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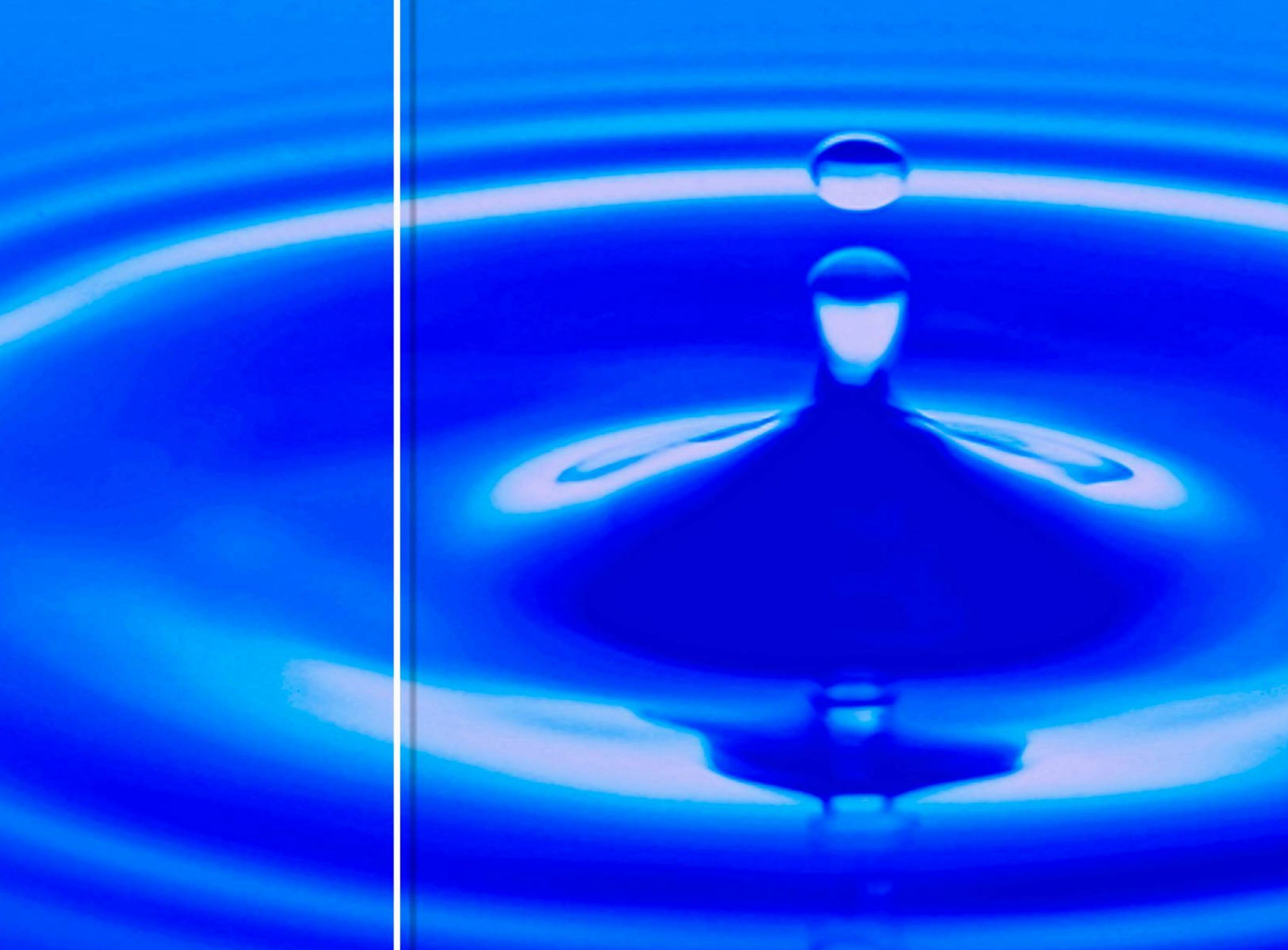

FLOOD MODELLING REPORT
Land Adjacent to Albion Park Airport (Existing Conditions)

for

Jordan Mealey - Consulting Engineers

April 2007

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FLOOD MODELLING REPORT
Land Adjacent to Albion Park Airport
(Existing Conditions)

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ABBREVIATIONS

	Abbreviation Description
AEP	Annual Exceedance Probability; The probability of a rainfall or flood event of given magnitude being equalled or exceeded in any one year.
AHD	Australian Height Datum: National reference datum for level
ALS	Air-borne Laser Scanning; aerial survey technique used for definition of ground height
ARI	Average Recurrence Interval; The expected or average interval of time between exceedances of a rainfall or flood event of given magnitude.
AR&R	Australian Rainfall and Runoff; National Code of Practice for Drainage published by Institution of Engineers, Australia, 1987.
EDS	Embedded Design Storm; synthesised design storm involving embedment of an AR&R design burst within a second design burst of much longer duration
FPDM	Floodplain Development Manual; Guidelines for Development in Floodplains published by N.S.W. State Government, 2005.
FSL	Flood Surface Level;
GIS	Geographic Information Systems; A system of software and procedures designed to support management, manipulation, analysis and display of spatially referenced data.
IFD	Intensity-Frequency-Duration; parameters describing rainfall at a particular location.
ISG	Integrated Survey Grid; ISG: The rectangular co-ordinate system designed for integrated surveys in New South Wales. A Transverse Mercator projection with zones 2 degrees wide (Now largely replaced by the MGA).
LEP	Local Environment Plan; plan produced by Council defining areas where different development controls apply (e.g. residential vs industrial)
LGA	Local Government Area; political boundary area under management by a given local Council. Council jurisdiction broadly involves provision of services such as planning, recreational facilities, maintenance of local road infrastructure and services such as waste disposal.
MGA	Mapping Grid of Australia; This is a standard 6° Universal Transverse Mercator (UTM) projection and is now used by all states and territories across Australia.
MHI	Maximum Height Indicator; measuring equipment used to record flood levels
PMF	Probable Maximum Flood; Flood calculated to be the maximum physically possible.
PMP	Probable Maximum Precipitation; Rainfall calculated to be the maximum physically possible.
RCP	Reinforced Concrete Pipe;
km	Kilometre; (Distance = 1,000m)
m	Metre; (Basic unit of length)
m2	Square Metre; (Basic unit of area)
ha	Hectare; (Area =10,000 m2)
m3	Cubic Metre; (Basic unit of volume)
m/s	Metres/Second; (Velocity)
m3/s	Cubic Metre per Second; (Flowrate)
s	Second; (basic unit of time)
SCC	Shellharbour City Council; name of the Council with jurisdiction over the Shellharbour LGA

TECHNICAL TERMS

Term	Description
Alluvium	Material eroded, transported and deposited by streams.
Antecedent	Pre-existing (conditions e.g. wetness of soils).
Catchment	Area draining into a particular creek system, typically bounded by higher ground around its perimeter.
Critical Flow	Water flowing at a Froude No. of one.
Culvert	An enclosed conduit (typically pipe or box) that conveys stormwater below a road or embankment.
Discharge	The flowrate of water.
Escarpment	A cliff or steep slope, of some extent, generally separating two level or gently sloping areas.
Flood	A relatively high stream flow which overtops the stream banks.
Flood storages	Those parts of the flood plain important for the storage of floodwaters during the passage of a flood.
Floodways	Those areas where a significant volume of water flows during floods. They are often aligned with obvious naturally defined channels and are areas which, if partly blocked, would cause a significant redistribution of flow.
Flood Fringes	Those parts of the flood plain left after floodways and flood storages have been abstracted.
Froude No.	A measure of flow instability. Below a value of one, flow is tranquil and smooth, above one flow tends to be rough and undulating (as in rapids).
Geotechnical	Relating to Engineering and the materials of the earth’s crust.
Gradient	Slope or rate of fall of land/pipe/stream.
Headwall	Wall constructed around inlet or outlet of a culvert.
Hydraulic	A term given to the study of water flow, as relates to the evaluation of flow depths, levels and velocities.
Hydrodynamic	The variation in water flow, depth, level and velocity with time
Hydrology	A term given to the study of the rainfall and runoff process.
Hydrograph	A graph of flood flow against time.
Hyetograph	A graph of rainfall intensity against time.
Isohyets	Lines joining points of equal rainfall on a plan.
Manning’s n	A measure of channel or pipe roughness.
Orographic	Pertaining to changes in relief, mountains.
Orthophoto	Aerial photograph with contours, boundaries or grids added.
Pluviograph	An instrument which continuously records rain collected
Runoff	Water running off a catchment during a storm.
Scour	Rapid erosion of soil in the banks or bed of a creek, typically occurring in areas of high flow velocities and turbulence.
Siltation	The filling or raising up of the bed of a watercourse or channel by deposited silt.
Stratigraphy	The sequence of deposition of soils/rocks in layers.
Surcharge	Flow unable to enter a culvert or exiting from a pit as a result of inadequate capacity or overload.
Topography	The natural surface features of a region.
Urbanisation	The change in land usage from a natural to developed state.
Watercourse	A small stream or creek.

EXECUTIVE SUMMARY

Macquarie Rivulet is located partly in the Shellharbour City Council local government area and partly in the Wollongong City Council local government area, on the New South Wales coastal plain approximately 100 km to the south of the city of Sydney. It drains an area of approximately 107 km^2 of mixed forest, pasture and urbanised land, discharging into the south-western corner of Lake Illawarra. Flooding in Macquarie Rivulet and its tributaries is adversely affected at some locations by bridges, culverts and intrusions of development onto floodplains. Flooding in the outfall reach of Macquarie Rivulet is in addition affected by the level of flooding in Lake Illawarra.

Modelling was undertaken to quantify existing flood behaviour in Macquarie Rivulet adjacent to Albion Park Airport between the Princes Highway Road Bridge and Albion Park village. This modelling involved data collection, construction, calibration and validation of hydrologic and hydraulic models and determination of flood levels and hazard levels within and/or adjacent to Lot 6 DP 1100435 and Lot B DP 109816 in a 100 year Average Recurrence Interval (ARI) and "Probable Maximum" design flood. It should be noted that this modelling specifically targets flood behaviour in this area in these events. It was not intended to and does not purport to provide information on flood behaviour outside of the study area.

Data collection included, aerial survey, creek and structure survey and the collection and collation of recorded rainfall, flood heights and lake level data for historic storms. Calibration of models was undertaken using the 11th June 1991 flood event, with a high level of correlation between recorded and simulated peak flood discharges and levels.

Using this calibration and allowing for changes occurring in the catchment after the June 1991 event, and Shellharbour City Council's draft blockage policy, flood behaviour in the study area was modelled for the 1% and PMF design flood events.

This modelling established a 1% AEP design flood surface adjacent to the north-south runway that has little surface gradient (RL 6.4 m AHD upstream of Meadow Bank rising to RL 6.5 m AHD adjacent to the western end of the east-west runway and RL 6.6 m AHD at the rear boundary of the existing heritage building site. There is then a steep rise in flood surface level up to RL 8.5m AHD immediately downstream of the culvert beneath Tongarra Road. Peak flood velocities adjacent to the study area are relatively low, being typically less than 0.1 m/sec but increasing to about 0.9m/sec around the western end of the east west runway and to about 1m/sec in the small channel immediately downstream of the Tongarra Road culvert.

In a PMF event, flood elevations in the study area are approximately 1.5 m higher than in a 1%AEP event but again exhibit a very flat surface gradient (ranging from RL 8.0m AHD at Meadowbank to RL 8.2 m AHD immediately downstream of the Tongarra Road culvert).

While the 1% AEP flood event would reach but not significantly overtop the north-south runway (currently RL 6.4mAHD at the western shoulder at the sag), the PMF event would do so at considerable depth (about 1.6m at the sag) overtopping all of the northern arm of the north-south runway in the process.

The western half of Lot 6, south of the runway and most of Lot 6 north of the runway would be inundated by a 1% or greater flood event. Lot B would be free of flooding in a 1%AEP event but the northern corner of the land would be inundated in a PMF event. The provisional flood hazard in areas of inundation would, for the most part, be 'high'.

