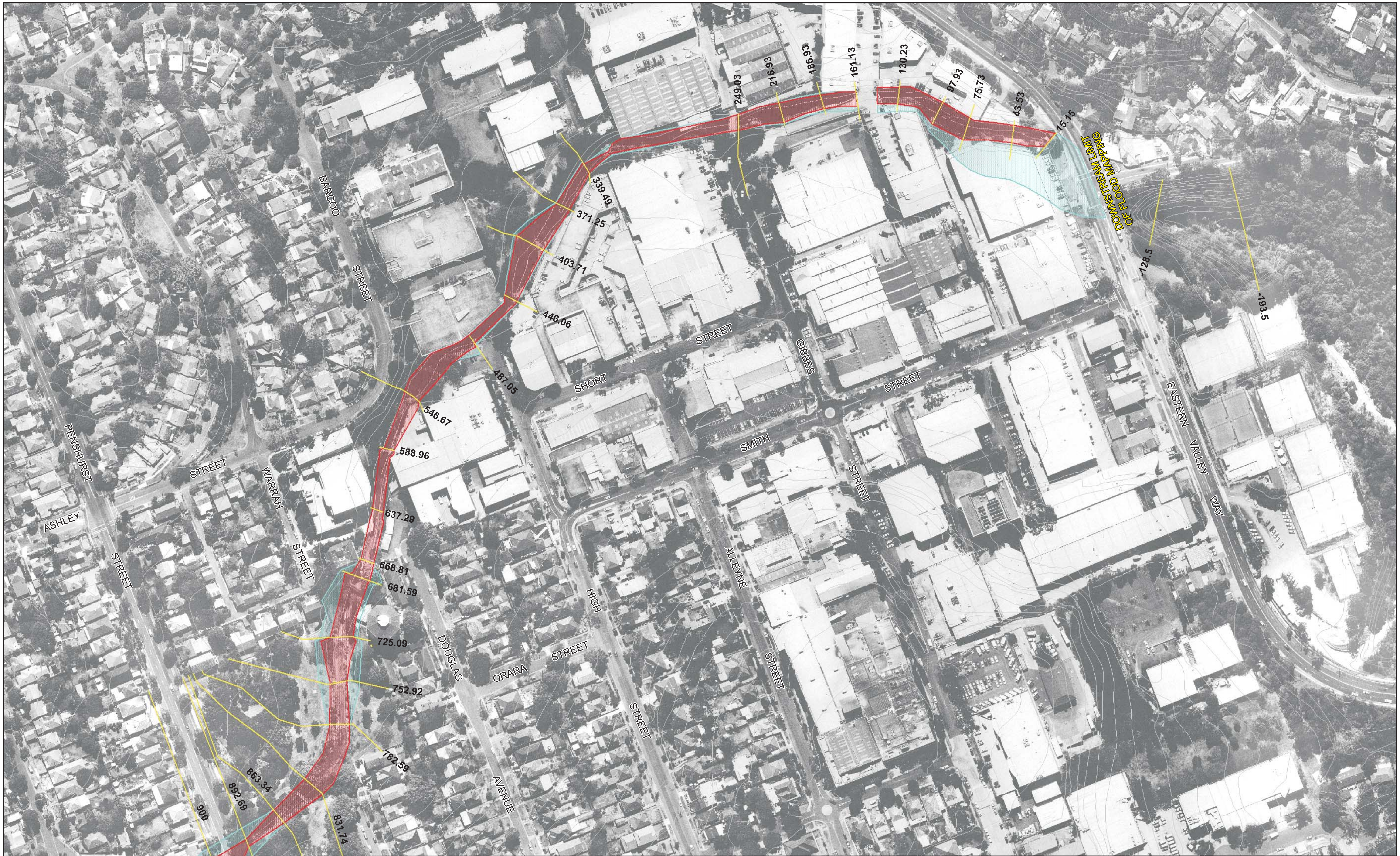
LEGEND

- HIGH HAZARD
- LOW HAZARD
- 1261.47 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK FLOOD STUDY

Figure 6.4a

PROVISIONAL FLOOD HAZARD DIAGRAM
20 YEAR ARI
HAVILAH STREET TO PENSHURST STREET



NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

LEGEND

- HIGH HAZARD
- LOW HAZARD
- 831.74 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK FLOOD STUDY

Figure 6.4b

PROVISIONAL FLOOD HAZARD DIAGRAM
20 YEAR ARI
PENSHURST STREET TO EASTERN VALLEY WAY

N

0 50 100 m
Scale

NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

LEGEND

FLOODWAY

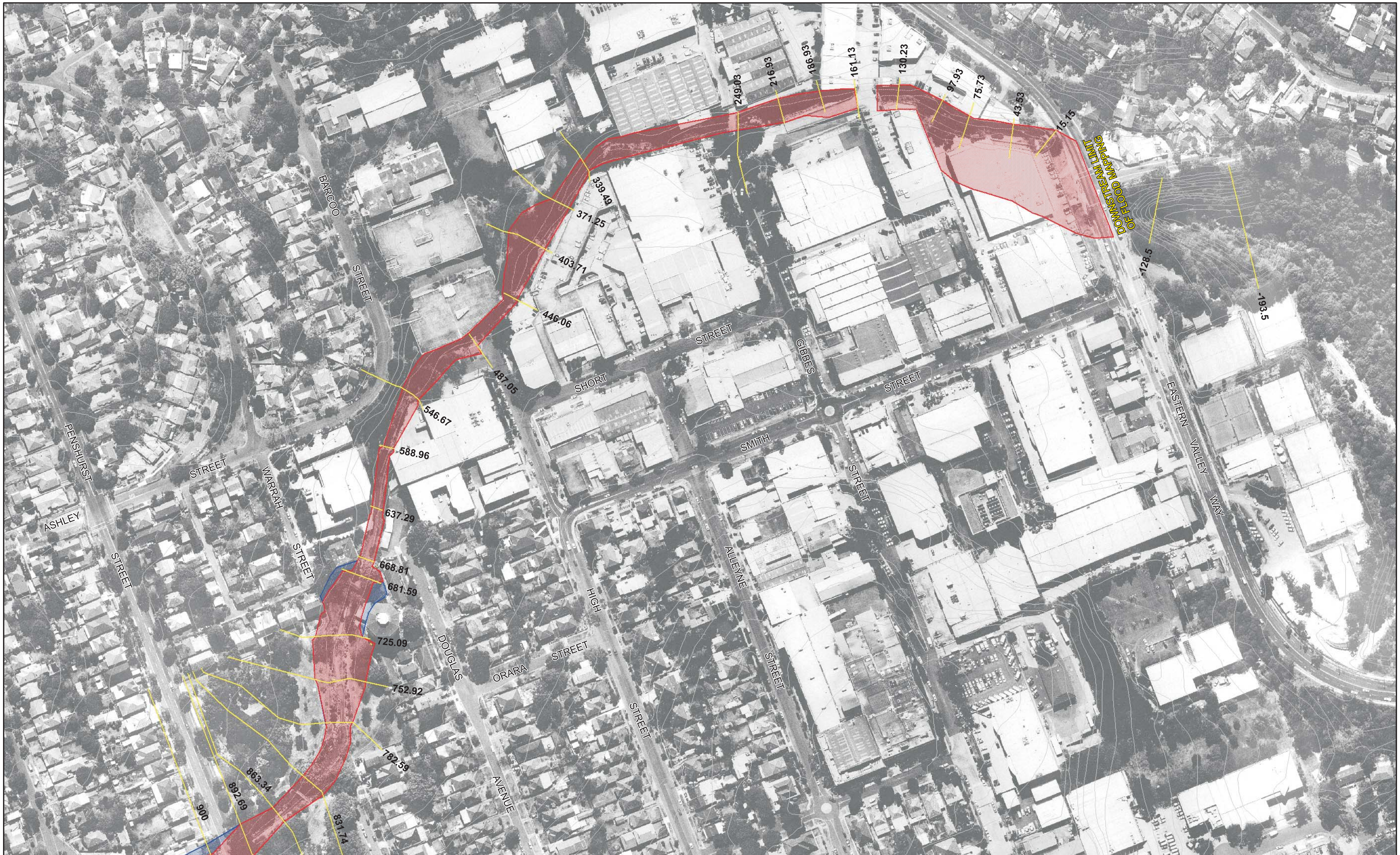
FLOOD FRINGE

1261.47 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK
FLOOD STUDY

Figure 6.5a

HYDRAULIC CATEGORISATION DIAGRAM
100 YEAR ARI
HAVILAH STREET TO PENSHURST STREET



NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

LEGEND

- FLOODWAY
- FLOOD FRINGE
- 831.74 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK FLOOD STUDY

Figure 6.5b

HYDRAULIC CATEGORISATION DIAGRAM
100 YEAR ARI
PENSHURST STREET TO EASTERN VALLEY WAY

N
0 50 100 m
Scale

NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATAAND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

LEGEND

FLOODWAY

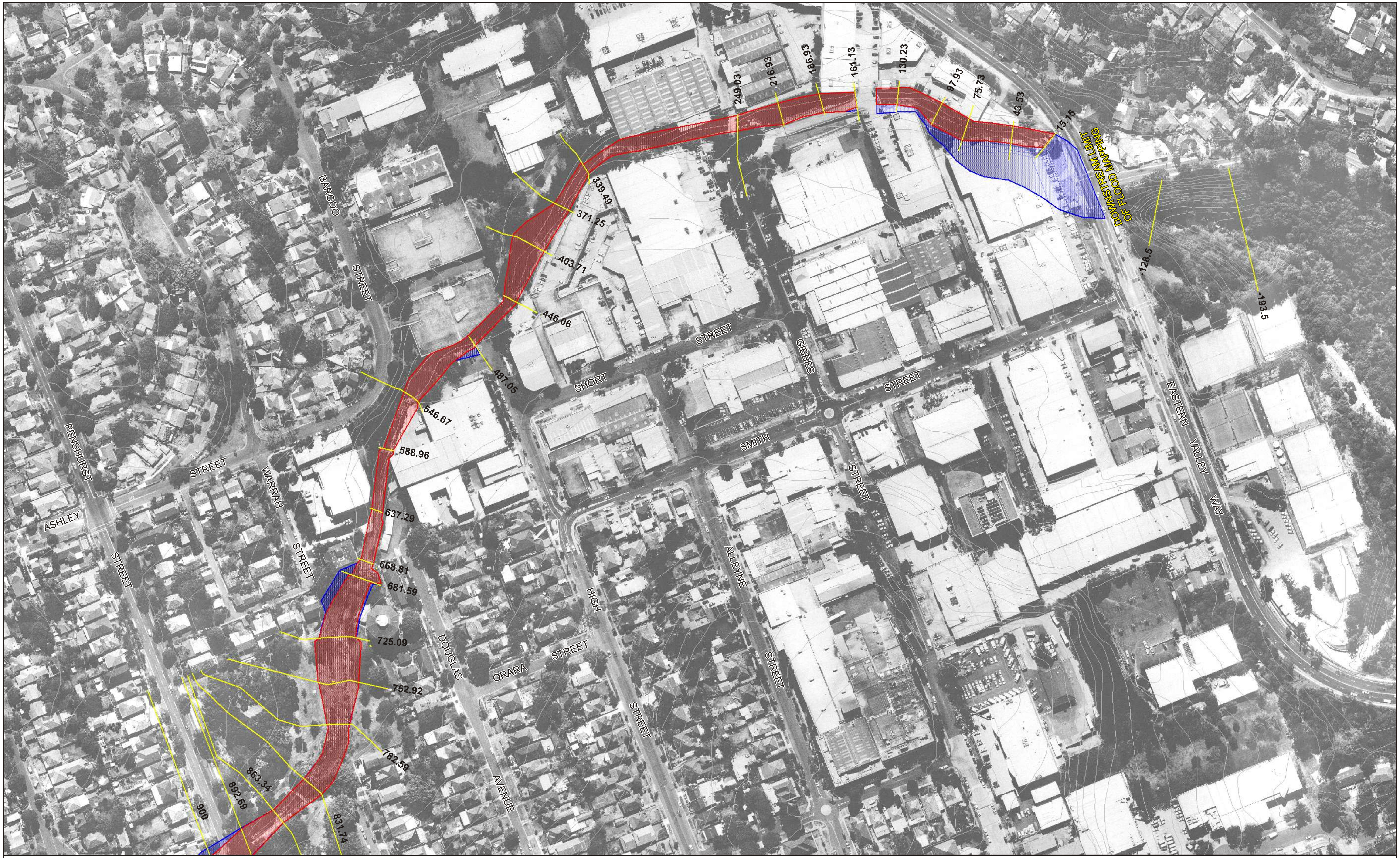
FLOOD FRINGE

1261.47 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK FLOOD STUDY

Figure 6.6a

HYDRAULIC CATEGORISATION DIAGRAM
20 YEAR ARI
HAVILAH STREET TO PENSHURST STREET



NOTE

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATAAND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE MUST BE CONFIRMED BY SITE SPECIFIC SURVEY.

LEGEND

FLOODWAY

FLOOD FRINGE

831.74 HEC-RAS CROSS SECTION AND RIVER STATION NUMBER

SCOTTS CREEK
FLOOD STUDY

Figure 6.6b

HYDRAULIC CATEGORISATION DIAGRAM
20 YEAR ARI
PENSHURST STREET TO EASTERN VALLEY WAY

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APPENDIX A

HISTORIC FLOODS AND MODEL TESTING

TABLE OF CONTENTS

LIST OF FIGURES

A1 INTRODUCTION

The procedure adopted for testing the DRAINS model of Scotts Creek, in situations where historic flood data are available, would involve the collection and analysis of rainfall data to ascertain the temporal and areal distribution of rainfall over the catchment. These rainfalls would then be applied to the model to generate flows within the catchment.

In situations where there was a stream gauging station located on the catchment, the modelled discharge hydrograph would then be compared with historic hydrographs and model parameters varied until a fit was achieved. Similarly, when sufficient data are available on historic flood levels along the channel it is possible to use the known discharges and adjust the parameters of the hydraulic model to achieve a fit between recorded and modelled levels. Thus it would be possible to achieve independent calibration of each of the models (hydrologic and hydraulic) in turn. However, in most situations the streams are not gauged and data is usually limited to some isolated flood marks along the stream plus some recorded rainfall data.

Under those circumstances, independent "calibration" of the models cannot be achieved. The usual procedure adopted is to use realistic values of the hydrologic model parameters, adopted from experience and the engineering literature, in conjunction with recorded rainfall data to estimate flows; and to vary the parameters of the hydraulic model to achieve a reasonable agreement with recorded flood levels. Sometimes the recorded flood marks or levels recorded at structures are used in conjunction with uniform flow or culvert formulae to estimate historic flood flows to assist with the selection of model parameters. However, in the absence of recorded stream flow data, the overall process as outlined above can at best be termed "model tuning" or "model testing" rather than calibration.

In the case of Scotts Creek there was the historic storm of 10 April 1998 for which there were several recorded flood marks in the overland flow path in Blakesley Street and in the channel upstream of Macquarie Street and Penshurst Street.

Pluviographic data for the April 1998 storm were recorded at the Chatswood Bowling Club and Sydney Observatory, as well as at a daily-read rain gauge at Northbridge. Recorded rainfalls were applied to the DRAINS model to estimate flows, which were then applied to the HEC-RAS model of the overland flow path between Havilah Street and the Temple Emanuel school and the Scotts Creek channel downstream of that location. The procedure and results are summarised in **Section A4** below**.**

A2 COMMUNITY NEWSLETTER

A Community Newsletter was prepared and distributed to residents bordering the creek to gain knowledge of flood behaviour in the study area. A total of 60 Newsletters were distributed and 12 responses were received.

One resident in the sag in the road in Blakesley Street noted that floodwaters had overtopped the eastern footpath by about 300 mm in April 1998.

