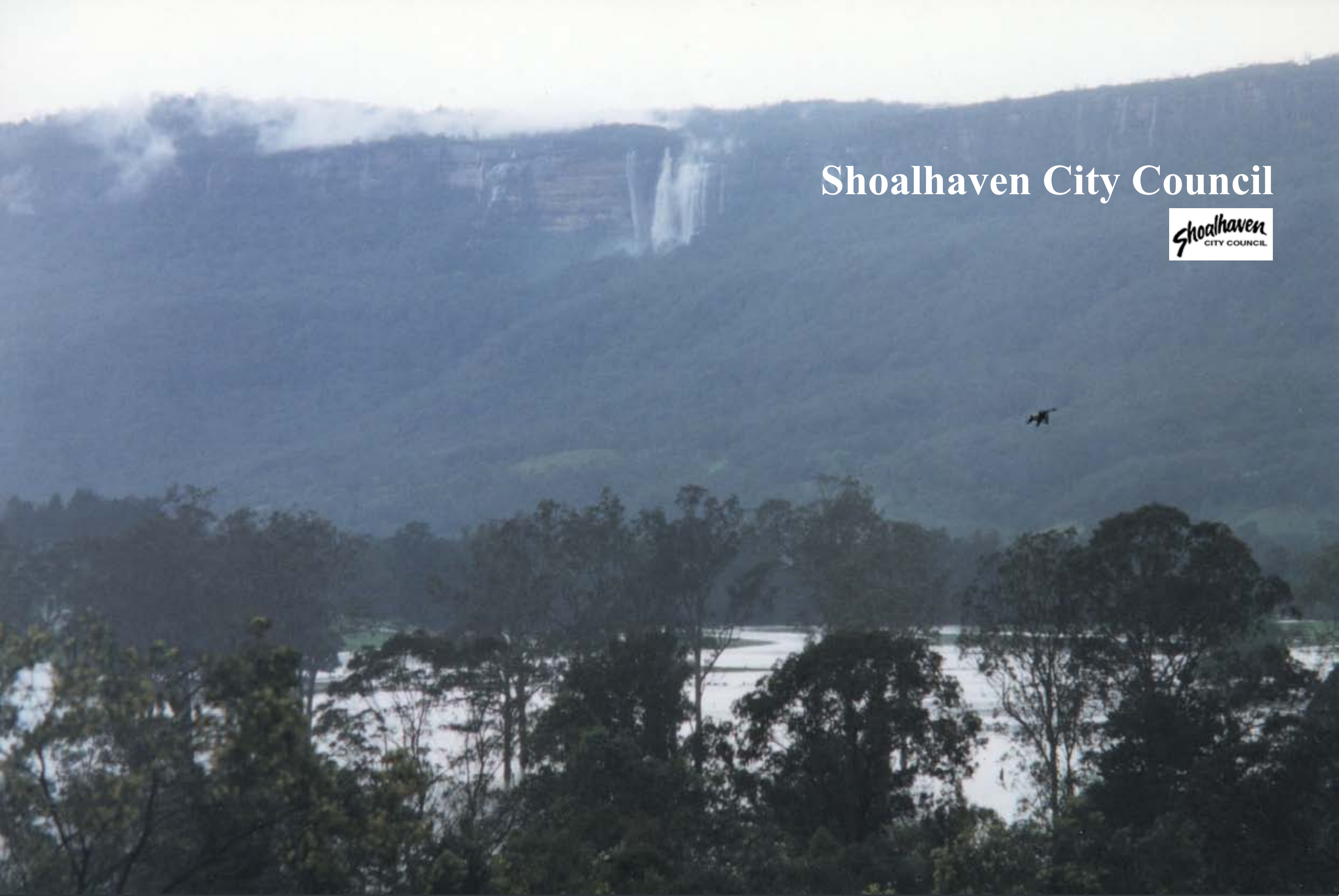

Shoalhaven City Council

Kangaroo Valley Flood Study
Final Report

8 December 2009

Project No: 31455

Prepared by

SMEC

SMEC Australia Pty Ltd

SHOALHAVEN CITY COUNCIL

KANGAROO VALLEY FLOOD STUDY

- FINAL REPORT -

Adopted by Shoalhaven City Council
8 December 2009

Prepared by:

SMEC

SMEC Australia Pty Ltd
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EXECUTIVE SUMMARY

A flood study of Kangaroo River and its floodplains and waterways was undertaken to determine flood behaviour in and around the town of Kangaroo Valley. The study produced information on flood extents, levels, velocities, and flows for the range of design events including the 20%, 10% 5%, 2%, 1%, 0.5% AEP and the Probable Maximum Flood (PMF).

The Kangaroo River at Kangaroo Valley has a catchment area of approximately 334km^2 to the Hampden Road Bridge. The land use is mainly forest and pasture with some farmed crops such as vineyards. The Kangaroo River passes through rugged mountainous terrain and some alluvial flats that is generally used for dairy farming.

The flood study was carried out using two computer models. The RAFTS hydrologic model was used to convert rainfall to runoff and produce the hydrographs, while the Mike-11 hydraulic model was used to simulate hydraulic behaviour of the water streams and to calculate water levels, velocities and flows within the study area.

The data analysis included review of available historic rainfall and streamflow data, flood information collection and revision as well as site reconnaissance. Council's Digital Terrain Model (DTM) data together with the additional land survey was used to establish cross sections required for hydraulic modelling.

Simulated hydrographs were calibrated against gauged flows obtained from the only station that is still operational within the study area, located on the Kangaroo River immediately upstream of the Hampden Road Bridge. A flood frequency analysis was also carried out using data from this gauging station. Calibration of the model reproduced past flood behaviour reasonably well indicating reliability of the assembled models.

Design AEP rainfall intensities were estimated in accordance with Australian Rainfall and Runoff (AR&R) 1997 while the PMF was estimated using methods by the Bureau of Meteorology. Design flows calculated using the RAFTS model were input into the Mike-11 hydraulic model for simulation of design flood levels and velocities.

Flood maps were developed using the computed hydraulic parameters to indicate the flood extents, flows, water levels and velocities for the PMF, 0.5%, 1%, 5% and 20% AEP design events. The hazard maps were prepared for the PMF, 1% and 5% AEP design events. In addition to a detailed presentation of maximum water levels, discharges and velocities for all modelled design events and modelling cross-sections, the report also provides a further assessment of flood behaviour including time of rise and duration of flooding and depths, as well as possible evacuation sites during flooding.

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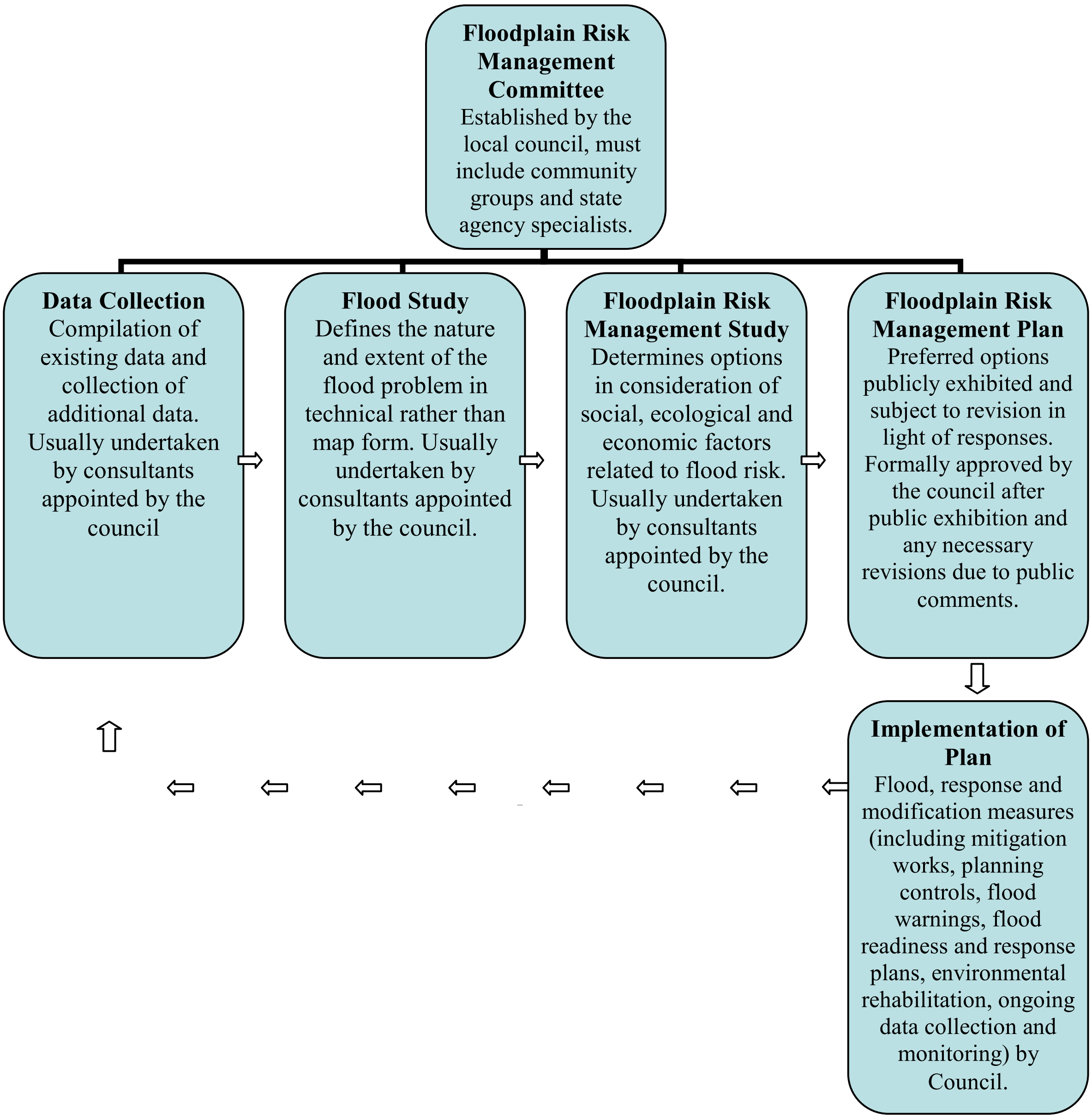
1 FOREWORD

The township of Kangaroo Valley has experienced flooding in the past resulting in damage to private property and roads. In response to this flooding and a desire to prepare a long-term management plan for the town, Shoalhaven City Council (SCC) are preparing a Floodplain Risk Management Plan to manage the existing and future flood risk to the town. This plan will be developed in accordance with the NSW Flood Prone Land Policy and the principles and guidelines in the Floodplain Development Manual 2005.

The process of developing a Floodplain Risk Management Plan is illustrated in Schematic 1 below.

Schematic 1: Process of Developing Floodplain Risk Management Plan



2 INTRODUCTION

As a part of the Shoalhaven City Council Floodplain Risk Management Programme, SMEC was engaged by Council to undertake a flood study including hydrology and hydraulic investigation of the floodplains and waterways in and around the town of Kangaroo Valley. The purpose of the flood study was to identify the technical flooding issues that affect the catchment area and develop detailed hydrologic and hydraulic models of the catchments that were used to establish flood behaviour under existing conditions and will later be used to assess floodplain risk management options, as part of a subsequent Floodplain Risk Management System.

The study area for the Kangaroo Valley Flood Study is shown in Figure 2.1. The Kangaroo Valley Catchment included Kangaroo River and its floodplain, extending 20km upstream of Hampden Bridge in the northeast direction alongside Upper Kangaroo River Road to 10km southeast along Moss Vale Rd. The study included small tributaries of Kangaroo River including Barrengarry Creek from the north and Nugents Creek, Sawyers Creek and Myrtle Creek from the south.

In light of the Governments' consideration of a proposal to raise the Full Supply Level (FSL) of Tallowa Dam, located 20km downstream of the township, SMEC was also commissioned by the Department of Commerce (DOC) and the Sydney Catchment Authority (SCA) to determine the impact of the proposed change on flood levels at the Kangaroo Valley township. A report was produced by SMEC in January 2006 entitled 'Kangaroo River-Tallowa Dam Flood Investigations'. That report presents flood levels along Kangaroo River between Hampden Bridge and Tallowa Dam under existing conditions and for specified raised dam conditions. That report was published by the Sydney Catchment Authority (SCA) and is available on its website. This Flood Study will draw on that information to determine tailwater conditions for water levels at Kangaroo Valley.

Tasks that form part of the Flood Study include:

- Data collection and review;
- Hydrologic model establishment and calibration;
- Hydraulic model establishment and calibration;
- Simulation of design events;
- Sensitivity runs of key model parameters;
- Reporting of flood behaviour; and
- Assessment of preliminary flood hydraulic and hazard categories.

3 BACKGROUND

3.1 Kangaroo River Catchment

3.1.1 General

The Kangaroo River at Kangaroo Valley has a catchment area of approximately 334km^2 and is shown in Figure 5.1. The catchment extends approximately 20km north from Hampden Bridge alongside Moss Vale Road, 10km southeast along Moss Vale Road, approximately 20 km east alongside Upper Kangaroo River Road, and to the west adjacent to the river confluence with Tanners Creek.

The Kangaroo River passes through rugged mountainous terrain for part of its length, however there are also areas of alluvial flats which are used for dairying. The land use in the catchment is predominately forest and pasture with some crops (for example, vineyards). Based on discussions with local residents, there have been some changes in land use and vegetation cover in the catchment, wholesale clearing at the time of original settlement (in the late 1800's) has given way to a gradual increase in forestation since the 1950's. The recent change in land use is particularly noticeable in the eastern part of the catchment and may be attributed to the decline of the local dairy industry.

Refer to Figure 2.1 for the Kangaroo Valley Township and study area.

Tallowa Dam is a mass concrete dam completed in 1976. It is located immediately downstream of the junction of the Kangaroo and Shoalhaven rivers. The dam collects runoff from a catchment that extends from Kangaroo Valley in the north-east to the upper Shoalhaven River south-west of Braidwood.

3.1.2 Floods

Flood behaviour in Kangaroo Valley is quite variable. Flooding duration can vary from several hours to several days. The largest floods in the past 30 years occurred in 1975, 1978, 1990, 1991, 1999 and 2005. Residents indicate that during flood events a number of local roads are closed by floodwaters, including Moss Vale Road, Glenmurray Road (<2m over causeway) and Walkers Lane. The causeway over Sawyers Creek and the bridge over Devils Glen Creek have also become impassable for short periods due to flooding. Overflowing of stormwater drains occurs at Moss Vale Road and Glenmurray Road. Two residents have reported flooding above floor level.

4 DATA COLLECTION

Reports, investigations, calculation files, stream gauge records, rainfall data and flood information relevant for the preparation of the Flood Study were collected and reviewed. Topographical surveys were carried out to obtain ground levels and channel cross sections required for establishing hydraulic models.

A summary of this information is given below.

4.1 Reports

4.1.1 General

i *Lower Shoalhaven River Flood Study (Report No. PWD 87049),* April 1990, Webb McKeown and Associates

This study is a technical investigation of the entire Shoalhaven River catchment. Hydrologic and hydraulic models were established and calibrated. The calibration events for the hydrologic model were the floods in August 1974, June 1975, October 1976, March 1978 and April 1988.

This report presents flood related information that was referenced for the current flood study. Relevant information includes rainfall and isohyetal maps for past storms.

ii *Shoalhaven City Local Flood Plan, Draft (October 2003),* SES

This document covers the Shoalhaven City Council area for all levels of flooding, including Kangaroo Valley. It covers preparedness measures, response operations and recovery measures. The document includes flood information for Berry and Kangaroo Valley. A relevant notes from the flood plan is that the stream gauge at Kangaroo Valley is monitored by the SES.

iii *Flood Policy, Interim – Caravan Parks on Flood Prone Land (July 1988),* SCC

This policy contains a discussion of the hazards and risks associated with caravan parks located on floodplains in the SCC region. No specific design flood levels are provided.

***iv Interim Flood Policy, General Conditions for the Whole City and Specific Areas* (September 1987), SCC**

This policy applies to all land within the City of Shoalhaven. It specifies a design ‘standard’ flood of the 1:100 year ARI event. This policy has limited application for the preparation of the current Flood Study.

v City of Shoalhaven Local Environmental Plan, 1985

This document provides guidelines for development and management of land use in the City by identifying land use zones and objectives for each zone, specifying desired environmental outcomes and establishing conditions and controls under which development may be carried out within certain areas. In terms of flooding, the document makes the references to the general restrictions on development of land for flood affected areas (Zone No.1g – Rural "G" Flood Liable Zone and Zone No.9a – Natural Hazards "A" Urban Flooding Zone). Further general comments with regards to protection of water streams, soil water and effluent management as well as development of flood liable land are made in the document in Division 5: Environmental Management (Sections 23, 26 and 29).

4.1.2 Kangaroo Valley

i *Flood and Risk Management Study Report for River Crossing in Kangaroo Valley* (May 1994), Water Resources Consulting Services

This report contains information regarding the existing river crossing on Gerringong Creek, Kings Creek and Upper Kangaroo River approximately 10km upstream of Kangaroo Valley village. As part of the study a MIKE 11 model was established. The model was outside the extent of the current study area however some cross sections were used for the hydrologic model in this current investigation.

ii *Development Control Plan No 66, Kangaroo Valley, Stage 1* (September 2000), Shoalhaven City Council

This DCP applies to Kangaroo Valley village area and its environs including Barrengarry. Stage 2 will cover Kangaroo Valley rural and escarpment lands. The guidelines within the DCP aim to maintain business confidence for future development, ensure natural and economic resources are conserved and managed, allow public monies to be used efficiently and conserve the character of the built environment.

The performance criteria related to flooding is for development to minimise impediment to the floodplain or urban floodway. Acceptable solutions include development to be above RL76.5m AHD unless supported by a flood study; no fill or grade modification below RL 76.5m AHD unless supported by a flood study and development not within the 1:100 year flood line of an urban floodway. On the attached plan a flood line along Kangaroo Valley River is shown along the 76.5m AHD contour.

This DCP has stormwater performance criteria that recommends a local drainage management, and erosion and sediment control plan to be submitted for works in excess of 30 sq metres.

iii *Assessment of Flood Levels at Kangaroo Valley Township* (1982), Allen, Price and Associates

This report considered past flood levels to recommend a flood planning level for a Lot within Kangaroo Valley. The proposed dwelling was at the rear of the Friendly Inn. The recommended floor level was RL 78.0m AHD.

4.2 Rainfall and Streamflow Data

4.2.1 Rainfall Stations

The number of rainfall stations in the vicinity of Kangaroo Valley catchment is sufficient to provide information on the geographical distribution of rainfall during historical storm events. The majority of stations are daily read gauges operated by the Bureau of Meteorology (BOM), with some stations operated by the Sydney Catchment Authority (SCA).

There are six pluviograph stations within and near the study area. Table 4.1 lists these stations with station number, names and period of record. All gauges are operated by BOM except the Robertson gauge which is operated by the SCA. These provide a continuous record of rainfall. Figures 5.2 to 5.6 show the isohyetal maps for the 1975, 1978, 1990, 1999 and 2005 events.

Table 4.1 – Pluviograph Stations

Station Number	*Station Name*	*Operational*
568 081	Gerringong Ck Falls	Sep1968-May 1981
68 117	Robertson (St Anthonys)	Nov 1962-present
568 079	Gerringong Ck Falls	May1981- present
568 078	Budderoo	Sep 1973- present
568 076	Brogers No2	Sep1968- present
568 128	Barren Ground	May1986- present

4.2.2 Streamflow Data

Within the study area of Kangaroo Valley catchment there have been 7 stream gauging stations operating at one time or another, but there is only one station currently operational, which is located on the Kangaroo River at Hampden Bridge. A list of the stream flow gauging stations is provided in Table 4.2. All stations were run by the SCA.

Table 4.2 – Stream Gauges Located in Kangaroo Valley Catchment

Station Number	*Station Name*	*Operational*
215220	Kangaroo River @ Hampden Bridge	13/07/1966-present
215226	Kangaroo River @ Cookes Crossing	13/07/1966-12/05/1971
215223	Brogers Ck at Clinton Park	13/07/1966-03/05/1971
215228	Barrengarry Creek @ Sunnyvale	08/08/1969-29/11/1971
215222	Barrengarry Creek @ Ascot	16/09/1967-08/03/1971
215221	Barrengarry Creek @ Willow Glen	05/06/1966-12/05/1971
215224	Gerringong Creek @ Nellsville	13/07/1966-12/05/1971

Stream Flow Gauge 215220 Kangaroo River at Hampden Bridge

Station 215220 is located on the Kangaroo River just upstream of Hampden Bridge. This station was operational from 13/07/1966 as a daily read station. The gauge height for Station 215220 is at 58.025mAHD. In 1970, the station was fitted with a continuos water level recorder which was upgraded in 1983 to record digital information. Recorded water levels and flows were taken from HYDSYS, a specialist data management tool for storing daily recorded stream flow information.

Recorded water levels and flows have been used during calibration of the hydrologic and hydraulic models. Flood frequency analysis was also carried out to provide estimates of design flows, which were compared with estimates obtained by hydrologic modelling.

Data checking showed that the stream flow gauge at Hampden Bridge was generally reliable, but the recorded levels for the flood event in October 1999 were found to be erroneous. The recorded maximum flood depth was 8.5m, but photographs taken near the gauge (at "the square lookout") show a water depth of 11.49m (i.e. the floor of the lookout). The SCA acknowledged that the gauge did not provide accurate results during this event and it is thought to be possibly related to a lack of gas in the gas purge system. Comparison with recorded flows on the Shoalhaven River, upstream and downstream of the junction with the Kangaroo River, indicate that the Hampden Bridge gauge performed reliably in other events.

The Hampden Bridge streamflow gauge is located about 90 metres upstream of Hampden Road Bridge. References made in this report to Hampden Bridge refer to a cross-section located 50 metres upstream of the road bridge or roughly halfway between the road bridge and the gauging station.

The peak discharge at the Hampden Bridge gauge during the October 1999 event was estimated using the rating curve, shown in figure 4.1 and a water depth of 11.49m (based on photographic evidence). The comparison between modelled flows and the actual peak flow is provided in Figure 5.10.

4.2.3 Zoning and Contours

SCC provided geographical information in digital format including roads, 10m contours, land use zones, waterways, properties, vegetation, acid sulphate soils and threatened species.

Digital Terrain Model (DTM) was provided from Shoalhaven Water for Kangaroo Valley. This data has been used to extract cross sections for hydraulic modelling. DTM information was also sourced by the Department of Commerce, and the cross sections they extracted were compared with the SMEC-produced cross sections to verify the topography. The data compared favourably, both in the vertical and horizontal planes.

4.2.4 Survey

Survey has been undertaken to obtain flood marks and details of drainage structures. This information was used for hydraulic modelling. Selected cross sections of the floodplains have also been surveyed to verify topographic information obtained from Digital Terrain Model (DTM). Data was supplied in ISG (Integrated Survey Grid) coordinates and to Australia Height Datum (AHD). Survey was also done of Hampden Bridge, both by SMEC and the Department of Commerce. The accuracy of this survey data was greater than for the DTM data.

4.2.5 Bridge and Culvert Drawings

No culvert or bridge drawings were available within the study area at Kangaroo Valley. Survey was commissioned for these structures.

4.2.6 Flood information – Newspapers, plans and questionnaires

Shoalhaven City Council forwarded local newspaper articles and photographs of past floods. This information has general flood information. There are few references to peak flood heights, velocities and discharges. A flood line from DCP66 is available for Kangaroo Valley. This flood line is set at RL 76.5m AHD.

4.2.7 Aerial Photographs

Council provided aerial photographs in electronic format.

4.3 Community consultation

A comprehensive community consultation process was undertaken to obtain flood information for past events. This involved sending a questionnaire, conducting three public meetings and communications with relevant community groups. The questions were concerned with the history of flooding on a property, the extent of flooding, and the evidence available for these flood events.

150 surveys were sent to residents in Kangaroo Valley and 55 completed surveys were returned. A collation of the responses from the surveys is given in Table 4.3. Key findings are presented below according to headings used in the survey questionnaire.

General Information

The 55 survey respondents were residents, farm owners or commercial land users who have been living in the area for a varying number of years. Thirty-five percent of the respondents were farm owners, five of whom have experienced flooding to their property. Twenty percent of the respondents resided in the area for over 20 years.

Table 4.3 – Collated Survey Results at Kangaroo Valley

General Information	
Surveys sent:	150
Responses received:	55
Response rate:	37%
Flood History	
What is the type of property?	Residential: 56% (31) Commercial: 9% (5) Farmland: 35% (19)
How long at that address?	Avg: 11.7 yrs Min: 0.5 yrs Max: 61 yrs
How long in the Kangaroo Valley area?	Avg: 14 yrs Min: 0.5 yrs Max: 61 yrs
Has your property been affected by flooding?	Yes: 20% (11) No: 80% (43)
Year of flood? (no. of responses)	1999: (1) 1990: (6) 1984: (5) 1978: (4) 1975: (5) 1971: (4)
What parts of your property were flooded and to what depth?	Grounds: 82% (9) (min = 0.25m, max = 2m) Garage/Shed: 0% (0) Building: 18% (2) (min = 0.05m, max = 2.1m)
How long did the flooding last?	Minimum duration: 4 hours Maximum duration: 3 days
Where was the water flowing to and from? (no. of responses)	Inadequate drainage: (1) Overflowing stormwater drains: (2) Kangaroo River: (8) Brogers Creek: (3) Nugents Creek: (2) Myrtle Creek: (1) Sawyers Creek: (3) Devils Glen Creek: (2)
Are there any flood marks on or near your property?	Yes: 11% 1976: (1) 1990: (3) 1999: (1) Unknown year: (1) No: 89%
What was the worst depth of flood?	Average: 1.15m Minimum: 0.05m Maximum: 2.1m
What was the worst velocity of flood? (no of responses)	Stationary: 11% (1) Walking pace: 33% (3) Running pace: 56% (5)
Do you have any photographs of records of these floods?	Yes: 11% (6) (All with copies) No: 89% (49)

Comments?	Flood waters across Moss Vale road; Glenmurray Rd experiences severe flooding (<2m over causeway) & road closures as well as significant safety risk due to poor design of causeway; Insufficient drainage at Glenmurray Rd; Assistance required to construct Dams to capture water during heavy rainfall periods; Moss Vale Rd occasionally cut by flood waters near the tennis courts and where the drain lies under the road near the Fudge Shop; The pony club grounds and land behind the pub flood up to 1m; Water problems in the main street of Kangaroo Valley during periods of heavy rainfall; Causeway and bridge for Sawyers Ck and Devils Glen Ck impassable after heavy rain; Moss Vale Road flooded in 1990 event for a few hours.
Ideas and Suggestions	Both sides of Cullen Crescent should have kerb and gutter and be drained to the eastern side of Moss Vale Rd.

Flood History

Flooding of property
Fifteen respondents (27%) have known of flooding in the area, eleven of whom have encountered flood waters on their properties. Nine respondents have had their grounds flooded, and two have had water encroaching into their building. Flood marks are visible at 7 properties. Above floor flooding was reported by two residents, one of whom experienced a depth of 2.1m above floor level.

Four of the respondents recalled all four of the flood events specified in the questionnaire (1984, 1978, 1975 and 1971), and 6 of the residents recalled flooding occurring in 1990. Eleven percent (6) of the respondents have photographs of flooding in the Kangaroo Valley area, half of which were taken during the 1990 flood event.

Flood Duration
Flood duration has been known to last from 4 hours to 3 days.

Flood Source and Destination
During a flood, respondents had witnessed water flowing mostly to and from the Kangaroo River. Other sources identified include Sawyers Creek, Devils Glen Creek, Nugents Creek, and Brogers Creek. Overflowing stormwater drains and inadequate drainage were considered to be another source of water.