1 INTRODUCTION

1.1 REPORT BACKGROUND

A light industrial development is proposed on land in Albion Park adjacent to the airport. This proposed development is located on two parcels of land to the immediate west of the north-south runway and to the immediate north and south of the east-west runway. Lot 6 DP 1100435 is located to the immediate south of the east west runway and Lot B DP 109816, to the immediate north.

Since these parcels of land abut the floodplain of Macquarie Rivulet and include land known to have been inundated in past flooding in Macquarie Rivulet, a review of flood behaviour in the vicinity of these sites was commissioned. Jordan Mealey – Consulting Engineers were commissioned to undertake this work and to provide advice to the owners on the best means of accommodating this flooding while meeting the owners vision for the proposed development. Since Rienco Consulting had previously built a hydrologic model of the catchment and hydrodynamic model of the lower reaches of Macquarie Rivulet, they were engaged by Jordan Mealy to undertake the modelling required to support Jordan Mealey's advice on flooding matters to the owners.

The modelling work was to proceed in two stages, initially quantifying flood behaviour under existing conditions and to then quantify the flood impacts associated with the development as proposed.

This current report documents the work undertaken in this first stage, quantifying flood behaviour in the vicinity of the proposed development sites, under existing conditions.

1.2 MODELLING OBJECTIVES

The primary objective of this present study is then the development of a reliable, quantified understanding of existing flood behaviour in the vicinity of the proposed development sites.

This in turn leads to a number of secondary objectives including:

- The collection and collation of a reliable body of data on the physical characteristics of the catchment and study area
- The collection and collation of a reliable body of data on historic storms and flooding in the catchment and study area
- The establishment of well calibrated and validated hydrologic and hydraulic models of the catchment and study area
- The determination of flooding characteristics in terms of flood extents, flood levels, flow depths and flow velocities for the 1% Annual Exceedence Probability (AEP) and Probable Maximum Flood (PMF) events, in the vicinity of the proposed development sites.

1.3 MODELLING METHODOLOGY

The study methodology adopted to meet the above objectives, included a series of sequential tasks as summarised below:

- Collection and collation of data describing the physical characteristics of the catchment and study area.
- Collection and collation of data describing historic rainfall and flooding in the catchment and study area.
- Collection and collation of data describing the temporal and spatial characteristics of (design) rainfall of a given probability, across the catchment .
- Construction of hydrologic and hydrodynamic models of the catchment and study area.
- Calibration and validation of the hydrologic and hydrodynamic models
- Application of the calibrated models to establish (design) flood behaviour in a 1% and PMF flood event, within the study area.

1.4 MODELLING SCOPE

This study is limited to the modelling of historic and design flood events, in the vicinity of the proposed development sites, This study area is indicated on the Overall Catchment Plan (**Appendix A.1**).

The study area includes:

- Lot 6 DP1100435 and Lot B DP 109816, to the immediate west of the Albion Park north-south runway (the proposed development sites).

- Croome Road properties and Albion Park airport generally.

- The floodplain of the combined Macquarie Rivulet, Frazer's Creek and Marshall Mount Creeks, to the west of the airport, between the Princes Highway Road Bridge and the downstream boundary of Albion Park village

- The floodplain of Macquarie Rivulet downstream of the Princes Highway road bridge , up to and including its outfall into Lake Illawarra

Assessment of design event flooding has been carried out based on catchment and reach conditions as existed at the time of data collection (2005). Design event flooding in the vicinity of the proposed development site has been quantified for the following flood events:

- 100 year ARI (~1% AEP) flood event
- PMF (~1x 10^{-7} AEP) flood event

For each of these design events, flood surfaces have been calculated to reflect SCC's Draft Blockage Policy with blockages and diversion adjusted to incorporate all likely scenarios. These flood surfaces have been used to identify and describe flood behaviour within the study area.

1.5 REPORT QUALIFICATIONS

Information presented in this report has been developed to address the modelling objectives set out above. This report is not and does not purport to be a report on flood behaviour outside of the nominated study area.

2 THE CATCHMENT

2.1 GENERALLY

The catchment of Macquarie Rivulet lies within the Lake Illawarra sub-basin of the Wollongong Coastal Basin (214) It drains 110km2 of mostly forested and rural lands and is located some 100km to the south of Sydney on a thin band of coastal land between the Illawarra escarpment and the Tasman Sea. Macquarie Rivulet has its headwaters on the escarpment, flowing east to discharge into Lake Illawarra before reaching the sea. The drainage network of Macquarie Rivulet comprises three main arms:

- Macquarie Rivulet (The main arm draining the central portion of the catchment)
- Frazers Creek (A secondary arm draining the south-eastern sector)
- Marshal Mount Creek (A secondary arm draining the northern sector)

All three arms combine on the flood plain above the Princes Highway, to the immediate west of the Albion Park airport. In large events, flows merge across the full width of this flood plain to form a single near level pool of floodwater.

All three sub-catchments are predominantly rural with some existing urban development in the lower reaches of Frazers Creek and Macquarie Rivulet, around Albion Park. Areas to the west and south west of Albion Park are at present undergoing significant urban development.

The location and extents of the catchment, with respect to adjacent catchments and Lake Illawarra, is shown in Fig 2.1 and reproduced at a larger scale in **Appendix A1**.

The Lake Illawarra Flood Study (Lawson & Treloar, 2001) indicates the lakes catchment is some 270 km^2, accordingly, Macquarie Rivulet at 107 km^2, represent a significant proportion of that total catchment..

Adjoining catchments within the Wollongong coastal basin include, Duck Creek to the north, Horsley and Rocklow Creeks to the south east and Minamurra River to the south

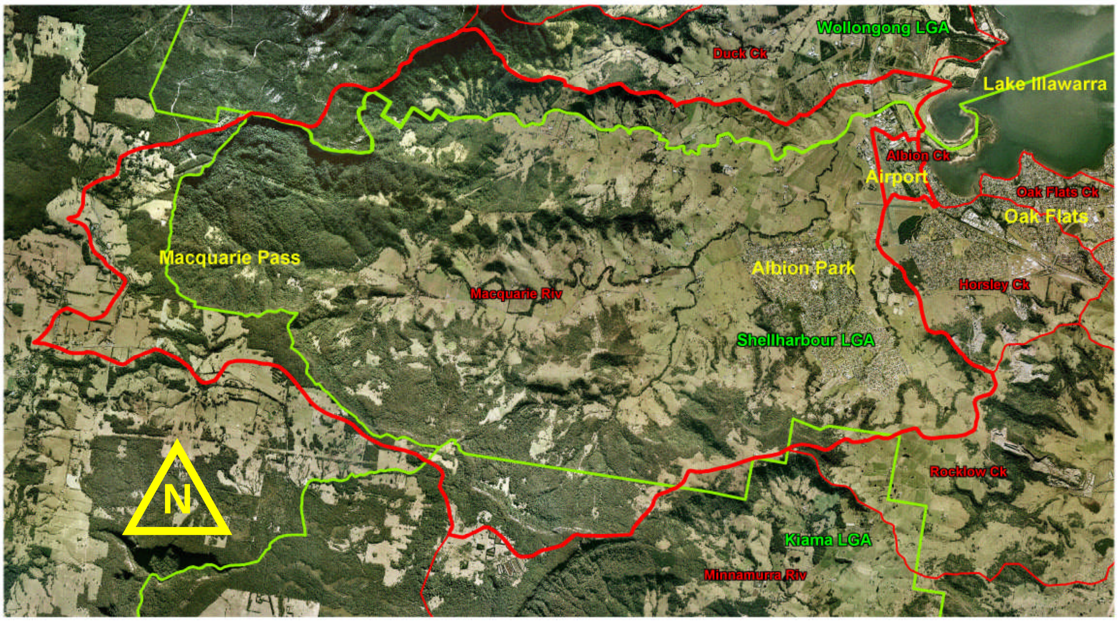


Figure 2.1: The Macquarie Rivulet Catchment

2.2 CLIMATE

The prevailing climate for the Macquarie Rivulet catchment is typical of other Illawarra catchments, being temperate with mild winters and only limited tropical (monsoonal) influences.

High rainfall intensity can be experienced due to the catchments proximity to the ocean (source of humidity) and the Illawarra escarpment (which enhances the amount of precipitation through an orographic rainfall effect). On an average annual basis, the area receives approximately 1300 mm of rainfall, with higher rainfall during the late summer and autumn months. Annual climate average data for southern Illawarra is summarised in Table 2.1. More detailed climate information is available from the Bureau of Meteorology's web site www.bom.gov.au.

When intense rainfall occurs, it generally occurs as a burst within a longer, less intense parent storm. These parent storms often occur in an episodic fashion in accordance with macro-climatic patterns of 'la nina'. During la nina episodes the probability of several large storms occurring in close succession is high. The most common climatic mechanism is a 'blocking pair' high and low pressure system producing moist onshore winds. These winds transport moisture laden air onshore. The moisture precipitates as the air cools when it passes up and over the escarpment. The episodic nature of rainfall in the catchment can result in high antecedent soil moisture levels for rainfall events occurring in the latter part of any rainfall phase.

Table 2.1: Annual Climate Average Data for Wollongong

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily max temp deg C	24.1	24.4	24.1	22.4	19.4	17.5	16.7	17.3	19.2	20.7	22.4	23.4	20.9
Mean 9am rel' humidity %	77	78	75	70	67	67	63	61	61	66	68	74	69
Mean 9am wind speed km/h	17	16	15	15	17	17	18	19	19	20	20	18	17
Mean monthly rainfall mm	116	158	184	93	89	140	63	88	55	108	94	90	1277
Mean no. of raindays	12	13	13	9	8	10	7	10	8	11	11	11	123
Highest monthly rainfall mm	351	575	529	350	421	465	220	286	189	424	600	366	-
Lowest monthly rainfall mm	19	5	16	14	1	0	0	6	4	8	12	11	-
Highest recorded daily rainfall mm	112	278	315	93	146	153	153	137	98	192	189	125	315
Mean no. of clear days	8	6	8	10	11	9	13	12	11	8	8	7	111

Source: BOM Port Kembla gauge

2.3 PHYSIOGRAPHY

2.3.1 PHYSIOGRAPHY

The catchment falls within a tapering wedge of coastal land confined to the east by the Tasman Sea and to the west by the Illawarra coastal escarpment. The width of this coastal belt of land is near zero at Stanwell Park some 40km to the north of Macquarie Rivulet, increasing to around 15 km in the vicinity of the Macquarie Rivulet at Shellharbour. At Kiama, to the immediate south of Macquarie Rivulet, the Illawarra escarpment runs down to the sea, severing this coastal belt of land.

Runoff from the foothills and escarpment has over the years created a series of primary spurs, running roughly east-west, from the escarpment down to the sea. Multiple lateral spurs have in turn developed on the primary spurs, running typically north-south. This pattern is readily evident on topographic maps of the area, the southern boundary of the catchment being a good example of this process. The topography of the catchment (represented by colour filled contours) is reproduced in Figure 2.3.1. and at a larger scale in **Appendix A2**.