Several respondents in the reach of the Sydney Water channel between its commencement just downstream of the Temple Emanuel school and Macquarie Street noted that in the April 1998 flood, water entered backyards and removed side fences of several allotments.

Another resident further downstream in Crick Street identified the location of the extent of the April 1998 flood and also, noted that the creek had broken its banks. Council provided further information on peak flood levels reached in the Macquarie Street area and further downstream at Penshurst Street. However, this flood does not appear to have resulted in inundation of residences bordering the creek. **Table A2.1** summarises those responses with flood information.

TABLE A2.1
DETAILS OF RESPONSES TO COMMUNITY QUESTIONNAIRE

Location	Details
16 Blakesley Street	Located in sag on eastern side of street. Water rose 34 cm above footpath level in April 1998 storm. Flooding lasted for 1 hour. (Estimated Peak flood level by survey RL 78.4 m AHD)
18 Blakesley Street	Water reached front door, 3 steps from ground. Overland flow east to Baldry Street. (Estimated Peak flood level by survey RL 78.4 m AHD)
14 Havilah Street	Located in sag on eastern side of road. Flooded allotment in April 1998. Flooding lasted for 1 hour.
44 Chatswood Avenue	Located on southern side of channel 2 doors upstream of Macquarie Street. Backyard flooded. (Estimated flood level by survey RL 73.4 m AHD)
38 Chatswood Avenue	Backyard flooded and back fences washed away. Neighbour's car submerged. April 1998 flood. Estimated flood level RL 73.32 m AHD (Council data). Location 4 doors upstream Macquarie Street.
14 Nicholson Street	Located on northern side of channel immediately downstream of Temple Emanuel School. Supplied photo shown on cover of Report for April 1998 flood.
6 Nicholson Street	April 1998 flood. Back fences washed away, most of backyard flooded. Macquarie Street bridge partly blocked. Estimated flood level RL 73.25 m AHD (Council data).
46 Chatswood Avenue	Located on southern side of Channel at intersection with Macquarie Street. Back fence washed away and yard flooded in April 1998.
Royal Street	Significant flooding in 1975, 1986, 1994 and 1998. Blockage of Penshurst Street bridge reported in last three floods.

Note: Only responses with quantitative flood data are included in **Table A2.1**

Rainfall Data

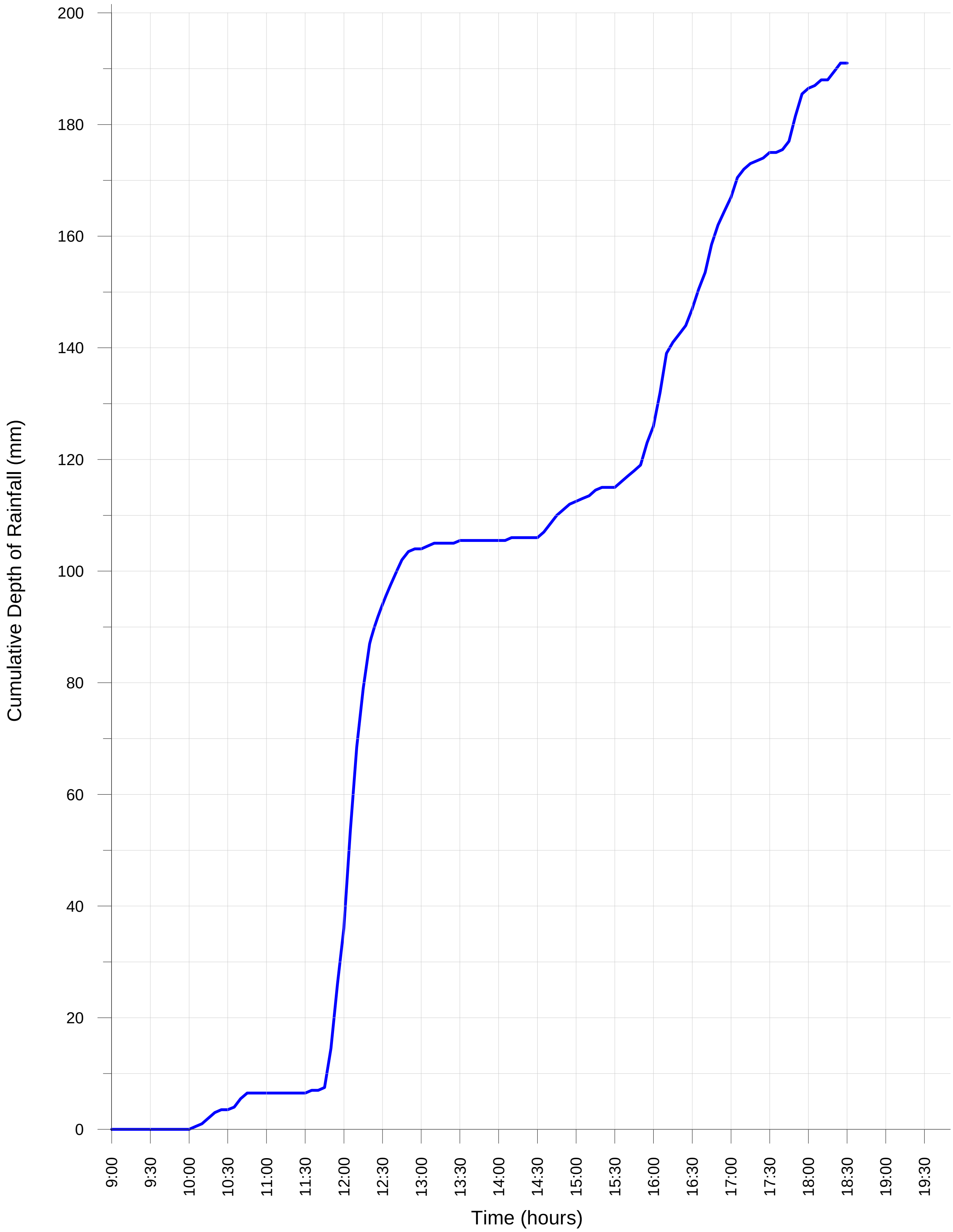
Australian Water Technologies (AWT) supplied rainfall intensity data for the pluviometer at the Chatswood Bowling Club, which is located on the Pacific Highway at the north east corner of the catchment. The Bureau of Meteorology sponsors a daily rain gauge at the Northbridge Bowling Club, situated to the east of the catchment.

These data were used to assess the temporal pattern of rainfall experienced on the Scotts Creek catchment for the April 1998 storm.

Figure A2.1 shows cumulative depths of rainfall recorded at the Chatswood Bowling Club.

The storm occurred on 10 April 1998, with the most intense burst occurring over the 30 minute period from 11:50am to 12:20pm when 72.5 mm fell. Over the one to two hours durations which maximise flows in the Scotts Creek catchment, the rainfall intensities approximated a 50 year to 100 year ARI storm.

About 180 mm of rainfall were experienced at Chatswood over the 24 hour period ending 0900 hours on 11 April 1998. This value is close to the 175 mm recorded at the daily read Northbridge gauge, which is situated to the south of the catchment near the Eastern Valley Way. From this information it appears that the pluviograph record at Chatswood is representative of rainfalls experienced over the Scotts Creek catchment and could be used to estimate flows in the drainage system.



SCOTTS CREEK
FLOOD STUDY

Figure A2.1

10 APRIL 1998 RAINFALL
AT CHATSWOOD BOWLING CLUB

A3 TESTING HYDROLOGIC AND HYDRAULIC MODELS

Pluviographic data for the April 1998 storm, as recorded at the Chatswood Bowling Club, were applied to the DRAINS model developed for the present investigation.

A3.1 DRAINS Model Parameters

Initial model testing was undertaken with the following parameters:

Soil Type = 2.5 (assessment of a soil's rate of infiltration.)

AMC = 3.0 (Antecedent Moisture Condition – assessment of a catchment's wetness at the start of storm event).

Paved area depression storage = 2.0 mm.

Grassed area depression storage = 10.0 mm.

Pit loss coefficients for piped sections of the trunk drainage system were assigned with values adopted in accordance with Missouri Charts, the DRAINS manual, various technical papers and in conformity with observed Flood behaviour.

A response time of 10 minutes was adopted in the commercial and industrial sub-areas and 5 minutes in the residential areas. In addition, the path of travel of runoff was adjusted to closely follow the pattern of the street system. The resulting flow length and slope was then used by DRAINS to assess the travel time of the floodwave.

A3.2 DRAINS Model Results for April 1998 Flood

The April 1998 storm occurred prior to the construction of the flood storage basin in Ferguson Lane. Flows on the northern headwaters between Help Street and the intersection of Archer Street and Victoria Avenue may have been reduced by a contemporary excavation for the Wallaceway project which is reported to have functioned as an informal detention basin.

It is also understood that severe flooding occurred in several commercial developments in Victoria Avenue downstream of its intersection with Archer Street. Overland flow in that street is also reported to have flowed down the entrance to the underground car park in Chatswood Chase at the intersection with Havilah Street and was pumped out over succeeding days. (There are no quantitative data on the severity of flooding in the commercial areas to the west of Havilah Street).

Table A3.1 shows peak flows generated by applying the Chatswood pluviograph data to the DRAINS model. For comparison, design storm flows are also presented. **Figure A3.1** shows modelled discharge hydrographs in the piped and open channel sections of the drainage system for 10 April 1998.

The model results agree with observed behaviour as follows:

- Overland flow was predicted by the model in Victoria Avenue.
- Floodwaters were predicted to enter Chatswood Chase.
- Surcharging of Sydney Water's covered channel and substantial overland flow in the residential allotments was predicted between Havilah Street and the Temple Emanuel school.

Table A3.1
PEAK FLOWS[1] ALONG SCOTTS CREEK
(m^3/s)

Location		**10 April 1998 Storm**	**Storm Frequency**					
			5 Year ARI[2]	**10 Year ARI[2]**	**20 Year ARI[2]**	**100 Year ARI[2]**	**200 Year ARI[2]**	**PMF/Extreme Flood[3]**
Havilah Street	-Covered Channel	25	25	25	25	25	25.1	25
	-Overland	7.9	3.5	4.7	6.1	8.7	15.5	35
Blakesley Street	-Covered Channel	26	26	26	26	26	25.8	26
	-Overland	8.5	3.5	4.7	6.2	9	15.6	36
Baldry Street	- Covered Channel	28	28	28	28	28	28.3	28
	-Overland	10	3.3	4.6	6.1	10.4	16.3	42
Commencement of Open Section of Channel (d/s side of Temple Emanuel School)		44.1	32.9	34.4	36.6	43.5	47.2	174
Macquarie Street		50.9	36.9	39.1	42.8	49.9	54.2	200
Crick Street		52.5	37.7	40.1	44	51.5	56	206
Royal Street		53.9	38.5	41.1	45.1	52.9	57.7	212
Penshurst Street		61.3	42.3	45.4	49.5	59.4	65.1	238
Douglas Avenue		68.9	46.8	50.9	56.1	67	73.2	268
High Street		73.4	49.2	53.8	59.7	71.7	78.5	287
Gibbes Street		82.7	53.1	58.7	66	80.5	88.7	322
Eastern Valley Way		101	61.2	70	79.8	98.9	110	396

1. Peak flows are quoted at a location immediately downstream of each road crossing.
2. Critical storm of 90 minutes duration.
3. Peak flows for the PMF/Extreme Flood are equal to 4 times the 100 year ARI event.

A3.3 HEC-RAS Model Results for April 1998 Flood

A3.3.1. HEC–RAS Model Parameters

The hydraulic roughness values estimated by site inspection and from the engineering literature are summarised below:

Description	Hydraulic Roughness
➢ Overland flow in the street system and over paved areas	0.02
➢ Concrete lined SW stormwater channel between Temple Emanuel and Penshurst Street	0.012 – 0.015
➢ Grassed overbanks of SW channel between channel coping and allotment fence	0.035
➢ Flow within the allotments bordering the SW channel (i.e. behind the paling fences)	0.1
➢ Rock lined or “Pillow Concrete” WCC channel d/s Penshurst Street	0.02 – 0.045
➢ Overbanks of WCC channel d/s Penshurst Street	0.05 – 0.08

A3.3.2. HEC – RAS Model Results

Modelled water surface profiles for the April 1998 flood are shown on **Figure A3.2**.

The results are in reasonable agreement with the recorded flood levels.

At the eastern side of Blakesley Street, the observed level was RL 78.4 m AHD compared with a modelled flood level of RL 78.35 m AHD.

Upstream of the Macquarie Street bridge, the recorded flood levels in the residential allotments bordering the creek ranged between RL 73.2 m and 73.4 m AHD. These levels were recorded over the 60 m extent of channel upstream of the road crossing. The model predicts the occurrence of a hydraulic jump about 50 m upstream of the bridge. The predicted levels increase from the (supercritical) RL 73.0 m to the (subcritical) RL 74.0 m AHD over the extent of the jump.

The bridge at Macquarie Street is known to have been overtopped and has a minimum level at weir flow is initiated of RL 73.7 m AHD. Therefore a flood level somewhat higher than that level would have been expected in the subcritical zone upstream of the bridge in April 1998.

The maximum recorded flood level, RL 73.4 m AHD, is 300 mm lower than the lowest natural surface level at the bridge deck. The lowest recorded flood level, RL 73.2 m AHD, is 200 mm higher than the modelled supercritical level. It therefore appears that some of the recorded levels may have been located within the "transition zone of the hydraulic jump, where flow is “rapidly varying” from the supercritical to subcritical regimes.

Further downstream at Penshurst Street the recorded flood level in the bridge backwater was RL 68.44 m AHD, about 100 mm above the floor level of the residence on the southern side of the channel. The modelled flood level in the subcritical zone within the backwater was RL 68.36 m AHD.

Unfortunately there are no recorded flood level data downstream of Penshurst Street. The retirement village and section of improved channel located downstream of Muston Park was constructed after the April 1998 flood and there have been no significant flood events in the last nine years.

A3.4 Selection of Model Parameters for Design

A3.4.1. Sensitivity of DRAINS Model Results

Sensitivity analysis is commonly carried out to assess the impact of model parameter assumptions on results. Changes were made to rainfall losses, pressure loss coefficients (Ku) and pipe roughness (n), as described below.

Hydrologic and hydraulic modelling was carried out to test the sensitivity of peak flows and flood levels to changes in:

i). pipe roughness; the adopted value of 0.012 was doubled to 0.024;

ii). rainfall losses; initial loss values for paved and grassed surfaces were reduced to 1 and 5 mm respectively. The soil type was also set equal to 3, which corresponds with a soil of comparatively high runoff potential;

iii). pit losses; adopted pit loss coefficients were increased by 25%; and

iv). pit blockage factors; blockage factors of 20% and 50% were applied to all sag and on-grade inlet pits respectively.

The findings of the sensitivity analysis for the CBD area of Chatswood are summarised in **Table A3.2**.

The doubling of pipe roughness in both Sydney Water and Council's drainage network will result in a significant increase in the magnitude of overland flow in the street system of the CBD. The increase in the magnitude of overland flow would result in a surcharging of the Ferguson Lane storage basin.

Depths of ponding in both Victoria Avenue and the Chatswood Chase carpark would also increase as a result of a doubling in pipe roughness, although these increases are limited given the capacity of the weir systems which control ponding levels in these two areas.

The characteristics of major flooding in the CBD area of Chatswood is not particularly sensitive to increases in pit losses, partial blockages of the pit inlet system or reductions in rainfall losses.