Flood Behaviour
The flood behaviour observed in Kangaroo Valley, ranged from fast flowing water to flows at walking pace. Only one respondent has witnessed static ponding during a flood, therefore this type of flood behaviour is considered to be uncommon.

Other Comments
Responses indicate minimal disruption to activities during floods. However, of the comments that were made, disruptions include flooding of Moss Vale Road, Glenmurray Road (<2m over causeway) and Walkers Lane. The causeway over Sawyers Creek and the bridge over Devils Glen

Creek become impassable for short periods due to flooding. Overflowing of stormwater drains has been known to occur at Moss Vale Road and Glenmurray Road.

It was considered by one of the farm owners that assistance is required to construct dams on rural land to capture water during periods of heavy rainfall.

One of the respondents made the suggestion that kerb and gutter be provided along Glenmurray Road to reduce flow depths during a flood.

5 HYDROLOGY

5.1 General

Design discharges were required at various locations throughout the Kangaroo Valley catchment for input into the hydraulic model to be used to investigate flood behaviour. The approach that has been adopted is to establish rainfall runoff models of the catchment as the primary tool for estimating discharges. The hydrologic model for Kangaroo Valley was calibrated using the stream flow gauge located on the Kangaroo River at Hampden Bridge. The calibrated model was used to estimate design discharges and the results verified against design discharges computed using flood frequency analysis.

Steps in the calibration process for Kangaroo River were:

- Establish a hydrologic model;
- Compute hydrographs for selected historical events;
- Adjust model parameters and vary the loss model until the computed hydrograph at Hampden Bridge matches the observed hydrograph;
- Compute design hydrographs for the 0.5%, 1%, 2%, 5%, 10% and 20% Annual Exceedance Probability (AEP[1]) flood events using design rainfall computed according to procedures outlined in Australian Rainfall and Runoff;
- Compare the design discharges computed from hydrologic modelling with the values determined from flood frequency analysis using data recorded at Hampden Bridge; and
- Adjust losses within the hydrologic model to arrive at a reasonable fit between the flood frequency curve and the flood hydrographs from the design rainfall.

5.2 Model Selection

There are a number of commercially available rainfall runoff models that could have been selected for hydrologic modelling. In this instance RAFTS-XP was selected. It is considered suitable for the study as it:

- models sub-catchment varied storms which are typical for the steep terrain in the study area;
- simulates storage within sub-catchments; and
- has been used extensively for similar catchments.

5.3 Kangaroo River RAFTS-XP Model

The Kangaroo Valley catchment was divided into 34 sub-catchments, as shown in Figure 5.1. Subcatchment boundaries were derived using 1:25 000 topographic maps. Eight dummy nodes were used in the model at the junction of tributaries. The characteristics of the subcatchments modelled are discussed below.

[1] Annual Exceedance Probability describes the probability of a flood of a given magnitude occurring in any given year. Hence, if the 1 in 100 flood has a magnitude of 300 m^3/s, then in any given year there is a 1 in 100 chance of a flood with a discharge exceeding 300 m^3/s.

Land use

The land within the catchment is predominantly forest. This type of land use/vegetation cover affects runoff by providing "resistance" to flow. The effect is simulated in RAFTS-XP by adjusting the storage delay coefficient using the parameter PERN. Suitable values for PERN were selected in accordance with the reference manual. The same value for PERN was adopted for all historical storm events. This would result in slightly more conservative estimates for earlier events, given that the catchment is more heavily forested than in the past. The values of PERN recommended in the manual, are given in Table 5.1. A value of 0.10 was used throughout the Kangaroo Valley catchment.

Table 5.1 – PERN Values

PERN	Description
0.015	Impervious Area
0.025	Urban Pervious Area
0.05 – 0.07	Rural Pastures
0.10	Forested Catchments

Slopes

The slopes within the sub-catchments range from mild to steep (0.5% to 28.5%). The slope affects the response time for runoff, with steeper slopes producing quicker responses to the watercourse.

To represent the effect of these slopes, RAFTS-XP uses a catchment average weighted slope derived from the maximum change in elevation over the longest flow path (reference should be made to the RAFTS-XP user manual for the derivation procedure). Topographic maps, with a 50 metre contour interval, were used to determine the catchment weighted slopes. The slope for each sub catchment is given in Table 5.2.

Impervious Areas

RAFTS-XP adjusts the storage delay coefficient according to the percentage of impervious area in a catchment. The impervious areas were estimated from aerial photographs. They were generally negligible, except in the township of Kangaroo Valley. The adopted values are shown in Table 5.2.

Base Flow

Base flow is the ongoing flow in a river that persists after rainfall has ceased and is derived from water seeping out of soil stores. Base flow varies as soil stores go through cycles of wet and dry. Base flow can represent a significant component of an observed hydrograph, depending on catchment soil conditions, topography and prior rainfall. Rainfall runoff models may or may not specifically simulate the base flow component of a hydrograph. RAFTS-XP has various options for accounting for soil losses. Where the Australian Representative Basins Module is adopted, then base flow is specifically computed. However, if a simple initial loss/continuing loss or initial loss/proportional loss module is adopted, then base flow is not computed. In the latter case, the base flow will need to be separated from the observed runoff, leaving only the surface runoff hydrograph, with calibration to be against the surface runoff hydrograph.

Investigation of the base flow shows to has an impact after peak flows occur. Therefore further consideration of base flow was determined irrelevant.

Channel Routing

RAFTS-XP software enables the routing of hydrographs between each sub-catchment by either:

- a Muskingum-Cunge routine that uses channel length, slope and cross section; or
- a simple translation by a fixed time period – hydrograph lagging.

The channel routing of the flows were modelled using a simplified methodology in the hydrologic model. This involved lagging the hydrographs by fixed time intervals between successive RAFTS-XP nodes. The channel routing was then later enhanced in the hydraulic model (i.e.MIKE11) due to its superior computational methods. The lag times that were input into RAFTS-XP are presented in Table 5.2.

Table 5.2 – Summary of RAFTS-XP Subcatchment Characteristics

Node Label	Area (Ha)	Slope (%)	Impervious (%)	B'	Downstream Lag (min)
KV_GG1	3040	5.0	0	2.26	2
KV_DB1	1282	13.0	0	0.91	0
KV_KR1	2907	7.0	0	1.87	35
KV_KR2	2058	11.0	0	1.23	36
KV_KR3	1537	7.8	0	1.27	35
KV_BG1	2431	7.4	0	1.66	32
KV_BG2	2008	9.8	0	1.30	45
KV_BG3	2322	8.8	0	1.48	23
KV_SY1	2246	5.7	0	1.81	24
KV_BG4	918	4.0	0	1.35	0
KV_KR4	1525	5.3	0	1.53	24
KV_KR5	622	3.6	0	1.17	0
KV_NG1	264	28.5	0	0.27	21
KV_NGTrib1	232	18.8	0	0.31	20
KV_NG2	554	8.3	8.7	0.50	9
KV_KR6	147	1.9	0	0.76	0
KV_CV1	46	17.4	2	0.1255	0
KV_KR7	23	4.9	4.2	0.151	0
KV_TTrib1	36	15.8	4.1	0.1061	0
KV_KR8	11	7.5	3.3	0.0835	0
KV_TTrib2	41	13.7	3.2	0.1261	0
KV_KR9	8	8	2.5	0.0728	0
KV_ML1	1054	2.9	0	1.722	22
KV_ML2	1554	13	0	1.009	22
KV_BY1	2991	6	1.2	1.938	47
KV_BY2	1786	4.9	0	1.726	19
KV_BY3	1000	2.3	0	1.852	12
KV_BY4	382	1.9	0	1.255	0

Node Label	Area (Ha)	Slope (%)	Impervious (%)	B’	Downstream Lag (min)
KV_KR10	214	0.5	0.9	1.687	0
KV_MG1	81	12.7	0	0.2156	0
KV_MGTrib1	39	17.4	0	0.1267	0
KV_MGTrib2	16	15.2	0	0.0848	0
KV_MG2	51	3.8	7.8	0.2227	0
KV_KR11	41	6.4	10.3	0.1382	0

Rainfall Losses

RAFTS-XP has two main methods for determining the losses from rainfall:

- Simplified approach, using an initial loss and continuing loss; or
- Australian Representatives Basin Model (ARBM) that considers the soil parameters and infiltration rates to the groundwater - reference should be made to the user manual for a detailed description of the parameters required for this method.

The simple initial loss/continuing loss model was adopted as it gave satisfactory results and is much simpler to apply. A background to the initial loss/ continuing loss model follows in order to justify varying the losses between events.

There are many processes involved in hydrology. Predicting runoff is fundamentally complex and each process when broken down into components is rarely the sum of the parts. That is one factor causing significant variation between events. However one trend that fundamentally occurs is that as the ground gets wetter the rate of infiltration into the ground is reduced. The exact shape is not known but the most appropriate loss model is generally an initial loss, continuing loss model that predicts a high level of losses initially and a lower loss-rate later. Mathematically this is done using initial loss (mm) and continuing loss (mm/h). Another major factor affecting the calibrations are the antecedent wetness at the start of he rainfall event.

The adopted parameters for five calibrated rainfall events (1975, 1978, 1990, 1999 and 2005) are shown in Table 5.3. For design events Australian Rainfall and Runoff (AR&R) recommends a value between 0 and 35 for initial loss and 1.0-2.5 for continuous loss.

Table 5.3 – Summary of Model Parameters used for Calibration

Event	Initial Loss (mm)	Continuing Loss (mm/hour)
1975	25	0
1978	90	0.5
1990	40	0
1999	145	3
2005	25	2.5

Catchment Storage

RAFTS-XP models catchment storage using a non-linear storage equation with “B” the linear

parameter and "n" the exponent.
$K(q)=Bq^{(n)}$

Where K(q) is the sub-area delay time (hours)as a function of q
q is discharge (m^3/s)
B is the storage delay time coefficient
n is the storage non-linear exponent

For each sub-catchment, the software determines a representative catchment storage parameter "B" based on area, slope and impervious percentage. The exponent "n" is specified by the user with a default value of –0.285 recommended for rural catchments. This default value was adopted throughout the catchment.

RAFTS estimates a default value for the coefficient B using the following equation:

$$B=0.285\ A^{0.52}(1+U)^{-1.97}Sc^{-0.5}$$

Where B is the mean value of coefficient B for the subcatchment
A is subcatchment area (km^2)
U is the fraction of the catchment that is urbanised
Sc is the main drainage slope of the subcatchments as a percentage.

The value of "B" can be modified individually for each subcatchment at the discretion of the user, or modified globally by a multiplying parameter ("Bx"). The global storage parameter "Bx" of 0.6 was adopted to achieve a representative level of storage for the Kangaroo River Catchment. This adjustment is usually necessary, where possible, as catchment characteristics are highly variable in different areas and normally vary from the default value of Bx=1 which is normally adopted for ungauged catchments. The resultant "B" values and other catchment data for each sub-catchment are given in Table 5.2.

Calibration

Calibration of the RAFTS rainfall-runoff model is an important component of flood investigations, as it ensures established models accurately represent the catchment responses during floods. Validation ensures the models are robust and can be reliably applied to a range of flood events.

The aim of calibration is to determine model parameters that represent a range of flood events. Calibration is a two stage process where, in the first stage, one or more major flood events are selected with sufficient data and model parameters are adjusted to match, within accepted limits, the model outputs with the recorded data. The second stage, validation, is checking the robustness of the model, by using the model with the same parameters with other events (not used in calibration) to ensure that the model is able to adequately represent these events.

To produce a robust and accurate model, events selected for calibration must ensure that:

- a number of events are selected of varying sizes;
- events represent different periods (separated by some days or weeks);
- there is sufficient stream flow data; and
- rainfall data reflects the temporal and spatial variation.

Subcatchment characteristics as in Table 5.2 and the global storage parameter (Bx) were not varied between events so as to reliably predict runoff behaviour in the design events. By achieving a consistent set of parameters in the calibration of historic events, using these parameters can reliably be adopted for the design events and hence for planning purposes. This is not withstanding the loss model which normally varies between events.

After examining available records, the following five events were used for calibration:

- June 1975;
- March 1978;
- August 1990;
- October 1999; and
- July 2005

These events were used in calibration as they had sufficient rainfall data and continuous river gauge records available. The largest recorded event in March 1975 was not used as it did not have stream gauge data available. Another significant flood event in June 1991 could not be used because there was insufficient rainfall and stream gauge data.

Rainfall Data

There are 23 daily read rainfall stations in or adjacent to the catchment and these were used to generate isohyetal maps for the 1975, 1978, 1990, 1999, 2005 events. These are presented in Figures 5.2 to 5.6. The spatial variation of rainfall for each sub-catchment was determined from the isopleths.

The temporal variation of rainfall events was modelled using the pluviograph stations listed in Table 5.4.

Table 5.4 – Available Pluviograph Records

Event	Station											
	568076	568078	568079	568081	568092	568128	568132	68117	561081	561124	568183	568184
1975	Yes	Yes	Yes	Yes	No	No	No	Yes	No	No	No	No
1978	No	No	Yes	No	No	Yes	No	Yes	No	No	No	No
1990	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	No
1999	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2005	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes

Streamflow Data

For calibration, gauging station 215 220 was used for all events.

Results

Modelled and recorded hydrographs for each event are presented in Figures 5.7 to 5.11. A summary of the results of the hydrologic model calibration, comparing observed flows to those modelled in RAFTS-XP, is provided in Table 5.5.

It can be seen from Figures 5.7 to 5.11 that the computed hydrographs match the shape of the observed hydrographs quite well. The computed peak discharges for all events except the 1978 event are within 10 percent of the observed peaks, while the difference in volume ranges from between 3.7 percent and 25 percent. The peak of the 1978 flood event differs by 21 percent, although the volumes are only 4 percent apart.

In general, the shapes of the hydrographs are comparable, and to a slightly lesser extent so are the discharge peaks for all events except the 1978 flood. This could be due to the rainfall data, which may not have fully represented the short-duration peak of the storm. The rainfall distribution in the rugged Kangaroo Valley catchment is highly spatially variable and there may have been localised areas of high intensity rainfall that were not covered by the gauges. This may also explain discrepancies between the other observed and modelled values.

Table 5.5 – Results for Calibration Events

	Peak Flow (m^3/s)			Volume of Surface Runoff (ML)		
Event	**Observed***	**Modelled**	**Difference**	**Observed***	**Modelled**	**Difference**
1975	2047	1950	-4.7%	107500	134400	25.0%
1978	1969	1536	-21.1%	182700	175800	-3.7%
1990	1468	1572	7.1%	130000	149700	15.2%
1999	1750+	1856	6.1%	+	39330	-
2005	997	1004	0.7%	36130	41890	15.9%

*Observed values taken at gauging station 215 220 (Hampden Bridge) and RAFTS-XP node KV-KR12

+Erroneous record for October 1999 event. Peak discharge calculated as discussed in section 4.2.2.

5.3.1 Design Floods

The calibrated model was used to estimate the 0.5%, 1%, 2%, 5%, 10% and 20% AEP flood discharges, by applying design rainfall intensities and temporal patterns computed using the procedures outlined in AR&R. Following AR&R procedures an areal reduction factor of 0.93 was adopted for the catchment. A non-uniform spatial pattern (based on the patterns within AR&R) was adopted for this particular catchment due to its steep topography. The Probable Maximum Precipitation (PMP) design event was estimated using the method outline by the Bureau of Meteorology (1994) “Estimation of Probable Maximum Precipitation in Australia; Generalised Short Duration Method” for durations up to 6 hours. For durations greater than 6hours the BOM’s “Generalised Southeast Australia Method” (GSAM) method was used.

The model was run for a range of storm durations and return periods in order to determine the critical duration. The critical duration for the Kangaroo Valley catchment was found to be 12 hours for all frequencies except the PMP event, where the critical duration was 3 hours. Note that these maximum design discharges are for the most downstream point considered in the study area, and the individual hydrographs may not necessarily be equivalent to the maximum design discharges for every other point in the catchment.

5.3.2 Flood Frequency Analysis and Verification

Flood frequency analysis was undertaken for the annual series of flood flows measured at Hampden Bridge for the years 1970 to 2003. The analysis fitted a log Pearson III distribution to the data, following the methodology in AR&R. A separate analysis was also undertaken which included the three major historic floods which occurred in the years 1870, 1898 and 1950. The flood frequency curves including the 5% and 95% confidence limits are shown in Figures 5.12 and 5.13 and in Table 5.6. The design discharges computed by the hydrologic model were adjusted to fit more closely to the line determined by frequency analysis. The frequency curve generated by inclusion of the three historical floods produced higher discharge estimates and was applied in preference to the frequency analysis without the historic records. A comparison of the flood frequency analysis results and those produced from RAFTS-XP is provided in Table 5.7.

It should be noted that the RAFTS model has been calibrated on relatively small floods and it is more appropriate for the results from the RAFTS model sub catchments to be input into a hydraulic model, which can account for the effects of flood plain storage. The MIKE 11 hydraulic model was selected for this purpose and a comparison with the flood frequency analysis is presented in Section 6.

The methodology for verifying the model results were as follows.

- Flood frequency analyses was ultimately used to verify peak flowrates from the MIKE11 hydraulic model against a statistical analysis of long term gauged flows in the frequency analysis;

- The calibration and verification of the RAFTS-XP models using the 5 events were used to determine storage and subcatchment characteristics for calculating full design hydrographs;

- The loss model was then iteratively adjusted in RAFTS-XP, entered into MIKE11 and the peak flows from MIKE11 compared with the Flood Frequency Curve for the Hampden Bridge gauging station;

- The results are shown in Figure 5.12 indicate a satisfactory verification of the RAFTS and MIKE11 models. Tables 5.7 presents the results from RAFTS modelling and Table 6.2 shows the MIKE11 results compared to flood frequency estimates.

Table 5.6 – Results from Flood Frequency Analysis

	With Historical Data			Without Historical Data		
AEP(%)	5% CL*	Quantile	95% CL	5% CL	Quantile	95% CL
80	405.65	534.59	676.82	202.2	296.9	441.0
50	734.9	923.96	1138.20	477.3	663.4	914.2
20	1251.06	1536.11	1895.43	976.6	1323.7	1768.5
10	1610.99	1973.63	2454.51	1306.6	1819.9	2473.8
5	1925.75	2408.94	3064.26	1563.5	2317.5	3416.3
2	2316.06	2990.23	4037.65	1810.7	2976.0	5065.0
1	2590.44	3437.44	5026.55	1933.4	3472.2	6773.8
0.5	2844.51	3892.33	6198.12	2010.6	3964.7	8908.3

* Confidence limit

Table 5.7 – Results from RAFTS-XP Modelling

AEP (%)	ARI (years)	Rainfall (mm)	Initial loss (mm)	Continuing loss (mm)	Critical storm duration (hrs)	RAFTS estimate (m^3/s)	Flood Frequency estimate (m^3/s)	$Q_{calc.}/Q_{flood\ freq.}$
20	5	189	90	2.5	12	1560	1400	111%
10	10	224	90	2.5	12	2275	2000	114%
5	20	269	100	2.5	12	2945	2500	118%
2	50	330	100	2.5	12	4230	3300	128%
1	100	384	100	2.5	12	5260	4050	130%
0.5	200	420	100	2.5	12	5915	4850	122%

6 HYDRAULICS

6.1 Model Selection

A hydraulic model was set-up for the Kangaroo Valley catchment. The MIKE 11 flood modelling software was chosen on the basis that:

- the model can connect the main stream and floodplains to simulate quasi 2-dimensional flow, storages and structures if necessary;
- the graphical interface enables the location of cross-sections and branches to be visualised;
- future development scenarios, such as changes to the floodplain, can easily be inserted into the model structure without extensive reconstruction of the overall model; and
- the model can simulate unsteady flows that vary with time.

MIKE 11 can model in-channel conveyance and storage, as well as structures such as culverts and bridges. Application of the software enables overtopping of channel banks onto floodplains and exchange of flows between floodrunners. It can be readily adjusted to model flood mitigation works that might be considered in the future Floodplain Risk Management Study.

Figure 6.1 shows the layout of the model used in Kangaroo Valley.

Consideration was given to utilising a two dimensional model, but the flow was considered to be essentially one dimensional and the hydraulic characteristics of road crossings were considered to be significant. Given that MIKE 11 is better able to represent the hydraulics at road crossings than a two dimensional model, it was selected as the most suitable option.

An independent model was also set up for Kangaroo River using HEC-RAS. This model was established to verify the performance of the MIKE 11 model. Backwater models such as HEC-RAS however were used to model steady state conditions where the peak flows were assessed. A MIKE 11 model on the other hand, can simulate dynamic unsteady flow conditions and can model the entire flow pattern.

6.2 Model Setup

The two primary channels modelled in the Kangaroo Valley catchment were Kangaroo River and Barrengarry Creek, however a number of other smaller tributaries were also modelled in this flood study. These are Myrtle Gully (Myrtle Tributary 1), Myrtle Tributary (Myrtle Tributaries 2 and 3), Town Tributaries 1,2 and 3, Caravan Park Creek (Jarretts Lane Creek) and Nugents Creek. These tributaries all join into Kangaroo River from the south, crossing Moss Vale Road at various points. In total, the MIKE 11 model set-up by SMEC was defined by 70 cross-sections, as shown in Figure 6.1.

The model was concentrated on the township of Kangaroo Valley, due to the extra detail required for structures, road crossings, obstructions and roughness variations. This is also the most relevant location for detailed information required for future development decisions. Most reaches were defined in the model as a single branch, apart from the floodrunner to the north of Kangaroo River at the township, which was modelled as a separate branch to the main channel, to more adequately model flow distributions. This branch is referred to as "KangarooOF" within this report.

The upper reaches of the Kangaroo River are relatively narrow although they still carry a relatively large flow that surcharge the banks. The river then begins to widen with a narrow incised main channel and wide flood plains to about chainage 5000. Towards the edge of the Kangaroo Valley township the river begins to narrow and the flow areas are reduced. This narrowing continues for the next five kilometres, resulting in a “bottleneck” to the flows in the Kangaroo River. This bottleneck in turn results in flood levels building up in the vicinity of the Kangaroo Valley Township. There is evidence to indicate that this bottleneck has improved following the 1974 floods which caused substantial changes to the channel form in the vicinity of the Township.

6.2.1 Model Integration

In addition to the MIKE 11 model produced by SMEC, another MIKE 11 model was developed by the Department of Commerce for the entire Tallowa Dam catchment. This model was integrated with the SMEC model to provide a combined model of the river system from the upper reaches of the Kangaroo River down to Tallowa Dam. A schematic diagram of the model as integrated is shown in Figure 6.2a-6.2b.

“The Tallowa Dam proposal was to raise the dam wall by 7m to have a Full Supply Level (FSL) of 63.34mAHD for all flows up to 11900 m3/s at Tallowa Dam (i.e 2%AEP event)” (SMEC, 2006). For larger events it was proposed to close the gates and allow the spillway to be fully operational. However the current study adopts the existing spillway for the Q-h relationship (i.e.discharge versus stage) at Tallowa Dam. This includes an invert level of 56.34mAHD for the spillway. The MIKE11 model in the study area upstream of Hampden Bridge was integrated with the Department of Commerce model downstream to help assess flooding in the area. Also a rigorous analysis of the dam wall and spillway was not undertaken in the present study that may look at a risk analysis with joint probability. Instead the study has focussed on the town of Kangaroo Valley upstream of Hampden Bridge.

The MIKE11 hydraulic model calibration was carried out using the floods of 1975, 1978, 1990, 1999 and 2005. Water level records were available at the SCA gauges at Hampden Bridge, Bendeela and at the Tallowa dam site and the process of calibration involved adjusting the roughness coefficients of the model to enable an accurate fit between the calculated and observed water levels at these locations. Following advice from the SCA the observed water levels at Hampden Bridge were adjusted to account for possible errors in the instrumentation during these events (Reference SCA.: Bob Craig personal communication 6th January 2006).

More detailed information regarding the proposed raising of Tallowa Dam can be found in the report prepared by SMEC for the Department of Commerce and Sydney Catchment Authority, titled *Kangaroo River – Tallowa Dam Flood Investigations*. For a sensitivity analysis of tailwaters, readers are referred to that study.

6.2.2 Cross Sections

The modelled cross sections draw on two data sets:

- Digital Terrain Model (DTM) from Shoalhaven Water; and
- Ground survey of the drainage structures (bridges, culverts, causeways, etc).

Roughness coefficients for each cross-section were determined on-site, through photographs, topographic maps and aerial photos. The procedure used for estimating channel and floodplain roughness coefficients was adopted from Arcement and Schneider (United States Geological Survey Water-Supply Paper 2339, http://www.fhwa.dot.gov/bridge/wsp2339.pdf). This method involved adopting a base roughness value based on soil type, and then applying adjustment factors based on factors such as vegetation, obstructions, irregularity and channel meander. These estimates were used as roughness parameters in locations where there were no available floodmarks for calibration. For areas where floodmarks were available, these estimates were used as a starting value, which could then be subsequently adjusted in order to provide a more accurate calibration.

Upstream of Hampden Bridge, the floodmarks were consistently higher than the modelled flood levels in the initial model runs. The roughness coefficients in this region were increased to match observed data, consistent with the dense vegetation and energy losses due to the constriction near the confluence of Kangaroo River and Barrengarry Creek. These changes were made in consultation with the Department of Natural Resources.

6.2.3 Boundary Conditions

The hydrographs generated by the hydrologic model are required as inputs into the hydraulic model. These include locations at selected cross sections throughout the model and at the upstream end of each branch. Refer to Figure 5.1 for the catchment map and Figures 6.1 for the cross-section locations.

The selection of downstream boundary conditions was an important consideration and has been sensitivity tested (refer to Section 6.4). A range of historical and design events have been run through the combined MIKE 11 model. For the historical events, a dynamic tailwater level was adopted based on the recorded levels at Tallowa Dam. For the design events, the stage-discharge rating curve of the existing Tallowa Dam spillway (as supplied by SCA) was adopted in the MIKE11 model. This is shown in Figure 5.14 and suggests that the maximum spillway level is at about 74mAHD. The peak tailwaters from these model runs are shown in Table 6.1.

Table 6.1 – Peak Tailwater Levels at Tallowa Dam

Frequency	Peak Discharge (m3/s)	TWL at Dam (m AHD)
20% AEP	3068	59.06
10% AEP	4542	59.83
5% AEP	5732	60.40
2% AEP	8109	61.39
1% AEP	10222	62.16
0.5% AEP	11572	62.62

6.2.4 Model Assumptions

A number of primarily conservative assumptions, as outlined below were made in the application of the calibrated model to the assessment of the impact of flood events in the Kangaroo Valley Township.

- Flood events in the Kangaroo River were assumed to coincide with flood events of the same frequency in the larger Shoalhaven catchment (including Kangaroo River) to Tallowa Dam. Thus if the Kangaroo River suffered a flood event with an AEP of 2%, it was assumed that the Tallowa Dam was coincidently being subject to the same event. However for the PMF the critical duration was determined as the 3 hour duration at Kangaroo Valley. As no 3 hour storm was available for the larger Tallowa Dam catchment, the 6 hour inflow was used for the region downstream of Hampden Bridge.

- The stage-discharge rating curve of Tallowa Dam's spillway was adopted for the tailwater conditions of design events. This relationship is shown in Figure 5.14

- Results of the RORB rainfall runoff modelling done by the SCA were accepted for conditions downstream of Hampden Bridge.

- All pipes and culverts, upstream of Hampden Bridge are assumed to be fifty percent blocked

6.3 Results

6.3.1 Historic Floods

The MIKE 11 model used in the study was calibrated to the same five historical events used in the calibration of the RAFTS-XP model. These were the 1975, 1978, 1990, 1999 and 2005 events. Water level calibration was applied to the 1975, 1990, and 1999 events as sufficient floodmark data was available. Flow calibration was applied to the 1978 and 2005 events. Floodmarks were sourced primarily from photographs showing water levels at identifiable locations. Information was also gleaned from discussions with local residents and landowners, community consultation surveys summarised in Section 4.3, discussions with Council representatives, and data from both the Bureau of Meteorology and Sydney Catchment Authority. General flood information sourced from these references includes:

- Debris accumulation against bridge piers, decks, fences, doors and chairs
- Water lines on concrete surfaces
- Flood photos showing water levels referenced to a known structure.