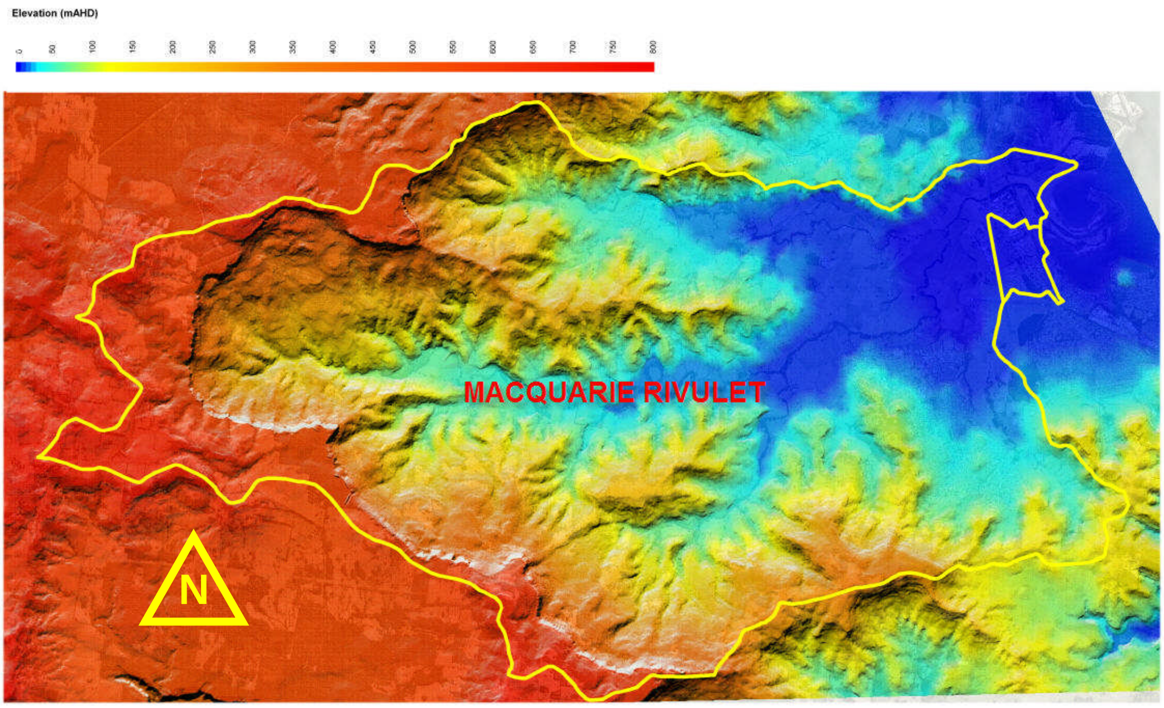


Figure 2.3.1: Macquarie Rivulet Topography

Macquarie Rivulet has a stream length of 22.5 km, with total fall from head waters to outlet of 680 metres. The Rivulet's equivalent mainstream slope is 8.4 m/km. The upper reaches are quite steep producing some spectacular water falls down the escarpment. For the majority of its length, the stream meanders along a relatively flat river valley with the lower reaches combining on a broad flat flood plain, above the Princes Highway. The combined streams then discharge into Lake Illawarra, where silt deposition has formed a pronounced delta.

Physiographic parameters for the catchment of Macquarie Rivulet as a whole, and its main sub-catchments are set out in Table 2.3.1.

Table 2.3.1 : Catchment Physiography

Catchment (Subcatchment)	Macquarie Rivulet Overall	Macquarie Rivulet to Sunnybank	Yellow Rock Creek	Marshall Mt Creek	Frazers Creek
Linear Parameters					
Mainstream Order	5	5	4	5	4
Mainstream Length (km)	22.5	11.9	8.5	10.8	10.0
Basin Length (km)	15.6	9.0	6.5	9.5	6.7
Meander Index	1.4	1.3	1.5	1.1	1.5
Bifurcation Ratio (Avg)	4.0	4.0	4.0	4.5	-
Overland Flow Length (Avgm)	100	-	-	-	-

Areal Parameters					
Basin Area (km^2)	105.2	35.0	17.0	20.2	13.8
Basin Shape (form factor)	0.43	0.43	0.56	0.18	0.31
Drainage Density (km^{-1})	3.2	2.8	3.0	3.9	3.1
Stream Frequency	5.0	4.2	4.3	7.2	4.1
Relief Parameters					
Weighted Mainstream Slope	0.016	0.04	0.04	0.01	0.01
Avg Valley Side Slopes	0.25	0.3	0.2	0.2	0.05
Mean Elevation (m)	300	350	260	140	90
Basin Relief (m)	770	760	710	600	350
Ruggedness No.	2.5	2.3	2.1	2.3	1.1
Geometry No.	10	7.6	10.6	11.7	21.6

Source: WRF report on Macquarie Rivulet as a Reference Catchment (1986)

As is apparent from the above, all sub-catchments are somewhat elongated (Marshall Mount Creek in particular) but with the exception of Frazers Creek are topographically similar. Frazers Creek stands out as a much flatter and lower relief sub-catchment than the other sub-catchments of the Macquarie Rivulet system.

2.4 GEOLOGY SOILS & STREAM MORHOLOGY

2.4.1 *GEOLOGY*

The stratigraphy of the catchment generally comprises Triassic age, Narrabeen Group sandstone and siltstone (cliffs), overlying Permian age Illawarra Coal Measures (base of cliffs) with talus foothill slopes (mixture of the above). These in turn run down to residual soils and clays overlying a Permian age Shoalhaven Group, Kiama tuff basement. Quaternary deposits of alluvium, sands and silts are present on flood plains and in swamps.

Throughout the Illawarra, this coastal wedge has a similar east-west profile, with the high (600 metre) escarpment to the west, falling sharply to around the 450 metre contour level, at which point the talus slopes commence. These slopes in turn run down at a 15 to 35% grade to around the 100 metre contour level, where residual soils and clays are encountered. In the residual soil/clay zone, surface slopes are typically in the 5 to 15% range.

At around the 4 metre contour level, the profile again changes, to an overburden of recently transported sediments deposited on a relatively flat grade.

A simplified geological plan of the catchment is reproduced in Figure 2.4.1 and at a larger scale in **Appendix A3**. A more detailed description of the geology of the area is provided by Bowman (1966) In the records of the Geological Survey of NSW Vol 14, part 2 and on 1:250,000 mapping by the NSW Department of Mines (sheet Wollongong 5I-56-9).

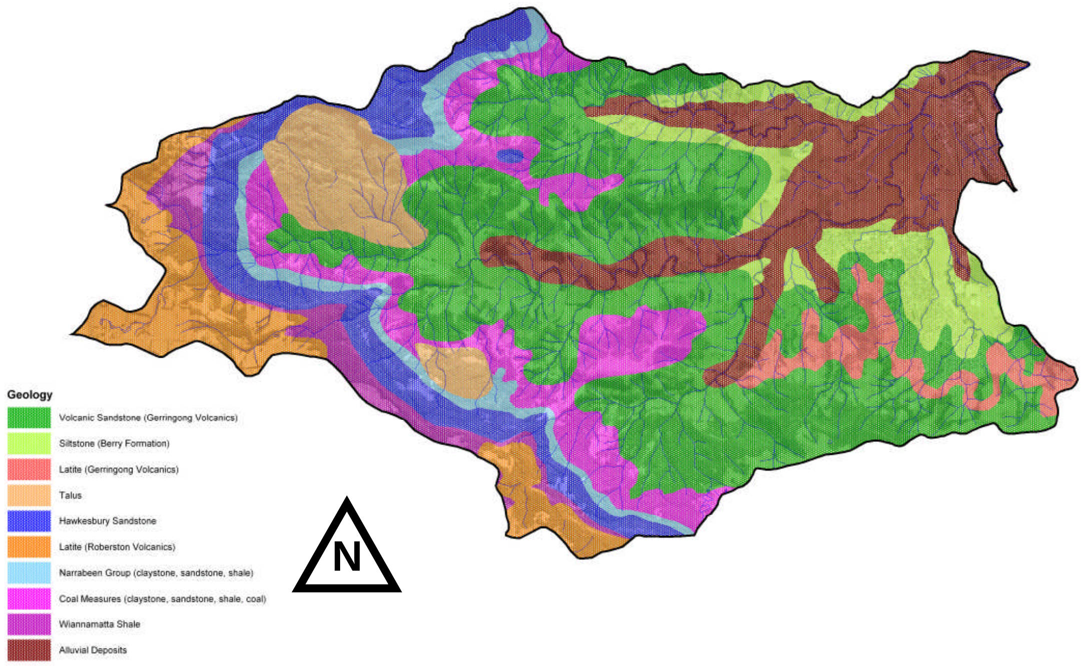


Figure 2.4.1: Geology of the Macquarie Rivulet Catchment

2.4.2 SOILS

The distribution and characteristics of soils within the catchment is described by Hazelton (1992) in Soil Landscapes of the Kiama Region prepared for the Department of Conservation and Land Management (NSW) and on the 1:100,000 CaLM Soil Landscape series (sheet 9028). A GIS compatible version of the data was obtained from the Department of Natural Resources and an extract included in Figure 2.4.2 (with catchment extent and photo underlay subsequently added). A larger scale version is reproduced in **Appendix A4.**

The soil descriptions provided by Hazelton are generic descriptions that apply across the coverage of each map sheet.

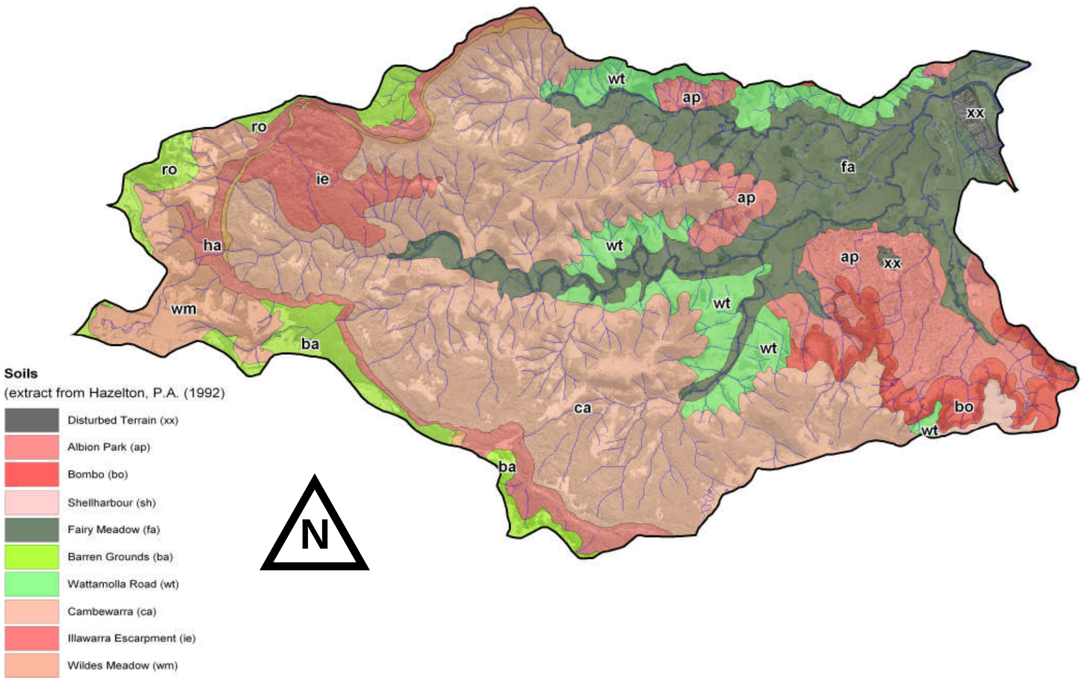


Figure 2.4.2: Soil Types in the Macquarie Rivulet Catchment, Hazelton (1992)

There are several soil types within the Macquarie Rivulet catchment identified in this mapping: Soil type in the catchment is however dominated by five soil types;

- Cambewarra (ca) soils in the foothills.
- Wattomolla Rd (wt) soils at the base of the foothills
- Fairy Meadow (fa) soils on the valley floor
- Albion Park (ap) soils in Albion Park and
- Disturbed (xx) soils in the far eastern section toward the catchment outlet.

These soils are described by Hazelton as;

1) Cambewarra (ca): This soil is described as being located on steep to very steep hills with broad colluvial benches on latite. Surface slopes are typically > 30%. The soil is relatively deep (>150mm) and is noted as having low water holding capacity.

2) Wattamolla Rd (wt): This soil is described as being located on long, gently to moderately inclined side slopes and undulating to rolling hills at slopes of between 5 and 15%. The soil is moderately deep (50-100mm) and is noted as being hard setting with a high organic content.