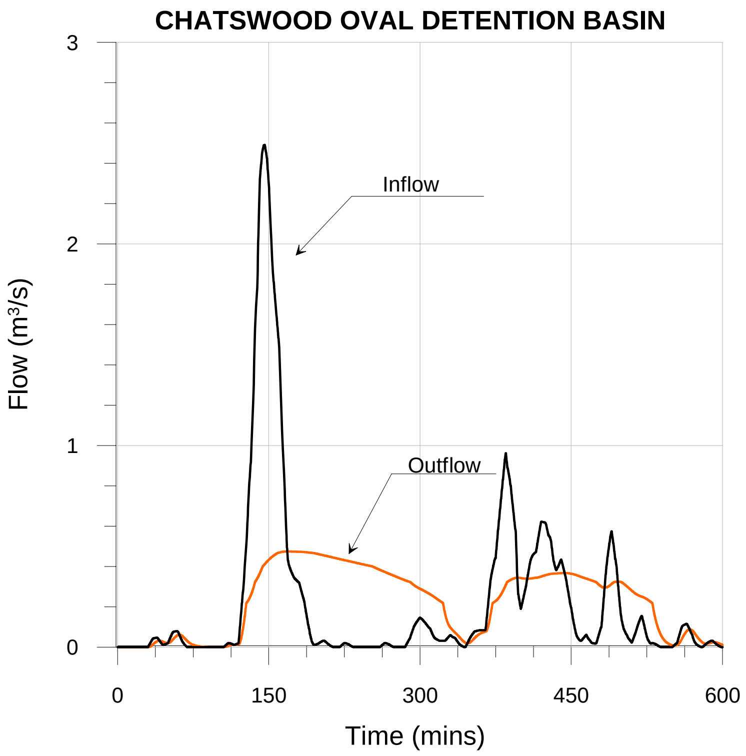
The sensitivity analysis showed that the magnitude of overland flow discharging through residential properties located downstream of Havilah Street will increase as a result of a doubling in pipe roughness. For example, overland flow crossing Baldry Street will increase from a peak of 10.4 m^3/s to a peak of 19.7 m^3/s during a 100 year ARI event. This increase in flow converts to a 200 mm increase in peak flood levels in the local road reserve and adjacent residential property.

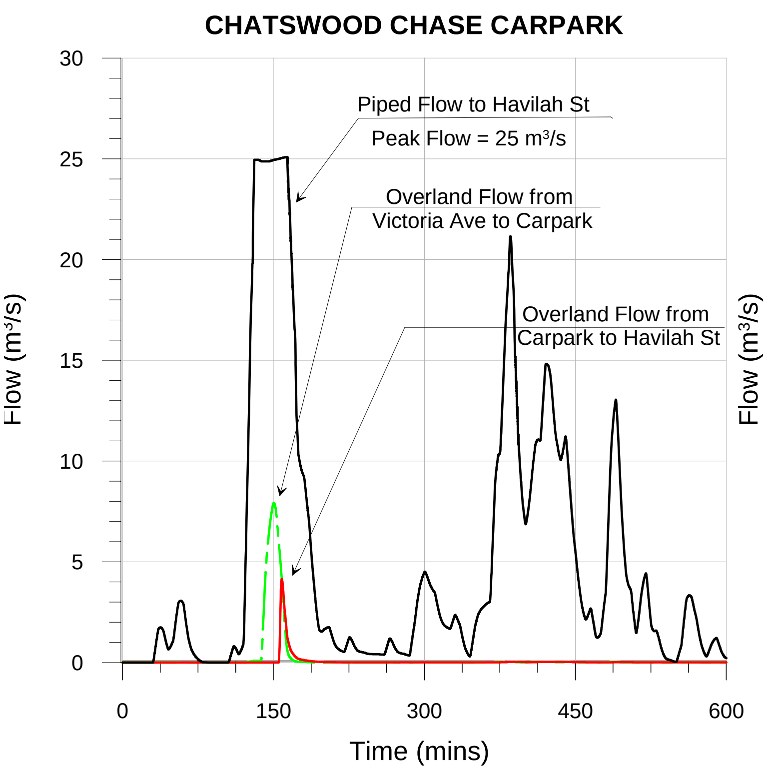
A3.4.2. Design Model Parameters

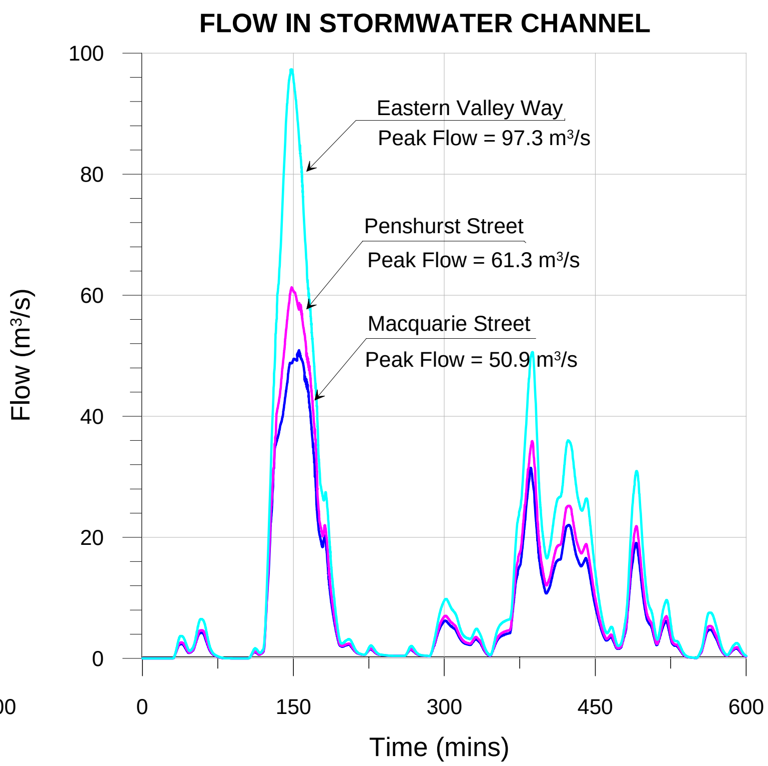
Model parameters set out in **Sections A3.1.1** and **A3.2.1** were adopted for design flood estimation.

TABLE A3.2
SUMMARY OF SENSITIVITY ANALYSES
CHATSWOOD CBD AREA
100 YEAR ARI EVENT

Modelled Case	Maximum Storage in Ferguson Lane Storage Basin (m^3)	Peak Flow Surcharging Ferguson Lane Storage Basin (m^3/s)	Maximum Depth of Ponding in Victoria Avenue (m)	Peak Overland Flow Discharging to Chatswood Chase Carpark (m^3/s)	Peak Flow Surcharging Chatswood Chase Carpark (m^3/s)	Maximum Depth of Inundation in Chatswood Chase Carpark (m)
Base Case Conditions	3570	0	0.64	8.5	4.1	4.66
100% Increase in Pipe Roughness	4078	5.2	0.78	13.1	13.0	4.87
25% Increase in Pit Loss Coefficients	3675	0	0.68	9.8	7.6	4.76
Partial Blockage of Inlet Pits	3649	0	0.64	8.5	3.6	4.33
Reduction in Initial Rainfall Losses	3620	0	0.67	9.4	6.8	4.74



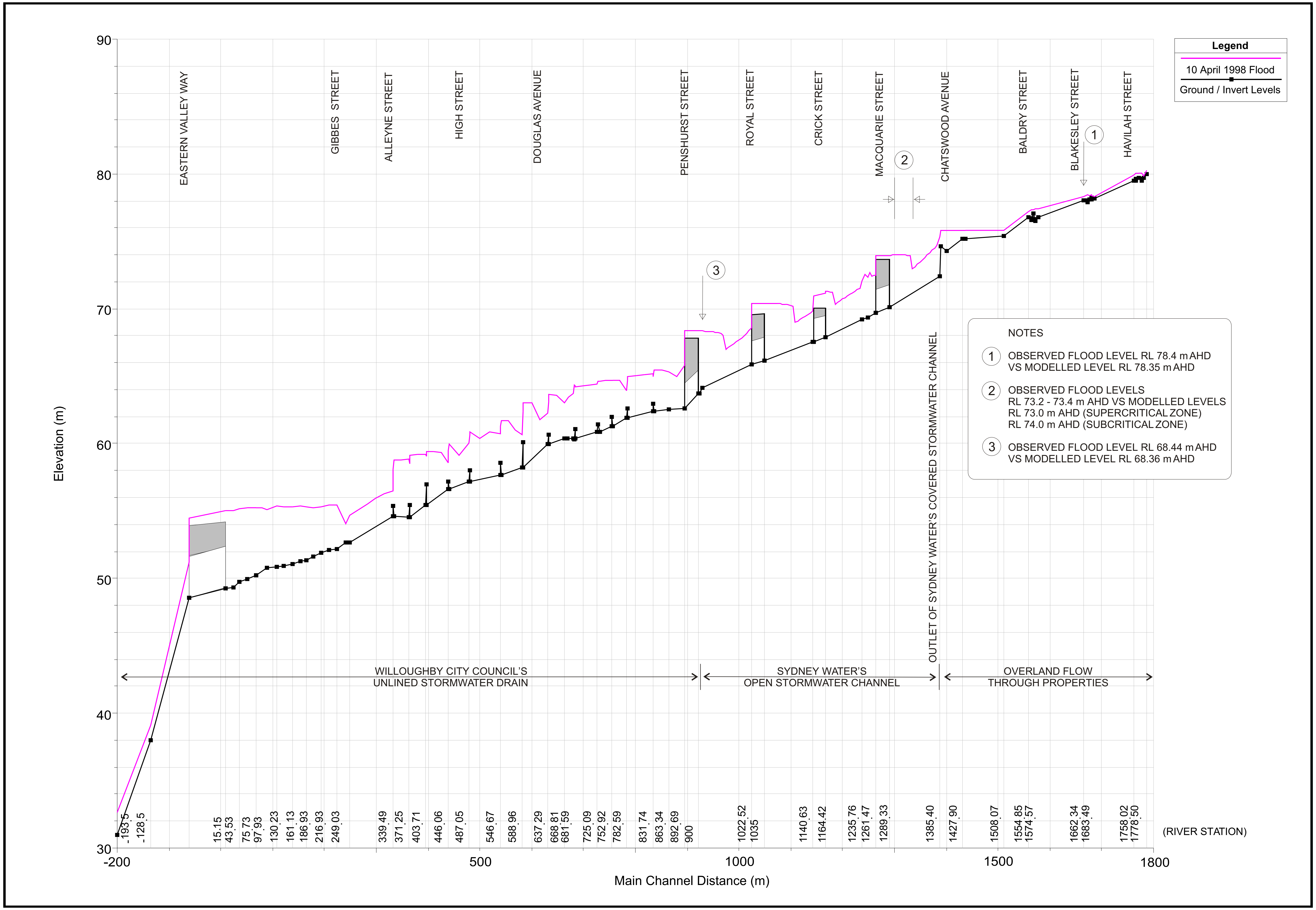




SCOTTS CREEK
FLOOD STUDY

Figure A3.1

DISCHARGE HYDROGRAPHS
10 APRIL 1998 STORM



SCOTTS CREEK
FLOOD STUDY

Figure A3.2

WATER SURFACE PROFILE
10 APRIL 1998 FLOOD

A4 REFERENCES

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APPENDIX B

TABULATIONS
FLOOD LEVEL, FLOW AND VELOCITY DISTRIBUTION – DESIGN FLOODS

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
1784.08	10-Apr-98	7.9	80.29	80.29	80.39		3.03	4.87		0.8	1.65	0.72
	5 year ARI	3.5	80.17	80.18	80.26		0.58	2.92		0.54	1.39	0.65
	10 year ARI	4.7	80.22	80.22	80.31		1.12	3.58		0.61	1.49	0.67
	20 year ARI	6.1	80.25	80.27	80.35		1.88	4.22		0.68	1.58	0.69
	100 year ARI	8.7	80.3	80.31	80.4		3.55	5.15		0.84	1.69	0.73
	200 year ARI	15.5	80.4	80.4	80.52	0	8.33	7.16	0.23	1.12	1.89	0.78
	Extreme Flood	34.9	80.57	80.56	80.75	0.37	22.67	11.86	0.7	1.68	2.31	0.88
1778.5	10-Apr-98	7.9	79.88	79.96	80.2		7.9	0		2.51	0.33	2.81
	5 year ARI	3.5	79.83	79.89	80.07		3.5			2.15		2.88
	10 year ARI	4.7	79.85	79.91	80.11		4.7			2.29		2.9
	20 year ARI	6.1	79.86	79.93	80.16		6.1			2.4		2.89
	100 year ARI	8.7	79.88	79.97	80.22		8.7	0		2.55	0.48	2.76
	200 year ARI	15.5	80.21	80.04	80.24	0.72	13.36	1.42	0.38	0.78	0.44	0.39
	Extreme Flood	34.9	80.43	80.19	80.47	3.41	26.12	5.37	0.58	0.98	0.71	0.4
1773.2	10-Apr-98	7.9	80.06	79.87	80.07	0.33	6.93	0.64	0.23	0.48	0.27	0.26
	5 year ARI	3.5	79.9	79.8	79.91	0.02	3.37	0.11	0.14	0.43	0.21	0.32
	10 year ARI	4.7	79.95	79.82	79.96	0.07	4.4	0.22	0.18	0.44	0.23	0.29
	20 year ARI	6.1	80	79.84	80.01	0.17	5.54	0.39	0.2	0.45	0.25	0.27
	100 year ARI	8.7	80.08	79.88	80.09	0.41	7.53	0.76	0.24	0.49	0.28	0.26
	200 year ARI	15.5	80.21	79.95	80.23	1.29	12.13	2.08	0.31	0.57	0.38	0.26
	Extreme Flood	34.9	80.43	80.11	80.46	4.78	24.15	5.97	0.54	0.78	0.6	0.3
1773.19	10-Apr-98	7.9	80.06	79.72	80.06	0.65	6.2	1.05	0.16	0.29	0.19	0.13
	5 year ARI	3.5	79.9	79.65	79.91	0.15	3.07	0.28	0.1	0.21	0.12	0.12
	10 year ARI	4.7	79.96	79.67	79.96	0.26	3.99	0.45	0.12	0.24	0.14	0.12
	20 year ARI	6.1	80.01	79.69	80.01	0.41	4.98	0.71	0.14	0.26	0.16	0.13
	100 year ARI	8.7	80.08	79.73	80.09	0.77	6.72	1.21	0.17	0.3	0.21	0.14
	200 year ARI	15.5	80.22	79.8	80.23	1.94	11.03	2.53	0.26	0.39	0.29	0.16
	Extreme Flood	34.9	80.44	79.96	80.46	5.52	22.95	6.43	0.46	0.61	0.49	0.21
1768	10-Apr-98	7.9	80.05	79.9	80.06	0.17	7.1	0.63	0.24	0.55	0.33	0.32
	5 year ARI	3.5	79.89	79.83	79.9	0	3.4	0.1	0.05	0.57	0.31	0.49
	10 year ARI	4.7	79.94	79.85	79.96	0.02	4.47	0.21	0.16	0.54	0.31	0.4
	20 year ARI	6.1	79.99	79.88	80.01	0.07	5.65	0.38	0.2	0.54	0.31	0.35
	100 year ARI	8.7	80.07	79.91	80.08	0.23	7.73	0.75	0.25	0.56	0.33	0.32
	200 year ARI	15.5	80.21	79.98	80.22	0.88	12.61	2.02	0.32	0.64	0.42	0.3
	Extreme Flood	34.9	80.42	80.13	80.45	3.84	25.01	6.05	0.54	0.87	0.66	0.34
1762.81	10-Apr-98	7.9	80.05	79.67	80.06	0.61	5.91	1.38	0.14	0.26	0.19	0.11
	5 year ARI	3.5	79.9	79.6	79.9	0.16	2.87	0.47	0.09	0.18	0.12	0.09
	10 year ARI	4.7	79.95	79.62	79.95	0.26	3.73	0.7	0.11	0.2	0.14	0.1
	20 year ARI	6.1	80	79.64	80	0.41	4.7	1	0.12	0.23	0.17	0.11
	100 year ARI	8.7	80.08	79.67	80.08	0.71	6.44	1.55	0.15	0.27	0.21	0.12
	200 year ARI	15.5	80.21	79.74	80.22	1.78	10.72	3	0.23	0.36	0.29	0.14
	Extreme Flood	34.9	80.43	79.89	80.45	5.17	22.57	7.16	0.42	0.58	0.49	0.19
1762.8	10-Apr-98	7.9	80.05	79.81	80.06	0.37	6.48	1.06	0.2	0.4	0.26	0.21
	5 year ARI	3.5	79.89	79.75	79.9	0.05	3.11	0.34	0.14	0.32	0.22	0.22
	10 year ARI	4.7	79.95	79.77	79.95	0.11	4.07	0.52	0.16	0.35	0.23	0.21
	20 year ARI	6.1	80	79.79	80	0.21	5.15	0.74	0.18	0.37	0.25	0.21
	100 year ARI	8.7	80.07	79.82	80.08	0.44	7.04	1.22	0.21	0.41	0.28	0.21
	200 year ARI	15.5	80.21	79.89	80.22	1.2	11.58	2.72	0.28	0.5	0.38	0.22
	Extreme Flood	34.9	80.42	80.04	80.45	4.39	23.62	6.89	0.49	0.73	0.6	0.27
1758.02	10-Apr-98	7.9	79.93	79.93	80.04	1.95	5.37	0.58	1.28	1.59	0.75	0.87
	5 year ARI	3.5	79.8	79.8	79.89	0.66	2.81	0.03	1.03	1.34	0.36	0.93
	10 year ARI	4.7	79.85	79.85	79.94	1.01	3.57	0.11	1.13	1.42	0.51	0.89
	20 year ARI	6.1	79.89	79.89	79.99	1.42	4.41	0.27	1.23	1.52	0.63	0.89
	100 year ARI	8.7	79.95	79.95	80.06	2.19	5.76	0.75	1.29	1.62	0.79	0.86
	200 year ARI	15.5	80.07	80.07	80.2	4.34	8.72	2.43	1.41	1.87	1.06	0.86
	Extreme Flood	34.9	80.25	80.25	80.43	11.11	13.21	10.58	1.94	1.82	1.77	0.95
1683.49	10-Apr-98	7.9	78.34	78.46	78.91		7.9			3.35		3.49
	5 year ARI	3.5	78.3	78.38	78.62		3.5			2.49		3.18
	10 year ARI	4.7	78.31	78.4	78.73		4.7			2.85		3.41
	20 year ARI	6.1	78.33	78.43	78.8		6.1			3.06		3.4