A large number of floodmarks were surveyed, however, only some of them could be tied to a date, and only a portion of these were actually located within the flood extents of Kangaroo River.

This information was used to verify the overall results for all calibration events. Given that the floodmarks for the 1999 event are more likely to be unchanged from the current situation, priority was given to those floodmarks during the calibration process. The majority of floodmarks were located in the town near the tennis courts, with some near the Friendly Inn Hotel.

The MIKE 11 model was run with the condition that all pipes and culverts modelled within the system were 50% blocked. This was done to reflect the real world situation where debris accumulates against structures reducing flow area. Model runs during the calibration process indicated that this condition resulted in water levels that more closely matched observed data.

There was no variation in the roughness coefficients between the events. Estimated flows from the RAFTS-XP model were used as inputs into the hydraulic model. The initial modelled water surface profiles were lower than the observed floodmarks upstream of Hampden bridge, due partly to low roughness parameters and partly due to the estimation of flows. The peak flows were adjusted by changing the infiltration losses, while the roughness parameters were increased.

For those events calibrated to floodmarks (1975, 1990 and 1999) the average difference between modelled and observed flood levels was_0.64m. The magnitude of this value can be explained by exceptionally large recorded water levels at two locations during the 1990 event (discussed in section 6.3.1.3). When these values are removed from the data set, the mean difference is 0.25m.

For the events calibrated by flows, the difference in the size of the peak for the 1978 event was 520m^3/s, while difference for the 2005 event was 86 cumecs. The 1978 event was well matched in terms of temporal pattern, while for the 2005 event the modelled hydrograph peak at about 7.5 hrs before the observed hydrograph. This indicates that the model responds more rapidly to this particular historic rainfall event, however given the results of the other events this was determined to be acceptable. Modelled (MIKE11) and observed hydrographs for these two events are presented in Part 1b of Appendix C.

As previously mentioned calibration to recorded values from the 1999 event was given greater priority given that it was a large event in recent times and general conditions within the channel were assumed to be closest to the present. The mean difference between recorded and modelled flood levels for this event is 0.18m and the maximum difference was 0.3m. These calibrated results were considered to be sufficiently accurate for the purposes of modelling design rainfall events. Flood levels for the historical events along the various reaches modelled are presented in Appendix A. Results of the calibration runs are illustrated in Part 1a of Appendix C.

6.3.1.1 June/July 2005 Event

The June/July event of 2005 displayed the lowest peak flow and volume generated of the five events used for calibration. As floodmarks weren't available for this event, the calibration of this event was based on gauged flows at Hampden Bridge.

The occurrence of the modelled and observed flow peaks matched very well, while the value of the peaks differed slightly. A possible reason for the non-match could be due to the misrepresentation of rainfall data as a result of available gauges not adequately accounting for the spatial variation of rainfall over the catchment. It was noted that the storm that generated this event was focussed south of Kangaroo River. Some intense rainfall however, would have also affected areas within the Kangaroo River catchment.

6.3.1.2 October 1999 Event

The rainfall event in October 1999 was of a relatively short duration, with the peak flow intermediate between the 1990 and 1978 events. The rainfall intensities were quite high, although the storage in the system upstream of Hampden Bridge attenuated the peak discharge in Kangaroo River.

The public provided photographs taken at the lookout just upstream of Hampden Bridge, some time after the flood peak had passed. The photographs showed the water level almost to the base of the viewing platform. Based on the statements made by the local residents, at this time Moss Vale Road near the tennis courts was impassable for vehicles for well over an hour.

The automatic gauge serviced by Sydney Water recorded water levels approximately 3 metres lower than the fixed metre gauges. It is not known how long before the flood event the automatic gauge had been faulty.

The water levels recorded by the gauge were discarded and have not been used for modelling. The peak discharge for this location was estimated using the creek stage-discharge curve for the water level based on photo evidence.

Water level profiles are given in Part 1a of Appendix C. The simulated profiles match closely at Hampden Bridge when compared to the stage-discharge relationship. From Hampden Bridge upstream, the modelled water levels matched observed levels to within 300mm.

6.3.1.3 August 1990 Event

The August 1990 event generated flows of similar volume to those of the 1975 event. Two floodmarks were available within the town, although they seem unusually high for the size of the event. The modelled peak flow matches the observed peak if there are no continuing infiltration losses throughout the event. The water level at Hampden Bridge is within 100mm of the observed gauge reading.

Water level profiles are given in Part 1a of Appendix C. The modelled level at Hampden Bridge is very close to both the gauge reading and the stage-discharge curve. However, the two floodmarks upstream near the town could not be matched, even with very large roughness values. The recorded levels of these marks are questionable, given that they are higher than the floodmarks in the much larger rainfall event in 1975. It is possible that they may refer to the event in 1991, which was the second largest recorded rainfall event in the catchment.

6.3.1.4 March 1978 Event

The largest overtopping of Tallowa Dam event was experienced in March 1978, and this event produced the largest volume of water on Kangaroo River at Hampden Bridge of the four calibration events. The observed peak flow was slightly less than the 1975 event. No floodmarks within the town were available for this event, so a flow based calibration was adopted.

6.3.1.5 June 1975 Event

June 1975 saw the largest peak flow at Hampden Bridge of the four calibration events considered. Two floodmarks have been recorded within the town, although their accuracy is questionable, given that they differ by 1.5m over only a 60m length.

The modelled peak discharge (1841m^3/s) did not match the recorded peak (2050m^3/s), even with zero infiltration loss. This indicates that there could be some rainfall data that does not fully represent the actual rainfall event. The water levels at Hampden Bridge correspond to the stage-discharge curve. If the peak flows were matched, there would have been a close match to the floodmark near CS4990. Nevertheless, the floodmarks in the town are matched to within 1.0m.

6.3.1.6 Summary of Historic Floods

Findings from the calibration of the hydraulic model are summarised as follows:

- Anecdotal evidence from past floods improved with the more recent events. Sparse and variable data typified the 1975 and 1978 events, while the 1990 event contained a more reliable set of data within the town. Floodmarks for the 2005 event were not obtained although reliable gauged flow data was available. Gauged flow data for the 1999 event was unreliable, meaning flow data had to be estimated from water level information.

- The distribution of rainfall will have had an impact on the calibration, given that the peak flows were often not precisely matched during the hydrologic calibration. Since the rainfall pattern seems to be spatially variable, even within the catchment itself, this will impact the relative size of flows for each creek or tributary. The missing peaks may have been due to some localised rainfall that was not picked up by the gauges in the catchment.
- Given the obstruction to flow due to trees and vegetation along the channel banks, as well as fences along the floodplain opposite the town of Kangaroo Valley, high roughness values were adopted to achieve reasonable calibration. Any changes to channel or overbank roughnesses could significantly impact the flood levels through the town.
- The effect of altered flow paths and reduced flow area through culverts and pipes due to debris accumulation was included by reducing the available flow area of these structures within the model by 50%.
- Modelled flood levels matched observed levels to between $\pm$0.25m.

Since the results from the calibration process represent observed flood behaviour closely, the hydraulic model is considered to be suitable for estimating design flood events.

6.3.2 Design Floods

The hydraulic model developed during calibration was run with the same geometric set-up for design conditions. Peak water levels and velocities are presented in Appendix B with water level profiles presented in Part 2 of Appendix C. Maps showing the flood extents, discharges and velocities, and flood contours are contained in Figures 6.3 to 6.17.

An examination of the water surface profiles suggest that a constriction just upstream of Hampden Bridge sets the pattern for water levels in the Kangaroo Valley township.

A comparison of the flood peaks generated by the MIKE11 model against the results of the flood frequency analysis is shown in Table 6.2 below. This indicates good agreement and has been presented as an indicator of model calibration to Hampden Bridge. The final result in MIKE11 produces a sufficiently accurate representation of the flood frequency curve over a range of flood events.

Table 6.2 –Peak Flows from MIKE11 modelling at Hampden Bridge

AEP (%)	Flood Frequency estimate (m^3/s)	MIKE11 estimate (m^3/s)	$Q_{calc.}/Q_{flood\ freq.}$
20	1400	1321	94%
10	2000	1805	90%
5	2500	2277	91%
2	3300	3049	92%
1	4050	3736	92%
0.5	4850	4184	86%

A summary of peak flood levels at different locations within the Kangaroo Valley township is presented in Table 6.3

Table 6.3 Peak Water Levels at Selected Locations

		Peak Water Levels (m.AHD)						
Branch Location	Chainage	PMF	0.5% AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Kangaroo River								
Friendly Inn Hotel	4269	83.41	77.95	77.13	75.81	74.12	73.58	72.33
Hampden Bridge	5948	81.31	75.22	74.37	72.98	71.19	69.79	68.04
Barrengarry Creek								
Upper River Road	212	83.36	77.83	76.99	75.61	74.04	72.54	70.96
Myrtle Tributary 1								
Mount Scanzi Road	125.7	88.47	87.91	87.91	87.73	87.49	86.69	86.16
Moss Vale Road	721.7	83.14	77.47	76.59	75.13	74.27	73.89	73.40
Jarretts Lane Creek								
Moss Vale Road	61	84.04	83.96	83.94	83.89	83.80	83.35	83.25
Nugents Creek								
Moss Vale Road	96	84.83	82.65	82.61	82.32	81.89	81.59	81.24
Town Tributary 1								
Moss Vale Road	46.5	83.35	77.82	76.98	75.61	74.76	74.59	-

6.4 Flood Behaviour

The main flow arrives from Kangaroo River with several minor inclusions from tributaries between Glenmurray Road and Hampden Bridge. The capability of MIKE11 to model unsteady flows that vary with time ensures that the model satisfactory simulates flood behaviour in the study area. Barrengarry Creek is the largest tributary to Kangaroo River in the study area joining just upstream of Hampden Bridge.

Most of the flows in the study area are not confined, with the exception of the area just downstream of Hampden Bridge where it narrows to be confined within the creek banks.

The floodmaps show the invert to the creek and its banks with the creek meandering on the way down the watercourse. However flood modelling has indicated that there is a minimal amount of conveyance capacity within these banks and flow essentially travels over the floodrunners. The model has been schematised with the separate branch “KangarooOF” between Kangaroo River and Barrengarry Creek where flows cross the watercourse taking a shortcut based on the appropriate hydraulics. In other areas the flow is essentially 1dimensional, even when the flow overtops the banks such as upstream of KangarooOF. Figures 6.3-6.7 show the flood extent maps and Figures 6.8-6.12 show the flow distributions for the PMF, 0.5%, 1%, 5%, and 20%AEP events. Note that even in the 20%AEP event flows overtop the banks and travel along KangarooOF. In the 1%AEP, 0.5%AEP and PMF this is more evident.

Provisional hazard maps based on depths and velocities are shown in Figures 7.1-7.3. These are presented for the PMF, 1%AEP, and 5%AEP events and are based on procedures in the NSW Floodplain Development Manual (see Sect7). Assessment of flood behaviour was also undertaken considering time of rise, maximum depths, distribution of flows, flow over roads, duration of flooding, depths of floods over roads, and velocity of flow over roads.

The time of rise to 1m depth for a number of locations from the upstream end of the MIKE11 model to Hampden Bridge are shown in Table 6.4 along with the maximum depth and the time it takes for the water levels to rise to the maximum depth after the initial increase. Note that in the 1%AEP event there is little response time available with the depth for the majority of cases rising to 1m in less than 1 hour. The average time of rise that was calculated was 0.6 hour. This leaves a minimal amount of time before the water levels rise to hazardous levels.

Also the water levels at along Kangaroo River reach a maximum depth in excess of 10m in a number of locations. Some of these include:

- sites near Glenmurray Road;
- at the junction of Kangaroo River and the floodrunner (Branch "KangarooOF");
- near the junction with Nugents Creek;
- near the junction with Trib3;
- at the junction of Kangaroo River and Myrtle Trib1;
- upstream of Hampden Bridge;
- downstream of the junction with Town Trib2; and

at Barrengarry Creek – Upper Kangaroo River Road.

-

Table 6.4 – Time of Rise 1%AEP Design Event

Branch	Chainage	Time of Rise to 1m depth (hours)	Max Depth (Time to max)	Description
Kangaroo River	0	0.4	13.2m (3.7hrs)	Near Glenmurray Rd
	2039	0.4	11.6m (4.1hrs)	Junction Kangaroo River & floodrunner
Kangaroo OF	385	0.3	4.3m (2.9hrs)	floodrunner
	1020	0.7	5.8m (2.9hrs)	floodrunner
	1415	0.3	7.7m (2.8hrs)	floodrunner
	1660	0.2	9.7m (3.0hrs)	floodrunner
Kangaroo River	3682	0.5	13.8m (4.1hrs)	-
	3446	0.4	13.5m (4.3hrs)	Near Junction with Nugents Ck
	4269	0.6	16.2m (4.5hrs)	Near Junction with Town Trib3
	5505	0.6	16.8m (4.7hrs)	Junction Kangaroo River & Myrtle Trib1
	5779	0.6	17.4m (4.6hrs)	Upstream of Hampden Bridge

Nugents Creek	0	0.4	3.7m (2.1hrs)	
	96	0.8	2.3m (2.3hrs)	Upstream of Moss Vale Rd
	1000	0.4	8.4m (3.9hrs)	
Jarretts Lane Creek	61	0.4	2.9m (1.8hrs)	Upstream of Moss Vale Rd
	400	2.5	3.2m (4.2hrs)	
Town Trib3	83	0.4	2.6m (2.0hrs)	Upstream of Moss Vale Rd
Town Trib2	41	0.5	4.3m (4.5hrs)	Upstream of Moss Vale Rd
Town Trib1	46.5	0.4	4.5m (4.6hrs)	Upstream of Moss Vale Rd
	200	1.0	11.4m (4.2hrs)	Downstream of Junction with Town Trib2
Myrtle Trib2	0	-	0.9m (2.3hrs)	
	64.5	0.7	2.2m (2.3hrs)	Upstream of Mount Scanzi Rd
Myrtle Trib3	0	2.0	1.1m (2.1hrs)	
	67	0.5	2.5m (2.1hrs)	Upstream of Mount Scanzi Rd
Myrtle Trib1	0	0.3	3.7m (2.0hrs)	
	126	0.4	3.4m (2.0hrs)	Upstream of Mount Scanzi Rd
	600	0.5	4.6m (4.5hrs)	Btwn Myrtle Trib2 & Kangaroo River
Barrengarry Creek	1	0.3	13.5m (5.0hrs)	Upper Kangaroo River Rd

Flood behaviour highlighting some properties of flow over structures are shown in Table 6.5. These properties include: the flowrate; duration of flooding; depth of flow; and peak velocity over road crossings for the 1%AEP event.

Moss Vale Road runs parallel to Kangaroo River for the majority of the study area until it crosses Kangaroo River at Hampden Bridge. This is shown in Figure 2.1 and in Table 6.5's results. In summary (**for Moss Vale Road**) Nugents Creek does not get overtopped in the 1%AEP event at the location of the road crossing, nor does Hampden Bridge. However at other creek crossings there is a relatively long duration of flooding at the Moss Vale Road crossings with most road crossings being out of service. Also the 1%AEP velocity at those sites are about 1 to 2 m/s. In the PMF event Hampden Bridge and Nugents Creek are submnerged with floodwaters.

It should be noted that flood mapping indicated that due to the configuration of the road at Nugents Creek crossing, it is possible that at the peak flows water would overflow towards the road low point located some 100m north-west from the road crossing, creating a water pond and a short duration inundation of the road crest of up to 200mm.

Table 6.5: 1%AEP Overtopping of Bridges and Culverts

Description	Overflow Threshold Elevation (mAHD)	Flow over road (m3/s)	Duration of flow over road (hours)	Depth of flow over road (m)	Velocity (m/s)	Branch	Chain-age (m)
Moss Vale Rd (at the road crossing)	83.31	-	0.0	0.00	0.0	Nugents Creek	96
Moss Vale Rd (at the road low point)	82.12	1.0*	0.50*	0.20*	0.25*	Nugents Creek	96
Moss Vale Rd	83.72	7.3	2.8	0.22	1.0	Jarretts Lane Creek	61
Moss Vale Rd	80.00	5.3	3.6	0.61	1.8	Town Trib3	83
Moss Vale Rd	75.66	1.7	3.9	1.32	1.1	Town Trib2	41
Moss Vale Rd	74.53	2.7	6.5	2.45	0.9	Town Trib1	46.5
Mount Scanzi Rd	88.33	0.0	0.0	0.00	0.0	Myrtle Trib2	64.5
Mount Scanzi Rd	87.40	0.5	0.3	0.09	0.6	Myrtle Trib3	67
Mount Scanzi Rd	87.32	7.7	2.3	0.59	1.7	Myrtle Trib1	125.7
Moss Vale Rd	73.97	16.4	6.5	2.62	1.6	Myrtle Trib1	721.7
Upper Kangaroo River Rd	74.50	-	4.9	2.49	-	Barrengarry Creek	212
Moss Vale Rd (Hampden Bridge)	77.30	0.0	0.0	0.00	0.0	Kangaroo River	5948

** Estimated (based on the overflow weir geometry and calculated water levels at the road centreline)*

Mount Scanzi Road crosses three creeks coming from the south and heading north on the way to Moss Vale Road. These creeks include Myrtle Trib's 1, 3, and 2. The maximum duration of flooding of these three creeks is 2.3 hours at Myrtle Trib1 with a velocity of 1.7m/s.

The maximum depth of flow over any road in Table 6.5 is at Myrtle Trib1 (Moss Vale Road) closely followed by Barrengarry Creek (Upper Kangaroo River Road) and Town Trib1 (Moss Vale Road).

KangarooOF, the floodrunner between Moss Vale Road and Upper Kangaroo River Road, conveys a significantly large quantity of flow for all events even in the 5%AEP event and has a relatively large depth of flow. Flows from Kangaroo River and KangarooOF cause a backwater up Barrengarry Creek. The flows from Barrengarry Creek also enter the system from the north with a peak discharge of 1020 m3/s in the 1%AEP event. Therefore Barrengarry Creek behaves as a floodway from its catchment while filling up a substantial volume of water as a storage area. This backwater can be seen in the flood extent and flood contour maps with the tailwater filling a significant amount of space in the PMF, 1% and 5%AEP events.

The PMF was used to assess possible evacuation sites during flooding. As was previously mentioned there is little time available for evacuation as the time of rise is small. However locations for evacuation include areas north of Kangaroo River where the terrain reaches a maximum height of 420 mAHD and south of Kangaroo River where the terrain reaches a maximum height of 340 mAHD. These areas are outside the PMF's flood extent. Approximate flood levels at these sites are 90mAHD and 85mAHD for the north and south areas respectively. However access to these locations may be difficult as the distances from various sites can be significant. Relative distances can be seen by noting the scale on the drawings. See Figure 6.18 showing the PMF with possible flood evacuation zones.

In summary peak water levels, depths, velocities, distribution of flow, duration of flooding, and the time of rise were used to assess flood behaviour. Several crossings such as the floodrunner between Moss Vale Road and Upper Kangaroo River Road, Kangaroo River, crossings at Moss Vale Road are considered to be of high hazard. Mount Scanzi Road is considered to be floodprone with a large period of time out of service. The modelling of Hampden Bridge indicated that the road level does not get overtopped in the 1%AEP event but would overflow with floodwaters in the PMF.

7 HYDRAULIC CATEGORISATION & PROVISIONAL HAZARD MAPPING

To achieve effective and responsible floodplain risk management, it is necessary to divide the floodplain into areas that reflect, first, the impact of development activity on flood behaviour, and second, the impact of flooding on development and people. Division of flood prone land on these two bases is referred to as 'hydraulic categories' and 'hazard categories'.

The NSW Floodplain Development Manual recognises three hydraulic categories of flood prone land – floodway, flood storage and flood fringe – and two hazard categories – low hazard and high hazard. Division of the floodplain on the basis of these two effects produces the following six categories of flood prone land:

- Low Hazard Flood Fringe
- Low Hazard Flood Storage
- Low Hazard Floodway
- High Hazard Flood Fringe
- High Hazard Flood Storage
- High Hazard Floodway

These categories form the basis for land management and development control.

Council has indicated that the hydraulic categorisation and assessment of the provisional flood hazards needs to be undertaken for the following three events:

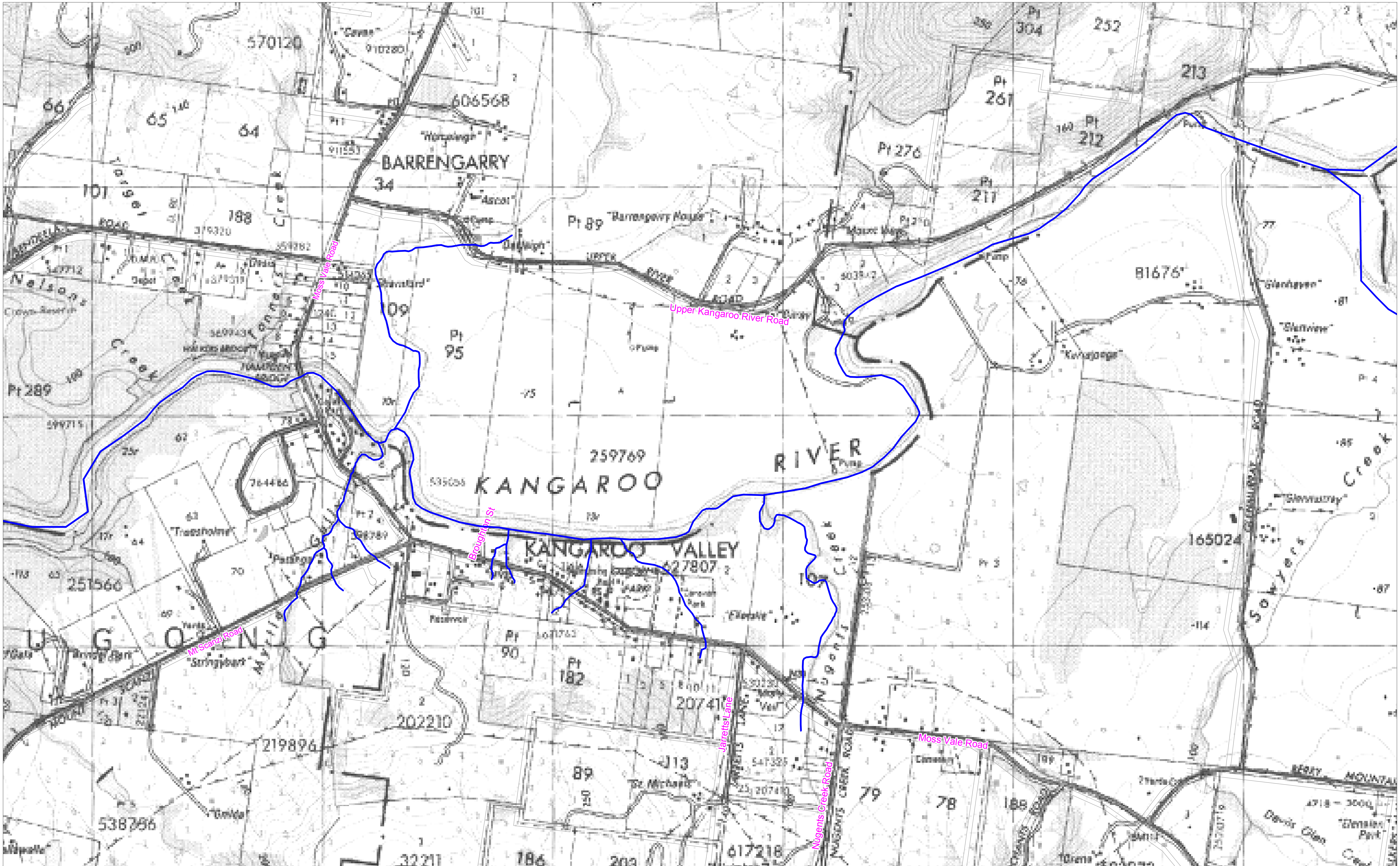
- 5% AEP – for use in planning in industrial areas
- 1% AEP – for use in planning in residential areas
- PMF – for emergency planning

The definition of hydraulic categories and assessment of provisional flood hazards was done in accordance with *NSW Floodplain Development Manual 2005*. The maps are shown in Figures 7.1-7.3. Refer to Sect 9.4 for more detailed information on flood behaviour.

8 FINDINGS

The figures in this section show GIS maps, contour plans, flow distributions and velocities, and hazard maps. Additional results shown in tables and flood profiles are in the Appendices. Note: All maps shown in this report are indicative only.