3) Fairy Meadow (fa): This soils is described as occurring on alluvial plains, floodplains and valley flats at slopes of between 5 and 10%. The soil is moderately deep (50-100cm) and noted to have a high permeability (high infiltration capacity), however high seasonal water tables can occur which would limit infiltration volumes.

4) Albion Park (ap): This soil is described as being located on short steep upper slopes with long gentle foot slopes. The soil is moderately deep (50-100cm) and is described as having limitations of waterlogging, seasonally high water table and a high available water holding capacity (amongst others). These limitations are all indicative of a clay based soil with limited infiltration capacity.

5) Disturbed Terrain (xx): Soils that have been highly disturbed by human activity. Within Macquarie Rivulet these include areas of substantial earthworks at locations such as Haywards bay, Macquarie Shores and at the Airport.

With respect to the hydrological properties of these catchment soils, the clay based soils, which dominate the catchment valley side slopes, permit only limited infiltration of runoff. during a storm event. There are however significant areas of deep loamy soils on the valley floor which do have the ability to absorb considerable runoff in the early stages of an event. The magnitude of this initial infiltration (loss) will however depend greatly on the extent to which these soils have been pre-saturated by earlier rainfall. The presence or otherwise of lead up rainfall prior to a modelled event is therefore likely to be a significant factor in setting initial losses in this catchment.

The Soil Hydrological Properties of Australia database produced by CRC for Catchment Hydrology was also investigated, however the data was found to be too coarse for application to the Horsley Creek study.

2.4.3 STREAM MORPHOLOGY

The catchment of Macquarie Rivulet site is drained by two characteristically different stream types. These are large perennial streams such as Macquarie Rivulet and Marshall Mount Creek running in the valley floor and numerous smaller mostly ephemeral streams (often unnamed), draining the valley sides.

The two large perennial streams convey runoff from contributory catchments (upstream of the Macquarie Rivulet – Marshal Mount Creek junction) of 86Km^2 and 19Km^2 respectively. They retain the general characteristics of a natural stream, with well-defined bed and banks, permanent pools, remnant riparian vegetation and alluvial terraces defining the extent of historic channel migration. This migration is generally slow, large episodic changes have been observed following large flood events occurring within the period of European settlement.

Both of the larger systems display the characteristic meander patterns of a large stream flowing through a semi-confined valley. These meanders indicate that these reaches are performing a sediment transfer function (i.e. transferring bed load materials along the channel in an efficient manner.

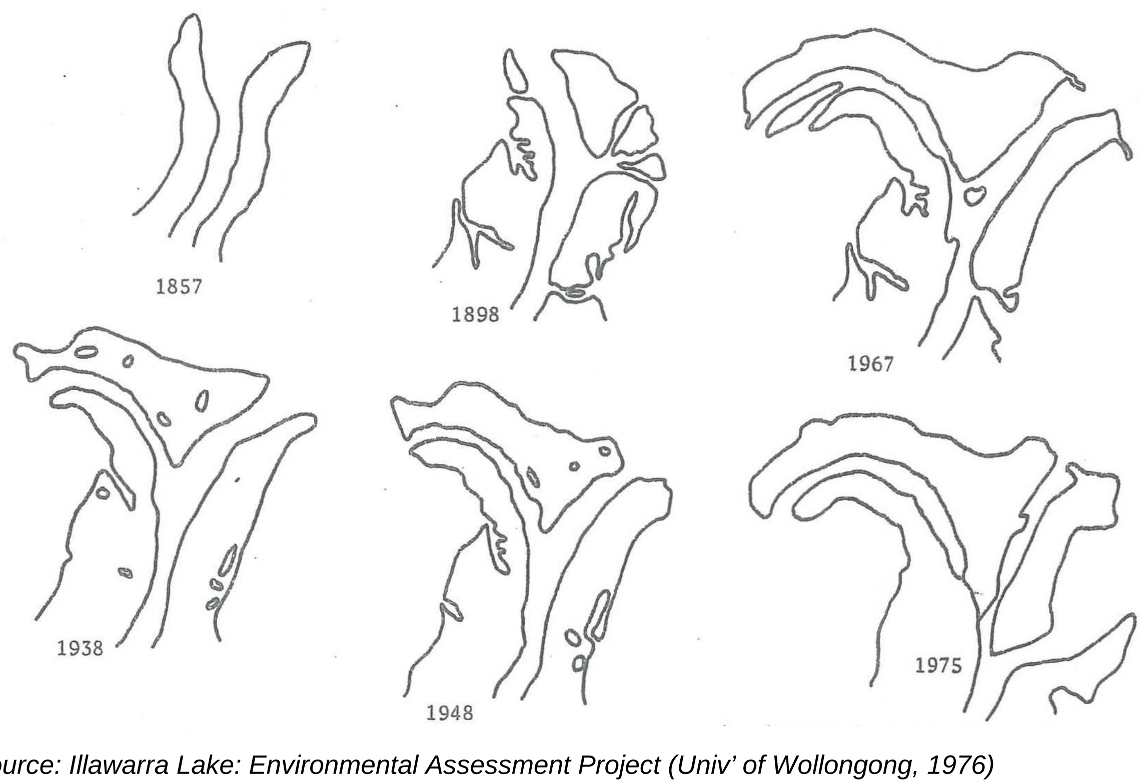
Where Macquarie Rivulet passes the site, there is no well defined meander pattern, suggesting that the rivulet is in a depositional regime in these reaches. However the application of an idealised fluvial system model may not be appropriate for the rivulet which also displays the characteristics of an osage stream (much larger meanders than would ordinarily be expected for such a relatively small river). In a study undertaken by Neller (1976), it is suggested that this geometry possibly reflects the morphological impact of rare flood events. This is thought to be a localised escarpment based phenomenon, whereby orographic uplift induces exceptionally intense rainfall bursts Channel geometry in turn develops in response to these episodic events with a greater bank full flow capacity than is found elsewhere in streams with comparable catchment area.

Both these larger streams have coarse bed sediments (sands and gravels), with very few exposures of bedrock indicating that they intersect a broad alluvial stratigraphy. Previous soil sampling (Huang *et al*, 1996), found that soil taken from the lower part of the banks in Marshall Mount Creek typically has high clay content. This provides a competent and resilient bank material, which supports near vertical banks.

The stability of the existing large streams also reflects the presence of remnant vegetation along the banks. The presence of vegetation has been found to be another dominant factor influencing channel geometry (Huang *et al*, 1996).

The smaller streams feeding into Macquarie Rivulet are highly modified from their natural condition, having poorly defined and in places heavily altered morphology because of past and present agricultural practices. Significant clearing activity has also meant that there is now very little or no remnant riparian vegetation in or along the banks of these streams. These smaller systems have very little permanent water except where they intersect the groundwater profile. Evidence of bed lowering induced by increased flowrates following removal of vegetation from the catchment is observed in several places. This bed lowering is exacerbated by the relatively steep bed grades where these small streams flow down the valley sides. The bed and banks where evident are often lined with pasture grasses (in contrast to the larger systems, which have exposed bed sediments).

Observations made of the rapid expansion and then stabilisation of the Macquarie Rivulet delta; confirm that massive sediment loads were transported from the catchment over the early period of European settlement (see **Figure 4**). The rate of erosion is now reaching an equilibrium (i.e. channel geomorphology has changed in response to the change in hydrology brought about by catchment clearing). Whilst sediment transport will always continue, its rate will diminish unless new changes occur within the catchment.



Source: Illawarra Lake: Environmental Assessment Project (Univ' of Wollongong, 1976)

Figure 2.4.3: Changes in Delta Form Macquarie Rivulet

2.5 SURFACE COVER AND LANDUSE

The early Illawarra escarpment and foothills supported a cover of dense sub-tropical rainforest. The first major impact on vegetation and land use arose in the early 1800's with felling of the cedar trees. This was in turn followed in the mid 1800's by the clearing of the less dense stands of Blackbutt and Turpentine, on the flatter land, for pasture. Beyond the urban (ever increasing) limits of the village of Albion Park there has been little change in land usage for over 100 years, most of the land around the village having been used as pastoral land since first being cleared in the mid to late 1800's.

In 1843 a road was built connecting Shellharbour with Jamberoo. A bridge was constructed over Macquarie Rivulet in 1858, which together with a punt across Minnamurra River, upgraded access from Shellharbour to the north. In 1909 the original bridge over Macquarie Rivulet was replaced and in 1932 the Princes highway was constructed between Macquarie Rivulet and the Minnamurra River. The Princes Highway road bridge was again replaced in 1971 with a concrete structure and the crossing duplicated to provide multi lane access in 1990.

In 1887 the Illawarra Rail line was opened and in 1920 the original `Albion Park' station (then located at Yallah) relocated to Albion Park Rail, forming the nucleus of the village of Albion Park Rail. The existing timber rail bridge over Macquarie Rivulet was replaced in 1982 with a new concrete structure.

The aerodrome at Albion Park was opened in 1941.

In 1972, an industrial estate was created on land to the south of Macquarie Rivulet, between the Princes Highway and Illawarra Rail line.

In the late seventies and early eighties, a series of ash ponds were constructed at Tallawarra power station, infilling part of the flood plain between Macquarie Rivulet and Duck Creek. Wollingurry Creek was diverted to flow around the south eastern corner of these ponds, at this time.

During 1996 a coal washery discard fill emplacement commenced on the northern floodplain of Macquarie Rivulet, downstream of the rail bridge, part of earthworks for a residential subdivision (Haywards Bay) to be constructed at this location. At about the same time, Koona Street was extended north over Albion Creek to service a new subdivision (Macquarie Shores) on land east of the railway line and to the immediate south of Macquarie Rivulet.

Over the last decade, considerable new residential development has occurred around the village of Albion Park. This remains an area of ongoing development with little sign of development abating. Most recently a new residential development has occurred at Tullimbar, on the western perimeter of Albion Park.

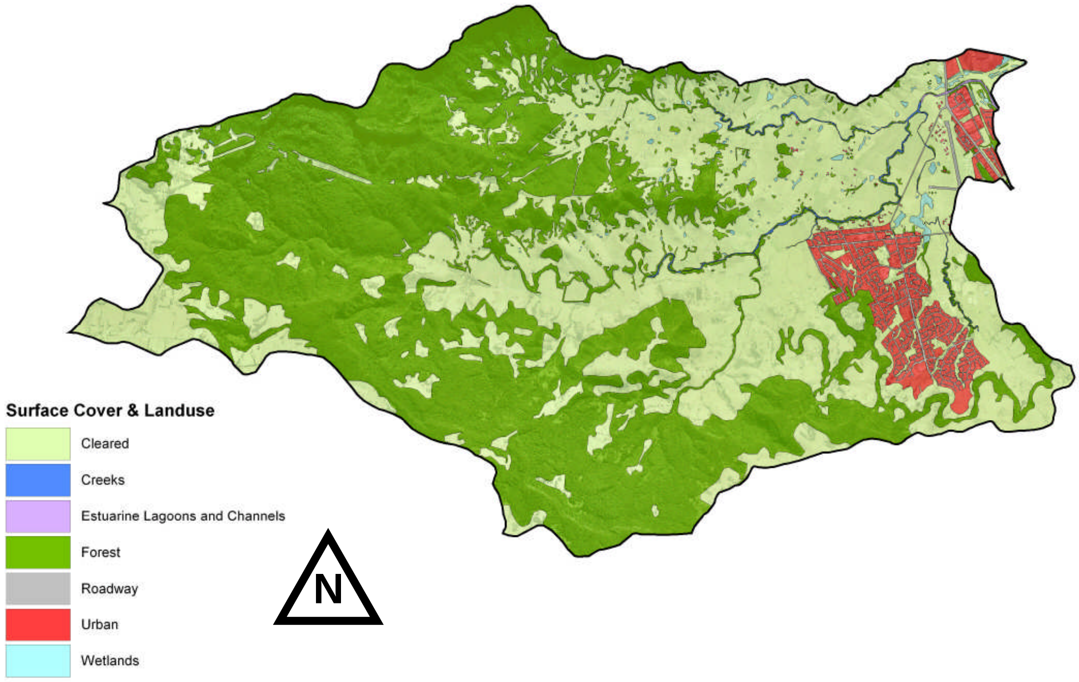


Figure 2.5: Surface Cover & Land Use

Residential, commercial and light industrial development is generally located in the downstream (eastern) portion of the catchment with pasture in the central portion and remnant forest in the upstream (western) portion of the catchment.