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
	100 year ARI	8.7	78.35	78.47	78.95		8.7			3.44		3.53
	200 year ARI	15.5	78.4	78.55	79.1		15.5			3.71		3.39
	Extreme Flood	34.9	78.51	78.71	79.28		34.9			3.88		2.89
1676.81	10-Apr-98	7.9	78.42	78.45	78.53		7.9			1.44		1.47
	5 year ARI	3.5	78.39	78.39	78.43		3.5			0.89		1.01
	10 year ARI	4.7	78.41	78.41	78.46		4.7			1		1.07
	20 year ARI	6.1	78.42	78.43	78.49		6.1			1.19		1.24
	100 year ARI	8.7	78.43	78.46	78.54		8.7			1.52		1.53
	200 year ARI	15.5	78.46	78.52	78.66	0	15.5		0.39	1.99		1.78
	Extreme Flood	34.9	78.54	78.65	78.92	0.16	34.72	0.02	1.09	2.72	0.59	1.96
1676.8	10-Apr-98	7.9	78.47	78.3	78.48	0.1	7.74	0.06	0.2	0.43	0.15	0.26
	5 year ARI	3.5	78.37	78.24	78.38	0.01	3.49	0	0.11	0.3	0.05	0.22
	10 year ARI	4.7	78.4	78.26	78.41	0.03	4.67	0.01	0.14	0.34	0.09	0.24
	20 year ARI	6.1	78.43	78.28	78.44	0.05	6.03	0.02	0.17	0.39	0.12	0.25
	100 year ARI	8.7	78.48	78.31	78.49	0.12	8.51	0.07	0.22	0.45	0.17	0.27
	200 year ARI	15.5	78.58	78.37	78.6	0.38	14.79	0.34	0.31	0.59	0.26	0.3
	Extreme Flood	34.9	78.8	78.5	78.83	1.7	31.19	2.01	0.44	0.79	0.41	0.33
1673.23	10-Apr-98	8.5	78.42	78.4	78.47	0	8.5		0.18	1.01		0.84
	5 year ARI	3.5	78.32	78.32	78.37		3.5			0.97		1.02
	10 year ARI	4.7	78.35	78.35	78.4		4.7			1.03		1.02
	20 year ARI	6.2	78.37	78.37	78.43		6.2			1.08		1.01
	100 year ARI	9	78.43	78.41	78.48	0	9		0.22	1		0.8
	200 year ARI	15.6	78.54	78.47	78.59	0.12	15.48	0	0.44	1	0.06	0.66
	Extreme Flood	35.8	78.76	78.61	78.82	1.15	33.85	0.8	0.61	1.14	0.45	0.54
1669.67	10-Apr-98	8.5	78.45	78.18	78.46	0.12	8.24	0.14	0.15	0.34	0.13	0.18
	5 year ARI	3.5	78.34	78.1	78.34	0.01	3.48	0.01	0.07	0.21	0.05	0.13
	10 year ARI	4.7	78.37	78.12	78.37	0.03	4.65	0.02	0.1	0.25	0.07	0.15
	20 year ARI	6.2	78.41	78.15	78.41	0.06	6.08	0.06	0.12	0.29	0.1	0.16
	100 year ARI	9	78.46	78.19	78.47	0.14	8.7	0.16	0.16	0.35	0.14	0.18
	200 year ARI	15.6	78.56	78.26	78.57	0.41	14.6	0.59	0.23	0.47	0.21	0.21
	Extreme Flood	35.8	78.79	78.4	78.81	1.87	30.62	3.32	0.38	0.67	0.37	0.25
1669.66	10-Apr-98	8.5	78.44	78.33	78.46	0.01	8.49	0	0.17	0.64	0.04	0.45
	5 year ARI	3.5	78.33	78.25	78.34		3.5			0.51		0.44
	10 year ARI	4.7	78.36	78.27	78.37		4.7			0.55		0.45
	20 year ARI	6.2	78.39	78.3	78.41	0	6.2		0.06	0.59		0.46
	100 year ARI	9	78.44	78.34	78.47	0.01	8.99	0	0.18	0.65	0.07	0.45
	200 year ARI	15.6	78.54	78.41	78.57	0.13	15.36	0.11	0.31	0.76	0.24	0.43
	Extreme Flood	35.8	78.76	78.55	78.8	1.12	32.97	1.71	0.49	0.96	0.44	0.42
1662.34	10-Apr-98	8.5	78.35	78.35	78.43	0.46	8.04		0.81	1.3		0.99
	5 year ARI	3.5	78.26	78.26	78.31	0.07	3.43		0.53	1.04		1
	10 year ARI	4.7	78.28	78.28	78.35	0.13	4.57		0.62	1.12		0.99
	20 year ARI	6.2	78.31	78.31	78.38	0.24	5.96		0.7	1.2		0.99
	100 year ARI	9	78.36	78.36	78.44	0.51	8.49		0.83	1.32		0.99
	200 year ARI	15.6	78.43	78.43	78.55	1.28	14.31	0.02	0.99	1.54	0.35	0.98
	Extreme Flood	35.8	78.61	78.61	78.78	4.82	30.22	0.77	1.3	1.9	0.82	0.93
1574.57	10-Apr-98	8.5	77.44	77.2	77.46	0.88	6.44	1.18	0.49	0.76	0.46	0.32
	5 year ARI	3.5	77.27	77.05	77.28	0.21	3.07	0.22	0.25	0.51	0.23	0.26
	10 year ARI	4.7	77.31	77.09	77.33	0.34	3.96	0.39	0.33	0.6	0.29	0.29
	20 year ARI	6.2	77.35	77.14	77.37	0.52	5.04	0.64	0.41	0.7	0.38	0.32
	100 year ARI	9	77.44	77.21	77.47	0.95	6.79	1.27	0.51	0.79	0.48	0.33
	200 year ARI	15.6	77.53	77.33	77.58	1.83	11.18	2.59	0.79	1.14	0.75	0.45
	Extreme Flood	35.8	77.87	77.59	77.95	4.69	22.93	8.17	0.99	1.31	1.19	0.49
1567.97	10-Apr-98	8.5	77.45	77.02	77.45	1.33	6.33	0.84	0.24	0.4	0.21	0.16
	5 year ARI	3.5	77.28	76.91	77.28	0.41	2.89	0.2	0.14	0.24	0.11	0.11
	10 year ARI	4.7	77.32	76.94	77.32	0.6	3.78	0.32	0.17	0.29	0.14	0.13
	20 year ARI	6.2	77.36	76.97	77.37	0.85	4.86	0.48	0.21	0.35	0.18	0.15
	100 year ARI	9	77.45	77.03	77.46	1.42	6.67	0.91	0.25	0.42	0.22	0.16
	200 year ARI	15.6	77.55	77.13	77.57	2.74	10.96	1.89	0.36	0.6	0.33	0.22
	Extreme Flood	35.8	77.91	77.34	77.93	8.64	20.49	6.67	0.54	0.76	0.49	0.23

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
1567.96	10-Apr-98	8.5	77.45	76.87	77.45	1.58	6.81	0.11	0.18	0.27	0.09	0.1
	5 year ARI	3.5	77.28	76.76	77.28	0.55	2.94	0.01	0.1	0.15	0.04	0.07
	10 year ARI	4.7	77.32	76.79	77.32	0.78	3.9	0.02	0.13	0.19	0.05	0.08
	20 year ARI	6.2	77.36	76.82	77.36	1.07	5.09	0.04	0.16	0.23	0.07	0.09
	100 year ARI	9	77.46	76.88	77.46	1.69	7.19	0.12	0.19	0.28	0.1	0.11
	200 year ARI	15.6	77.56	76.98	77.56	3.27	11.98	0.35	0.29	0.41	0.16	0.15
	Extreme Flood	35.8	77.91	77.17	77.93	9.16	24.46	2.18	0.46	0.59	0.34	0.17
1564.46	10-Apr-98	10	77.34	77.34	77.44	1.12	8.88		1.01	1.44		0.99
	5 year ARI	3.3	77.22	77.22	77.27	0.2	3.1		0.7	1.08		0.99
	10 year ARI	4.6	77.25	77.25	77.32	0.34	4.26		0.79	1.18		0.99
	20 year ARI	6.1	77.28	77.28	77.36	0.52	5.58		0.87	1.28		1
	100 year ARI	10.4	77.35	77.35	77.45	1.18	9.22		1.02	1.46		0.99
	200 year ARI	16.3	77.43	77.43	77.55	2.29	14.01		1.17	1.63		0.99
	Extreme Flood	41.6	77.83	77.65	77.92	9.56	31.54	0.5	1	1.37	0.49	0.55
1560.96	10-Apr-98	10	77.32	76.89	77.33	3.09	6.84	0.06	0.3	0.35	0.11	0.15
	5 year ARI	3.3	77.12	76.77	77.12	0.93	2.37	0	0.16	0.19	0	0.1
	10 year ARI	4.6	77.17	76.8	77.18	1.3	3.29	0	0.19	0.23	0.04	0.11
	20 year ARI	6.1	77.22	76.83	77.22	1.77	4.32	0.01	0.22	0.27	0.06	0.13
	100 year ARI	10.4	77.33	76.9	77.34	3.23	7.1	0.07	0.3	0.35	0.12	0.15
	200 year ARI	16.3	77.46	76.97	77.46	5.27	10.77	0.26	0.38	0.44	0.17	0.17
	Extreme Flood	41.6	77.88	77.18	77.9	13.82	25.29	2.49	0.58	0.64	0.39	0.19
1560.95	10-Apr-98	10	77.31	77.04	77.33	2.83	7.17	0	0.42	0.51	0.08	0.26
	5 year ARI	3.3	77.12	76.92	77.12	0.84	2.46		0.28	0.33		0.21
	10 year ARI	4.6	77.17	76.95	77.17	1.22	3.38		0.32	0.37		0.22
	20 year ARI	6.1	77.22	76.98	77.22	1.66	4.44		0.35	0.42		0.24
	100 year ARI	10.4	77.32	77.05	77.34	2.95	7.45	0	0.42	0.51	0.09	0.26
	200 year ARI	16.3	77.45	77.12	77.46	4.98	11.24	0.08	0.5	0.59	0.18	0.26
	Extreme Flood	41.6	77.87	77.33	77.9	13.79	25.95	1.86	0.69	0.76	0.41	0.25
1554.85	10-Apr-98	10	77.19	77.19	77.31	5.29	4.71		1.53	1.51		0.98
	5 year ARI	3.3	77.04	77.04	77.11	1.65	1.65		1.18	1.21		0.99
	10 year ARI	4.6	77.08	77.08	77.16	2.36	2.24		1.28	1.28		0.99
	20 year ARI	6.1	77.12	77.12	77.21	3.19	2.91		1.36	1.34		0.98
	100 year ARI	10.4	77.2	77.2	77.32	5.52	4.88		1.55	1.53		0.98
	200 year ARI	16.3	77.28	77.28	77.44	8.91	7.39		1.83	1.73		0.97
	Extreme Flood	41.6	77.54	77.54	77.86	23.98	17.62		2.64	2.29		0.95
1508.07	10-Apr-98	10	75.85	76	76.35		10			3.14		1.89
	5 year ARI	3.3	75.67	75.76	75.98		3.3			2.46		2.15
	10 year ARI	4.6	75.71	75.82	76.08		4.6			2.7		2.11
	20 year ARI	6.1	75.75	75.87	76.17		6.1			2.87		2.05
	100 year ARI	10.4	75.86	76.01	76.37		10.4			3.16		1.87
	200 year ARI	16.3	75.98	76.16	76.58		16.3			3.42		1.75
	Extreme Flood	41.6	77.36	76.63	77.53		41.6			1.83		0.44
1430.54	10-Apr-98	10	75.8	75.59	75.84		10			0.85		0.41
	5 year ARI	3.3	75.57	75.44	75.59		3.3			0.57		0.37
	10 year ARI	4.6	75.6	75.47	75.63		4.6			0.7		0.43
	20 year ARI	6.1	75.65	75.51	75.68		6.1			0.79		0.45
	100 year ARI	10.4	75.79	75.6	75.83		10.4			0.92		0.45
	200 year ARI	16.3	75.83	75.69	75.92		16.3			1.3		0.61
	Extreme Flood	41.6	77.44	75.99	77.47		41.6			0.74		0.17
1427.9	10-Apr-98	10	75.82	75.51	75.83		10			0.42		0.22
	5 year ARI	3.3	75.58	75.39	75.58		3.3			0.32		0.21
	10 year ARI	4.6	75.61	75.42	75.62		4.6			0.38		0.25
	20 year ARI	6.1	75.66	75.45	75.67		6.1			0.42		0.25
	100 year ARI	10.4	75.81	75.51	75.82		10.4			0.45		0.24
	200 year ARI	16.3	75.88	75.58	75.89		16.3			0.6		0.3
	Extreme Flood	41.6	77.46	75.79	77.46	0.35	40.39	0.86	0.03	0.27	0.03	0.06
1398.45	10-Apr-98	10	75.83	74.69	75.83	2.08	6.63	1.29	0.13	0.21	0.17	0.06
	5 year ARI	3.3	75.58	74.55	75.58	0.61	2.26	0.43	0.05	0.09	0.07	0.03
	10 year ARI	4.6	75.62	74.59	75.62	0.86	3.13	0.6	0.07	0.12	0.1	0.03
	20 year ARI	6.1	75.67	74.63	75.67	1.18	4.12	0.8	0.09	0.15	0.12	0.04