FIGURES



LEGEND

Kangaroo River and associated streams

Roads

0 500 1,000

Meters

N

Figure 2.1 - Study Area: Kangaroo Valley Town Map

SMEC

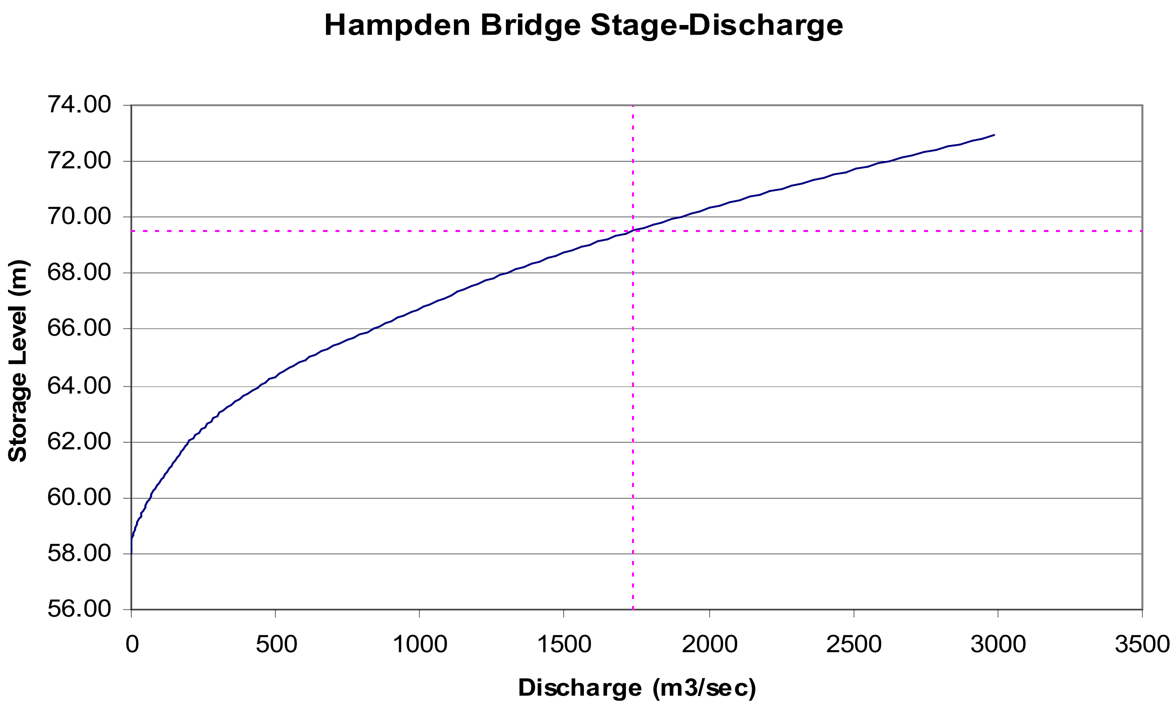
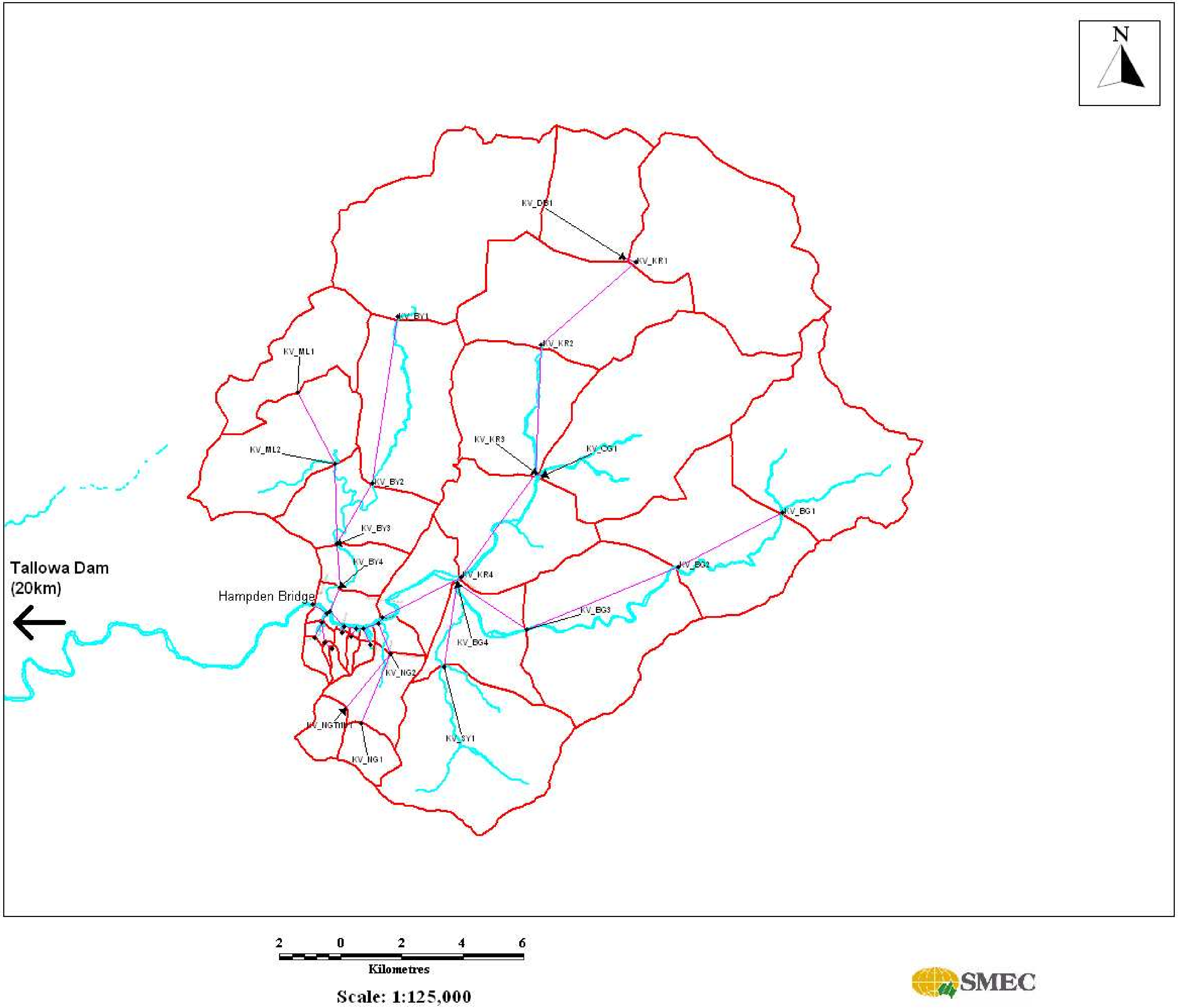


Figure 4.1 – Hampden Bridge Rating Curve



Legend

Subcatchment Boundary

Watercourse

Figure 5.1

Kangaroo Valley Catchment
RAFTS-XP Subcatchment Layout

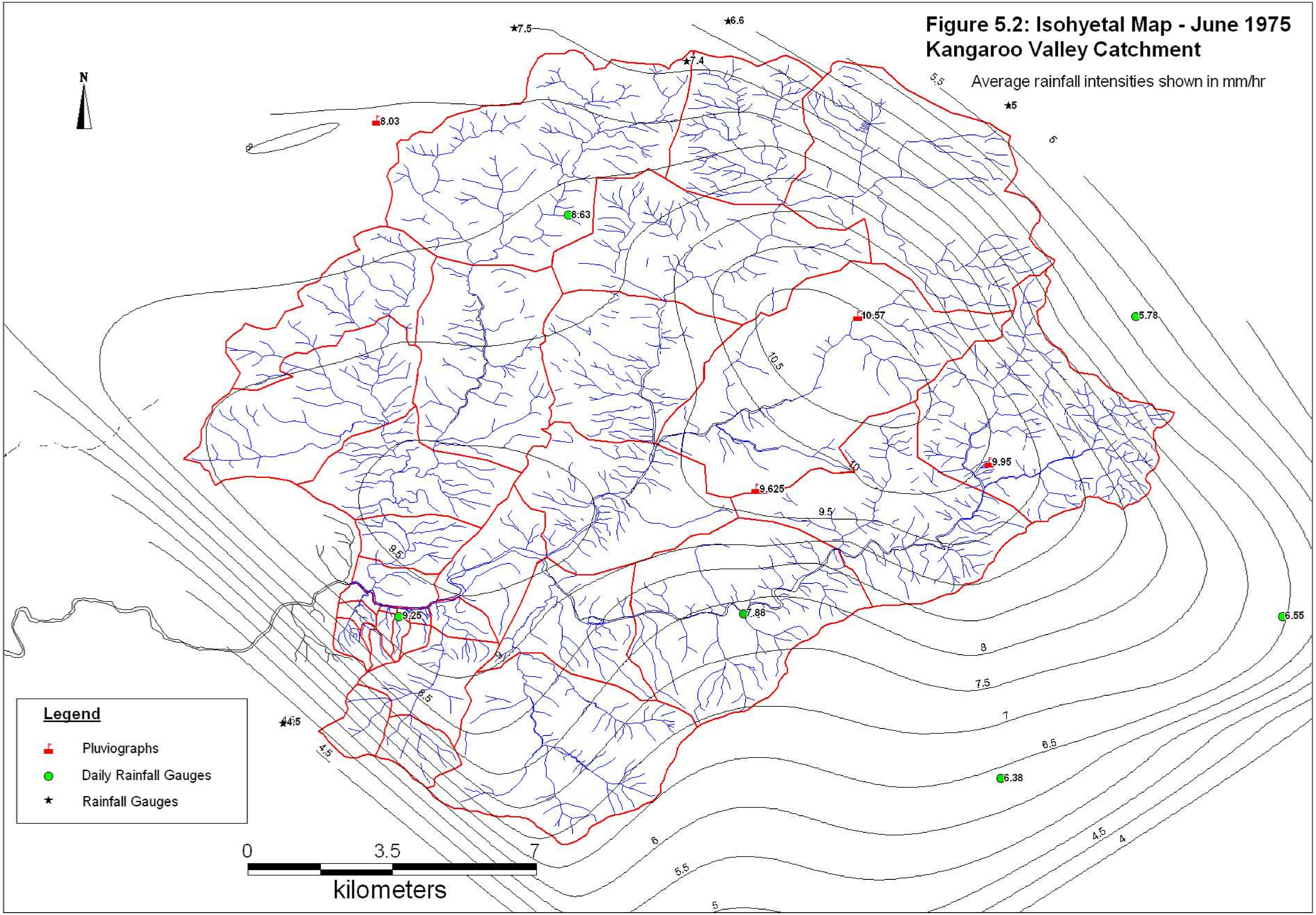


Figure 5.2: Isohyetal Map - June 1975
Kangaroo Valley Catchment
Average rainfall intensities shown in mm/hr
N
Legend
Pluviographs
Daily Rainfall Gauges
Rainfall Gauges
0
3.5
7
kilometers
7.5
6.6
7.4
5
8.03
8.63
10.57
5.78
10.5
10
9.95
9.625
9.5
9.25
7.88
6.55
6.38
4.5
8
7.5
7
6.5
6
5.5
5
4

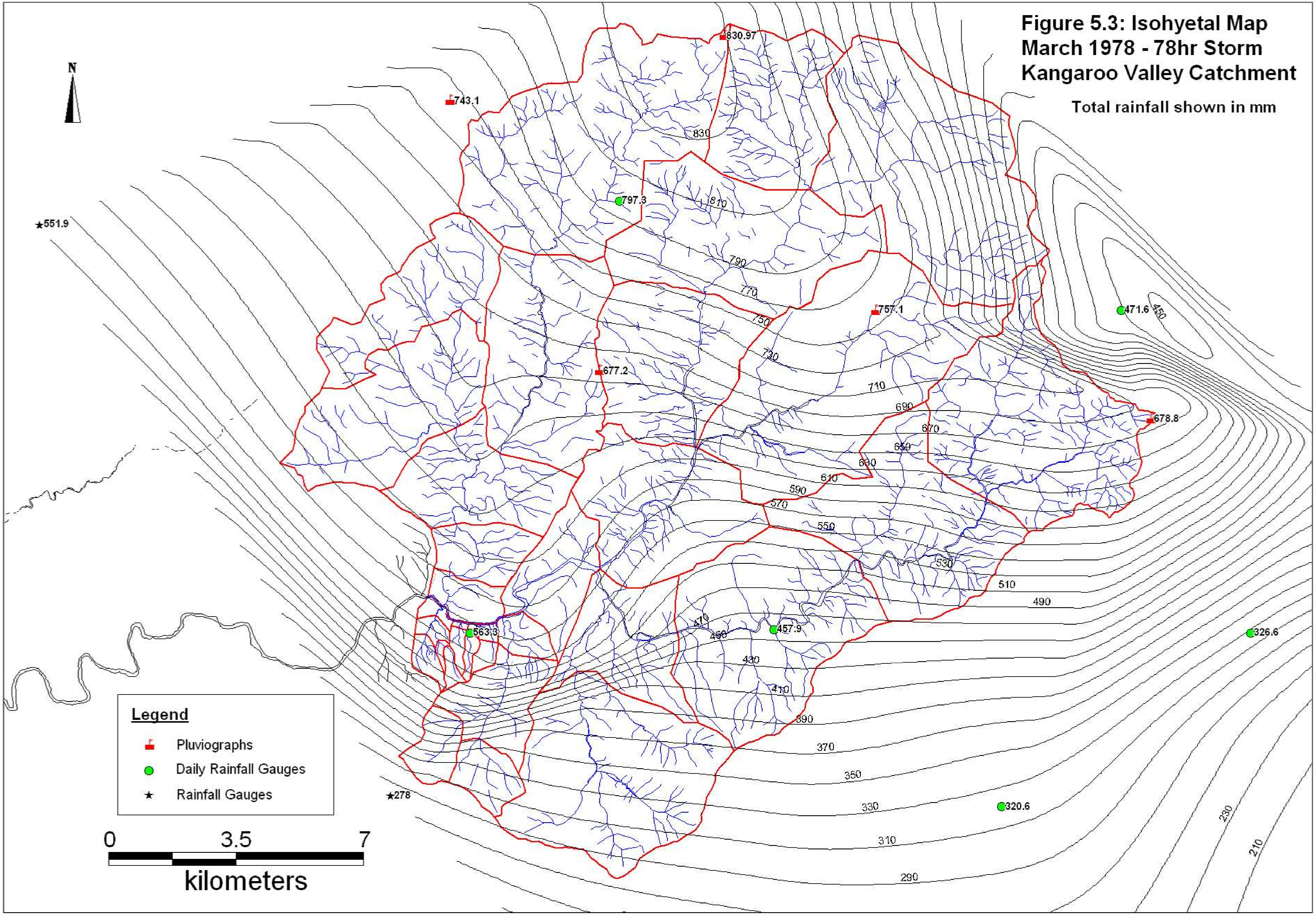


Figure 5.3: Isohyetal Map
March 1978 - 78hr Storm
Kangaroo Valley Catchment
Total rainfall shown in mm
N
830.97
743.1
830
797.3
810
551.9
790
770
750
757.1
471.6
450
730
677.2
710
690
678.8
670
650
630
610
590
570
550
530
510
490
470
450
457.9
563.3
326.6
430
410
390
370
350
330
320.6
310
290
230
210
278
Legend
Pluviographs
Daily Rainfall Gauges
Rainfall Gauges
0
3.5
7
kilometers

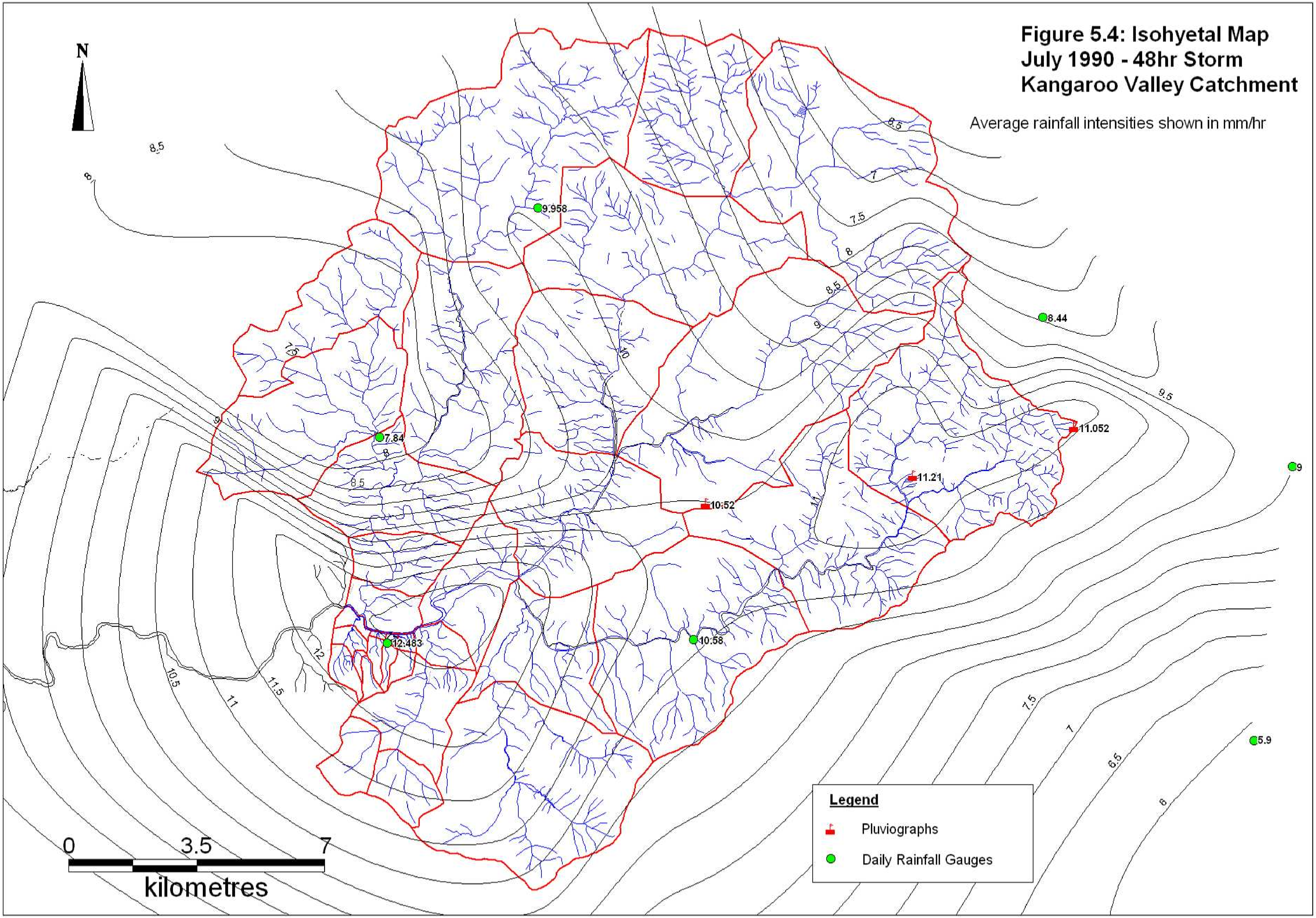


Figure 5.4: Isohyetal Map
July 1990 - 48hr Storm
Kangaroo Valley Catchment
Average rainfall intensities shown in mm/hr
N
9.958
8.44
7.84
11.052
11.21
10.52
9
12.483
10.58
5.9
Legend
Pluviographs
Daily Rainfall Gauges
0
3.5
7
kilometres