2.6 DRAINAGE CHARACTERISTICS

2.6.1 STREAM NETWORK

The Macquarie Rivulet catchment is drained by several major streams that meet on the floodplain above the Princes Highway road bridge, before discharging into Lake Illawarra.

The major streams include;

- Macquarie Rivulet
- Marshal Mount Creek and
- Frazers Creek (West and East arms)

Several smaller streams of relevance to the study include;

- Town Creek and
- Cooback Creek

And while not within the catchment, Albion Creek (as a stream potentially likely to receive diverted flow from Macquarie Rivulet in larger events).

Of the above, only Macquarie Rivulet and Marshal Mount Creek remain in a relatively natural condition and even these streams have been impacted over the years by clearing of vegetation from their banks to facilitate stock access.

Frazers, Town and Cooback Creeks have all been significantly altered as a consequence of urbanisation. Flow in these systems is impacted by a number of retarding basins, underground pipe systems and road culverts as well as changes to their plan form and bed profile.

These location of these streams are shown on the Stream Network plan included as **Appendix A.8** and reproduced in Figure 2.6.1 below.

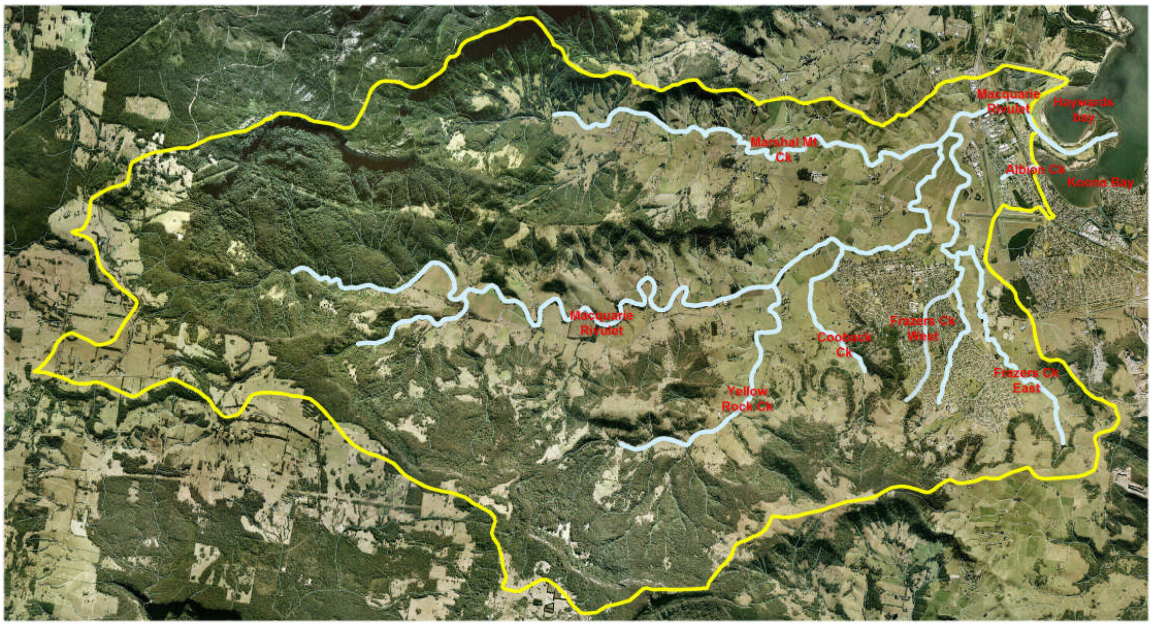


Figure 2.6.1: Macquarie Rivulet Catchment Stream Network

Photography of the various streams, culverts and bridge structures, within the study area, is provided in **Appendix A.2**.

Streams within the catchment have a highly variable flow regime with limited base flow, some being entirely ephemeral. Flowrates can rise rapidly following periods of intense rainfall however these conditions last for short periods only (hours).

The proximity and elevation of Lake Illawarra with respect to the lower reaches of Macquarie Rivulet results in a significant length of the lower reach of Macquarie Rivulet containing permanent water. A weir, constructed by a local farmer (Mr McDonald) in Macquarie Rivulet in 1966 to isolate fresh water from the brackish water of the Lake, acts as the terminus for this permanent backwater. The Lake has a mean water surface elevation of 0.3 m AHD. However, as identified in the Lake Illawarra Flood Study (Lawson & Treloar, 2001), flood levels in the lake can rise to as much as 3.2 m AHD under extreme (PMF) conditions. This would result in significant flooding of parts of the lower Maquarie Rivulet catchment even if no flow was occurring at that time within the main creek channels.

It is noted that the level of water stored in Lake Illawarra is largely isolated from the diurnal impact of oceanic tides. Tidal conditions are therefore not a consideration in assessing flooding in the Macquarie Rivulet catchment. Interactions between the water surface in the lake and flood discharges in Macquarie Rivulet are however a significant feature of flooding in the lower reaches of catchment.

The Macquarie Rivulet catchment adjoins several major catchments. It is topographically isolated from all of these with the exception of Albion Creek to the east. Earlier studies have raised the possibility that flood levels in Macquarie Rivulet could rise sufficiently in a major event to overtop the Albion Park Airport runway into the headwaters of Albion Creek. As an assessment of this diversion is needed to properly reflect flood behaviour in the study area, it has been included in this study.

3 AVAILABLE DATA

3.1 GENERALLY

Data previously available or collected in support of this study, that has been reviewed or used more directly in this study, included the following material in so far as it relates to the Macquarie Rivulet catchment.;

- Topographic Mapping
- Geological Mapping
- Soils Mapping
- Riparian Zone Mapping
- Cadastral and Zoning Mapping
- Aerial Photography
- ALS Survey Data
- Field Survey Data
- Creek and Structure Photography
- Rainfall and Stream Gauging Data
- Reports and Records of Historic Rainfall and Flooding
- Previous Studies and Reports

Several of these datasets have been discussed in the previous Section 2 describing 'The Catchment'. The remainder are discussed in the following.

3.2 CATCHMENT MAPPING

3.2.1 TOPOGRAPHY

Two metre contour topographic mapping of the catchment is available based on the 2 metre contour data set available from the NSW Department of Lands. This data is similar to the contour information used in the Department's standard 1:10,000 scale orthophoto mapping.

Whilst this data was available, it was used only in the very early stages of development of the study, principally in support of survey brief development for ground survey. More detailed Air-borne Laser Scanning (ALS) survey was used as the primary source of topographic data for the balance of the study including development of hydrologic and hydraulic models. This ALS dataset is separately described in **Section 3.3**.

3.2.2 CADASTRE AND ZONING

In order assist with the assessment of the spatial distribution of landuse and assist with estimation of impervious surface cover (described in **Section 4**), cadastre and zonings contained within SCC's Local Environmental Plan 2000 (LEP 2000) were obtained for the study area. This data was made available by Council in GIS format to facilitate its use in the study.

3.2.3 GEOLOGY AND SOILS

Information with respect to soils and geology was obtained and reviewed for the purpose of this study as described in **Section 2.4.** ..

3.3 AERIAL PHOTOGRAPHY

3.3.1 HISTORIC

Historic aerial photography of the catchment reviewed in this study included photography taken in;

- circa 1948
- August 1963
- December 1974
- May 1993
- April 2001
- April 2003
- June 2004

This data is of variable quality but generally poor compared to current high resolution aerial photography. A copy of an early 1948 photograph of the Yellow Rock Creek junction with Macquarie Rivulet is appended together with a more recent (2004) photograph of the same area.

Figure 3.3.1: Aerial photo of Albion Park- circa 1949 & June 2004

As is apparent on the above photographs, there are few changes in this area over the intervening 55 year period.

3.3.2 PRESENT AERIAL PHOTOGRAPHY

In late 2006 detailed aerial photography of the Macquarie Rivulet catchment was obtained by Jordan Mealey from specialist aerial survey consultants AAM Hatch.. This data, flown in June 2005 is of high resolution (0.2m pixel), giving good definition of surface features. The aerial photo dataset comprises a series of 1500mx1500m photo tiles covering the lower reaches of Macquarie Rivulet as shown below in Figure 3.3.2a. .An extract from one tile in the vicinity of the Eastern Frazer's creek crossing is reproduced in Figure 3.3.2b as an indication of the resolution obtained.

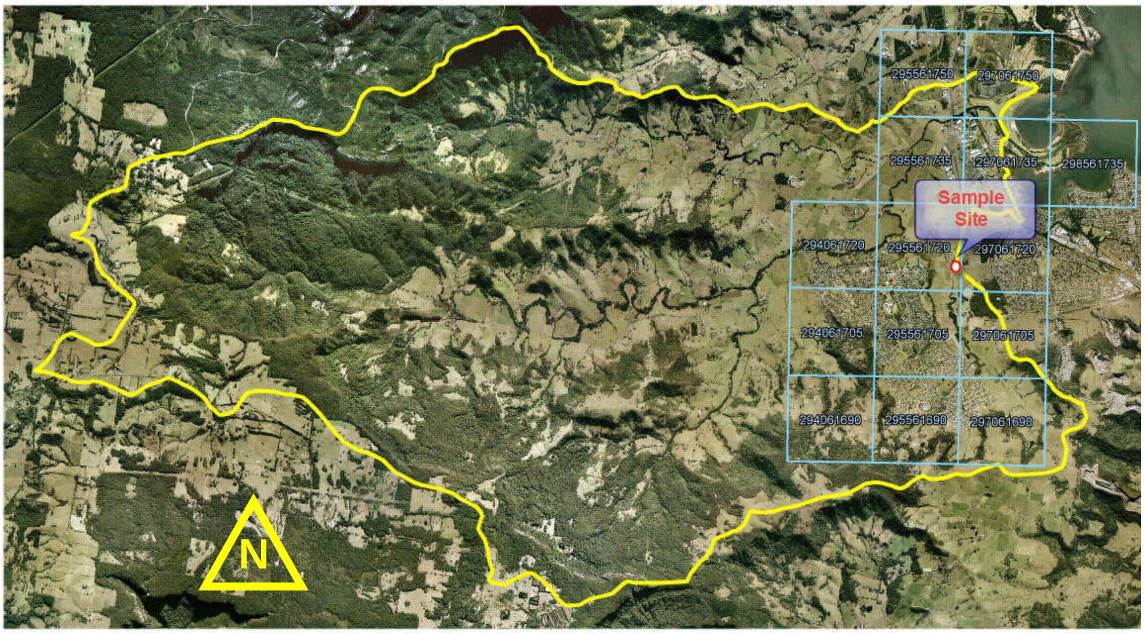


Figure 3.3.2a: 2005 Aerial Photography –Tile Coverage

Figure 3.3.2b: 2005 Aerial Photography – Sample Site
(Frazers Creek Eastern Arm Crossing Tongarra Road)

All aerial photos were orthorectified and geo-referenced to MGA Zone 56 (GDA94) by AAMHatch, to facilitate use with other GIS datasets. This data was used to assist with the development of subareal boundaries, impervious cover for hydrologic models and with the generation of roughness data for use in hydraulic models.

3.4 AERIAL SURVEY (ALS)

3.4.1 METHODOLOGY

For the present study, aerial survey techniques were used as the primary method of collecting topographic data. Specialist aerial survey firm, AAM Hatch were sub-contracted by Jordan Mealey to prepare this data.