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
	100 year ARI	10.4	75.81	74.7	75.82	2.15	6.9	1.34	0.14	0.22	0.18	0.06
	200 year ARI	16.3	75.88	74.78	75.89	3.47	10.73	2.1	0.2	0.32	0.26	0.09
	Extreme Flood	41.6	77.45	75.05	77.46	11.77	25.14	4.69	0.19	0.36	0.27	0.07
1386.4	10-Apr-98	10	75.83	75.04	75.83		10			0.21		0.08
	5 year ARI	3.3	75.58	74.88	75.58		3.3			0.11		0.05
	10 year ARI	4.6	75.61	74.92	75.62		4.6			0.14		0.06
	20 year ARI	6.1	75.67	74.96	75.67		6.1			0.17		0.07
	100 year ARI	10.4	75.81	75.05	75.82		10.4			0.22		0.09
	200 year ARI	16.3	75.88	75.14	75.89		16.3			0.31		0.12
	Extreme Flood	41.6	77.46	75.4	77.46	0.82	37.71	3.08	0.1	0.2	0.1	0.04
1385.4	10-Apr-98	44.1	75.34	75.34	75.78	8.31	31.81	3.98	0.68	3.45	0.58	0.65
	5 year ARI	32.9	75.12	75.12	75.54	4.4	26.86	1.64	0.55	3.15	0.42	0.62
	10 year ARI	34.4	75.16	75.16	75.57	4.93	27.53	1.95	0.57	3.19	0.45	0.62
	20 year ARI	36.6	75.2	75.2	75.62	5.69	28.51	2.4	0.59	3.25	0.48	0.63
	100 year ARI	43.5	75.33	75.33	75.77	8.1	31.55	3.85	0.67	3.44	0.58	0.65
	200 year ARI	47.2	75.39	75.39	75.84	9.42	33.12	4.66	0.71	3.53	0.62	0.66
	Extreme Flood	174	76.59	76.59	77.38	61.44	75.87	36.69	1.36	5.75	1.57	0.9
1289.33	10-Apr-98	50.9	73.96	72.47	74.05	11.35	31.15	8.4	0.53	1.62	0.38	0.26
	5 year ARI	36.9	72.75	71.95	72.97	4.05	29.85	3	0.96	2.27	0.42	0.45
	10 year ARI	39.1	73.04	72.02	73.2	5.31	29.54	4.25	0.75	2.03	0.41	0.38
	20 year ARI	42.8	73.44	72.16	73.56	7.64	29.23	5.93	0.6	1.76	0.39	0.31
	100 year ARI	49.9	73.92	72.44	74.01	10.97	30.78	8.15	0.52	1.62	0.38	0.27
	200 year ARI	54.2	74.07	72.55	74.16	12.49	32.52	9.19	0.53	1.65	0.39	0.27
	Extreme Flood	199.6	75.76	74.21	76.07	60.55	95.84	43.21	1.16	3.4	0.69	0.46
1280		Macquarie St										
1261.47	10-Apr-98	50.9	72.51	71.97	73.02	2.14	47.29	1.47	0.59	3.27	0.59	0.62
	5 year ARI	36.9	72	71.46	72.45	0.51	35.83	0.56	0.39	3.04	0.49	0.64
	10 year ARI	39.1	72.1	71.52	72.56	0.76	37.65	0.69	0.44	3.05	0.51	0.63
	20 year ARI	42.8	72.24	71.69	72.71	1.16	40.73	0.92	0.5	3.11	0.54	0.63
	100 year ARI	49.9	72.48	71.94	72.98	2.01	46.5	1.4	0.58	3.25	0.59	0.63
	200 year ARI	54.2	72.6	72.06	73.13	2.55	49.94	1.71	0.62	3.34	0.62	0.63
	Extreme Flood	199.6	75.74	74.65	76.02	64.28	101.41	33.91	0.67	3.25	0.59	0.42
1245.63	10-Apr-98	50.9	72.36	71.84	73.01	4.09	43.72	3.09	0.62	3.84	0.85	0.71
	5 year ARI	36.9	71.91	71.51	72.44	1.98	32.95	1.97	0.61	3.4	0.74	0.68
	10 year ARI	39.1	72	71.58	72.55	2.19	34.75	2.16	0.59	3.46	0.76	0.68
	20 year ARI	42.8	72.11	71.71	72.7	2.64	37.7	2.46	0.59	3.6	0.79	0.69
	100 year ARI	49.9	72.32	71.81	72.97	3.86	43.03	3.01	0.62	3.82	0.84	0.71
	200 year ARI	54.2	72.44	72	73.12	4.81	46.07	3.32	0.64	3.93	0.87	0.71
	Extreme Flood	199.6	74.75	74.43	76.01	63.08	125.94	10.58	1.67	6.15	1.19	0.85
1235.76	10-Apr-98	51	72.04	72.04	72.85	2.03	44.97	4	0.59	4.26	1.05	0.8
	5 year ARI	37	71.48	71.48	72.33	0.37	35.37	1.26	0.48	4.16	1.76	0.87
	10 year ARI	39.2	71.58	71.58	72.42	0.58	37.06	1.57	0.52	4.18	1.67	0.86
	20 year ARI	42.8	71.75	71.75	72.57	1.02	39.53	2.25	0.56	4.15	1.42	0.83
	100 year ARI	49.9	72	72	72.82	1.89	44.26	3.75	0.59	4.24	1.08	0.81
	200 year ARI	54.3	72.13	72.13	72.96	2.44	47.09	4.78	0.59	4.31	1	0.8
	Extreme Flood	199.6	74.27	74.27	75.67	34.26	123.93	41.41	0.83	6.59	1.59	0.93
1164.42	10-Apr-98	52.5	71.27	70.7	71.59	6.64	37.51	8.35	0.39	2.95	0.69	0.51
	5 year ARI	37.7	71.1	70.09	71.3	4.09	28.01	5.6	0.31	2.32	0.53	0.42
	10 year ARI	40.1	71.13	70.13	71.35	4.49	29.56	6.05	0.32	2.42	0.56	0.43
	20 year ARI	44	71.18	70.48	71.43	5.16	32.07	6.77	0.34	2.59	0.6	0.46
	100 year ARI	51.5	71.26	70.68	71.57	6.46	36.87	8.17	0.38	2.91	0.68	0.51
	200 year ARI	56	71.3	70.78	71.65	7.24	39.76	9	0.41	3.1	0.73	0.54
	Extreme Flood	206	72.62	72.62	73.85	49.61	115.37	41.03	0.95	6.46	1.68	0.95
1141.13		Crick St										
1140.63	10-Apr-98	52.5	69.84	70.58	71.44	1.21	50.39	0.89	0.85	5.72	0.95	1.23
	5 year ARI	37.7	69.12	69.81	71.17	0.01	37.59	0.1	0.3	6.36	0.73	1.67
	10 year ARI	40.1	69.23	69.9	71.22	0.04	39.88	0.17	0.47	6.26	0.8	1.58
	20 year ARI	44	69.42	69.93	71.3	0.21	43.45	0.33	0.64	6.11	0.87	1.46

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
	100 year ARI	51.5	69.79	70.56	71.43	1.03	49.66	0.81	0.83	5.78	0.95	1.26
	200 year ARI	56	70.08	70.67	71.5	1.7	53	1.3	0.63	5.42	0.95	1.11
	Extreme Flood	206	72.33	72.33	73.45	62.09	115.29	28.63	1.44	6.14	1.07	0.9
1047.02	10-Apr-98	53.9	70.39	68.8	70.6	7.74	39.92	6.24	0.6	2.35	0.34	0.36
	5 year ARI	38.5	69.63	68.34	69.84	4.36	31.2	2.93	0.52	2.24	0.27	0.38
	10 year ARI	41.1	69.85	68.44	70.05	5.11	32.3	3.69	0.53	2.18	0.28	0.36
	20 year ARI	45.1	70.07	68.58	70.26	6.01	34.51	4.57	0.55	2.2	0.3	0.35
	100 year ARI	52.9	70.36	68.79	70.57	7.56	39.27	6.07	0.59	2.33	0.33	0.36
	200 year ARI	57.7	70.48	68.83	70.71	8.44	42.36	6.9	0.63	2.44	0.36	0.37
	Extreme Flood	211.6	71.84	71.31	73.22	35.72	142.67	33.22	1.65	6.26	1.01	0.84
1035		Royal St										
1022.52	10-Apr-98	53.9	68.57	68.57	69.36	6.53	45.45	1.92	0.77	4.3	0.5	0.84
	5 year ARI	38.5	68.16	68.16	68.86	3.04	34.87	0.59	0.73	3.89	0.32	0.83
	10 year ARI	41.1	68.24	68.24	68.96	3.59	36.7	0.81	0.74	3.96	0.36	0.83
	20 year ARI	45.1	68.35	68.35	69.09	4.48	39.48	1.14	0.75	4.06	0.41	0.83
	100 year ARI	52.9	68.54	68.54	69.33	6.29	44.78	1.83	0.77	4.27	0.49	0.84
	200 year ARI	57.7	68.65	68.65	69.47	7.48	47.96	2.26	0.78	4.39	0.53	0.85
	Extreme Flood	211.6	70.86	70.86	72.21	59.85	129.27	22.47	1.03	6.55	0.96	0.94
927.66	10-Apr-98	53.9	68.35	66.84	68.39	2.35	23.8	27.75	0.25	1.38	0.37	0.22
	5 year ARI	38.5	67.36	66.57	67.45	0.45	22.5	15.55	0.25	1.72	0.4	0.31
	10 year ARI	41.1	67.81	66.63	67.87	0.96	20.82	19.32	0.24	1.39	0.35	0.24
	20 year ARI	45.1	68.08	66.71	68.13	1.5	21.24	22.36	0.25	1.32	0.35	0.22
	100 year ARI	52.9	68.31	66.84	68.36	2.24	23.53	27.13	0.25	1.38	0.37	0.22
	200 year ARI	57.7	68.4	66.9	68.45	2.65	25.15	29.9	0.26	1.44	0.39	0.23
	Extreme Flood	211.6	69.52	68.2	69.75	18.86	74.91	117.83	0.52	3.39	0.98	0.47
920.66	10-Apr-98	61.3	68.36	66.48	68.39	3.95	24.46	32.89	0.22	1.28	0.35	0.19
	5 year ARI	42.3	67.4	66.2	67.45	1.04	21.16	20.1	0.24	1.4	0.36	0.23
	10 year ARI	45.4	67.83	66.25	67.87	1.53	20.47	23.39	0.18	1.21	0.32	0.19
	20 year ARI	49.5	68.09	66.32	68.13	2.38	20.96	26.16	0.18	1.16	0.32	0.18
	100 year ARI	59.4	68.33	66.46	68.36	3.71	23.87	31.82	0.21	1.25	0.35	0.19
	200 year ARI	65.1	68.41	66.53	68.45	4.44	25.65	35.01	0.23	1.32	0.37	0.2
	Extreme Flood	237.6	69.57	67.94	69.75	34.37	74.91	128.32	0.65	3.09	0.91	0.41
900		Penshurst St										
892.69	10-Apr-98	61.3	65.81	65.81	66.4	6.27	46.1	8.93	0.9	3.88	1.25	0.72
	5 year ARI	42.3	65.36	65.36	65.97	2.22	37.02	3.05	0.72	3.66	0.92	0.74
	10 year ARI	45.4	65.46	65.46	66.05	2.86	38.55	3.98	0.76	3.68	0.98	0.72
	20 year ARI	49.5	65.57	65.57	66.15	3.71	40.57	5.22	0.8	3.72	1.06	0.72
	100 year ARI	59.4	65.78	65.78	66.37	5.85	45.22	8.33	0.88	3.85	1.22	0.72
	200 year ARI	65.1	65.88	65.88	66.47	7.15	47.74	10.21	0.92	3.93	1.3	0.72
	Extreme Flood	237.6	68.52	67.41	68.76	64.79	74.81	98	0.98	3.29	1.67	0.44
863.34	10-Apr-98	61.3	65.34	64.82	65.82	0.29	60.87	0.13	0.39	3.08	0.34	0.66
	5 year ARI	42.3	65.02	64.41	65.33	0.04	42.26	0.01	0.21	2.5	0.15	0.58
	10 year ARI	45.4	65.07	64.48	65.42	0.06	45.32	0.02	0.25	2.6	0.19	0.6
	20 year ARI	49.5	65.15	64.57	65.53	0.1	49.36	0.03	0.29	2.73	0.23	0.62
	100 year ARI	59.4	65.31	64.77	65.77	0.26	59.03	0.11	0.38	3.02	0.32	0.66
	200 year ARI	65.1	65.39	64.89	65.9	0.38	64.54	0.18	0.42	3.18	0.37	0.68
	Extreme Flood	237.6	67.74	67.74	68.54	31.15	184.23	22.22	1.02	4.45	0.94	0.66
833.74	10-Apr-98	61.3	65.49	64.24	65.67	2.55	55.86	2.88	0.51	1.97	0.45	0.37
	5 year ARI	42.3	65.1	63.88	65.23	1.09	39.75	1.46	0.37	1.62	0.35	0.33
	10 year ARI	45.4	65.17	63.94	65.31	1.3	42.44	1.67	0.39	1.69	0.37	0.34
	20 year ARI	49.5	65.26	64.02	65.4	1.58	45.96	1.96	0.43	1.77	0.39	0.35
	100 year ARI	59.4	65.45	64.2	65.63	2.39	54.29	2.72	0.5	1.94	0.44	0.37
	200 year ARI	65.1	65.56	64.3	65.75	2.91	58.98	3.21	0.54	2.03	0.46	0.38
	Extreme Flood	237.6	68.04	66.36	68.34	35.51	155.95	46.14	0.84	2.89	0.89	0.4
832.74	10-Apr-98	61.3	64.97	64.97	65.62	1.67	56.18	3.45	0.82	3.71	0.98	0.96
	5 year ARI	42.3	64.65	64.65	65.19	0.7	39.75	1.85	0.69	3.34	0.88	0.98
	10 year ARI	45.4	64.71	64.71	65.26	0.83	42.48	2.09	0.71	3.41	0.9	0.97
	20 year ARI	49.5	64.78	64.78	65.36	1.03	46.05	2.42	0.74	3.49	0.92	0.97