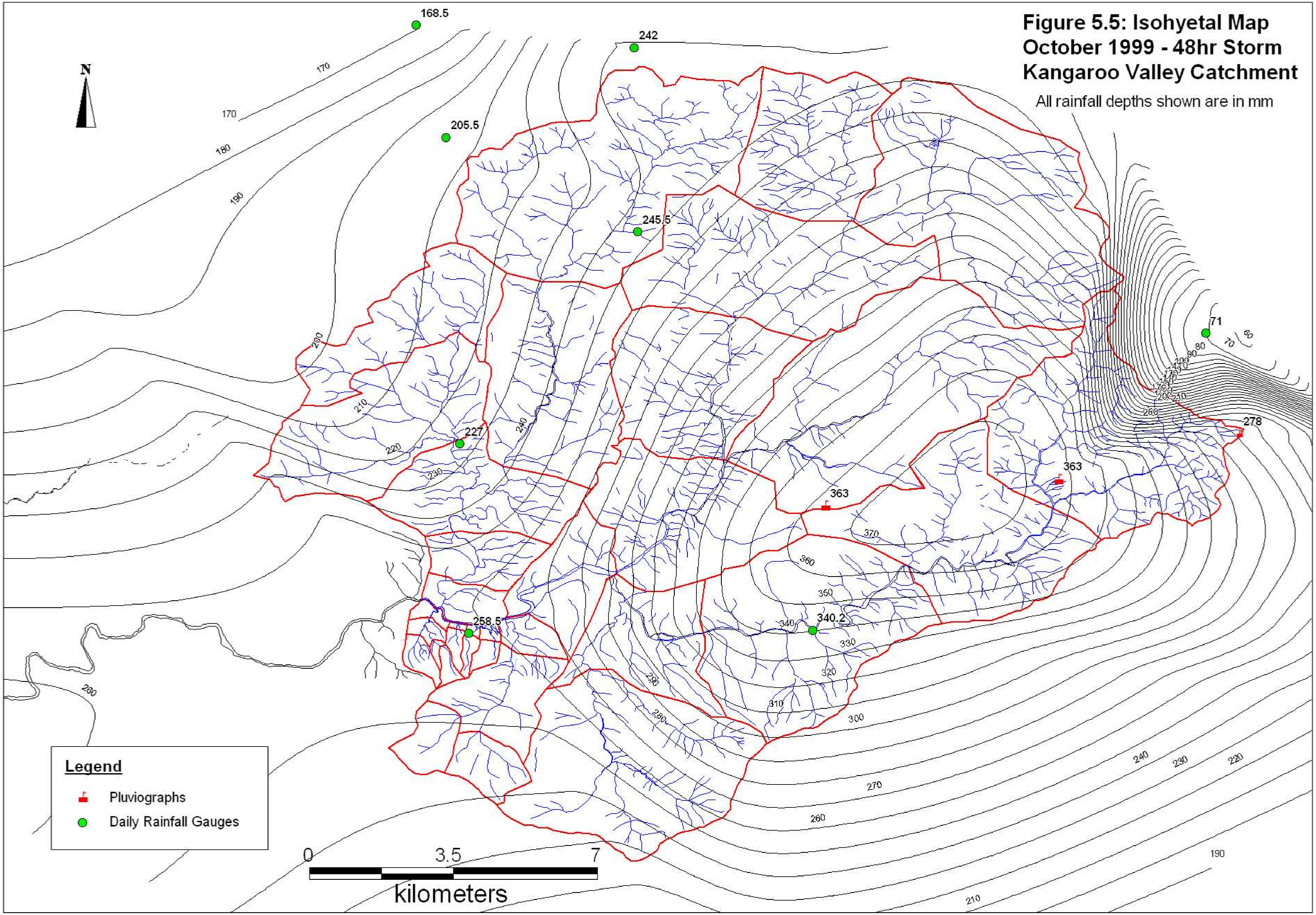


Figure 5.5: Isohyetal Map October 1999 - 48hr Storm Kangaroo Valley Catchment

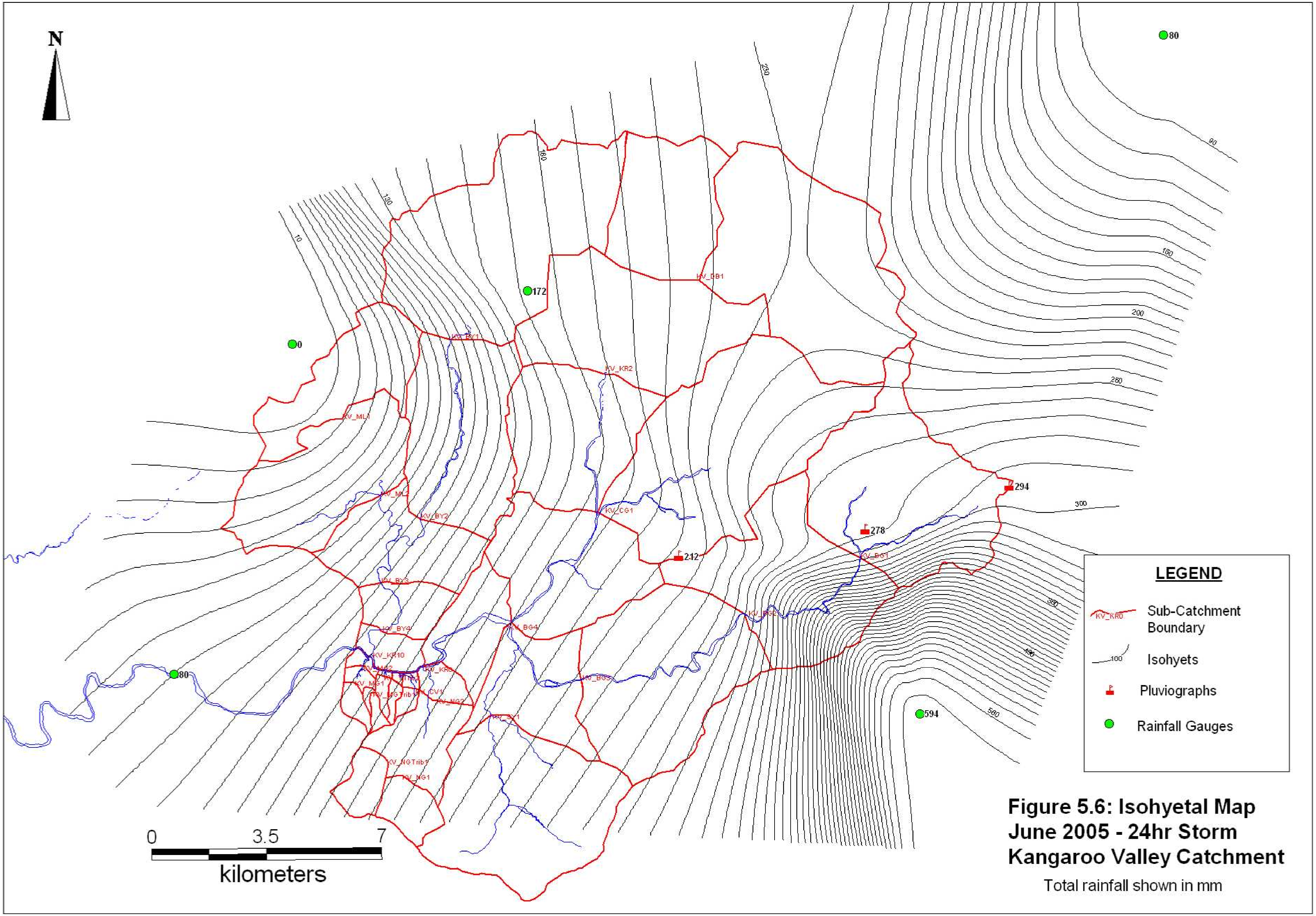


Figure 5.6: Isohyetal Map June 2005 - 24hr Storm Kangaroo Valley Catchment

Total rainfall shown in mm

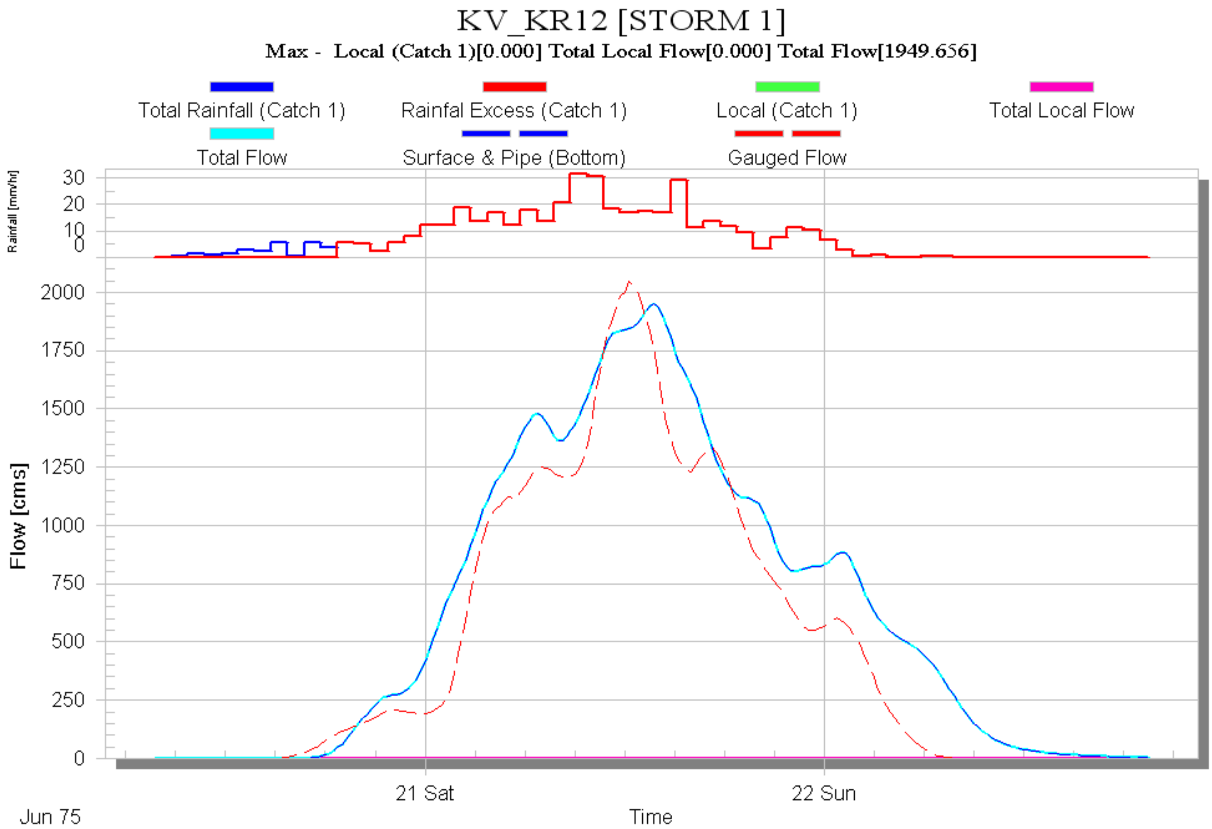


Figure 5.7 – 1975 Event – Modelled vs Gauged Hydrographs

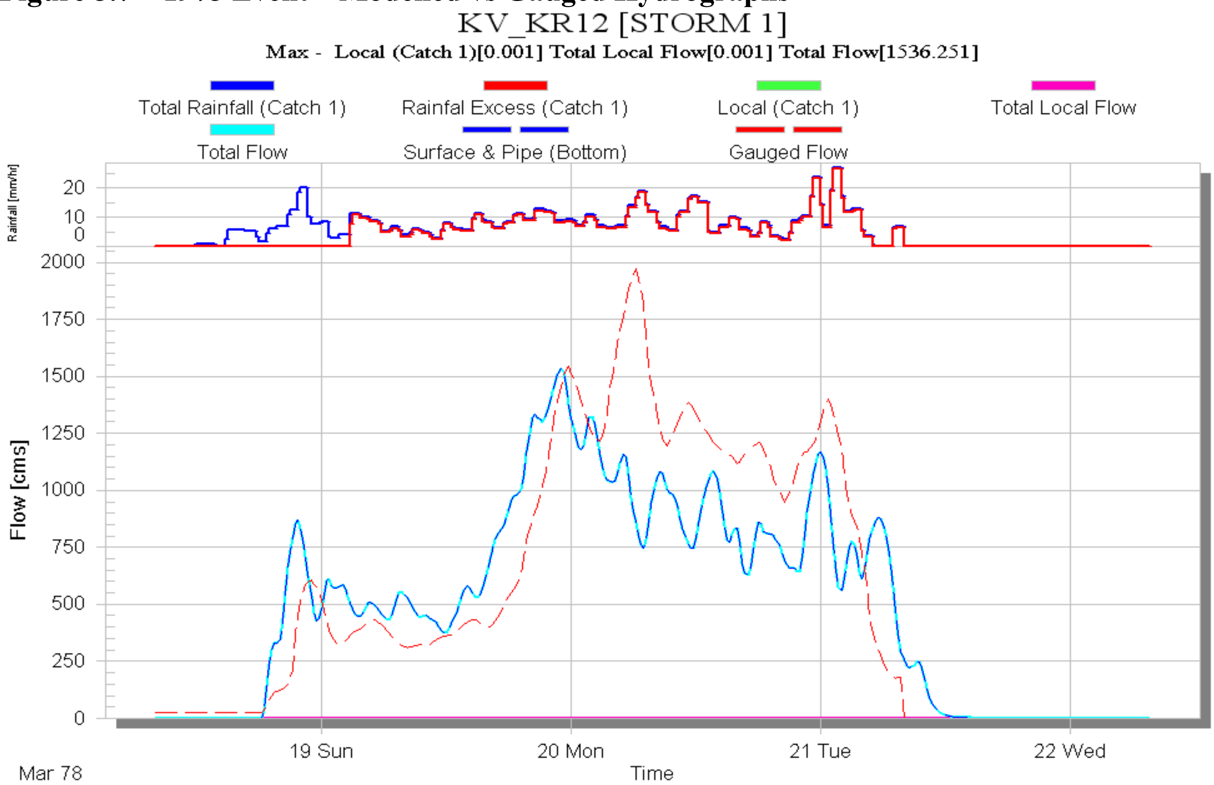


Figure 5.8 – 1978 Event – Modelled vs Gauged Hydrographs

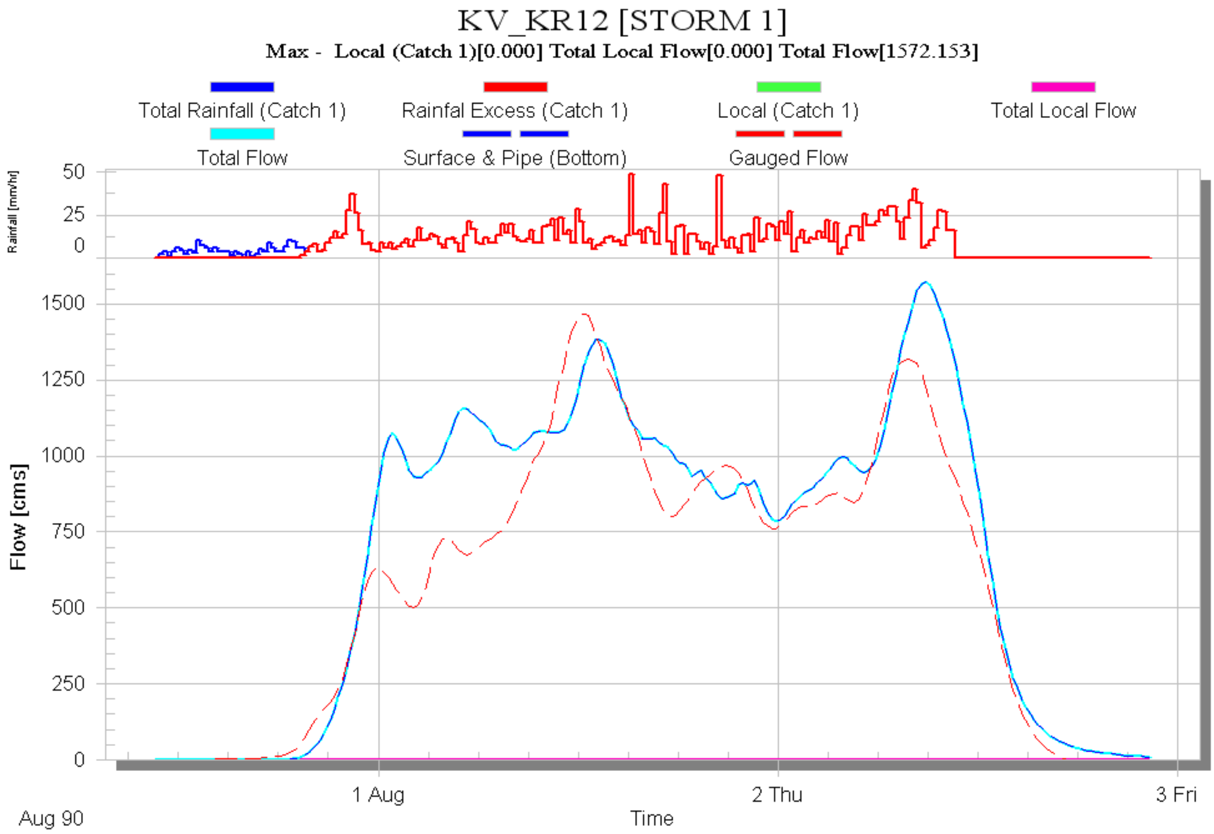


Figure 5.9 – 1990 Event – Modelled vs Gauged Hydrographs

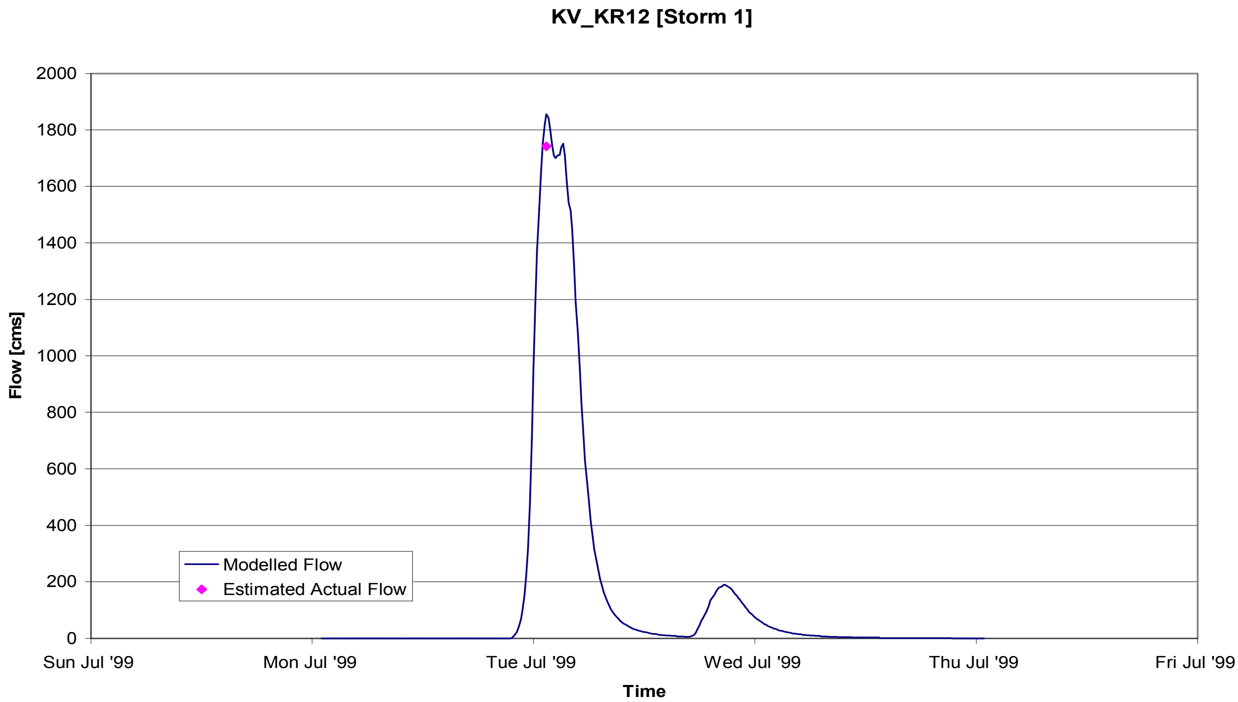


Figure 5.10 – 1999 Event – Modelled vs Gauged Hydrographs

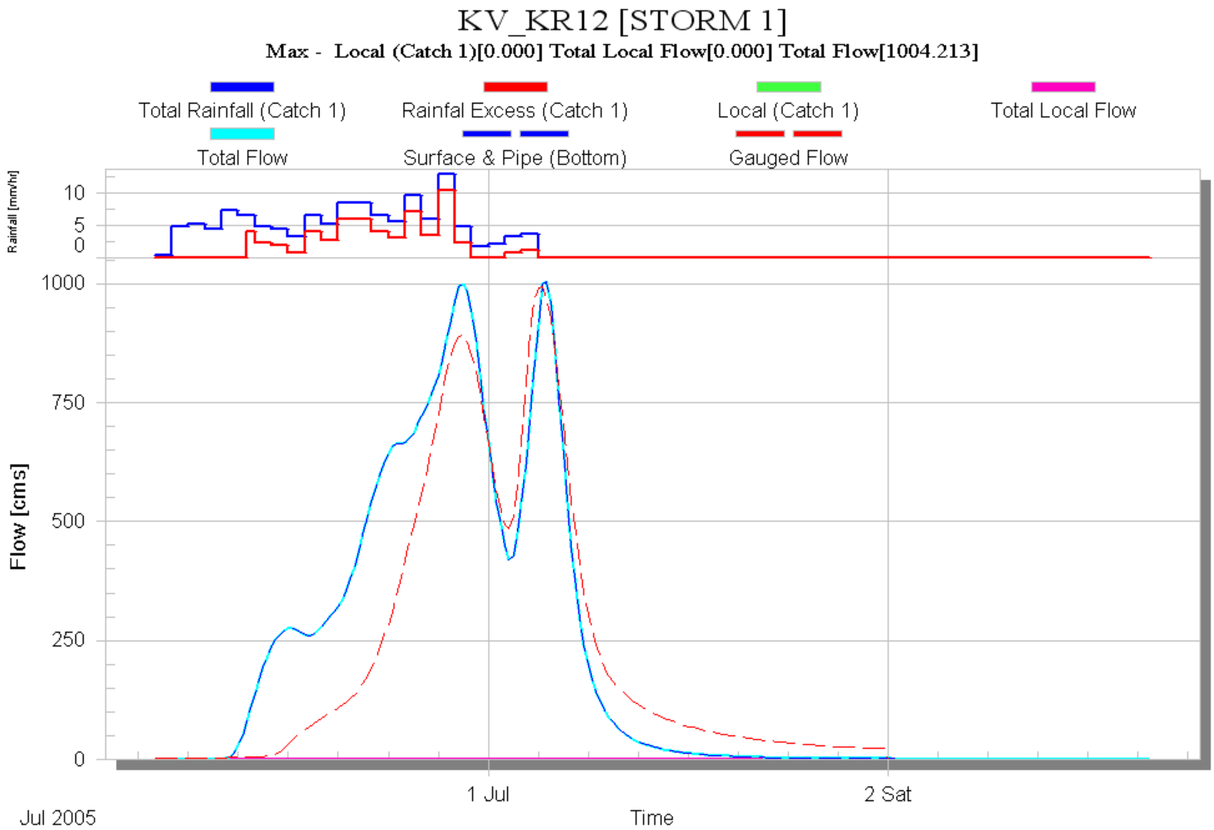


Figure 5.11 – 2005 Event – Modelled vs Gauged Hydrographs

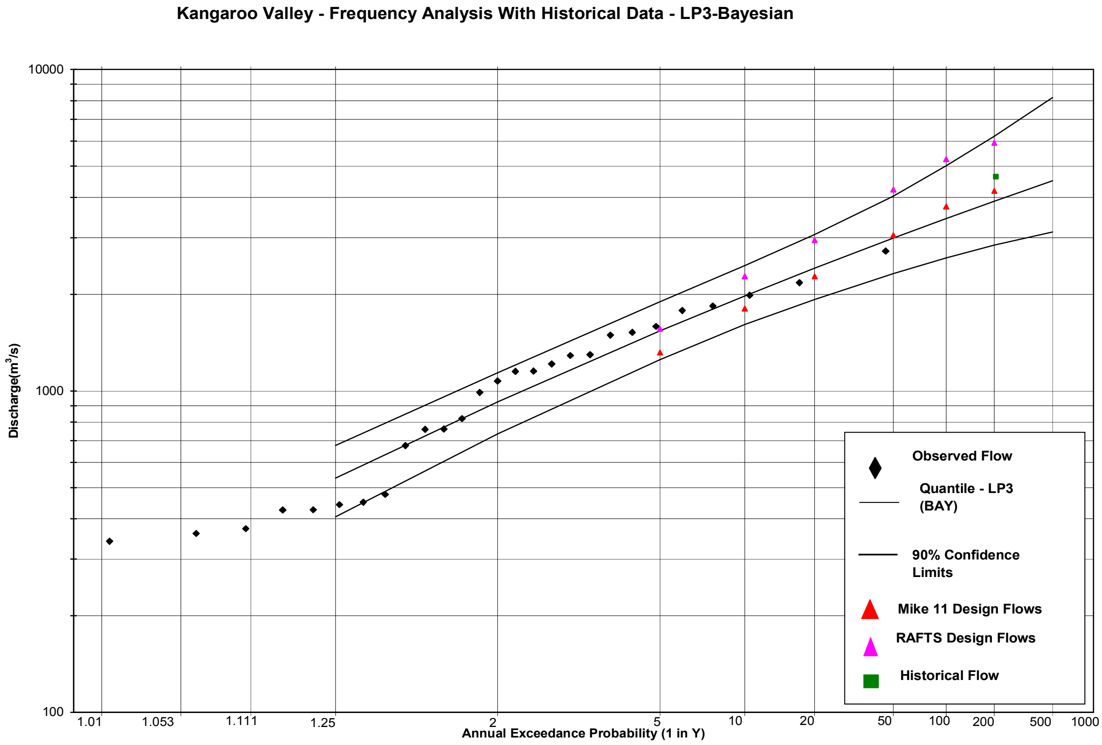


Figure 5.12 – Flood Frequency Analysis with Historical Data

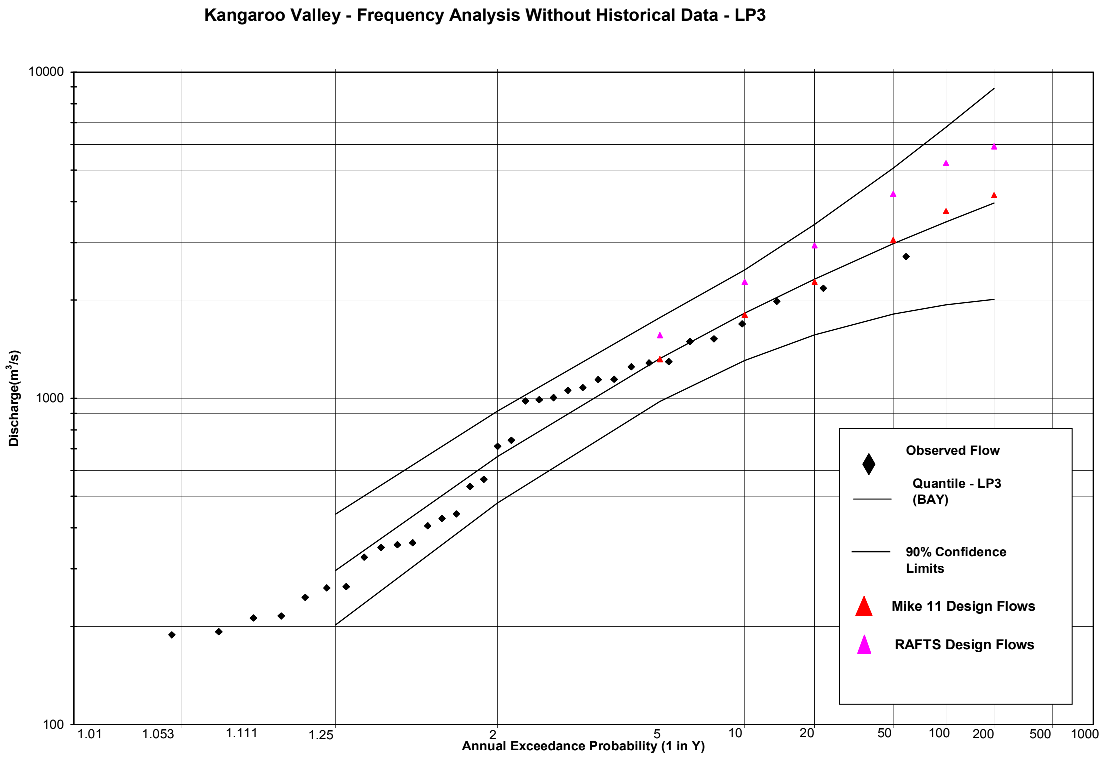


Figure 5.13 – Flood Frequency Analysis without Historical Data

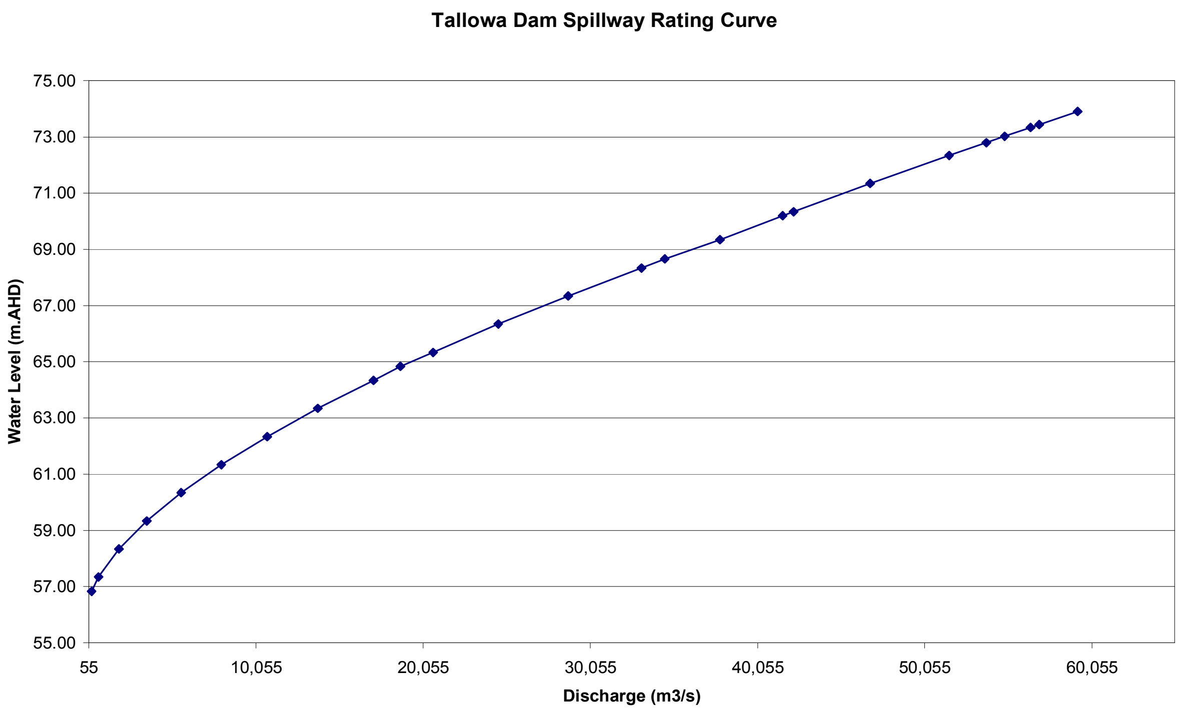
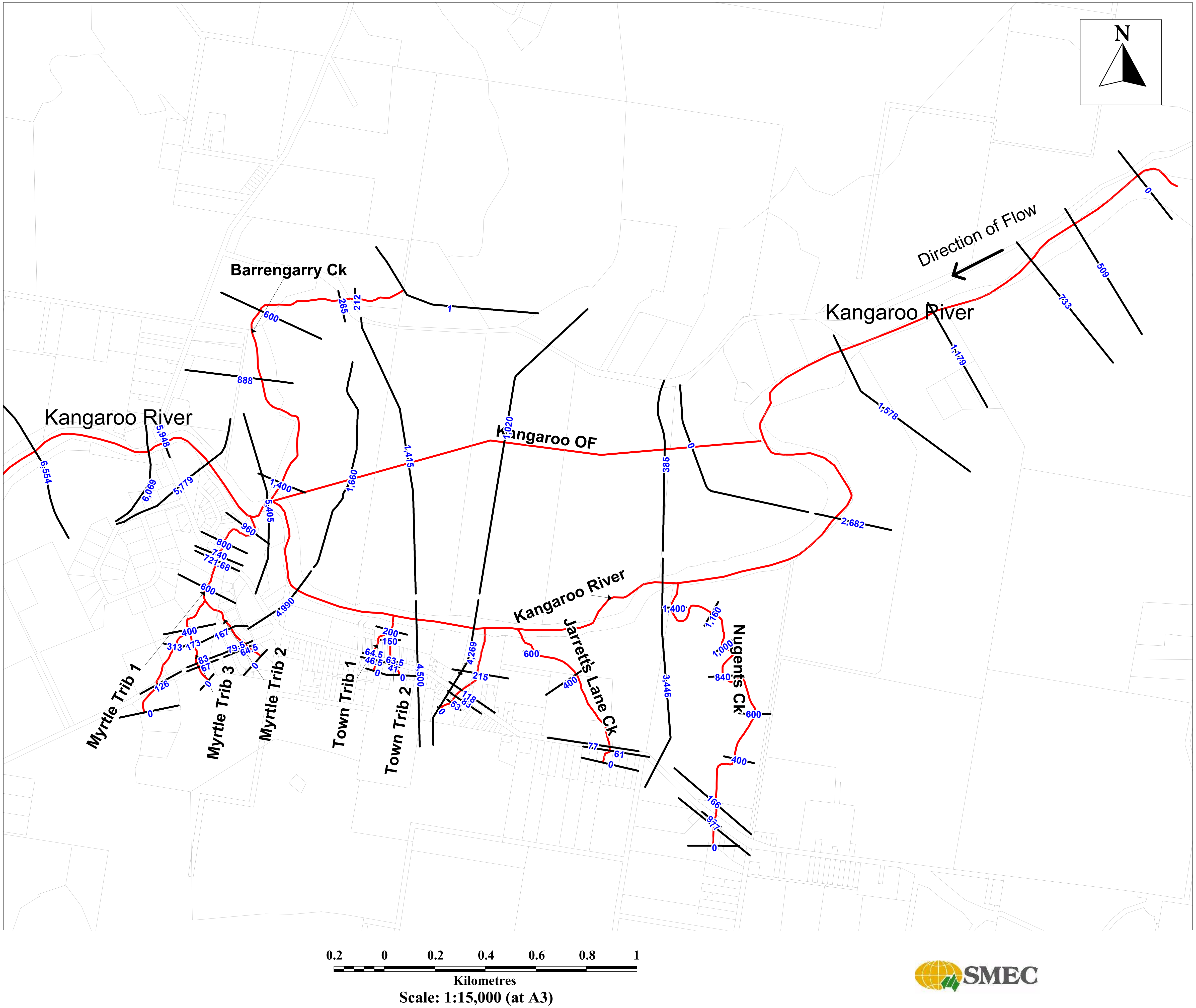