The methodology employed is known as Air-borne Laser Scanning (ALS). The ALS equipment is deployed by fixed wing aircraft flying over the site. The ALS equipment emits a continuous stream of laser beam pulses, and records the time taken for each laser pulse to return to the aircraft. This travel time is used to calculate a distance and therefore height of the ground surface relative to the aircraft. Data filtering algorithms are used to remove data that does not represent the true ground surface such as data points collected from roof surfaces or the canopy of a forest.

While this method of survey capture is useful for collection of data over large areas it is limited in that it is unable to collect ground surface data where laser beam pulses cannot penetrate (e.g. from underneath structures such as culverts and bridges or from beneath the water surface). Separate ground survey and bathymetry was therefore obtained to supplement the ALS data in these areas.

3.4.2 DATA COLLECTED

ALS data was collected for the lower Macquarie Rivulet area where detail 2D hydrodynamic modelling was proposed. The ALS dataset obtained for this study comprised a series of 2000m x 2000m tiles of geo-referenced spot heights. Each tile contained in the order of 500,000 individual spot height data points.

ALS coverage of the Macquarie Rivulet catchment is shown shaded pink in Figure 3.4.2 below. When constructing the 2D model it was found desirable to extend the elevation dataset a little further up the northern side slopes of Marshal Mount Creek. Elevation data in the area shown in green in Figure 3.4.2 was created by merging the LPI contour data into the more accurate ALS data.

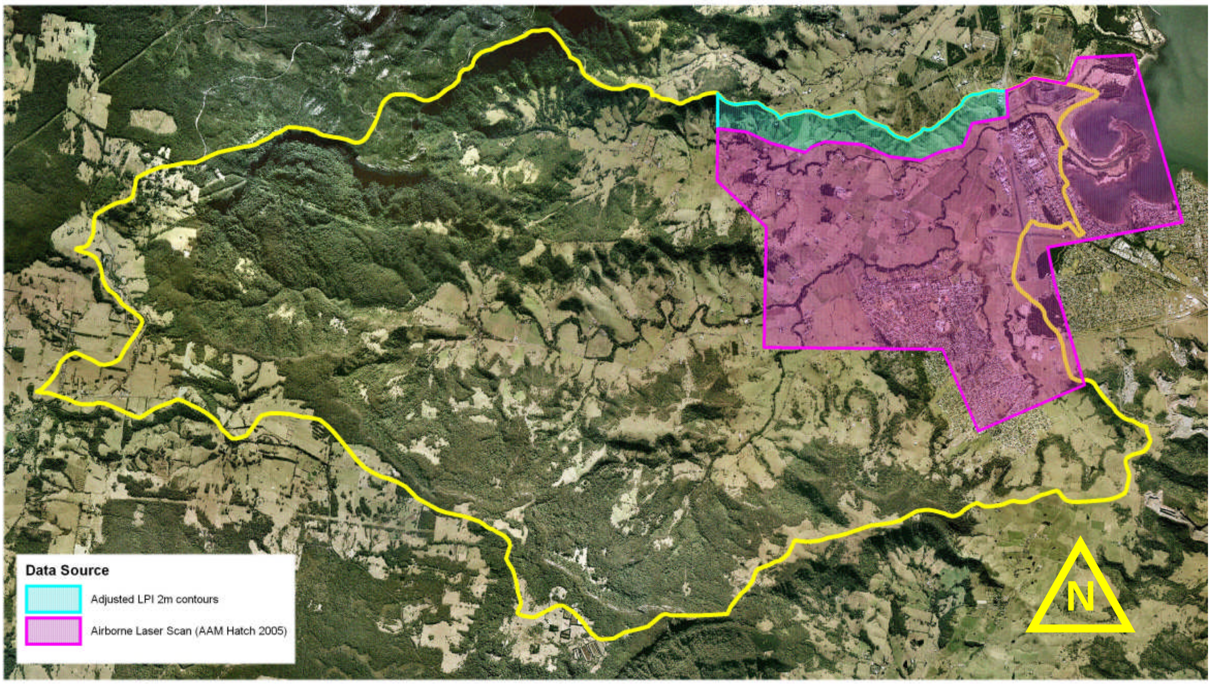


Figure 3.4.2: 2005 Air-borne Laser Scanning (ALS) Tile Coverage

3.4.3 ACCURACY

The filtered data is quoted by the supplier as having an 0.1m vertical accuracy. The spacing of data points varies but typically a spot height has been obtained for every square metre or so of the surveyed surface. This vertical accuracy and dense coverage provides excellent definition of ground features as can be seen from the sample extract below which shows a small area at the northern end of the main runway, coloured according to elevation. The survey data is of sufficient accuracy that even small drains are well defined and features such as the kerb lines in adjoining streets can be easily identified.

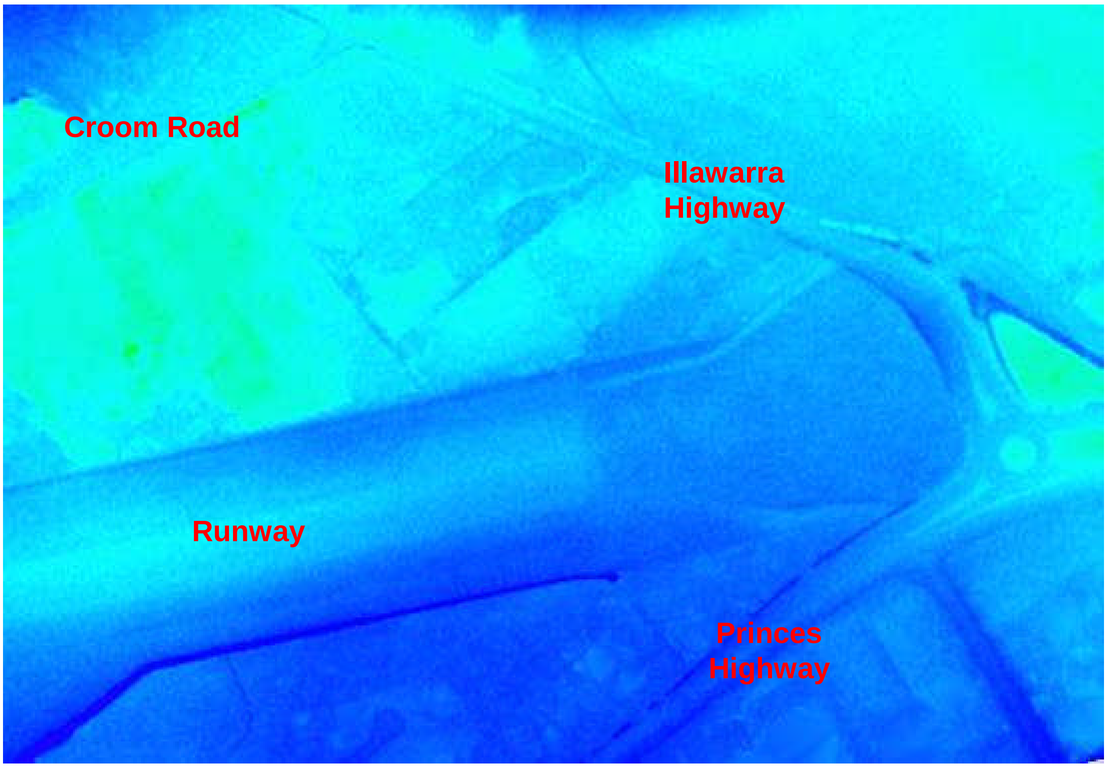


Figure 3.7: 2005 Air-borne Laser Scanning (ALS) Example

Ground truthing of the ALS data was carried out at selected locations where ALS and ground survey was available in the same area (often in the vicinity of structures). It was found that whilst the quoted vertical accuracy of 0.1m was achieved by the ALS in paved or well grazed ares, some over estimation of levels occurred with the bed levels of incised creek channels and in more densely vegetated areas, such as some of the reedy wetlands.. Overestimation in the incised creeks was expected and is due to the shadow effect of banks (inhibiting penetration of laser beam pulses), presence of heavy vegetation on the banks and pooled water within the channel invert. In the highly vegetated wetlands, pulses can not reach the underlying ground (at all) with no way of then being able to filter the higher vegetation canopy out using the scatter in elevation returned by adjacent pulses.

The impact of this error on the ultimate conclusions of this study are negligible since the magnitude of flood events investigated in this study (i.e. 1% AEP and PMF) are such that the lower portion of these small creek channels represents a very small percentage of total conveyance. Any underestimation in the depth of these smaller incised channels could therefore only contribute in an entirely insignificant way to uncertainty in flood level estimates in the study area..

3.5 CREEK AND DRAINAGE STRUCTURES (SURVEY)

3.5.1 GENERALLY

In order to supplement the Air-borne Laser Scanning data, separate ground survey of the catchment land surface was required at several locations throughout the catchment. Local registered surveyor David Yates was sub-contracted by Jordan Mealey to obtain this data.

Data was supplied in both electronic form (for direct input to model construction) and hard copy. All data was supplied in a suitably geo-referenced form.

3.5.2 BATHYMETRIC SURVEY

Bathymetric data for Macquarie Rivulet downstream of the weir was extracted from an earlier survey (1990) undertaken by D Allen Surveyor, presented in the report by the WFR(1996).

Bathymetric data for Haywards Bay in the general vicinity of the outfall delta of Macquarie Rivulet was obtained from the Lake Illawarra Authority.

This data was merged with the land based ALS dataset to form a contiguous topographic dataset across the area to be modelled.

3.5.3 STRUCTURE SURVEY

A structure survey was undertaken to determine the configuration and dimensions of all significant vehicular, pedestrian and rail crossings in the study area.

An initial review of the catchment was undertaken by RIENCO and each of the structures requiring survey identified. It should be noted that the structures included are a subset of structures present in the catchment. Only those structures likely to have an impact on flood behaviour in the study area were included. A brief description of each structures configuration is provided in Table 3.5.3. Their location within the catchment is shown in Figure 3.5.3 and at a larger scale in **Appendix B4**.