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
	100 year ARI	59.4	64.94	64.94	65.58	1.56	54.56	3.28	0.81	3.67	0.97	0.96
	200 year ARI	65.1	65.03	65.03	65.7	1.9	59.4	3.8	0.85	3.78	1	0.96
	Extreme Flood	237.6	67.92	67.02	68.32	34.08	153.41	50.11	0.91	3.44	0.93	0.52
831.74	10-Apr-98	62.3	65.17	64.26	65.43	1.78	58.23	2.29	0.54	2.31	0.5	0.46
	5 year ARI	43.1	64.83	63.9	65.01	0.69	41.3	1.12	0.37	1.89	0.39	0.41
	10 year ARI	46.2	64.89	63.96	65.08	0.84	44.08	1.29	0.4	1.97	0.41	0.42
	20 year ARI	50.4	64.97	64.04	65.18	1.06	47.81	1.53	0.43	2.06	0.44	0.43
	100 year ARI	60.4	65.14	64.22	65.39	1.66	56.58	2.16	0.52	2.27	0.49	0.46
	200 year ARI	66.3	65.23	64.33	65.5	2.06	61.67	2.57	0.57	2.39	0.53	0.48
	Extreme Flood	241.6	67.97	66.42	68.3	34.92	161.26	45.42	0.88	3.03	0.93	0.42
784.58	10-Apr-98	62.3	65	64.29	65.31	4.03	52.88	5.39	0.75	2.66	0.99	0.51
	5 year ARI	43.1	64.7	63.77	64.92	2.04	38.31	2.75	0.56	2.15	0.73	0.43
	10 year ARI	46.2	64.76	63.86	64.99	2.34	40.72	3.14	0.6	2.24	0.77	0.44
	20 year ARI	50.4	64.83	64.01	65.08	2.76	43.94	3.7	0.64	2.35	0.83	0.46
	100 year ARI	60.4	64.97	64.25	65.28	3.82	51.47	5.11	0.73	2.62	0.97	0.5
	200 year ARI	66.3	65.05	64.37	65.38	4.48	55.82	5.99	0.79	2.76	1.05	0.52
	Extreme Flood	241.6	68.01	66.46	68.21	71.29	109.4	60.91	1.07	2.67	1.29	0.35
783.58	10-Apr-98	62.3	64.7	64.7	65.28		62.3			3.36		1
	5 year ARI	43.1	64.38	64.38	64.88		43.1			3.14		1
	10 year ARI	46.2	64.44	64.44	64.95		46.2			3.18		1
	20 year ARI	50.4	64.51	64.51	65.04		50.4			3.25		1.01
	100 year ARI	60.4	64.67	64.67	65.24		60.4			3.34		1
	200 year ARI	66.3	64.76	64.76	65.35		66.3			3.4		1
	Extreme Flood	241.6	68.01	66.35	68.2	20.13	206.92	14.55	0.6	2.07	1.01	0.34
782.59	10-Apr-98	62.3	63.9	64.29	65.18	0.25	61.47	0.58	0.67	5.05	0.91	1.22
	5 year ARI	43.1	63.32	63.77	64.76		43.1			5.32		1.58
	10 year ARI	46.2	63.41	63.86	64.83		46.2	0		5.29	0.14	1.51
	20 year ARI	50.4	63.54	64.01	64.93		50.37	0.03		5.23	0.48	1.42
	100 year ARI	60.4	63.84	64.25	65.15	0.15	59.81	0.44	0.6	5.08	0.86	1.25
	200 year ARI	66.3	64.01	64.37	65.26	0.52	64.84	0.94	0.78	5.01	0.99	1.18
	Extreme Flood	241.6	68	66.46	68.2	71.07	109.79	60.74	1.07	2.69	1.29	0.36
754.88	10-Apr-98	62.3	64.69	63.64	64.79		62.3			1.37		0.36
	5 year ARI	43.1	64.05	63.33	64.17		43.1			1.54		0.45
	10 year ARI	46.2	64.17	63.39	64.28		46.2			1.49		0.42
	20 year ARI	50.4	64.33	63.46	64.44		50.4			1.44		0.4
	100 year ARI	60.4	64.64	63.61	64.74		60.4			1.38		0.36
	200 year ARI	66.3	64.8	63.69	64.9	0	66.3		0.06	1.36		0.35
	Extreme Flood	241.6	68.08	65.12	68.14	18.62	174.45	48.52	0.36	1.14	0.89	0.17
753.88	10-Apr-98	62.3	64.66	63.9	64.78		62.3			1.56		0.43
	5 year ARI	43.1	63.95	63.64	64.15		43.1			2.01		0.65
	10 year ARI	46.2	64.1	63.69	64.27		46.2			1.86		0.58
	20 year ARI	50.4	64.28	63.75	64.43		50.4			1.71		0.51
	100 year ARI	60.4	64.6	63.88	64.73		60.4			1.58		0.44
	200 year ARI	66.3	64.77	63.95	64.89	0	66.3		0.06	1.52		0.41
	Extreme Flood	241.6	68.09	65.29	68.14	31.59	162.43	47.58	0.61	1.09	0.87	0.16
752.92	10-Apr-98	62.3	64.68	63.63	64.78		62.3			1.39		0.36
	5 year ARI	43.1	64	63.32	64.13		43.1			1.61		0.47
	10 year ARI	46.2	64.13	63.38	64.25		46.2			1.54		0.44
	20 year ARI	50.4	64.31	63.45	64.42		50.4			1.46		0.41
	100 year ARI	60.4	64.62	63.61	64.72		60.4			1.4		0.37
	200 year ARI	66.3	64.79	63.69	64.88	0	66.3		0.05	1.37		0.35
	Extreme Flood	241.6	68.08	65.12	68.14	18.58	174.51	48.51	0.36	1.14	0.89	0.17
730.09	10-Apr-98	62.3	64.6	63.39	64.74	3.25	52.36	6.69	0.52	1.78	0.55	0.34
	5 year ARI	43.1	63.9	63.02	64.06	1.28	39.98	1.84	0.48	1.82	0.42	0.4
	10 year ARI	46.2	64.04	63.09	64.19	1.59	42.08	2.53	0.49	1.79	0.45	0.38
	20 year ARI	50.4	64.22	63.17	64.37	2.04	44.84	3.52	0.49	1.77	0.48	0.36
	100 year ARI	60.4	64.54	63.35	64.68	3.04	51.23	6.12	0.51	1.78	0.54	0.35
	200 year ARI	66.3	64.71	63.46	64.85	3.68	54.67	7.94	0.53	1.79	0.57	0.34
	Extreme Flood	241.6	68.06	65.31	68.13	67.95	101.28	72.37	0.68	1.53	0.67	0.2

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
727.09	10-Apr-98	64.1	64.64	63.26	64.71	0.58	63.52		0.56	1.14		0.27
	5 year ARI	43.1	63.95	62.9	64.02		43.1			1.21		0.34
	10 year ARI	46.9	64.09	62.97	64.16	0	46.9		0.19	1.18		0.32
	20 year ARI	52	64.27	63.07	64.34	0.06	51.94		0.36	1.16		0.3
	100 year ARI	62.2	64.59	63.23	64.65	0.46	61.74		0.54	1.14		0.27
	200 year ARI	68.2	64.76	63.32	64.82	0.86	67.31	0.03	0.6	1.14	0.16	0.26
	Extreme Flood	248.8	68.08	64.74	68.12	50.09	148.98	49.74	0.78	0.94	0.69	0.13
725.09	10-Apr-98	64.1	64.4	63.63	64.68	5.71	53.11	5.28	0.58	2.57	0.62	0.49
	5 year ARI	43.1	63.67	63.12	63.99	1.03	39.99	2.07	0.4	2.61	0.58	0.58
	10 year ARI	46.9	63.81	63.22	64.13	1.58	42.72	2.6	0.43	2.61	0.59	0.56
	20 year ARI	52	64	63.35	64.31	2.47	46.17	3.35	0.46	2.61	0.61	0.53
	100 year ARI	62.2	64.34	63.59	64.63	5.16	52.08	4.96	0.57	2.58	0.62	0.49
	200 year ARI	68.2	64.52	63.71	64.8	6.87	55.38	5.95	0.61	2.57	0.63	0.48
	Extreme Flood	248.8	68.03	65.69	68.11	76.26	89.26	83.28	0.71	1.89	0.68	0.24
683	10-Apr-98	64.1	64.24	63.26	64.61	5.97	55.93	2.2	0.65	2.9	0.29	0.52
	5 year ARI	43.1	63.63	62.86	63.9	4.34	38.15	0.61	0.78	2.45	0.29	0.49
	10 year ARI	46.9	63.76	62.94	64.04	5	41.08	0.83	0.81	2.51	0.32	0.49
	20 year ARI	52	63.91	63.05	64.22	5.87	45.29	0.84	0.86	2.61	0.23	0.49
	100 year ARI	62.2	64.18	63.25	64.55	5.63	54.71	1.86	0.66	2.89	0.28	0.52
	200 year ARI	68.2	64.37	63.34	64.73	7.3	57.82	3.08	0.68	2.87	0.32	0.51
	Extreme Flood	248.8	67.77	65.68	68.07	77.89	130.09	40.82	1.16	3.18	0.62	0.39
682.6	10-Apr-98	64.1	64.24	63.46	64.61	3.37	57.52	3.21	0.43	2.82	0.38	0.54
	5 year ARI	43.1	63.54	63	63.89	1	41.17	0.93	0.35	2.7	0.38	0.6
	10 year ARI	46.9	63.68	63.09	64.04	1.33	44.37	1.19	0.37	2.73	0.39	0.58
	20 year ARI	52	63.85	63.21	64.22	1.83	48.54	1.62	0.38	2.77	0.41	0.57
	100 year ARI	62.2	64.18	63.43	64.55	3.08	56.2	2.92	0.42	2.82	0.39	0.54
	200 year ARI	68.2	64.37	63.55	64.73	3.97	60.34	3.88	0.46	2.83	0.38	0.53
	Extreme Flood	248.8	67.46	65.74	68.04	26.41	175.32	47.07	0.79	4	0.64	0.52
681.59	10-Apr-98	66.9	64.37	63.19	64.55	6.13	59.82	0.95	0.7	1.95	0.23	0.39
	5 year ARI	45.8	63.65	62.69	63.84	2.02	43.78		0.58	1.99		0.46
	10 year ARI	49.7	63.79	62.79	63.98	2.71	46.99	0	0.62	1.98	0.03	0.45
	20 year ARI	54.7	63.97	62.91	64.16	3.56	51.05	0.08	0.63	1.97	0.13	0.43
	100 year ARI	65	64.31	63.15	64.49	5.7	58.54	0.75	0.69	1.95	0.22	0.39
	200 year ARI	70.9	64.5	63.27	64.67	7	62.46	1.44	0.72	1.94	0.25	0.38
	Extreme Flood	260	67.69	65.19	67.94	38.08	182.36	39.57	1.08	2.59	0.65	0.34
679.58	10-Apr-98	66.9	63.74	63.42	64.49		64.91	1.99		3.88	0.61	0.78
	5 year ARI	45.8	63.21	62.9	63.8		45.21	0.59		3.42	0.42	0.77
	10 year ARI	49.7	63.32	63	63.93		48.87	0.83		3.5	0.47	0.76
	20 year ARI	54.7	63.47	63.12	64.11		53.47	1.23		3.57	0.54	0.75
	100 year ARI	65	63.72	63.38	64.43		62.97	2.03		3.8	0.64	0.76
	200 year ARI	70.9	63.79	63.52	64.6		68.92	1.98		4.04	0.56	0.8
	Extreme Flood	260	66.59	66.14	67.84		198.89	61.11		5.6	1.44	0.77
672.58	10-Apr-98	66.9	63.42	63.42	64.42		65.51	1.39		4.47	0.65	0.96
	5 year ARI	45.8	62.9	62.9	63.73		45.49	0.31		4.04	0.47	0.98
	10 year ARI	49.7	63	63	63.87		49.27	0.43		4.15	0.51	0.98
	20 year ARI	54.7	63.12	63.12	64.04		54.11	0.59		4.28	0.52	0.98
	100 year ARI	65	63.38	63.38	64.37		63.75	1.25		4.43	0.63	0.95
	200 year ARI	70.9	63.52	63.52	64.54		69.17	1.73		4.52	0.7	0.94
	Extreme Flood	260	66.14	66.14	67.76		205.15	54.85		6.3	1.53	0.91
668.81	10-Apr-98	66.9	63.04	63.31	64.35		66.02	0.88		5.12	0.7	1.22
	5 year ARI	45.8	62.65	62.85	63.67		45.5	0.3		4.5	0.57	1.21
	10 year ARI	49.7	62.72	62.94	63.81		49.31	0.39		4.64	0.61	1.22
	20 year ARI	54.7	62.81	63.06	63.98		54.19	0.51		4.82	0.65	1.23
	100 year ARI	65	63	63.28	64.3		64.19	0.81		5.07	0.69	1.22
	200 year ARI	70.9	63.11	63.4	64.47		69.85	1.05		5.21	0.72	1.22
	Extreme Flood	260	65.21	66.04	67.64		215.79	44.21		7.55	1.53	1.21
639.3	10-Apr-98	66.9	63.65	62.68	64.01	0.52	66.07	0.31	0.3	2.68	0.26	0.52
	5 year ARI	45.8	63.16	62.19	63.42	0.08	45.68	0.04	0.17	2.26	0.15	0.48
	10 year ARI	49.7	63.25	62.29	63.53	0.13	49.51	0.06	0.2	2.35	0.17	0.49
	20 year ARI	54.7	63.37	62.41	63.68	0.21	54.38	0.11	0.22	2.45	0.2	0.5

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
	100 year ARI	65	63.61	62.64	63.96	0.47	64.27	0.27	0.29	2.65	0.25	0.51
	200 year ARI	70.9	63.74	62.76	64.12	0.65	69.84	0.41	0.32	2.75	0.26	0.52
	Extreme Flood	260	66.61	64.97	66.77	3.4	110.61	145.99	0.32	2.16	1.39	0.29
638.3	10-Apr-98	66.9	63.09	63.09	63.96	0.11	66.75	0.04	0.32	4.15	0.26	0.99
	5 year ARI	45.8	62.67	62.67	63.37	0	45.8		0.05	3.71		1.01
	10 year ARI	49.7	62.76	62.76	63.49	0	49.7	0	0.13	3.79	0.04	1
	20 year ARI	54.7	62.86	62.86	63.63	0.02	54.68	0	0.2	3.89	0.13	1
	100 year ARI	65	63.05	63.05	63.91	0.09	64.88	0.03	0.3	4.12	0.25	0.99
	200 year ARI	70.9	63.16	63.16	64.06	0.16	70.67	0.07	0.35	4.22	0.3	0.99
	Extreme Flood	260	66.6	65.04	66.77	3.49	107.2	149.32	0.33	2.25	1.43	0.31
637.29	10-Apr-98	68.9	62.23	62.72	63.88		68.9			5.68		1.47
	5 year ARI	46.8	61.74	62.23	63.28		46.8			5.49		1.57
	10 year ARI	50.9	61.84	62.32	63.4		50.9			5.52		1.54
	20 year ARI	56.1	61.96	62.45	63.54		56.1			5.57		1.51
	100 year ARI	67	62.2	62.68	63.83		67			5.66		1.47
	200 year ARI	73.2	62.32	62.8	63.98		73.2			5.72		1.45
	Extreme Flood	268	66.6	65	66.77	3.51	114.25	150.24	0.33	2.23	1.44	0.3
590.96	10-Apr-98	68.9	63.05	61.44	63.28	0.27	68.55	0.08	0.28	2.16	0.21	0.38
	5 year ARI	46.8	62.54	60.91	62.7	0.06	46.73	0.02	0.18	1.74	0.13	0.34
	10 year ARI	50.9	62.64	61.02	62.81	0.08	50.79	0.02	0.2	1.83	0.14	0.35
	20 year ARI	56.1	62.77	61.15	62.96	0.13	55.94	0.04	0.22	1.93	0.16	0.36
	100 year ARI	67	63.01	61.4	63.24	0.25	66.68	0.07	0.28	2.13	0.2	0.38
	200 year ARI	73.2	63.14	61.53	63.39	0.34	72.76	0.1	0.3	2.23	0.22	0.39
	Extreme Flood	268	65.62	64.13	66.62	7.02	257.45	3.53	0.87	4.52	0.67	0.6
589.96	10-Apr-98	68.9	62.39	62.39	63.22	0.19	68.66	0.05	1.05	4.06	0.75	0.99
	5 year ARI	46.8	61.98	61.98	62.65	0	46.8	0	0.39	3.61	0.24	1
	10 year ARI	50.9	62.06	62.06	62.76	0.01	50.88	0	0.56	3.7	0.38	1
	20 year ARI	56.1	62.16	62.16	62.9	0.04	56.05	0.01	0.73	3.81	0.51	0.99
	100 year ARI	67	62.35	62.35	63.18	0.16	66.8	0.04	1.01	4.03	0.71	0.99
	200 year ARI	73.2	62.46	62.46	63.32	0.27	72.85	0.08	1.14	4.13	0.81	0.98
	Extreme Flood	268	64.79	64.79	66.54	16.1	245.93	5.97	2.9	6.08	1.75	0.96
588.96	10-Apr-98	68.9	60.65	61.44	63.06		68.9			6.87		1.81
	5 year ARI	46.8	60.16	60.91	62.47		46.8			6.73		1.98
	10 year ARI	50.9	60.26	61.02	62.59		50.9			6.76		1.93
	20 year ARI	56.1	60.38	61.15	62.73		56.1			6.79		1.87
	100 year ARI	67	60.61	61.4	63.01		67			6.86		1.81
	200 year ARI	73.2	60.74	61.53	63.16		73.2			6.9		1.79
	Extreme Flood	268	63.25	64.13	66.4	1.48	266.09	0.43	1.11	7.89	0.8	1.36
548.67	10-Apr-98	68.9	61.72	61.04	62.04	1.2	67.67	0.04	0.46	2.53	0.25	0.55
	5 year ARI	46.8	61.32	60.69	61.55	0.38	46.41	0.01	0.33	2.12	0.19	0.51
	10 year ARI	50.9	61.4	60.76	61.65	0.49	50.39	0.02	0.36	2.21	0.2	0.52
	20 year ARI	56.1	61.5	60.85	61.76	0.67	55.41	0.02	0.39	2.31	0.22	0.53
	100 year ARI	67	61.69	61.01	62	1.11	65.86	0.04	0.45	2.5	0.25	0.55
	200 year ARI	73.2	61.79	61.09	62.12	1.41	71.75	0.04	0.48	2.59	0.26	0.56
	Extreme Flood	268	64.09	63.11	64.95	21.01	242.78	4.21	1.1	4.3	0.78	0.65
547.67	10-Apr-98	68.9	61.29	61.29	61.99	0.64	68.24	0.02	0.61	3.73	0.35	0.98
	5 year ARI	46.8	60.96	60.96	61.51	0.13	46.66	0.01	0.43	3.31	0.26	0.99
	10 year ARI	50.9	61.03	61.03	61.61	0.2	50.69	0.01	0.47	3.38	0.28	0.99
	20 year ARI	56.1	61.1	61.1	61.72	0.29	55.8	0.01	0.51	3.51	0.31	1
	100 year ARI	67	61.26	61.26	61.96	0.58	66.4	0.02	0.6	3.7	0.35	0.99
	200 year ARI	73.2	61.35	61.35	62.08	0.77	72.4	0.03	0.64	3.82	0.37	0.99
	Extreme Flood	268	63.35	63.35	64.88	18.22	249.22	0.56	1.4	5.66	0.57	0.96
546.67	10-Apr-98	70.8	60.75	61.07	61.93	0.03	70.77	0	0.39	4.82	0.28	1.42
	5 year ARI	47.9	60.43	60.72	61.45		47.9			4.47		1.48
	10 year ARI	52.2	60.49	60.78	61.55		52.2	0		4.54	0.09	1.51
	20 year ARI	57.6	60.57	60.87	61.66	0	57.6	0	0.06	4.63	0.16	1.48
	100 year ARI	69	60.73	61.04	61.9	0.02	68.98	0	0.36	4.79	0.26	1.42
	200 year ARI	75.5	60.82	61.13	62.02	0.06	75.44	0	0.46	4.86	0.31	1.39
	Extreme Flood	276	62.85	63.16	64.82	14.14	261.46	0.4	1.5	6.38	0.74	1.13