Figure 5.14 – Tallowa Dam Rating Curve



Legend

Properties

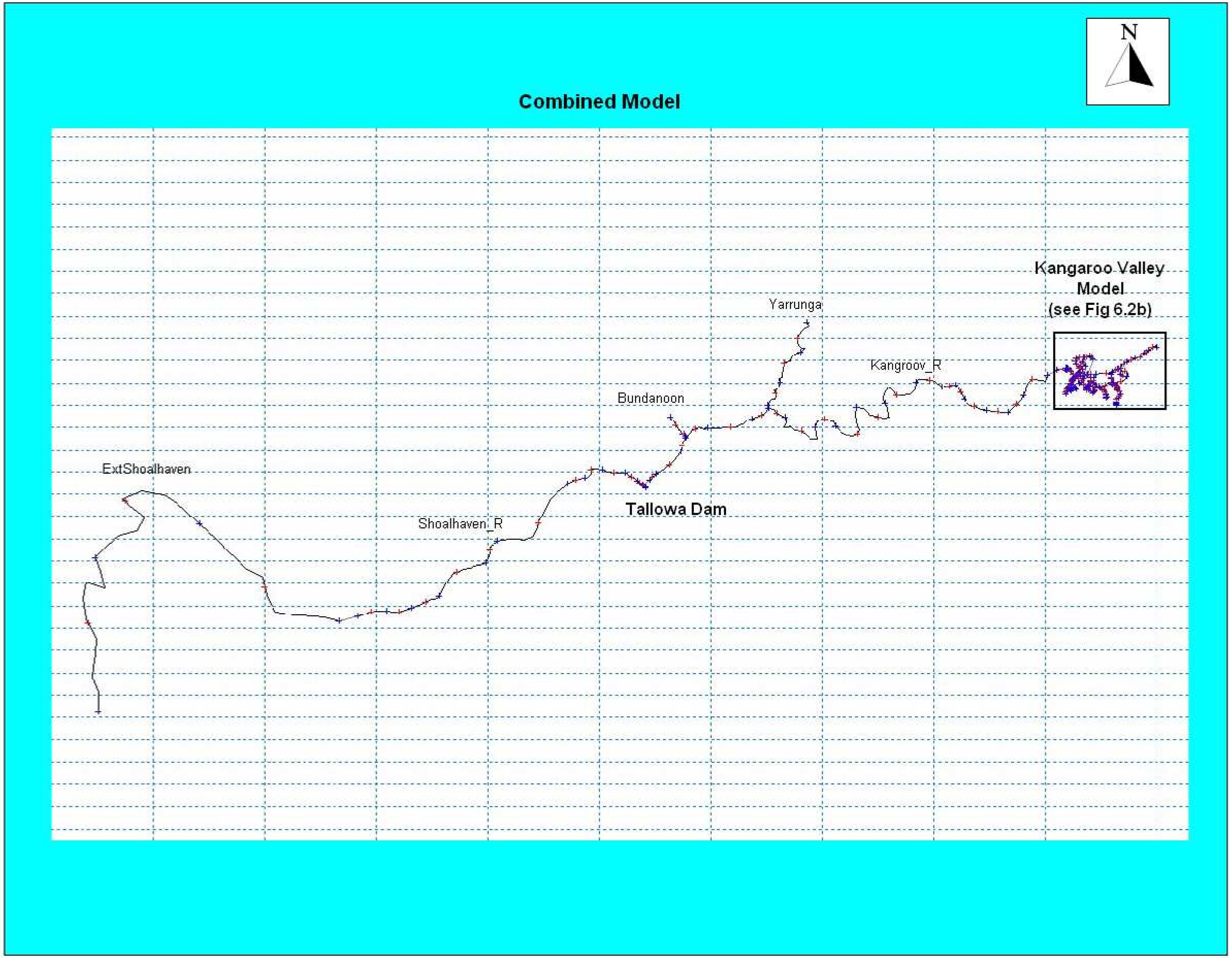
MIKE11 Cross Section

733 Chainage

Figure 6.1

Kangaroo Valley Catchment
MIKE11 Model Layout
Within Study Area

SMEC



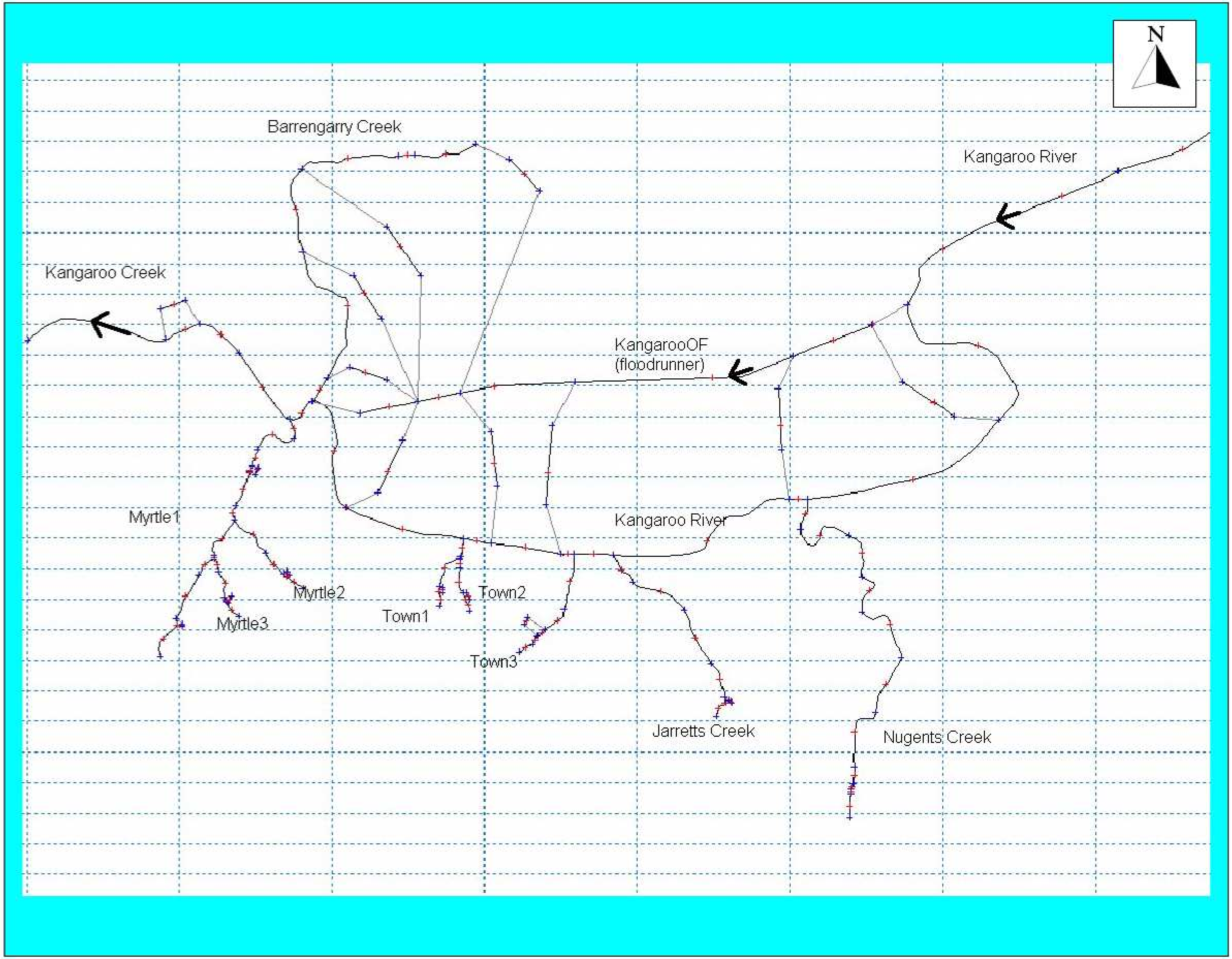
Legend

MIKE11 Branch

Figure 6.2a

Kangaroo Valley Catchment
Schematic of MIKE11 model
Overall View

SMEC



Legend

MIKE11 Branch

Figure 6.2b

Kangaroo Valley Catchment
Schematic of MIKE11 model
within Study Area

SMEC

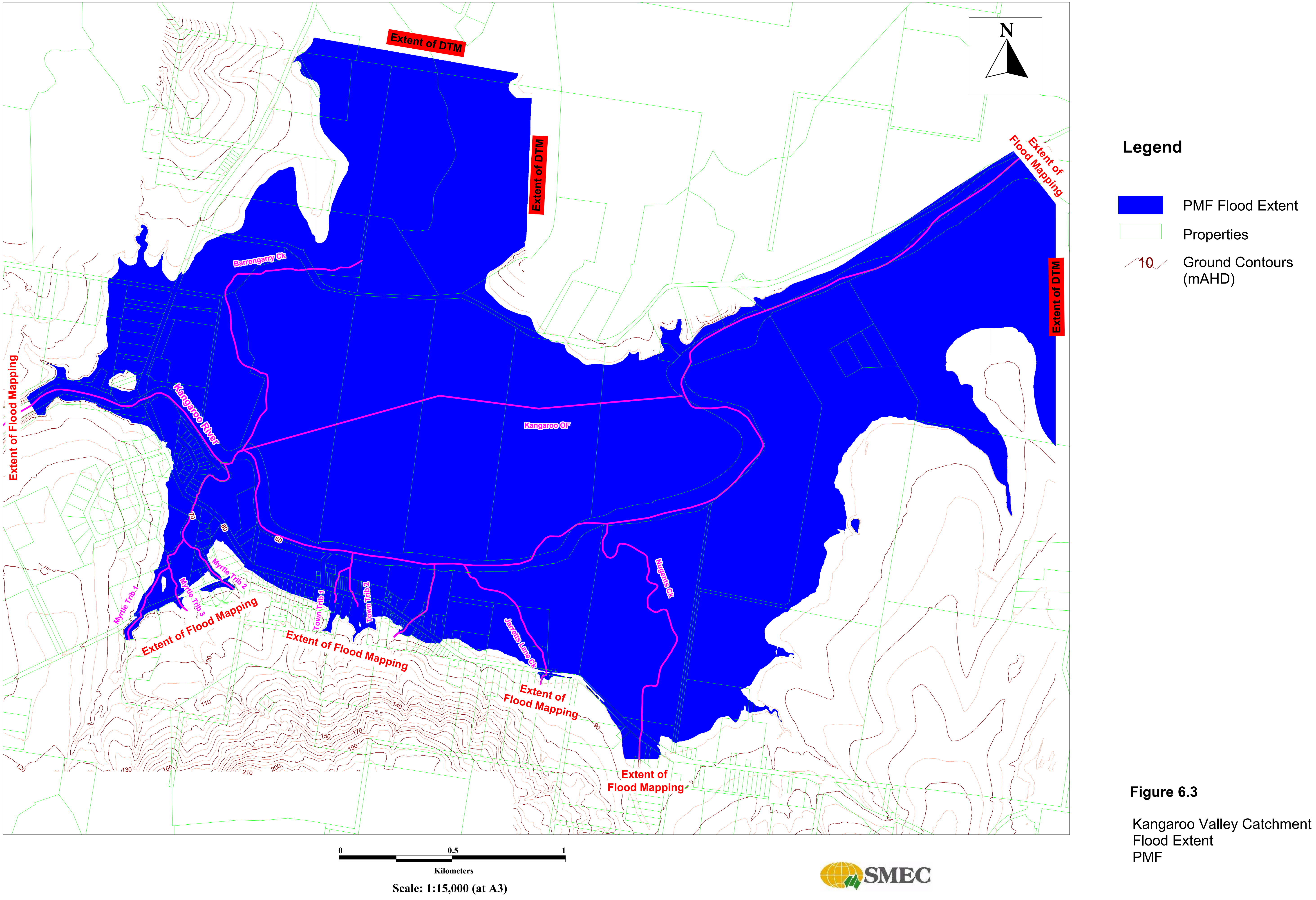
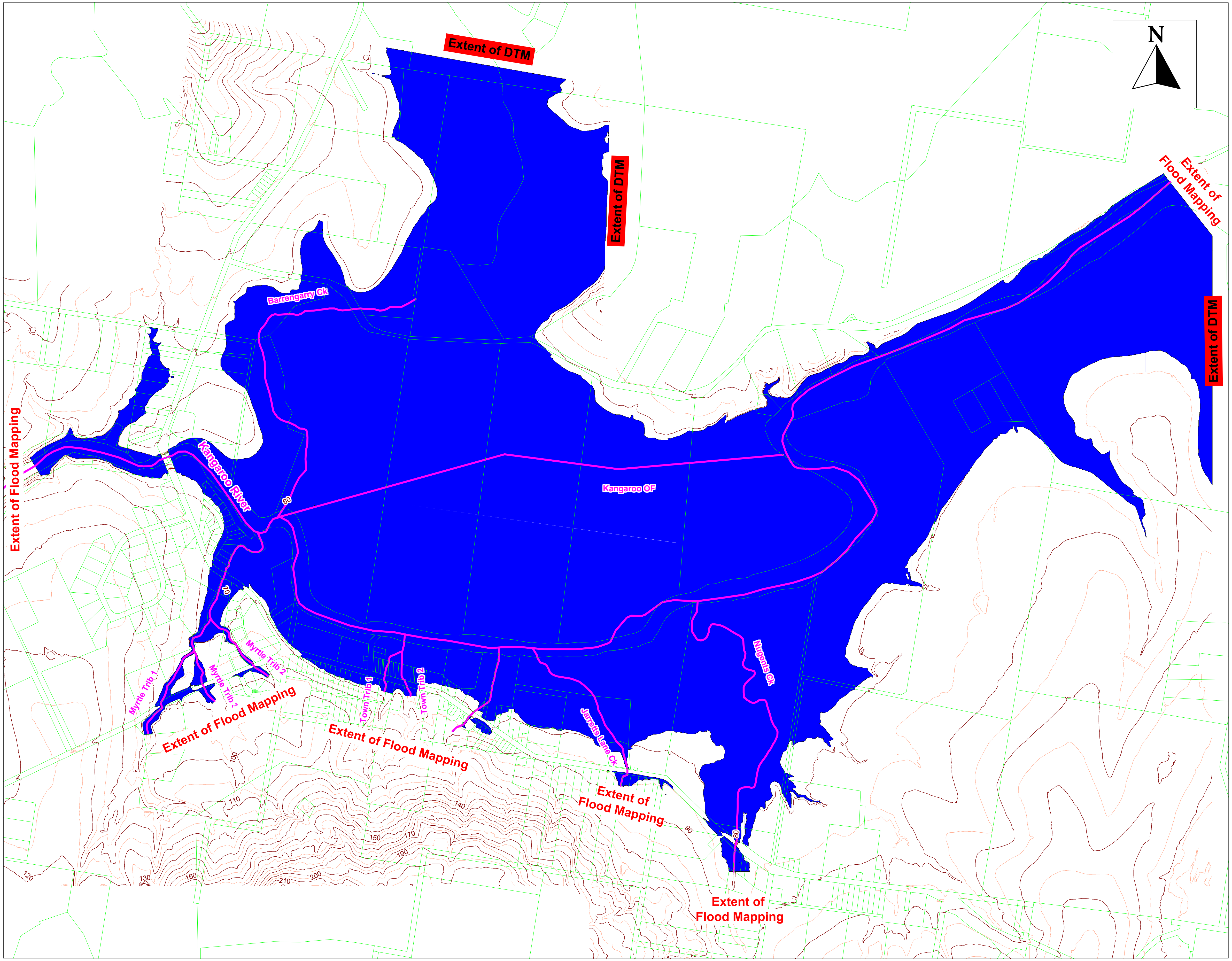


Figure 6.3

Kangaroo Valley Catchment
Flood Extent
PMF



Legend

	0.5%AEP Flood Extent
	Properties
10	Ground Contours (mAHD)

0 0.5 1

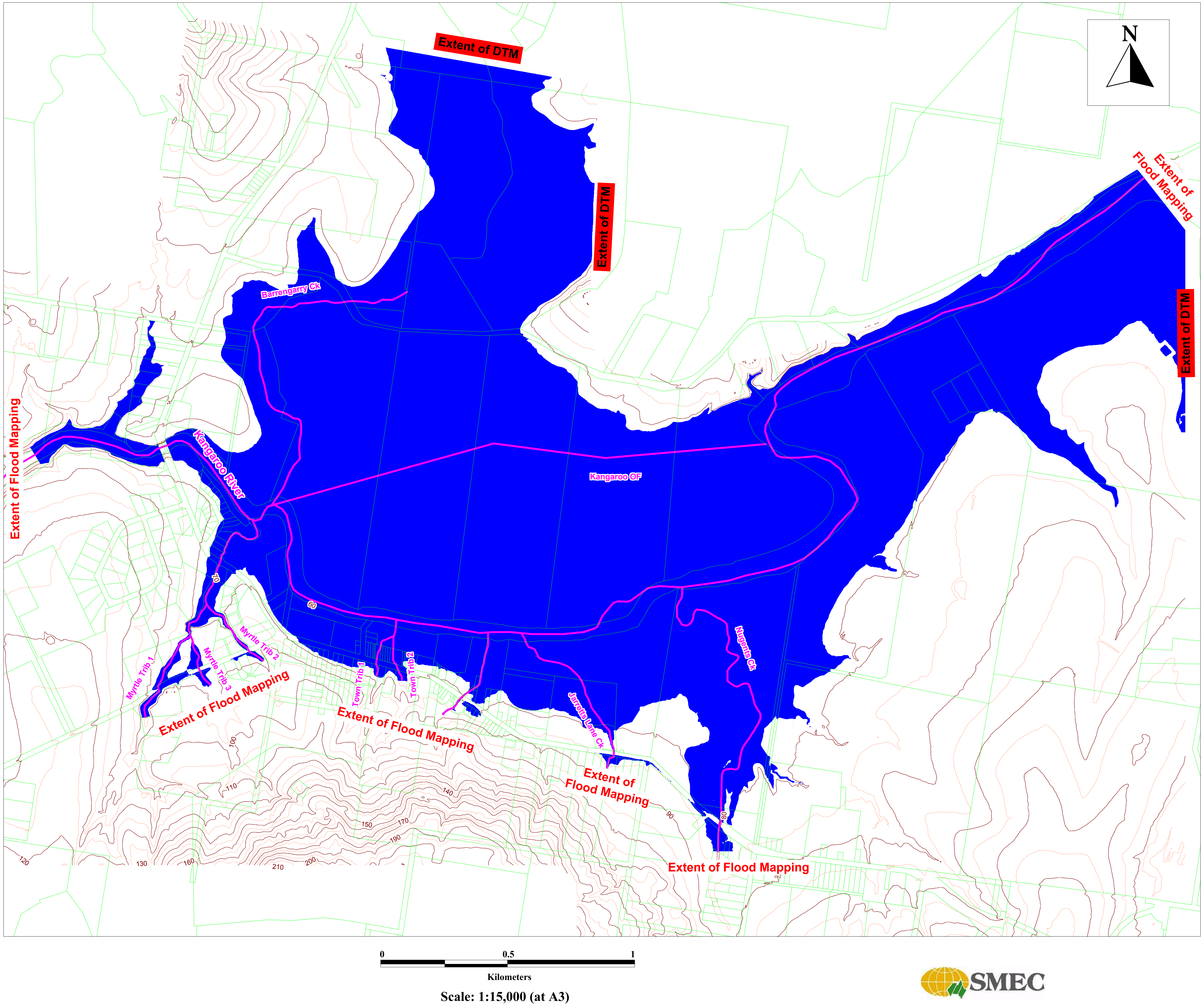
Kilometers

Scale: 1:15,000 (at A3)

SMEC

Figure 6.4

Kangaroo Valley Catchment
Flood Extent
0.5%AEP Design Event

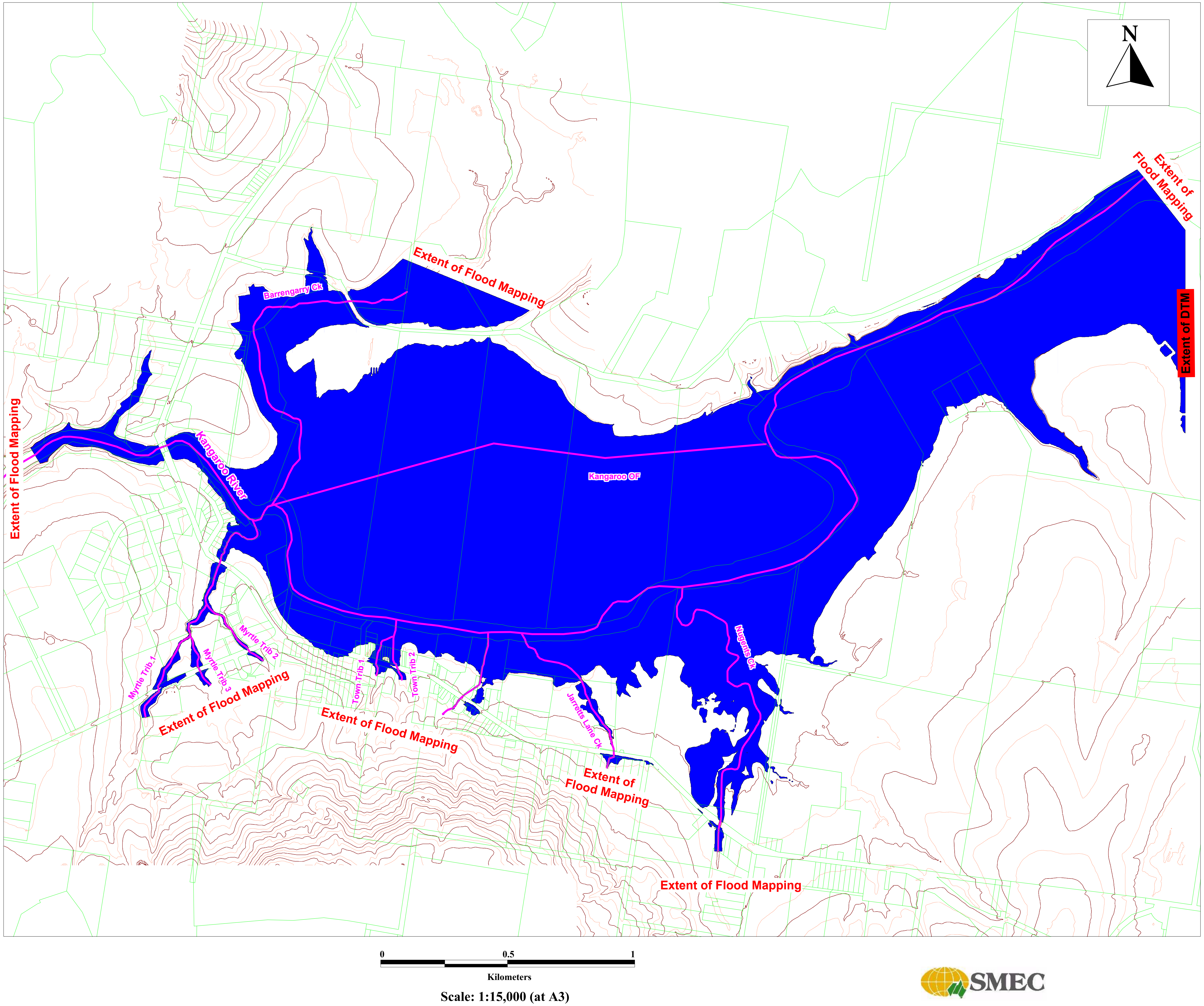


Legend

- 1%AEP Flood Extent
- Properties
- Ground Contours (mAHD)

Figure 6.5

Kangaroo Valley Catchment
Flood Extent
1%AEP Design Event



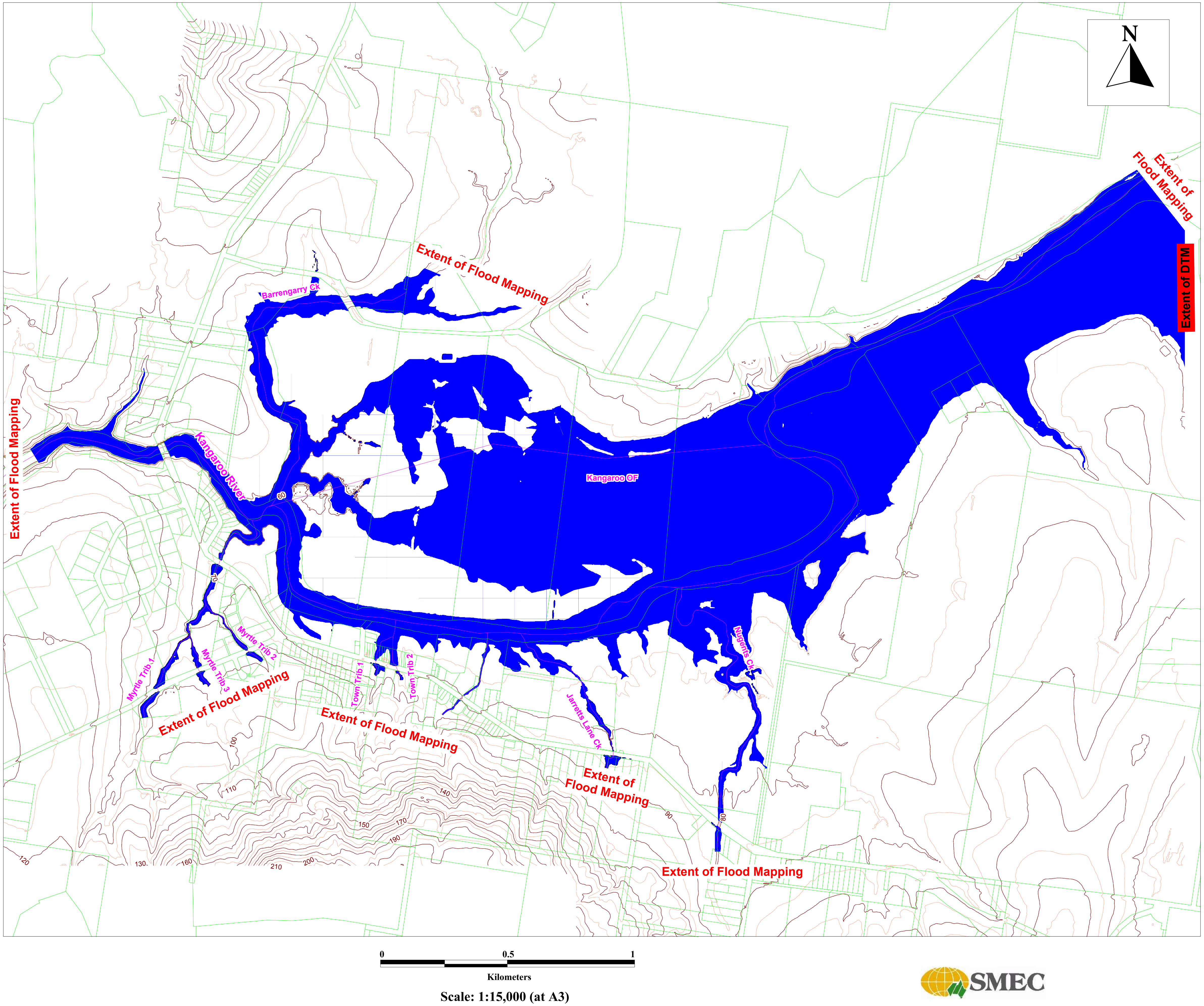
Legend

- 5%AEP Flood Extent
- Properties
- 10 Ground Contours (mAHD)

SMEC

Figure 6.6

Kangaroo Valley Catchment
Flood Extent
5%AEP Design Event



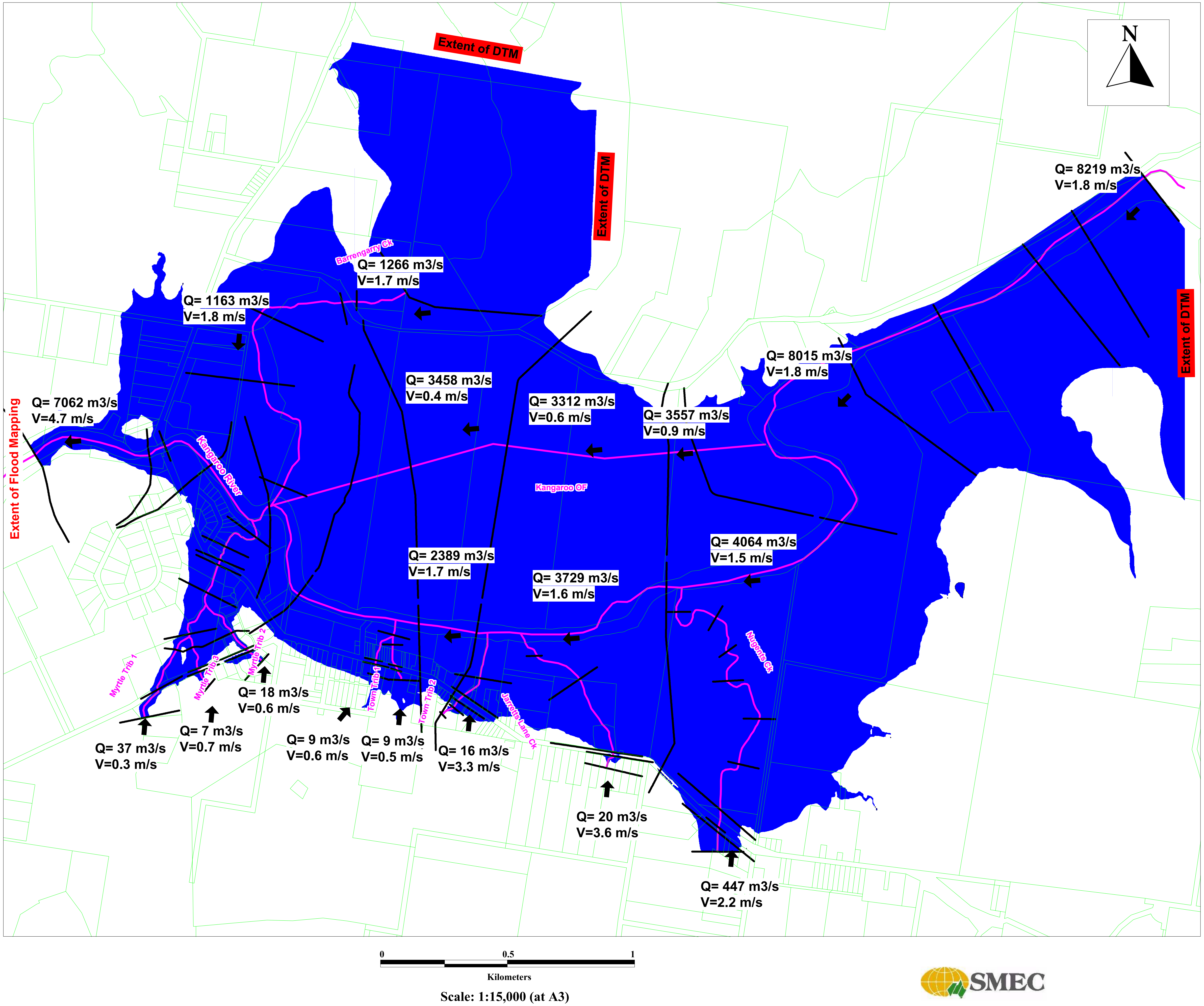
Legend

- 20%AEP Flood Extent
- Properties
- Ground Contours (mAHD)