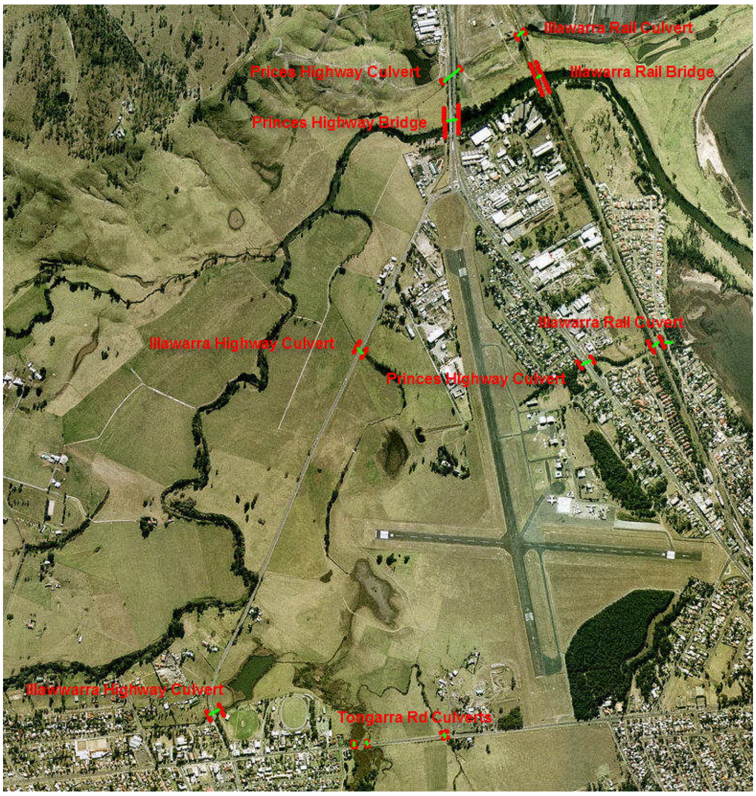


Figure 3.5.3: Surveyed Structures

Table 3.5.3: Surveyed Structures

Location	Structure	Dimensions	U/S Inv (m)	D/S Inv (m)	L (m)	'n'
Albion Creek @Shearwater Dr	Single Bebo Arch	1 * 10mW * 3mH	0.5	0.5	20	0.012
Albion Creek @ Illawarra Rail	Multi Barrel Pipe Culvert	5 * 2.6m Dia Rail over at RL xxxxx	-0.35	-0.35	30	0.012
Albion Creek @ Princes Hway	Multi Cell Box Culvert	Xxxxxxxxxx Road Over at RL xxxx				
Macquarie Riv @ Illawarra Rail	Multi Span Conc Bridge	17 * 7.6m Spans RL 4.54m Obvert RL 5.64m Top of rail	Vble	Vble	6	-
Macquarie Rivulet @ Princes Hway	Twin Multi Span Conc Bridge	5 * 22m Spans RL 6.35 Obvert RL 8.07 Top of Kerb	Vble	Vble	25	-
Wollongurry Creek @ Illawarra Rail	Multi Cell Box Culvert	2 * 2.7mW * 2.7mH Rail over at RL xxxx	0.91	0.81	28	0.012
Wollongurry Creek @ Princes Hway	Multi Barrel Pipe Culvert	3 * 1.75m Dia Road over at RL xxxx	1.83	1.41	81	0.012
Frazers Creek @ Illawarra Hway	Multi Barrel Pipe Culvert	4 * 1.05m Dia Road over at RL 2.85	1.4	1.4	15	0.012
Frazers Creek @ Tongarra(west)	Multi Cell Box Culvert	4 * 2.5mW * 1.55mH Road over at RL 6.58	4.54	4.64	16	0.012
Frazers Creek @ Tongarra(central)	Single Cell Box Culvert	1 * 2.4mW * 1.25mH Road over at RL 6.58	4.75	4.68	16	0.012
Frazers Creek @ Tongarra(east)	Single Span Conc Bridge	8.1m Span RL 9.17m Obvert Road over at RL10.13	Vble	Vble	16	-
Town Creek @ Illawarra Hway	Multi barrel Pipe Culvert	3 * 0.9m Dia Road over at RL 6.0	4.5	4.5	15	0.012

3.5.4 DRAINAGE INFRASTRUCTURE

A review of drainage infrastructure was undertaken by RIENCO in the latter part of 2006. The objective of this review was to determine the configuration and dimensions of all major trunk drainage lines that might influence flood behaviour within the study area.

This review did not identify any trunk drainage infrastructure that would influence flood behaviour in the study area. It was noted that there is a significant, rapidly expanding drainage network associated with recent development around the periphery of the village of Albion Park, but this would have minimal impact on major flooding in the study area.

3.6 CREEK AND DRAINAGE STRUCTURES (PHOTOGRAPHY)

A comprehensive photographic survey of the catchment was carried out including photography of each of the creek and drainage structures surveyed. A selection of these photos, relating to the study area in particular, are reproduced in **Appendix B.3**.(Stream Photography) and **Appendix B.4** (Structure Photography)

3.7 RAINFALL GAUGING

Continuously recording rainfall gauges were installed by the Public Works Department (now Department of Natural Resources) at Clover Hill (aka Macquarie pass), Calderwood, Upper Calderwood, North Macquarie and Yellow Rock in the mid eighties. These gauges are managed by the Manly Hydraulics Laboratory (MHL) of the Department of Commerce (NSW) for the Department of Natural Resources (NSW).

Rainfall gauge locations are as noted in Table 3.7 and shown graphically in Figure 3.7 and **Appendix A7**

Table 3.7a : Rainfall Gauges in Macquarie Rivulet

Gauge Name	Gauge ID	Easting GDA94/56	Northing GDA94/56	Period of Operation
Calderwood Rd	MHL35	290410	6174300	Jan83-Jun85
Upper Calderwood	MHL36	288600	6174935	Jul85 - present
Nth Macquarie	MHL37	291280	6171330	Jun85 - present
Clover Hill (aka Macquarie pass)	MHL38	284090	6172270	Aug85 - present
Yellow Rock	MHL39	292780	6167430	Jan83 -present
Albion Park Airport	MHL(?)	297190	6173750	Jun91 to Mar95
Albion Pk	SW	295208	6172396	Not Known

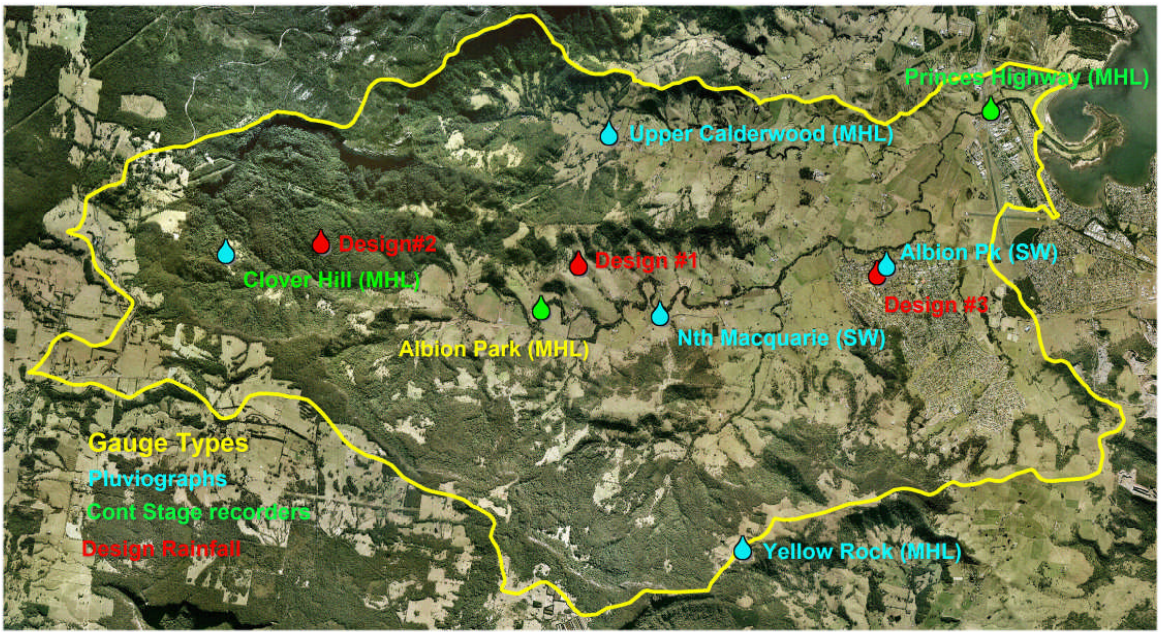


Figure 3.7 : Macquarie Rivulet Catchment Gauges

3.8 STREAM GAUGING

2.12.1 Generally

The former Department of Water Resources, now Department of Natural Resources, has recorded flood stage in Macquarie Rivulet near Sunnybank, since August 1949 (S/N 214003). The former Public Works Department, also now Department of Natural Resources, has maintained both a continuous and maximum height recorder near the Princes Highway bridge since 1988 (S/N .

2.12.2 Albion Park (aka SunnyBank) Gauge (S/N 214003)

The Albion Park gauge was installed by the Department of Water Resources in 1949. Over the years, the gauge was relocated several times. In October 1961 the gauge was relocated to a site some 640m upstream of the original gauge site and in March 1978 again relocated a further 500m upstream of the interim site. During the time these various gauges were in service, a number of rating curves were developed to reflect changes in stream geometry and gauging data for each site.

As indicated in Table 2.12.2, no rating data above a discharge of about 10% of the 100 year ARI flow have however been confirmed by measurement at any of these gauge sites.

Table 2.12.2 Albion Park Gauges – Peak Gauging

Site	Flowrate (m3/s)	Gauge Height (m)	Date
3 (1978 to date)	14	1.00	7/11/84
2 (1961-1978)*	64*	1.79*	21/6/75*
2 (1961-1978)	7	1.05	19/10/76
1 (1949-1961)	11	1.1	22/10/59

Source: WRF report on Macquarie Rivulet as a Reference Catchment (1986)

**1975 estimate only based on surface floats (DWR records)*

The NSW Department of Water Resources extrapolated the rating curve to higher flows based upon the creek cross section at the gauge and average stream bed grade. It is likely, however, that the section has since altered as a result of scour and the DWR rating curve should be considered approximate only. In a study undertaken for the Water Research Foundation (WRF (1996)), this concern was reinforced when difficulties were experienced by several committee members while trying to calibrate models to discharges predicted by the DWR rating curve. To explore the problem further, cross sections of the stream were surveyed and a static 1D hydraulic model (HEC2) used to simulate the stage/discharge relationship at this gauge. Both the current DWR and WRF rating curves for the Sunny Bank site are reproduced in Figure 2.12.2 and at a larger scale in **Appendix B8**. As will be apparent from the two plots, the original DWR curves predicts much greater discharges for and stage than does the HEC2 based curve.

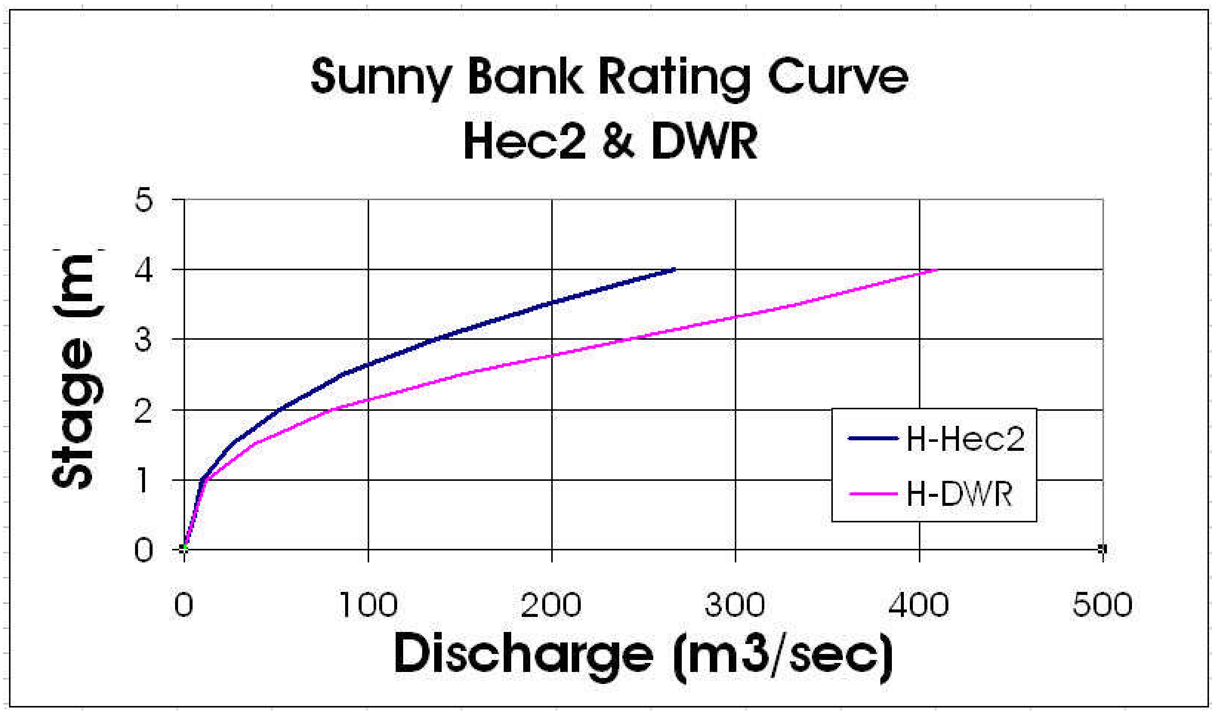


Figure 2.12.2 : Albion Park CSR Rating Curves

Photographs of the stream in the vicinity of the present gauge are reproduced in **Appendix B3** . The present gauge location is shown graphically on an aerial photographic underlay in **Appendix A7.**

2.12.3 Princes Highway Gauge (S/N 214402)

The former NSW Public Works Department, now Department of Natural Resources, installed a Maximum Height Indicator (MHI) and a continuous flood stage recorder (CSR) on Macquarie Rivulet at the Princes Highway in 1988. These gauges are located on the south bank of Macquarie Rivulet, a short distance downstream of the Princes Highway road bridge

No formal rating curve has been developed for the continuos stage recorder. In a study for the Water Research Foundation (1996) a provisional rating curve was however developed based upon a static, two dimensional hydraulic model of Macquarie Rivulet. This rating curve is reproduced in Figure 2.12.3, together with a larger scale version in **Appendix B9**.