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
489.05	10-Apr-98	70.8	60.9	60.18	61.13	0.27	61.08	9.45	0.33	2.29	1.06	0.49
	5 year ARI	47.9	60.6	59.68	60.79	0.06	45.49	2.36	0.19	1.97	0.55	0.45
	10 year ARI	52.2	60.72	59.8	60.9	0.11	47.71	4.38	0.22	1.94	0.71	0.43
	20 year ARI	57.6	60.77	59.93	60.97	0.15	51.84	5.62	0.25	2.06	0.81	0.46
	100 year ARI	69	60.88	60.16	61.11	0.26	59.84	8.9	0.32	2.26	1.02	0.49
	200 year ARI	75.5	60.93	60.36	61.19	0.32	64.3	10.88	0.35	2.37	1.14	0.5
	Extreme Flood	276	61.05	61.85	63.84	1.49	226.04	48.47	1.29	7.93	4.22	1.64
488.05	10-Apr-98	70.8	60.69	60.69	61.11	0.15	61.96	8.69	0.35	3.03	1.54	0.74
	5 year ARI	47.9	60.14	60.14	60.75		47.9			3.44		1.01
	10 year ARI	52.2	60.21	60.21	60.85	0	52.2	0	0.04	3.55	0.06	1.02
	20 year ARI	57.6	60.54	60.54	60.95	0.06	54.07	3.47	0.28	2.89	1.05	0.74
	100 year ARI	69	60.67	60.67	61.09	0.14	60.88	7.98	0.34	3.01	1.49	0.74
	200 year ARI	75.5	60.74	60.74	61.17	0.2	64.52	10.79	0.38	3.07	1.69	0.74
	Extreme Flood	276	61.14	61.88	63.76	1.84	196.13	78.03	1.39	7.6	6.09	1.65
487.05	10-Apr-98	73.4	60.06	60.22	61.05		73.4			4.4		1.15
	5 year ARI	49.2	59.24	59.72	60.65		49.2			5.26		1.41
	10 year ARI	53.8	59.38	59.84	60.77		53.8			5.22		1.41
	20 year ARI	59.7	59.59	59.97	60.85		59.7			4.97		1.34
	100 year ARI	71.7	60	60.19	61.02		71.7			4.47		1.18
	200 year ARI	78.5	60.33	60.57	61.12	0.01	78.37	0.13	0.19	3.96	0.27	0.98
	Extreme Flood	286.8	61.16	61.9	63.71	1.81	227.42	57.58	1.33	7.64	4.38	1.55
448.07	10-Apr-98	73.4	60	59.06	60.27	1.65	71.43	0.32	0.74	2.32	0.27	0.48
	5 year ARI	49.2	59.54	58.67	59.74	0.52	48.68		0.51	1.95		0.44
	10 year ARI	53.8	59.64	58.75	59.84	0.7	53.1		0.57	2.03		0.45
	20 year ARI	59.7	59.75	58.84	59.98	0.96	58.74		0.63	2.13		0.46
	100 year ARI	71.7	59.97	59.03	60.23	1.55	69.92	0.23	0.73	2.3	0.23	0.48
	200 year ARI	78.5	60.09	59.13	60.37	1.93	75.93	0.64	0.77	2.37	0.35	0.48
	Extreme Flood	286.8	61.92	61.21	62.81	15.63	248.09	23.07	1.61	4.45	1.58	0.69
447.07	10-Apr-98	73.4	59.49	59.49	60.22	0.65	72.75		0.71	3.8		0.98
	5 year ARI	49.2	59.11	59.11	59.69	0.16	49.04		0.5	3.38		0.99
	10 year ARI	53.8	59.19	59.19	59.8	0.23	53.57		0.54	3.48		0.99
	20 year ARI	59.7	59.27	59.27	59.93	0.33	59.37		0.6	3.6		1
	100 year ARI	71.7	59.46	59.46	60.18	0.6	71.1		0.7	3.78		0.99
	200 year ARI	78.5	59.56	59.56	60.32	0.81	77.69		0.77	3.88		0.98
	Extreme Flood	286.8	61.78	61.36	62.79	5.48	218.73	62.59	1	4.48	4.59	0.74
446.06	10-Apr-98	73.4	58.6	59.06	60.12	0	73.4		0.22	5.47		1.63
	5 year ARI	49.2	58.13	58.67	59.59		49.2			5.35		1.51
	10 year ARI	53.8	58.25	58.75	59.7		53.8			5.33		1.45
	20 year ARI	59.7	58.39	58.84	59.84		59.7			5.34		1.54
	100 year ARI	71.7	58.57	59.03	60.09	0	71.7		0.12	5.45		1.64
	200 year ARI	78.5	58.66	59.13	60.22	0	78.5		0.43	5.53		1.61
	Extreme Flood	286.8	61.83	61.21	62.77	15.39	248.98	22.43	1.65	4.56	1.6	0.71
405.71	10-Apr-98	73.4	59.39	58.07	59.55	6.5	66.9		0.52	1.84		0.38
	5 year ARI	49.2	59.03	57.65	59.13	2.57	46.63		0.36	1.5		0.32
	10 year ARI	53.8	59.1	57.74	59.22	3.21	50.59		0.39	1.57		0.33
	20 year ARI	59.7	59.19	57.85	59.32	4.1	55.6		0.44	1.66		0.35
	100 year ARI	71.7	59.36	58.05	59.51	6.12	65.58		0.51	1.83		0.38
	200 year ARI	78.5	59.5	58.16	59.66	7.82	70.68		0.54	1.86		0.37
	Extreme Flood	286.8	62.26	60	62.46	93.91	190.51	2.38	0.94	2.32	0.51	0.33
404.71	10-Apr-98	73.4	59.09	58.95	59.51	7.4	66		0.92	3.02		0.78
	5 year ARI	49.2	58.62	58.62	59.09	1.65	47.55		0.68	3.11		0.92
	10 year ARI	53.8	58.69	58.69	59.18	2.36	51.44		0.74	3.15		0.91
	20 year ARI	59.7	58.77	58.77	59.28	3.34	56.36		0.82	3.23		0.91
	100 year ARI	71.7	59.01	58.93	59.48	6.45	65.25		0.93	3.15		0.83
	200 year ARI	78.5	59.28	59.01	59.63	9.8	68.7		0.91	2.79		0.69
	Extreme Flood	286.8	62.24	60.68	62.46	104.01	178.57	4.22	1.05	2.5	0.91	0.38
403.71	10-Apr-98	83.1	59.21	58.25	59.46	5.83	77.27		0.61	2.29		0.48
	5 year ARI	53.5	58.42	57.74	58.69	0.28	53.22		0.29	2.32		0.55
	10 year ARI	59.2	58.58	57.84	58.85	0.77	58.43		0.37	2.33		0.54
	20 year ARI	65	58.74	57.94	59.01	1.61	63.39		0.44	2.34		0.53

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
	100 year ARI	81	59.15	58.21	59.41	5.26	75.74		0.59	2.3		0.49
	200 year ARI	89.1	59.35	58.36	59.59	7.58	81.52		0.64	2.27		0.47
	Extreme Flood	324	62.19	60.39	62.45	104.77	216.57	2.66	1.07	2.68	0.59	0.38
373.25	10-Apr-98	83.1	59.14	57.01	59.38	0.77	82.33		0.25	2.16		0.35
	5 year ARI	53.5	58.44	56.45	58.59		53.5			1.71		0.3
	10 year ARI	59.2	58.59	56.56	58.75	0.01	59.19		0.08	1.81		0.31
	20 year ARI	65	58.73	56.68	58.91	0.07	64.93		0.13	1.9		0.32
	100 year ARI	81	59.09	56.97	59.33	0.64	80.36		0.24	2.13		0.35
	200 year ARI	89.1	59.27	57.12	59.52	1.22	87.88		0.29	2.23		0.36
	Extreme Flood	324	61.9	60.77	62.37	89.19	232.79	2.02	1.03	3.55	0.67	0.44
372.25	10-Apr-98	83.1	58.48	58.29	59.31	0	83.1		0.08	4.05		0.88
	5 year ARI	53.5	57.91	57.73	58.54		53.5			3.5		0.86
	10 year ARI	59.2	58.03	57.85	58.7		59.2			3.62		0.86
	20 year ARI	65	58.15	57.96	58.86		65			3.73		0.87
	100 year ARI	81	58.44	58.25	59.26	0	81		0.01	4.01		0.88
	200 year ARI	89.1	58.58	58.39	59.45	0.02	89.08		0.19	4.14		0.88
	Extreme Flood	324	61.36	61.2	62.32	79.38	243.31	1.31	1.2	4.97	0.67	0.72
371.25	10-Apr-98	83.1	58.86	57.02	59.14	0.23	82.87		0.2	2.34		0.39
	5 year ARI	53.5	58.23	56.44	58.4		53.5			1.83		0.33
	10 year ARI	59.2	58.36	56.56	58.56		59.2			1.94		0.35
	20 year ARI	65	58.49	56.68	58.71	0	65		0.05	2.04		0.36
	100 year ARI	81	58.82	56.98	59.09	0.17	80.83		0.19	2.31		0.39
	200 year ARI	89.1	58.98	57.12	59.28	0.44	88.66		0.25	2.43		0.4
	Extreme Flood	324	61.62	60.77	62.2	80.43	241.85	1.72	1.05	3.85	0.69	0.49
341.5	10-Apr-98	83.1	58.78	57.3	59.09	1.16	80.96	0.98	0.46	2.46	0.46	0.43
	5 year ARI	53.5	58.15	56.59	58.35	0.11	53.31	0.08	0.25	2.01	0.22	0.39
	10 year ARI	59.2	58.28	56.72	58.51	0.22	58.82	0.16	0.3	2.11	0.28	0.4
	20 year ARI	65	58.41	56.84	58.66	0.37	64.34	0.29	0.34	2.21	0.32	0.41
	100 year ARI	81	58.74	57.25	59.04	1.04	79.08	0.88	0.45	2.44	0.44	0.43
	200 year ARI	89.1	58.9	57.44	59.22	1.52	86.28	1.3	0.5	2.54	0.49	0.44
	Extreme Flood	324	61.54	60.55	62.12	62	234.81	27.19	1.19	3.89	1.25	0.5
340.5	10-Apr-98	83.1	58.1	58.1	59.02	0.17	82.8	0.13	0.47	4.26	0.49	0.97
	5 year ARI	53.5	57.56	57.56	58.3		53.5			3.81		1
	10 year ARI	59.2	57.68	57.68	58.45		59.2			3.9		1.01
	20 year ARI	65	57.78	57.78	58.6	0	65	0	0.19	4	0.12	1
	100 year ARI	81	58.07	58.07	58.98	0.14	80.77	0.1	0.44	4.23	0.46	0.98
	200 year ARI	89.1	58.2	58.2	59.15	0.29	88.57	0.24	0.53	4.34	0.57	0.97
	Extreme Flood	324	60.82	60.82	62.05	42.02	255.9	26.09	1.21	5.49	1.63	0.81
339.49	10-Apr-98	83.3	56.52	57.3	58.87		83.3			6.79		1.66
	5 year ARI	53.6	55.94	56.59	58.13		53.6			6.57		1.94
	10 year ARI	59.3	56.05	56.72	58.29		59.3			6.63		1.87
	20 year ARI	66.6	56.21	56.88	58.44		66.6			6.62		1.77
	100 year ARI	81.1	56.47	57.25	58.82		81.1			6.79		1.68
	200 year ARI	89.3	56.64	57.44	58.99		89.3			6.8		1.61
	Extreme Flood	324.4	59.82	60.55	61.95	17.74	293.27	13.38	1.35	6.78	1.66	1.04
257.63	10-Apr-98	82.7	54.66	55.27	56.66	1.55	81.15		1.63	6.32		1.62
	5 year ARI	53.1	54.28	54.75	55.77	0.18	52.92		0.88	5.43		1.55
	10 year ARI	58.7	54.36	54.87	55.96	0.32	58.38		1.03	5.63		1.56
	20 year ARI	66	54.46	55	56.19	0.58	65.42		1.19	5.85		1.58
	100 year ARI	80.5	54.64	55.24	56.6	1.39	79.11		1.56	6.27		1.61
	200 year ARI	88.7	54.73	55.36	56.82	2	86.7		1.81	6.48		1.63
	Extreme Flood	322	59.56	58.44	59.77	18.8	143.19	160.01	1.27	2.6	1.41	0.33
249.03	10-Apr-98	82.7	54.02	54.71	56.31		82.7			6.7		2.08
	5 year ARI	53.1	53.74	54.26	55.45		53.1			5.79		2.02
	10 year ARI	58.7	53.8	54.35	55.63		58.7			6		2.04
	20 year ARI	66	53.87	54.47	55.85		66			6.24		2.05
	100 year ARI	80.5	54	54.68	56.26		80.5			6.65		2.08
	200 year ARI	88.7	54.07	54.79	56.47		88.7			6.86		2.09
	Extreme Flood	322	59.59	57.77	59.73		167.97	154.03		1.87	1.47	0.24