Figure 6.7

Kangaroo Valley Catchment
Flood Extent
20%AEP Design Event

SMEC

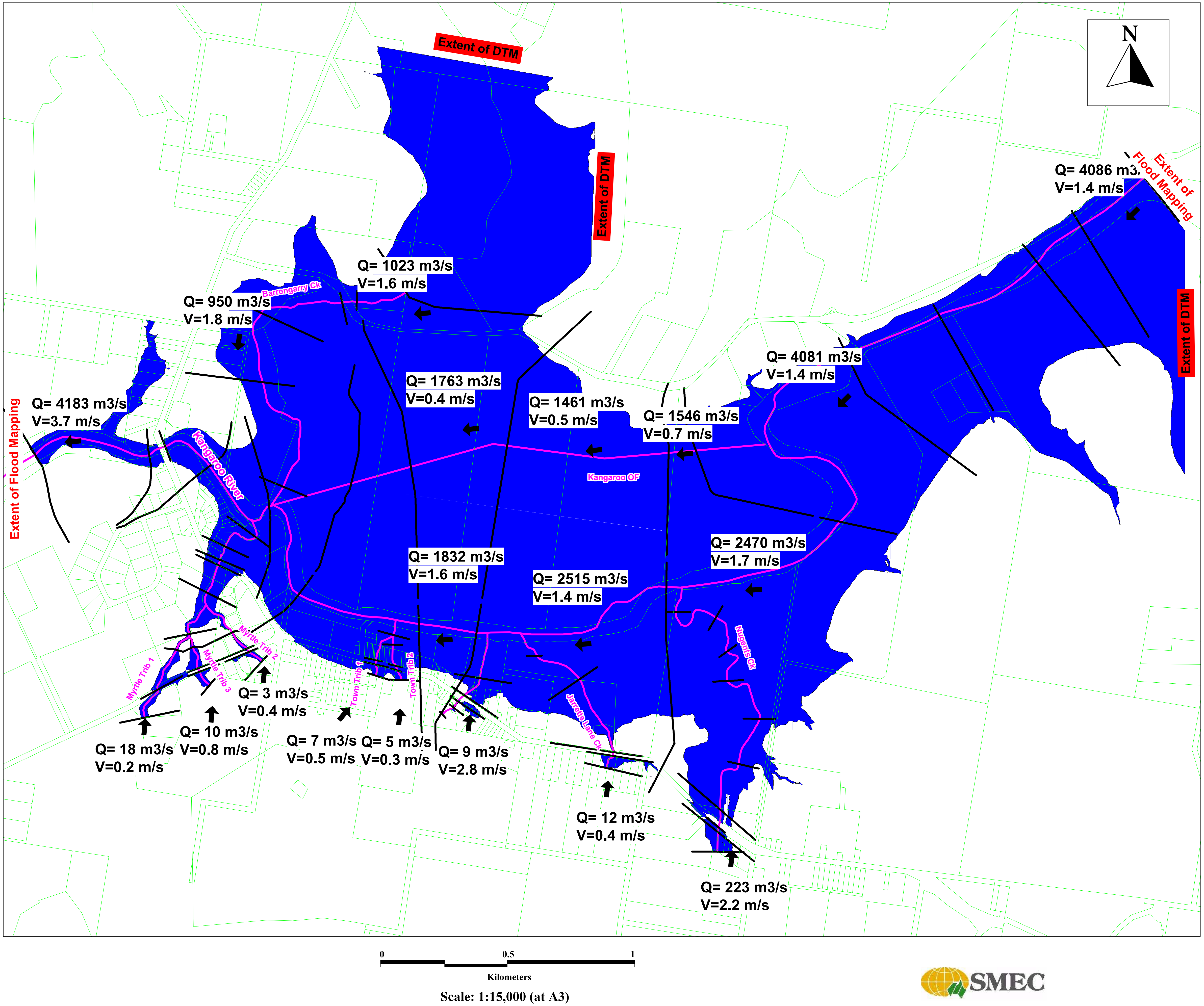


Legend

- PMF Flood Extent
- Properties
- Q Peak Discharge (m3/s)
- V Peak Velocity (m/s)

Figure 6.8

Kangaroo Valley Catchment
Flow and Velocity Peaks
PMF



Legend

- 0.5%AEP Flood Extent
- Properties
- **Q** Peak Discharge (m3/s)
- **V** Peak Velocity (m/s)

SMEC

Figure 6.9

Kangaroo Valley Catchment
Flow and Velocity Peaks
0.5%AEP Design Event

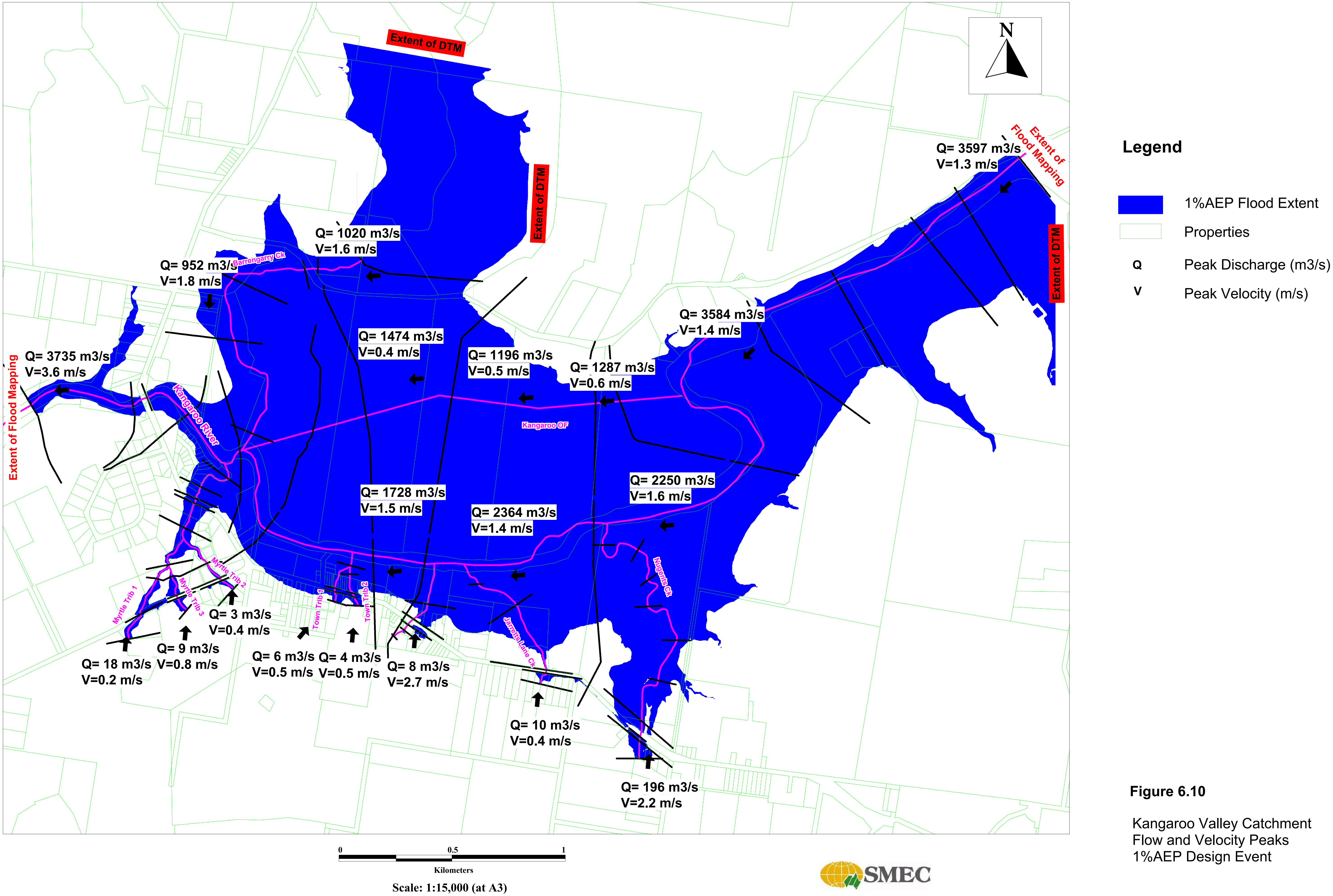
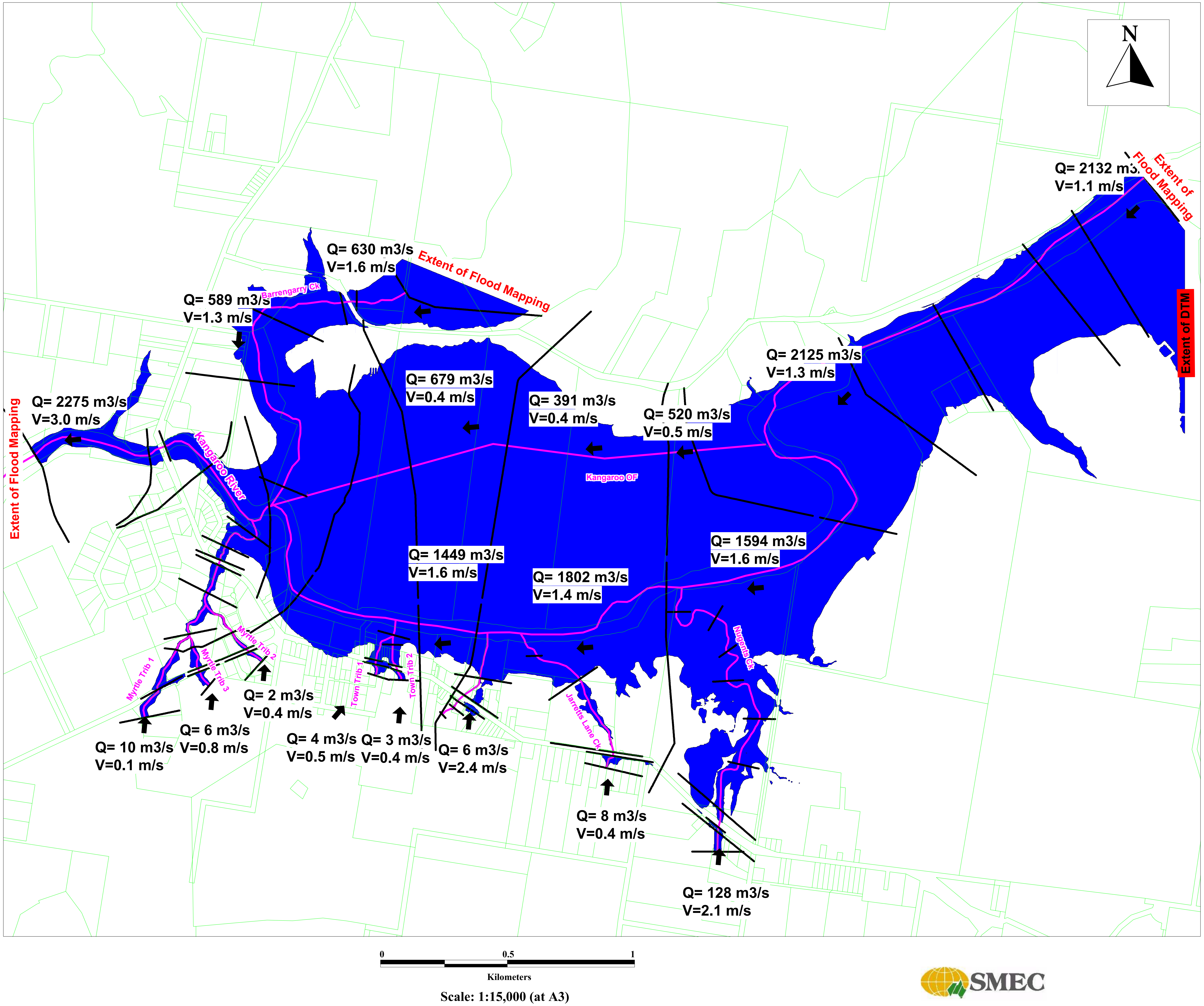


Figure 6.10

Kangaroo Valley Catchment
Flow and Velocity Peaks
1%AEP Design Event



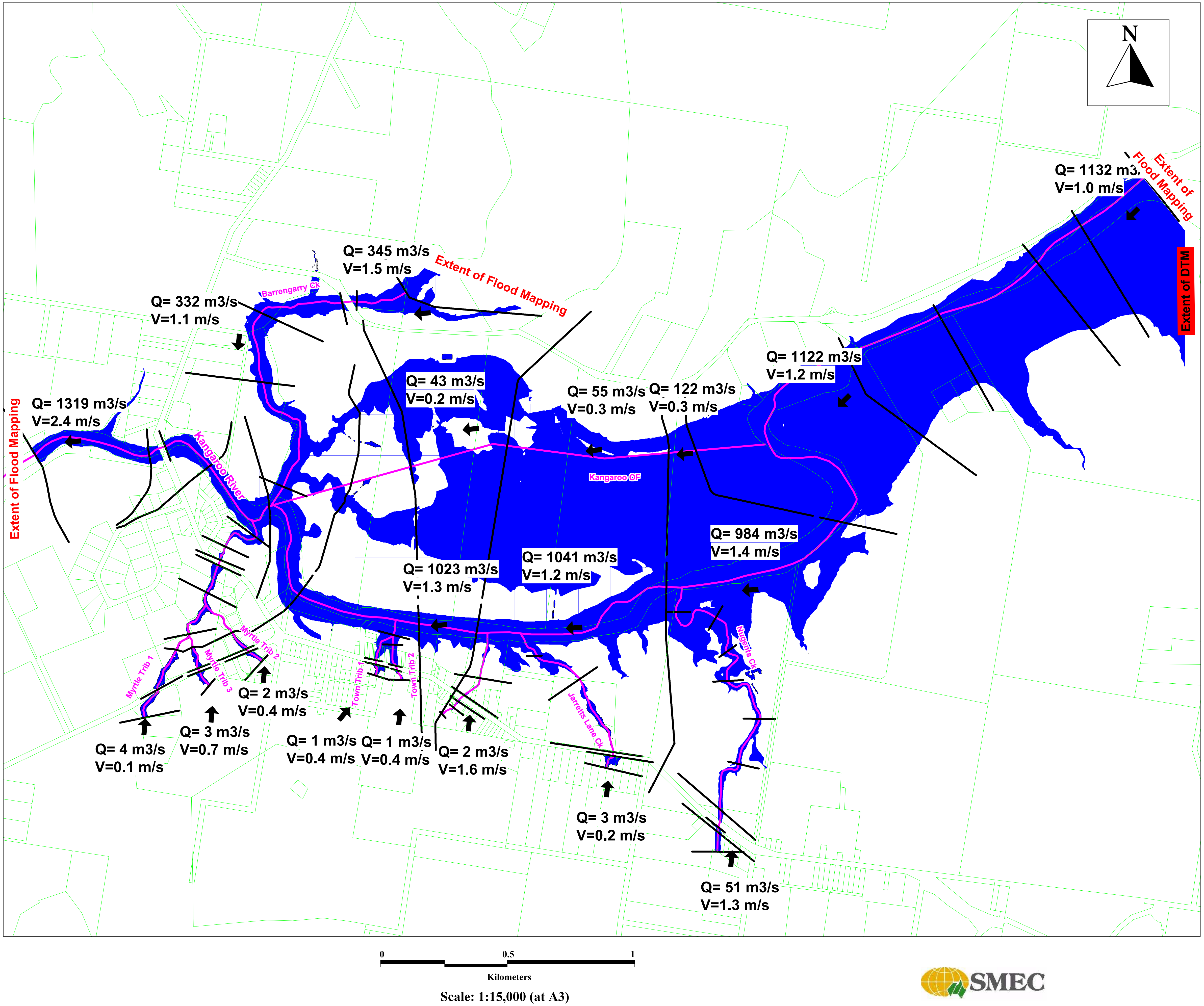
Legend

	5%AEP Flood Extent
	Properties
Q	Peak Discharge (m3/s)
V	Peak Velocity (m/s)

SMEC

Figure 6.11

Kangaroo Valley Catchment
Flow and Velocity Peaks
5%AEP Design Event



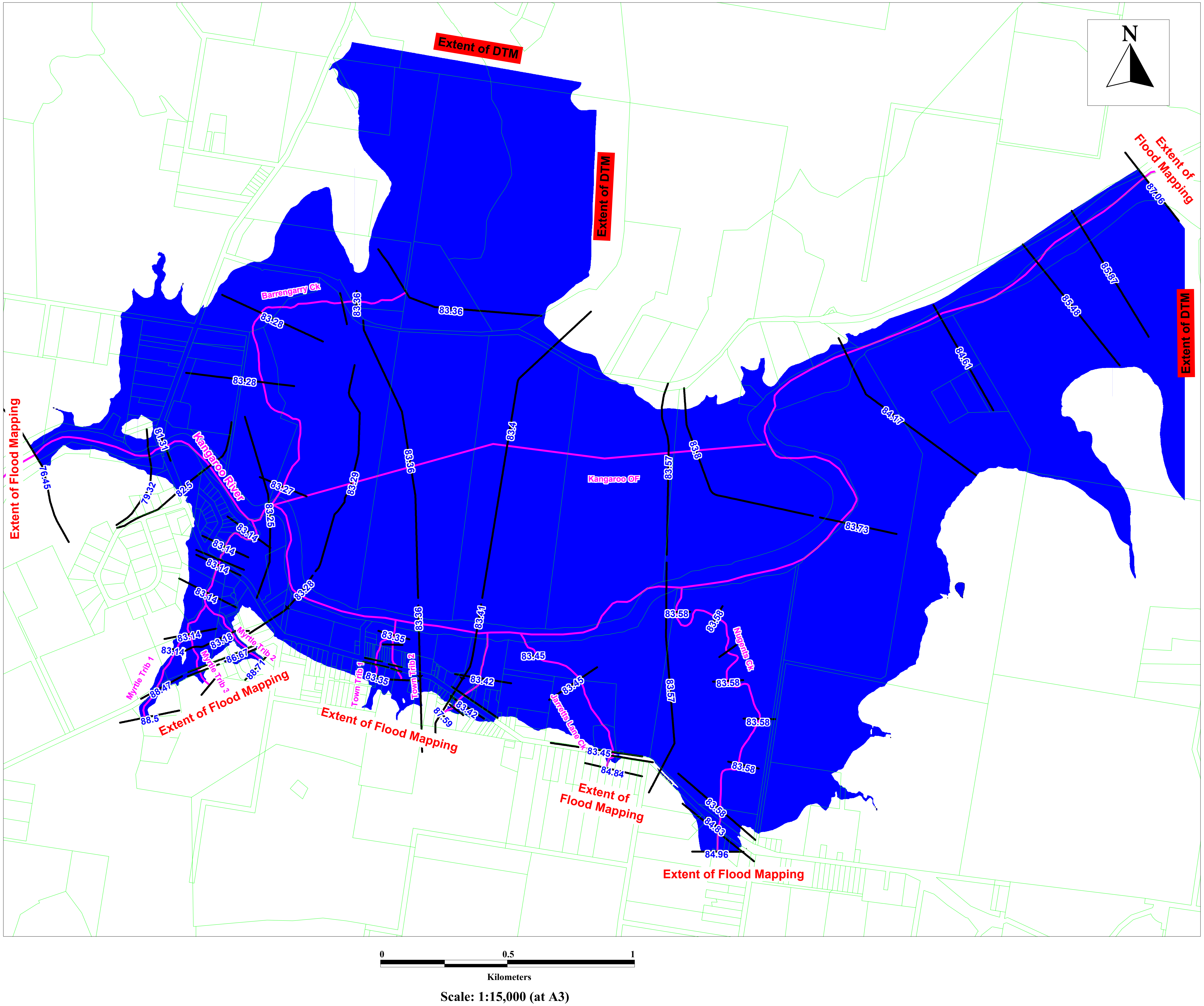
Legend

	20%AEP Flood Extent
	Properties
Q	Peak Discharge (m3/s)
V	Peak Velocity (m/s)

SMEC

Figure 6.12

Kangaroo Valley Catchment
Flow and Velocity Peaks
20%AEP Design Event



Legend

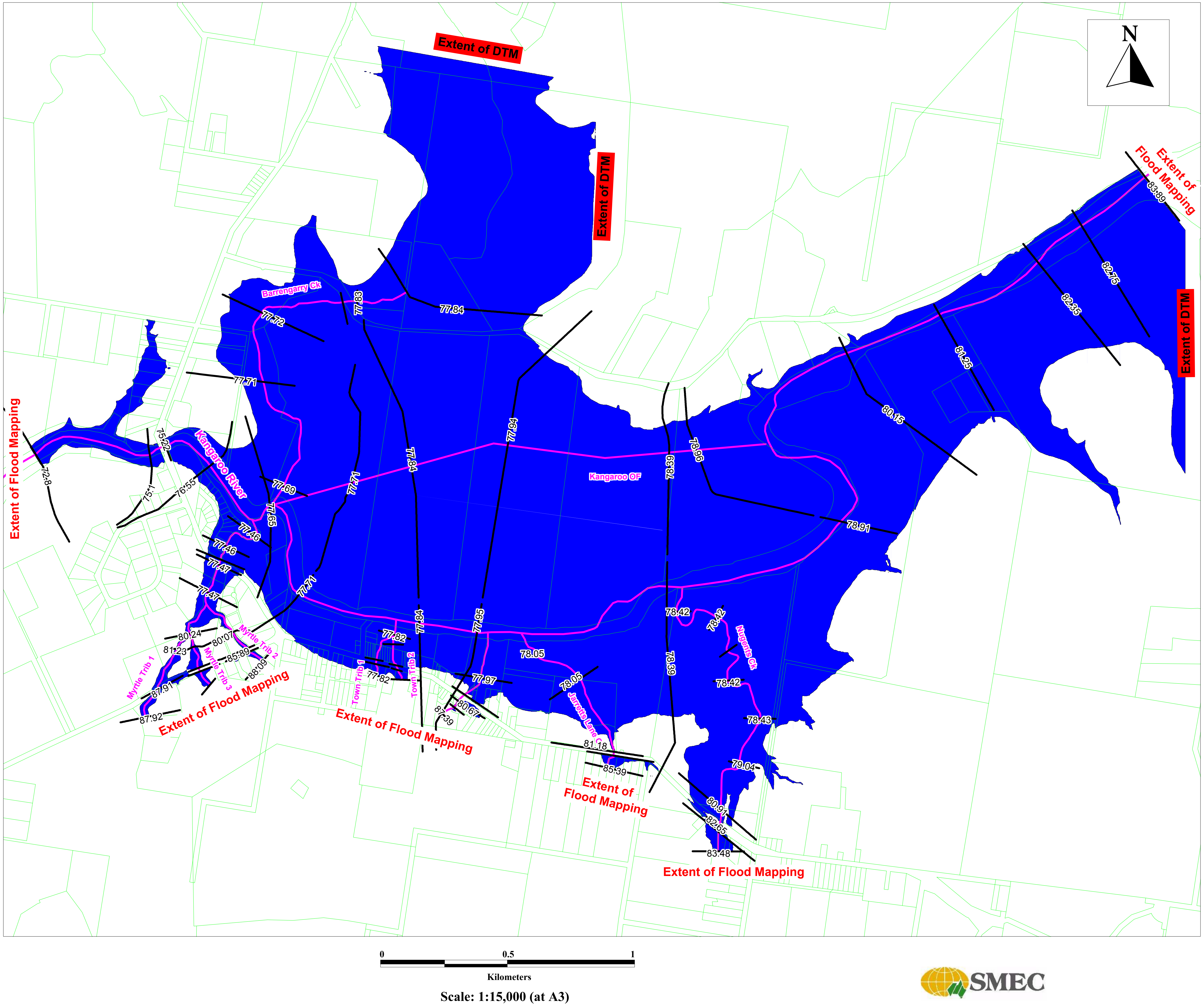
PMF Flood Extent

Properties

83.57 Floodlevel -PMF

Figure 6.13

Kangaroo Valley Catchment
Floodlevel Contours
PMF



Legend

- 0.5%AEP Flood Extent
- Properties
- 78.39 Floodlevel -0.5%AEP

Figure 6.14

Kangaroo Valley Catchment
Floodlevel Contours
0.5%AEP Design Event

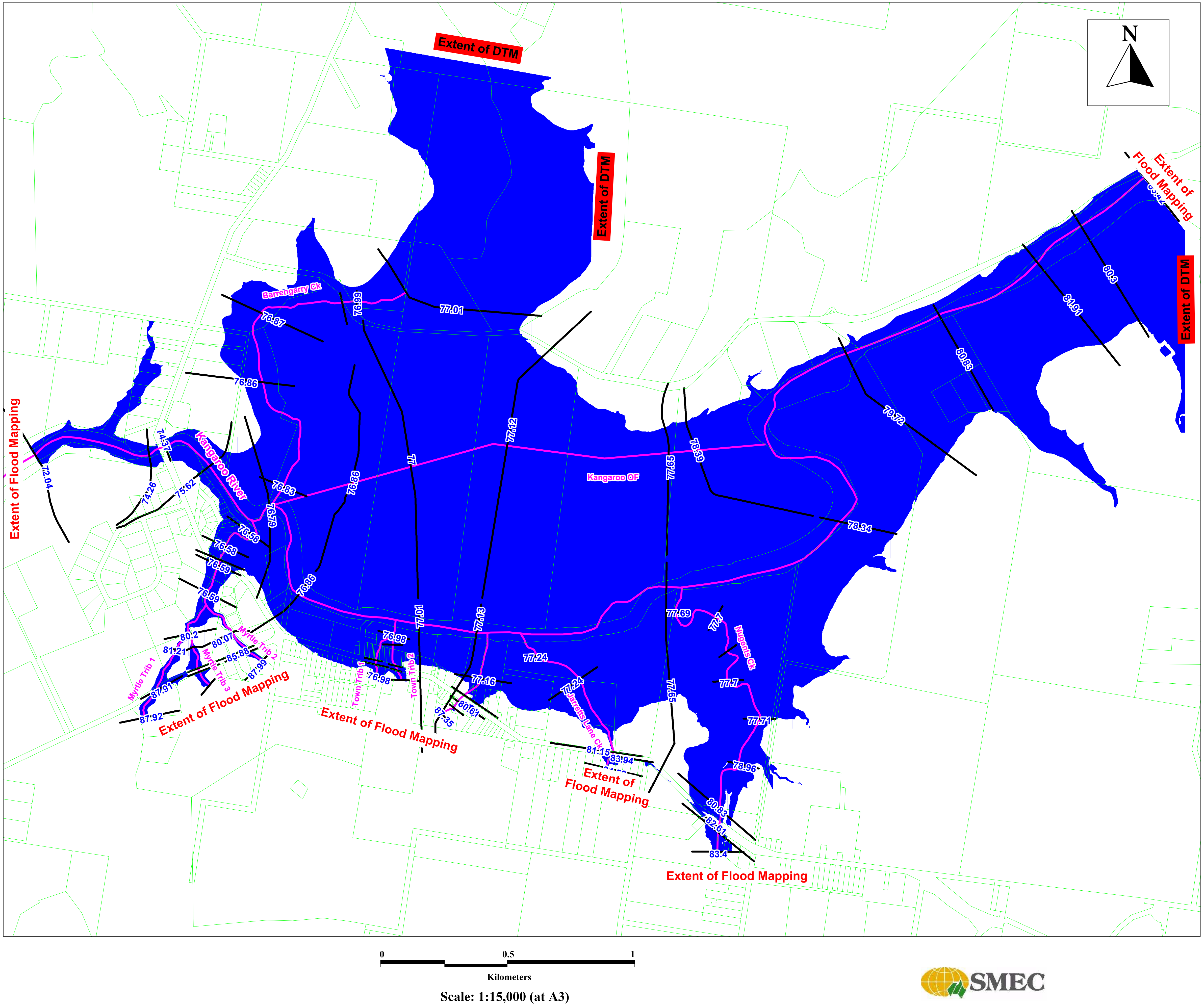
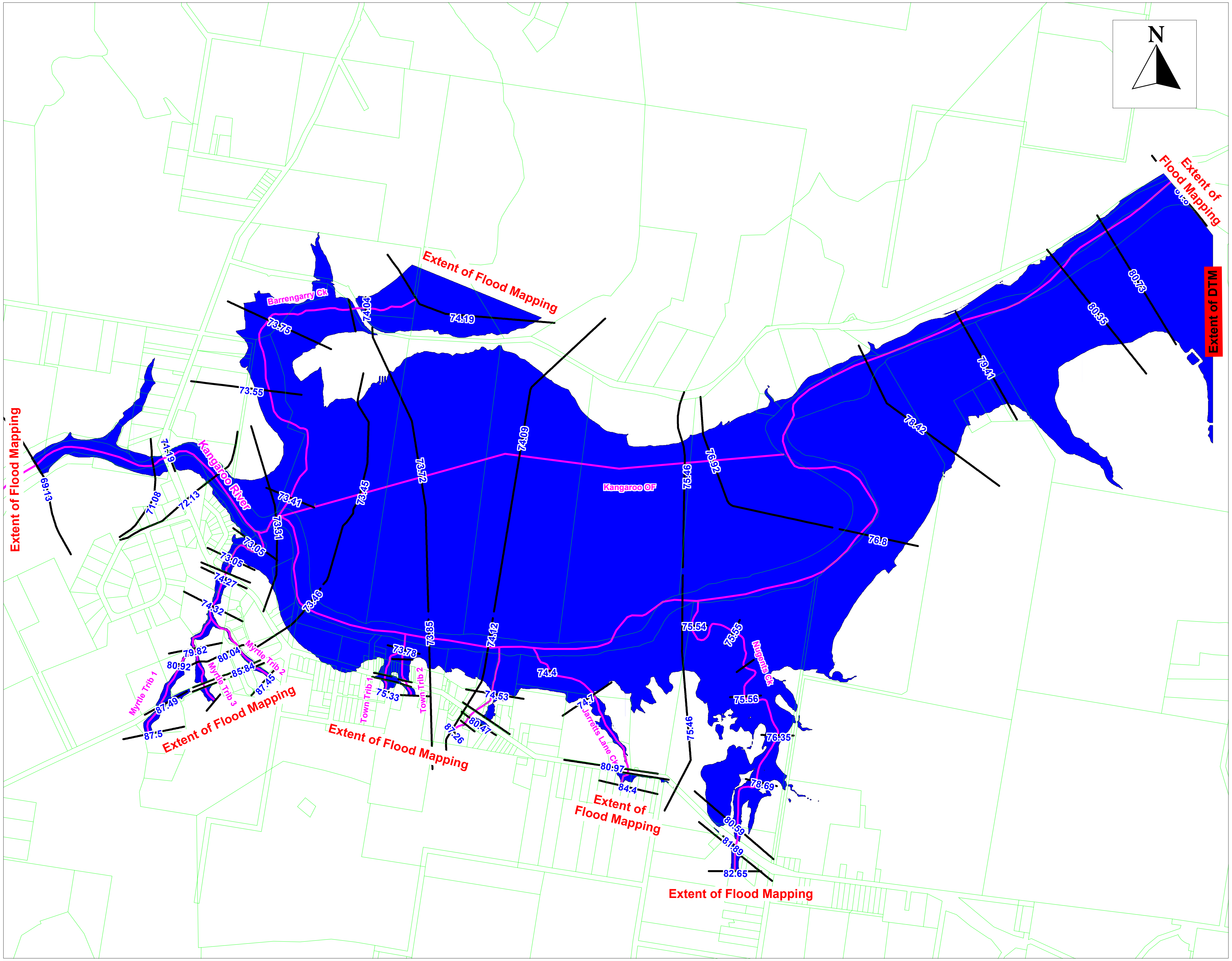