Above RL 2.0m AHD Lake levels have little impact on levels at the gauge. Below RL 2.0m AHD, the rating curves become progressively impacted by the elevation of the lake into which the rivulet discharges, requiring a family of rating curves to relate stage to discharge for each lake tailwater level. It should be noted that modelling for this rating curve has not considered the impact of lake levels above RL 2.00m AHD or the hysteresis present in a dynamic situation when discharges on the rising limb differ from that on the falling limb for a particular flood stage at the gauge. Provided Lake levels do not exceed RL 2.0m AHD, this rating curve should however provide a reasonable correlation between stage and discharge.

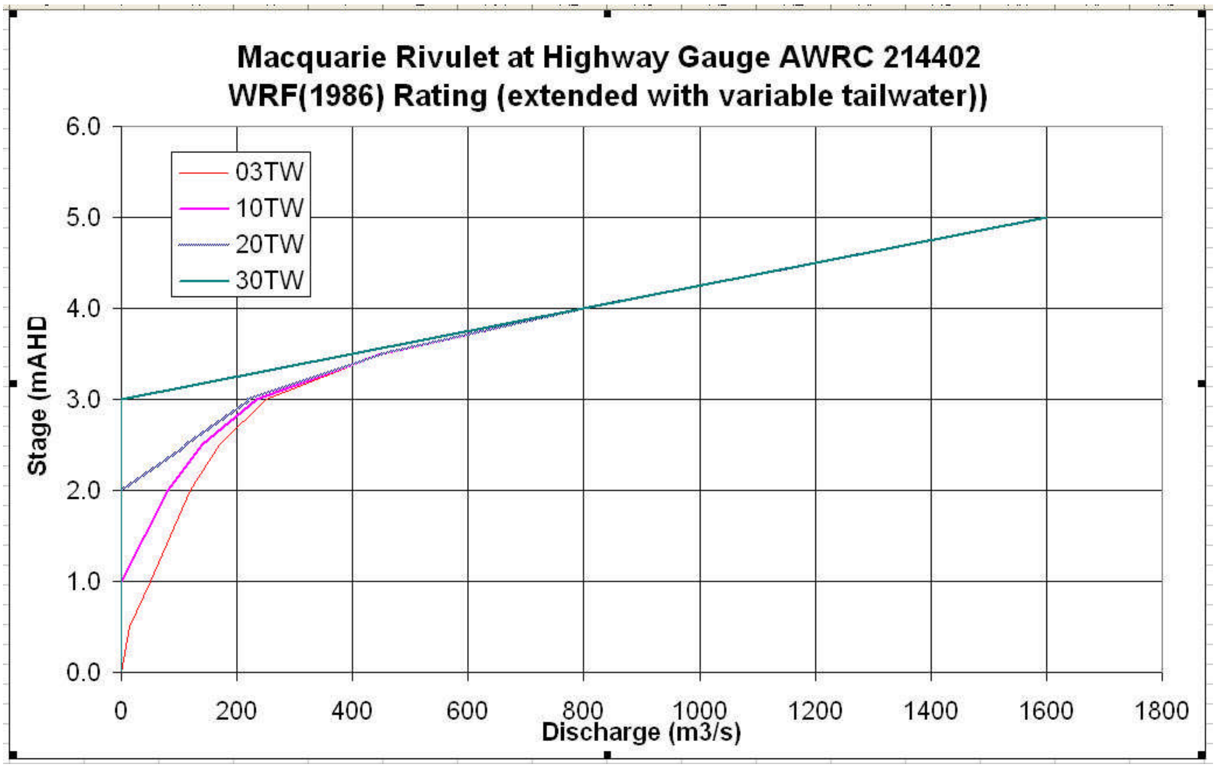


Figure 2.12.3 : Princes Highway Provisional CSR Rating Curve

Photographs of the stream in the vicinity of the present gauge are reproduced in **Appendix B3** and the gauge locations shown graphically on an aerial photographic underlay in **Appendix A7**.

3.9 HISTORIC RAINFALL AND FLOODING

3.9.1 HISTORIC RAINFALL

Historic rainfall data was sourced from rainfall gauges administered by Manly Hydraulics Lab (MHL). Some data for the June 1991 flood event was also obtained directly by RIENCO from gauges administered by Sydney Water and the NSW Rural Fire Service. Since meaningful rainfall data is only available for the events occurring after rainfall gauges were installed in the catchment in the early eighties, this review was restricted to storms occurring from February 1984 up to the present time, as listed in Table 3.9.1 below.

Table 3.9.1: Rainfall Data Reviewed for Current Study

Event	**Description**	**Rainfall (Daily)**	**Gauge Data Reviewed**
February 1984	This was an extremely severe event, centered on West Dapto causing extreme flooding in Mullet Creek. A steep rainfall gradient away from the Mullet Creek catchment created only moderate to minor flooding in adjoining catchments.	850mm	Two MHL rainfall gauges were present in the catchment at this time however only one (Calderwood) was operable. The Sunnybank CSR xxxxx
August 1986	253mm in four days. Albion Park rail under water up to 0.5m but Shellharbour suffered little damage	110mm	xxxxx
August 1987	Major flooding in northern suburbs of Wollongong but only minor flooding in Shellharbour	160mm	xxxxx
April 1988	Moderate flooding throughout Shellharbour Wollongong but Shellharbout not as impoacted as northern suburbs.		xxxxxx
June 1991	This was a severe event of the order of 10-50 year ARI centered on catchments around Lake Illawarra. It was a relatively long duration event and therefore did not cause major flooding in smaller catchments but did create significant flood discharges in larger catchments (such as Macquarie Rivulet) and did elevate lake Illawarra significantly (RL 1.9m AHD)	310mm (800-1000 mm over 5 days)	Data was available from six MHL rainfall gauges located within or near to the catchment and a Sydney Water gauge within the catchment. All were operable. Both the Sunnybank and Princes Highway CSRs captured this event.
August 1998	This was a very severe event in the northern suburbs of Wollongong with relatively little rain falling south of the Wollongong CBD.	316mm	Six MHL rainfall gauges were located within or near to the catchment. Only three were however operable. Sunnybank Princes Highway

In reviewing available rainfall data, all data was first checked for missing and/or unreasonable data and any clearly erroneous datasets discarded from further consideration. The data was then assessed for its suitability for model calibration. Suitability for model calibration was based on:

- The data being from a location within or close to the catchment and therefore representative of rain falling on the catchment
- The data being of high quality (no missing rainfall values)(sensible volumes)
- The data extending for the full duration of storm
- The event being of sufficient severity as to generate flooding of some consequence
- Corresponding historic flood level information being available for modelled reaches (either from continuous stage recorders (CSRs), Maximum Height Indicators (MHIs) or surveyed flood debris).

Whilst all of the above storms were reviewed, only the June 1991 data was identified as suitable for model calibration and subsequently processed into a format suitable for modelling. Whilst the June 1991 event did not generate particularly severe flooding, it did involve significant overbank flooding and was the only event for which substantial reliable historic rainfall and flood level information was available.

The June 1991 rainfall hyetographs for each gauge used in modelling the calibration event, are reproduced in **Appendix B5**.

As is apparent in these plots, the June 1991 event was of long duration (5days) with several peaks in rainfall intensity during that time. The two most intense rainfall peaks occurred on the first and last days of the storm event. For a 9 hour or so duration ('critical' duration for the catchment as a whole), the storm corresponds to about a 5 to 10 year ARI rainfall event.

Further discussion on rainfall data is provided in **Section 6**.

3.9.2 HISTORIC FLOODING

Historically, the village of Albion Park has been subject to flooding on several occasions in the past. This recurrent flooding was the trigger for the flood study prepared by the Water Resources Commission in the early eighties.

The low section of the Illawarra Highway between the Princes Highway and Tongarra Road floods every few years, as does Tongarra Road in the vicinity of the West Frazer's Creek crossing. Construction of a new (higher) Princes Highway bridge has eliminated the flooding that also took place at this crossing every few years. Mansons Bridge (Calderwood Rd) also has been observed to overtop in major events. Local storm drainage system inadequacies had been a recurrent source of flooding in the village of Albion park.

While not directly part of the Macquarie Rivulet catchment, the Princes Highway in the vicinity of the Albion Creek crossing also floods every few years.

Information on historic flooding prior to the February 1884 event has been collected from various sources and is reproduced in the following.

Event of March 1983

- 5 hours of torrential rain on 22 March 1983 following three days of continuous rain.
- Flooding at Fairy Meadow
- Flooding of many houses in northern and southern suburbs. In Shellharbour reports of flooded houses.

Source - Little Lake Flood Study Compendium of Data

Event of October 1983

- Constant rain throughout night of 13th and morning of 14th October 1983 caused flooding in southern Wollongong suburbs.
- Albion Park township flooded. Airport under 0.5 m water. Roads into Albion Park were cut off.

Source - Illawarra Mercury 15/10/83

Event of April 1978

- Moderate flooding in some suburbs.
- Mr Trevor Batson of Hillside Drive had flood waters in all the rooms of his new home.

Source - Public Works Brief for Macquarie Rivulet Flood Plain Management Study.

3.1.9 Event of March 1975

- Heavy thunderstorms occurred over the Illawarra and Sydney Metropolitan areas between Sunday 9 March and Tuesday 11 March 1975.
- For the 24 hours ending 9am, 11 March 1975, rainfall depths of up to 300 mm were recorded in the eastern portion of the Macquarie Rivulet catchment.

(Source - Bureau of Meteorology, 1976)

Other Events

(Source :Public Works Brief for Macquarie Rivulet Flood Plain Management Study)

Event of May 1969

- Mrs J. McGregor of Station Street had flood waters to the porch of her house. It was blamed on the inadequacy of the three storm water pipes under Station Street.

Event of December 1960

- Terry Street was closed by flood waters up to 4 feet deep and stretching for 200 yards.

Event of October 1959

- Many homes in Station Street had floor coverings ruined by flood waters.

Event of February 1959

- Flood waters were reported to be 2 feet deep on the bitumen approach to Macquarie Rivulet bridge.

Event of March 1959

- Terry Street was completely submerged by 3 - 4' of water between Albion Park and Meadow View Farm.

Event of May 1950

- The highway at Albion Park was closed for a distance of half a mile by flood waters which were up to 6 feet deep.

- The flood waters lapped into the Commercial Hotel and newspaper shop and there was 18 inches of water across the intersection of Flinders and Terry Streets.

Event of June 1949

- Flood waters reached the corner of Terry and Flinders Streets and the posts along the road north of Albion Park were not visible.

Event of May 1941

- Flood waters were 6 inches high in O'Gorman and Sons Butchery.

Resident Interviews

Mr King

Local resident, Mr King recalled that in 1950 the flood waters reached the verandah of the Commercial Hotel. Mr O’Gorman’s butcher shop had to have the front and back doors sand bagged to prevent the entry of flood waters. The Commercial Hotel at this time was located on the N.W. side of the intersection of Terry and Flinders Streets. The original hotel was burnt down in 1954 and rebuilt on the adjacent corner where it is now. The 1950 flood also caused 18” of water across the intersection of Terry and Flinders Streets. According to Mr King, the floods have never reached such a height since Council’s drainage works on the northern side of the Town.

Minor flooding also occurs in Calderwood Road and flood waters have been up to 2 fee over the deck of Manson’s Bridge, but the water has never entered the homes in the bridge’s vicinity.