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
231.33	10-Apr-98	82.7	55.46	54.47	55.75	0.39	82.31		0.69	2.4		0.5
	5 year ARI	53.1	54.53	53.97	54.84		53.1			2.49		0.61
	10 year ARI	58.7	54.72	54.08	55.03		58.7			2.46		0.59
	20 year ARI	66	55.01	54.2	55.3	0	66		0.2	2.36		0.54
	100 year ARI	80.5	55.42	54.43	55.7	0.31	80.19		0.65	2.38		0.5
	200 year ARI	88.7	55.65	54.56	55.93	0.93	87.77		0.58	2.36		0.48
	Extreme Flood	322	59.53	56.96	59.72	45.74	206.55	69.71	1.51	2.09	1.5	0.27
216.93	10-Apr-98	93.6	55.45	54.32	55.73	0	93.6		0.06	2.32		0.48
	5 year ARI	58.5	54.54	53.81	54.8		58.5			2.23		0.53
	10 year ARI	65.8	54.72	53.93	54.99		65.8			2.28		0.52
	20 year ARI	74.9	55.01	54.06	55.27		74.9			2.26		0.49
	100 year ARI	91.7	55.41	54.3	55.68		91.7			2.32		0.48
	200 year ARI	101	55.64	54.42	55.91	0.35	100.65		0.42	2.32		0.46
	Extreme Flood	366.8	59.3	56.75	59.69	60.01	306.79		2.33	2.84		0.37
201.83	10-Apr-98	93.6	55.28	54.58	55.69		93.6			2.85		0.63
	5 year ARI	58.5	54.02	54.02	54.71		58.5			3.69		1
	10 year ARI	65.8	54.4	54.15	54.93		65.8			3.21		0.81
	20 year ARI	74.9	54.79	54.3	55.23		74.9			2.91		0.69
	100 year ARI	91.7	55.23	54.55	55.64		91.7			2.86		0.63
	200 year ARI	101	55.48	54.68	55.88		101			2.8		0.6
	Extreme Flood	366.8	59.17	56.99	59.67	52.99	313.81		2.56	3.22		0.42
186.93	10-Apr-98	93.6	55.27	54.4	55.65		93.6			2.75		0.57
	5 year ARI	58.5	53.61	53.8	54.57		58.5			4.35		1.2
	10 year ARI	65.8	54.41	53.94	54.85		65.8			2.93		0.69
	20 year ARI	74.9	54.79	54.1	55.17		74.9			2.74		0.61
	100 year ARI	91.7	55.22	54.37	55.6		91.7			2.75		0.58
	200 year ARI	101	55.46	54.5	55.84		101			2.74		0.55
	Extreme Flood	366.8	59.14	57.14	59.65	63.75	303.05		2.66	3.28		0.42
172.23	10-Apr-98	93.6	55.3	54.29	55.59		85.93	7.67		2.44	1.59	0.49
	5 year ARI	58.5	53.67	53.67	54.43		58.5			3.87		1
	10 year ARI	65.8	54.37	53.81	54.79		65.8			2.87		0.66
	20 year ARI	74.9	54.76	53.98	55.13		74.85	0.05		2.68	0.23	0.59
	100 year ARI	91.7	55.25	54.26	55.54		85.07	6.63		2.47	1.52	0.5
	200 year ARI	101	55.52	54.4	55.78		89.02	11.98		2.33	1.79	0.45
	Extreme Flood	366.8	59.2	56.51	59.6		235.41	131.39		2.42	3.43	0.32
161.13	10-Apr-98	94.6	55.34	53.83	55.56	3.56	84.69	6.35	0.59	2.14	1.04	0.38
	5 year ARI	58.8	53.93	53.28	54.25	1.26	57.54		0.66	2.53		0.57
	10 year ARI	66.4	54.48	53.41	54.72	1.95	64.43	0.02	0.61	2.21	0.2	0.45
	20 year ARI	75.5	54.85	53.55	55.07	2.53	71.63	1.34	0.59	2.13	0.61	0.41
	100 year ARI	92.5	55.29	53.8	55.51	3.44	83.29	5.76	0.59	2.14	1.01	0.38
	200 year ARI	102	55.54	53.94	55.75	3.99	89.22	8.78	0.59	2.13	1.14	0.36
	Extreme Flood	370	59.19	56.32	59.59	24.97	261.88	83.16	0.86	3.05	2.27	0.36
145.53	10-Apr-98	94.6	55.34	53.85	55.54	2.5	72.91	19.18	0.5	2.23	1.05	0.37
	5 year ARI	58.8	53.84	53.24	54.22	0.29	54.89	3.62	0.44	2.77	1.66	0.58
	10 year ARI	66.4	54.43	53.38	54.7	0.86	59.42	6.12	0.46	2.39	1.51	0.45
	20 year ARI	75.5	54.77	53.53	55.05	1.46	68.04	6	0.51	2.45	0.9	0.43
	100 year ARI	92.5	55.28	53.82	55.5	2.4	72.63	17.48	0.5	2.26	1.02	0.37
	200 year ARI	102	55.55	53.97	55.74	2.9	73.31	25.79	0.48	2.12	1.11	0.34
	Extreme Flood	370	59.33	56.27	59.53	21.94	147.63	200.43	0.6	2.2	1.87	0.25
130.23	10-Apr-98	94.6	55.31	53.56	55.53	6.23	87.7	0.67	0.59	2.16	0.33	0.37
	5 year ARI	58.8	53.88	52.93	54.17	0.43	58.37		0.3	2.38		0.5
	10 year ARI	66.4	54.45	53.07	54.67	2.09	64.31		0.45	2.09		0.4
	20 year ARI	75.5	54.81	53.23	55.02	3.49	71.95	0.06	0.5	2.06	0.16	0.38
	100 year ARI	92.5	55.27	53.52	55.49	5.94	85.97	0.59	0.58	2.14	0.31	0.36
	200 year ARI	102	55.5	53.66	55.72	7.35	93.64	1.02	0.62	2.19	0.38	0.36
	Extreme Flood	370	58.81	56.28	59.47	43.38	313.41	13.21	1.21	3.9	0.91	0.47
115.13	10-Apr-98	94.6	55.38	53.14	55.49	0.46	93.68	0.46	0.24	1.52	0.17	0.27
	5 year ARI	58.9	53.97	52.61	54.11		58.9			1.64		0.36
	10 year ARI	66.4	54.52	52.74	54.63	0	66.4		0.04	1.46		0.3
	20 year ARI	75.5	54.87	52.88	54.98	0.06	75.44		0.14	1.45		0.28

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
	100 year ARI	92.6	55.33	53.12	55.45	0.4	91.84	0.36	0.23	1.51	0.15	0.27
	200 year ARI	102	55.56	53.24	55.68	0.7	100.32	0.98	0.27	1.54	0.22	0.26
	Extreme Flood	370.4	59.06	55.65	59.36	8.69	334.98	26.74	0.59	2.54	0.74	0.31
97.93	10-Apr-98	96.8	55.13	53.35	55.45	0.86	60.87	35.07	0.43	1.26	3.84	0.22
	5 year ARI	60.1	53.63	52.68	54.04		47.13	12.97		1.79	5.03	0.41
	10 year ARI	68.3	54.27	52.81	54.58	0.02	48.44	19.84	0.2	1.36	4.08	0.28
	20 year ARI	77.7	54.64	52.97	54.94	0.21	52.42	25.07	0.31	1.28	3.82	0.25
	100 year ARI	94.7	55.09	53.3	55.41	0.78	59.93	33.99	0.41	1.26	3.82	0.22
	200 year ARI	105	55.3	53.54	55.64	1.19	64.48	39.33	0.47	1.27	3.92	0.22
	Extreme Flood	378.8	58.21	56.73	59.26	11.19	201.18	166.43	0.97	2.14	6.44	0.27
76.23	10-Apr-98	96.8	55.26	52.73	55.33	10.9	67.88	18.03	1.75	1.14	1.15	0.18
	5 year ARI	60.1	53.64	52.16	53.77	1.18	58.92		1.6	1.61		0.32
	10 year ARI	68.3	54.33	52.29	54.43	4.3	63.41	0.59	1.74	1.37	0.37	0.24
	20 year ARI	77.7	54.73	52.44	54.81	6.65	64.44	6.61	1.71	1.24	0.87	0.21
	100 year ARI	94.7	55.21	52.7	55.29	10.46	67.32	16.92	1.74	1.15	1.13	0.18
	200 year ARI	105	55.44	52.82	55.52	12.61	69.86	22.53	1.78	1.13	1.22	0.17
	Extreme Flood	378.8	58.74	55.19	58.96	56.28	160.75	161.77	2.53	1.48	2.35	0.17
75.73	10-Apr-98	97.3	55.21	52.7	55.33	30.31	51.33	15.66	2.22	1.14	1.01	0.17
	5 year ARI	60.3	53.58	52.16	53.77	17.1	43.2		2.67	1.47		0.27
	10 year ARI	68.5	54.27	52.28	54.43	23.15	45.24	0.11	2.44	1.26	0.16	0.21
	20 year ARI	77.9	54.67	52.42	54.81	26.03	47.1	4.77	2.31	1.18	0.68	0.19
	100 year ARI	95.1	55.16	52.67	55.28	29.82	50.73	14.56	2.21	1.14	0.99	0.17
	200 year ARI	105	55.39	52.76	55.51	31.83	53.03	20.15	2.19	1.13	1.09	0.16
	Extreme Flood	380.4	58.69	55.66	58.95	81.36	128.06	170.98	2.78	1.63	2.42	0.18
59.03	10-Apr-98	97.3	55.23	52.52	55.31	11.79	62.45	23.06	1.71	1.18	0.84	0.17
	5 year ARI	60.3	53.6	51.94	53.73	4.04	54.14	2.12	1.89	1.56	0.54	0.28
	10 year ARI	68.5	54.3	52.08	54.4	7.41	56.12	4.97	1.8	1.32	0.5	0.22
	20 year ARI	77.9	54.7	52.23	54.78	9.19	57.33	11.37	1.73	1.22	0.65	0.19
	100 year ARI	95.1	55.19	52.49	55.26	11.52	61.71	21.88	1.7	1.18	0.82	0.17
	200 year ARI	105	55.42	52.62	55.49	12.7	64.62	27.68	1.7	1.18	0.89	0.17
	Extreme Flood	380.4	58.74	55.19	58.92	38.9	158.99	182.51	2.23	1.73	1.95	0.19
43.53	10-Apr-98	97.3	55.14	52.75	55.29	3.46	79.3	14.54	0.52	1.85	1.08	0.28
	5 year ARI	60.3	53.45	52.09	53.69	0.76	59.54		0.47	2.2		0.41
	10 year ARI	68.5	54.18	52.25	54.37	1.91	66.59		0.51	1.97		0.33
	20 year ARI	77.9	54.58	52.42	54.76	2.6	72.36	2.94	0.53	1.93	0.61	0.31
	100 year ARI	95.1	55.09	52.71	55.24	3.38	78.37	13.35	0.52	1.85	1.05	0.28
	200 year ARI	105	55.33	52.88	55.48	3.74	81.83	19.43	0.52	1.84	1.19	0.27
	Extreme Flood	380.4	58.56	55.77	58.9	11.4	193.63	175.36	0.66	2.58	2.64	0.29
31.63	10-Apr-98	101	55.02	52.26	55.27	0.14	87.45	13.41	0.29	2.3	1.37	0.31
	5 year ARI	61.2	53.41	51.45	53.67		61.2			2.27		0.37
	10 year ARI	70	54.11	51.64	54.35	0	69.81	0.19	0.13	2.2	0.27	0.33
	20 year ARI	79.8	54.47	51.85	54.74	0.03	78.65	1.12	0.21	2.3	0.45	0.33
	100 year ARI	98.9	54.97	52.22	55.22	0.12	86.81	11.97	0.29	2.3	1.31	0.31
	200 year ARI	110	55.21	52.43	55.46	0.19	90.19	19.62	0.31	2.29	1.6	0.31
	Extreme Flood	395.6	58.19	56.05	58.85	3.54	183.36	208.69	0.65	3.06	4.04	0.33
15.5	10-Apr-98	101	55.06	51.89	55.23	0.34	86.34	14.32	0.31	1.89	1.36	0.25
	5 year ARI	61.2	53.44	51.17	53.62		61.2			1.88		0.3
	10 year ARI	70	54.14	51.34	54.31	0.01	69.97	0.03	0.12	1.83	0.14	0.27
	20 year ARI	79.8	54.52	51.52	54.69	0.07	77.15	2.58	0.22	1.87	0.69	0.26
	100 year ARI	98.9	55.01	51.85	55.18	0.31	85.52	13.07	0.3	1.89	1.31	0.25
	200 year ARI	110	55.25	52.04	55.42	0.5	89.85	19.65	0.34	1.91	1.53	0.25
	Extreme Flood	395.6	58.27	55.71	58.8	9.07	198.47	188.06	0.8	2.78	3.72	0.3
0		Eastern Valley Way										
-54.5	10-Apr-98	101	51.18	51.18	52.45		101			4.99		1
	5 year ARI	61.2	50.45	50.45	51.37		61.2			4.23		1
	10 year ARI	70	50.62	50.62	51.62		70			4.43		1.01
	20 year ARI	79.8	50.8	50.8	51.89		79.8			4.63		1
	100 year ARI	98.9	51.14	51.14	52.39		98.9			4.96		1
	200 year ARI	110	51.33	51.33	52.67		110			5.13		1

River Sta	Profile	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	
	Extreme Flood	395.6	54.62	54.62	56.4	6.94	312.88	75.78	1.56	6.53	2.46	0.85
-128.5	10-Apr-98	101	39.09	40.57	49.07		101			13.99		4.91
	5 year ARI	61.2	38.76	40	47.98		61.2			13.45		5.49
	10 year ARI	70	38.84	40.14	48.25		70			13.59		5.32
	20 year ARI	79.8	38.93	40.28	48.51		79.8			13.72		5.16
	100 year ARI	98.9	39.08	40.54	49.01		98.9			13.97		4.93
	200 year ARI	110	39.16	40.68	49.29		110			14.1		4.83
	Extreme Flood	395.6	40.63	43.29	53.73		395.6			16.04		3.75
-193.5	10-Apr-98	101	32.62	33.66	37.31		101			9.59		3.32
	5 year ARI	61.2	34.31	33.16	34.43		61.2			1.49		0.36
	10 year ARI	70	34.49	33.29	34.61		70			1.54		0.36
	20 year ARI	79.8	32.49	33.41	36.46		79.8			8.83		3.19
	100 year ARI	98.9	32.6	33.64	37.23		98.9			9.52		3.31
	200 year ARI	110	32.66	33.76	37.64		110			9.88		3.37
	Extreme Flood	395.6	33.63	35.71	44.95		395.6			14.91		4.04

APPENDIX C

PHOTOGRAPHS

Plate 1

Landscaped Mound along
Eastern Boundary of
Chatswood Chase in Havilah St.

Plate 2

Overland Flow Path Through
Residential Properties
Eastern Side Havilah St.

Plate 3

Macquarie St. Looking Upstream at
Low Lying Residential Allotments
Northern Side of SW Channel

Plate 4

Macquarie St.
Looking Downstream

Plate 5

Penshurst St.
Looking Downstream

Plate 6

Looking Downstream at Rock Weir on
Downstream Side Retirement Village

Plate 7

Looking Upstream at Retirement Village
Downstream of Muston Park

Plate 8

Semi-Natural Channel
Near High St.

Plate 9

Semi-Natural Channel
between High St. and Gibbes St.

Plate 10

Semi-Natural Channel
Looking Upstream from Gibbes St. Bridge

Plate 11

Improved Channel
Looking Downstream from Gibbes St. Bridge

SCOTTS CREEK
FLOOD STUDY

PHOTOGRAPHS OF SCOTTS CREEK