Figure 6.15

Kangaroo Valley Catchment
Floodlevel Contours
1%AEP Design Event



0 0.5 1

Kilometers

Scale: 1:15,000 (at A3)

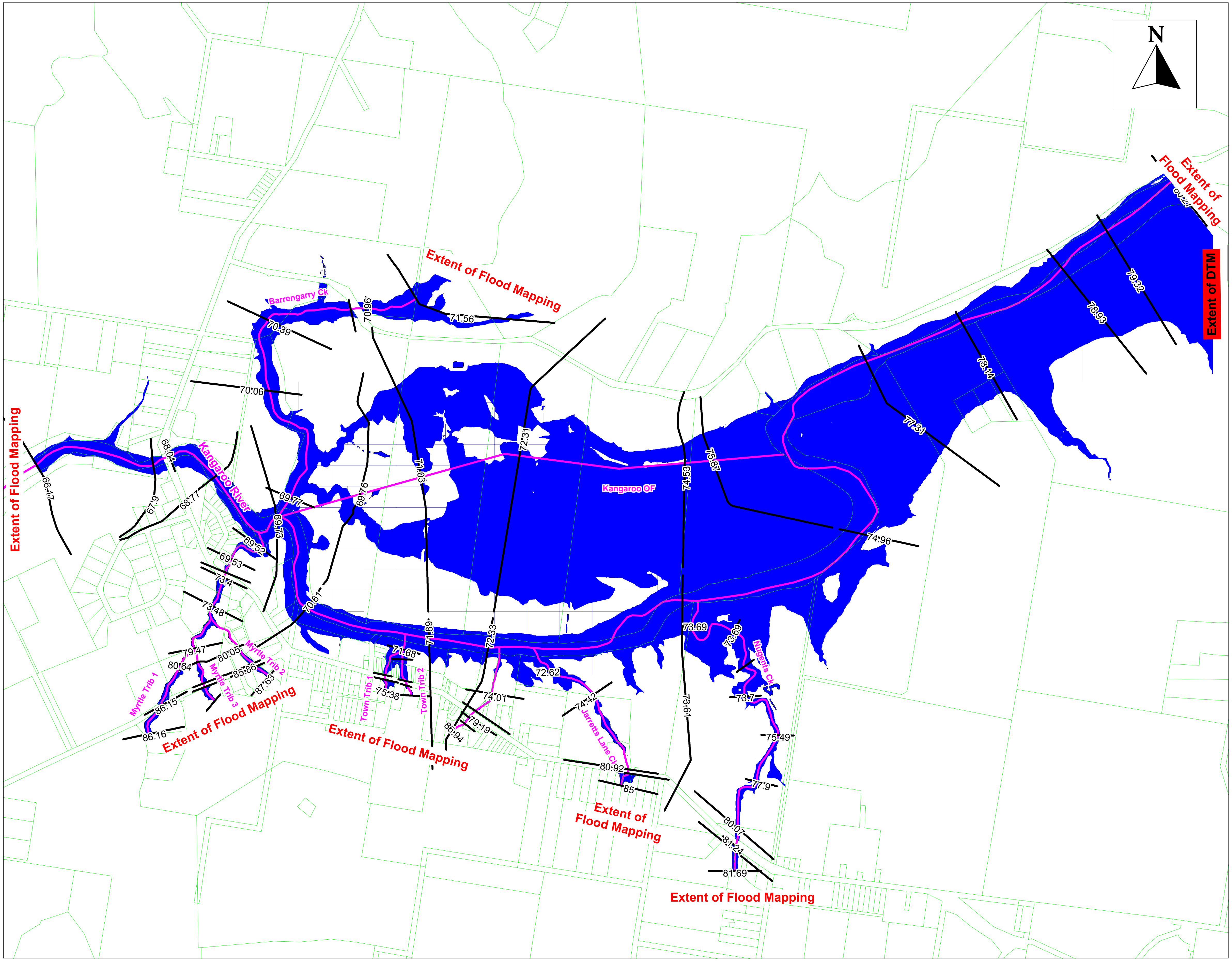
Legend

- 5%AEP Flood Extent
- Properties
- 75.46 Floodlevel -5%AEP

Figure 6.16

Kangaroo Valley Catchment
Floodlevel Contours
5%AEP Design Event

SMEC



Kilometers

0 0.5 1

Scale: 1:15,000 (at A3)

SMEC

Legend

- 20%AEP Flood Extent
- Properties
- 74.53 Floodlevel -20%AEP

Figure 6.17

Kangaroo Valley Catchment
Floodlevel Contours
20%AEP Design Event

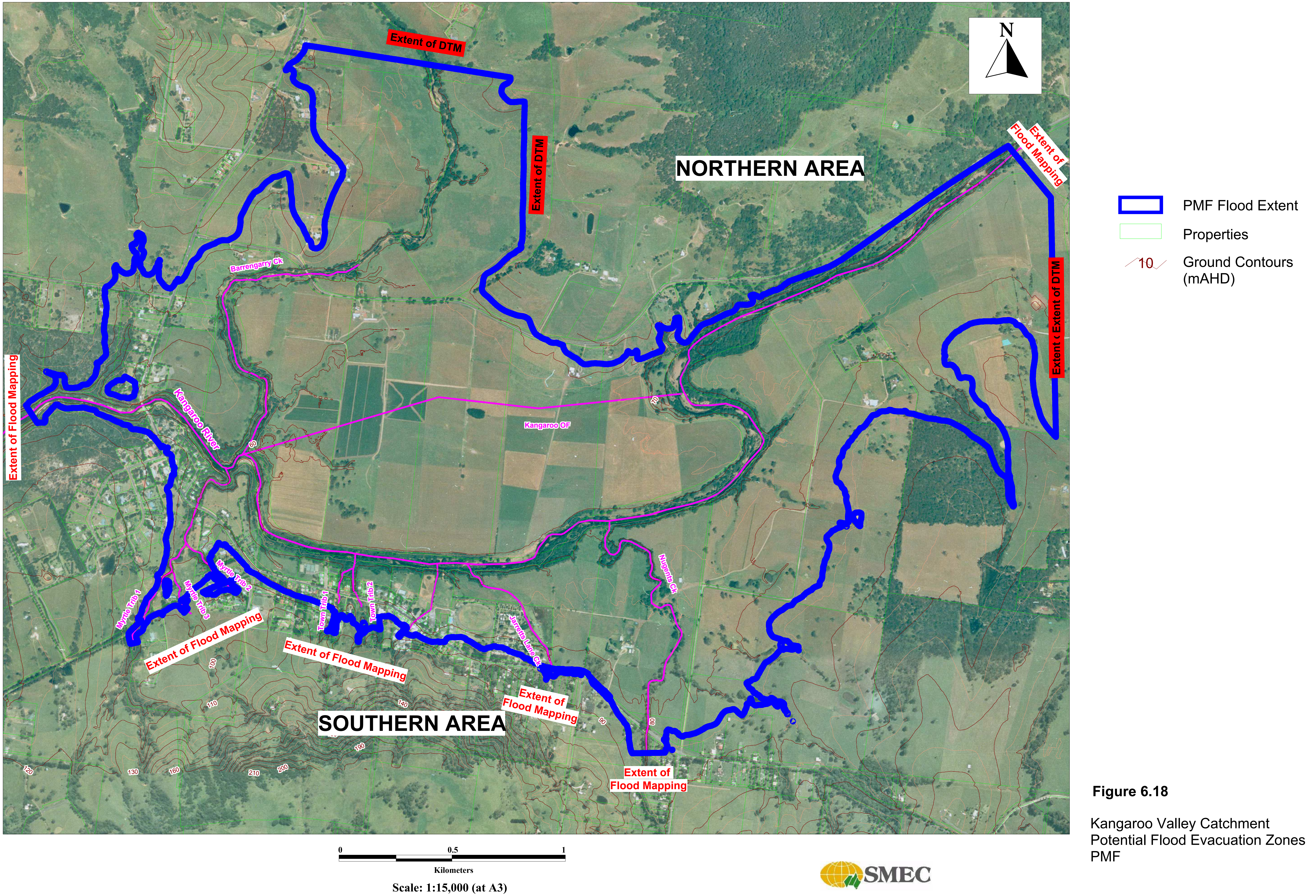
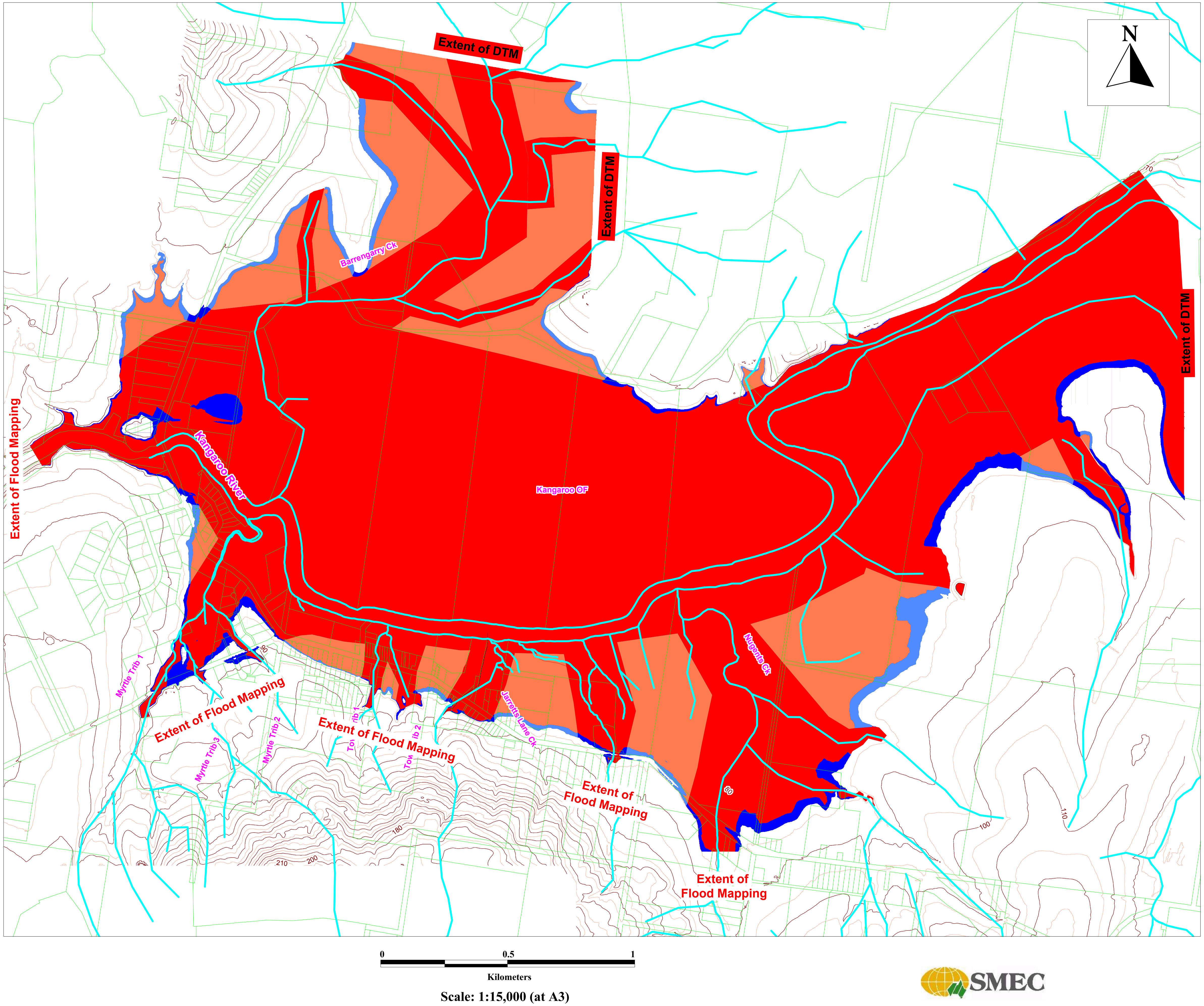


Figure 6.18

Kangaroo Valley Catchment
Potential Flood Evacuation Zones
PMF



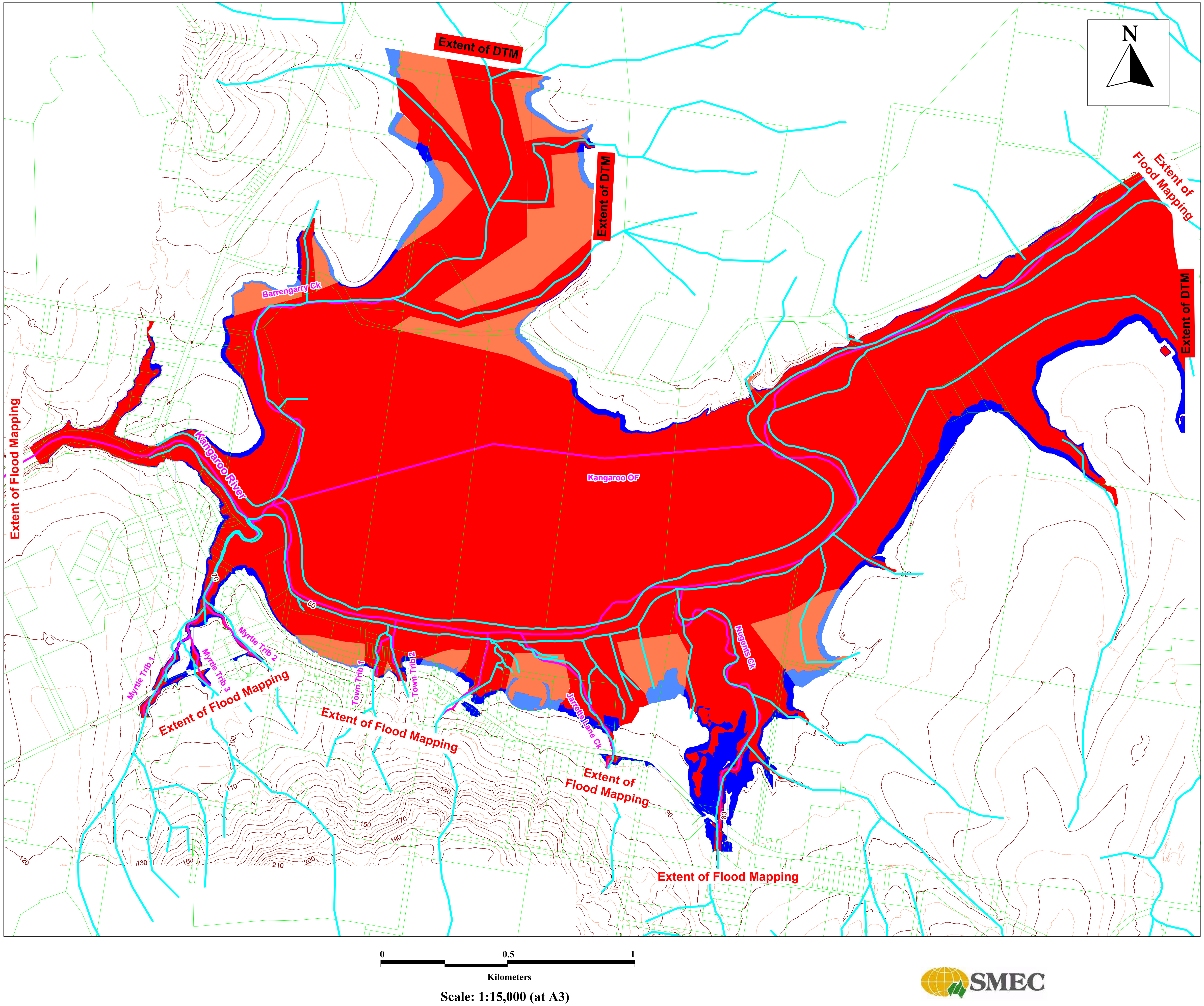
Legend

- Properties
- 10 Ground Contours (mAHD)
- High Hazard Floodway
- High Hazard Storage
- High Hazard Fringe (none in study area)
- Low Hazard Floodway
- Low Hazard Storage
- Low Hazard Fringe (none in study area)

SMEC

Figure 7.1

Kangaroo Valley Catchment
Hazard Map
PMF



Legend

Properties

Ground Contours (mAHD)

High Hazard Floodway

High Hazard Storage

High Hazard Fringe (none in study area)

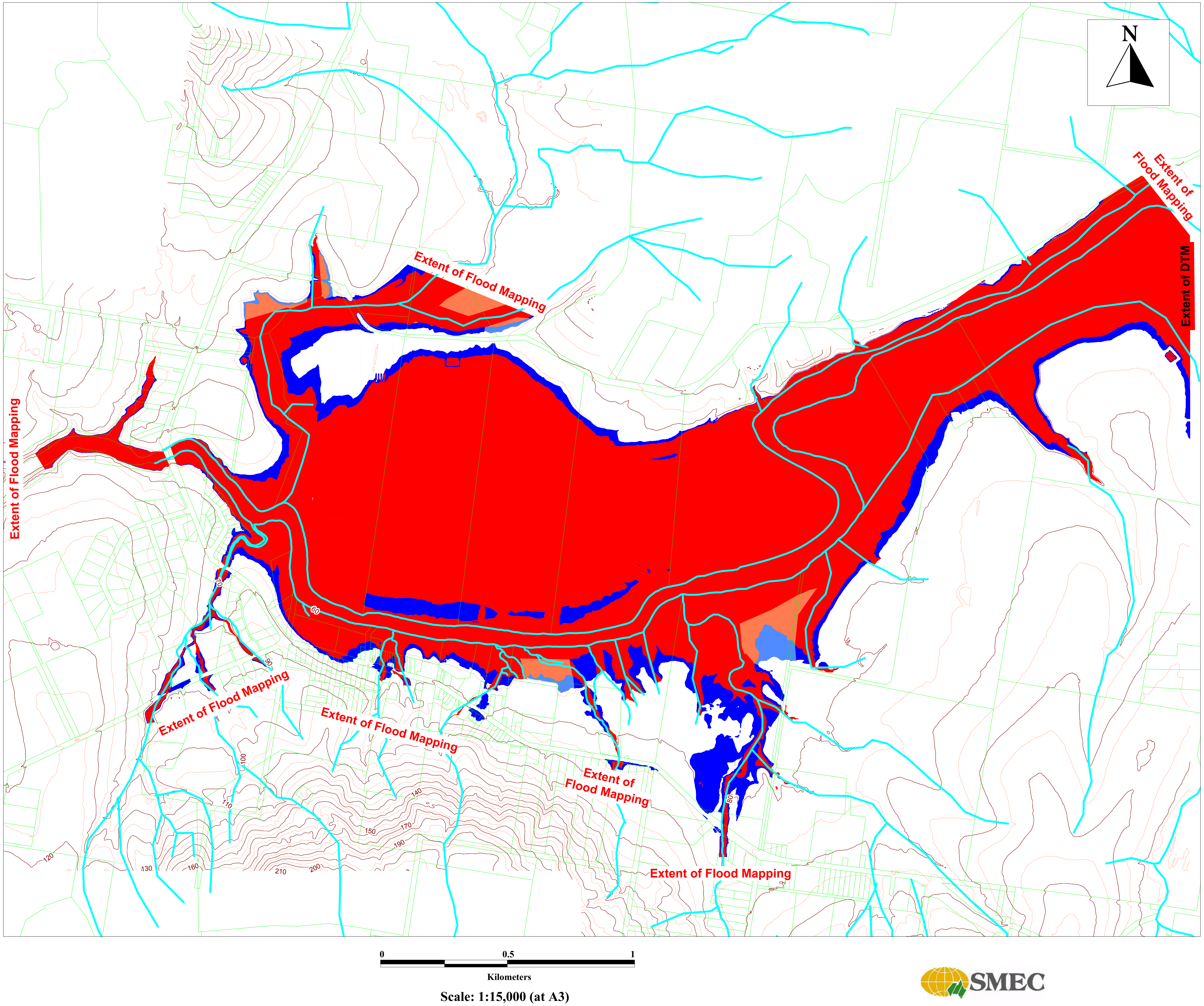
Low Hazard Floodway

Low Hazard Storage

Low Hazard Fringe (none in study area)

Figure 7.2

Kangaroo Valley Catchment
Hazard Map
1%AEP Design Event



Legend

Properties

10 Ground Contours (mAHD)

High Hazard Floodway

High Hazard Storage

High Hazard Fringe (none in study area)

Low Hazard Floodway

Low Hazard Storage

Low Hazard Fringe (none in study area)

SMEC

Figure 7.3

Kangaroo Valley Catchment
Hazard Map
5%AEP Design Event

9 SUMMARY AND CONCLUSIONS

The results for the calibration and design events in the hydraulic model include:

- Calibration on average reproduced past flood behaviour to within 0.25m.
- The Hampden Bridge flood frequency curve showing the annual maxima, historic floods and the peak design flows over a range of frequencies indicate that the MIKE11 model is giving reliable flows. The calibration to floodmarks also indicates that the model is also reliable for water levels. These models were used to develop floodmaps and to describe flood behaviour at Kangaroo Valley.
- Satisfactory representation of observed flood levels was achieved when blockage of structures within the Kangaroo Valley Township was included in the model. Blockage was set to 50%.
- The distribution of rainfall may have had a significant impact on the calibration. Given the variability of the topography of the Kangaroo Valley catchment, there would be significant spatial variation of the rainfall pattern. This would affect the runoff generated within the catchment. A possible explanation for some modelled flood levels not matching observed levels more closely could be that rainfall gauges used did not adequately represent localised regions of higher rainfall intensity.
- The floodrunner between Moss Vale Road and Upper Kangaroo River Road has high depths with little time available for evacuation before floodwaters inundate the land. Mount Scanzi Road crosses three watercourses in the study area and was modelled to be out of service for a period of 2.3hours in the 1%AEP event. Most of the sites throughout the study area were assessed as having a relatively small time to rise and are considered to be of a high hazard category. Moss Vale Road has a relatively long period of inundation in the 1%AEP event (6.5hours at Town Trib1)
- At Kangaroo River @ Hampden Bridge the model indicated that floodwaters do not inundate the roadways in the 1%AEP event, and do inundate the roadways in the PMF. At Nugents Creek @ Moss Vale Road the road crossing is not inundated in the 1% AEP event, however the overflow may spill towards the nearby road low point creating a water pond and a short duration inundation of the road crest of up to 200mm. There are two main areas that can be used to plan evacuation due to flooding in the PMF event. These are north and south of the PMF's flood extent where the flood levels reach approximately 90mAHD and 85mAHD respectively.
- The hydrologic model was calibrated with a storage multiplier of Bx=0.6. This was considered to be at the lower end of the scale of reasonable values. The sensitivity test indicated that the peak flow at the outlet changed by up to 23% to the median value and a further 26% to the higher end of storage. This 23% resulted in a change to the PMF's peak flow of 2272m3/s from the estimated average value. The value adopted during calibrated resulted in a satisfactory flood frequency curve and is therefore considered to give reliable results.
- The sensitivity analysis indicated that by varying the roughness coefficient by ±20% there were changes in water levels of up to 1.0m and an average change of 0.6m during the 1%AEP event. Although these are relatively high differences, it is envisaged that these changes will have a relatively minor influence on flood extents.
- The proposal to raise the Tallowa Dam spillway caused an increase in the 1%AEP water levels of 0.3m at Hampden Bridge and no significant increase for the PMF.

10 GLOSSARY OF TERMS

10.1 GLOSSARY OF ACRONYMS

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
DNR	Department of Natural Resources
LEP	Local Environmental Plan
LGA	Local Government Area
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation

10.2 GLOSSARY OF TECHNICAL TERMS

Annual Exceedance Probability (AEP) - the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a peak flood discharge of 500 m^3/s or larger occurring in any one year (see average recurrence interval).

Australian Height Datum (AHD) - a common national surface level datum approximately corresponding to mean sea level.

Average Annual Damage (AAD) - depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.

Average Recurrence Interval (ARI) - the long-term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

Catchment - the land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

Development - is defined in clause 4 of the Environmental Planning and Assessment Act (EP&A Act).

Disaster Plan (DISPLAN) - a step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

Discharge - the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

Effective warning time - the time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

Emergency management - a range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

Extreme event - an extreme flood is one which has a very low probability of occurrence and can be used to consider flood damages and emergency management within a floodplain.

Flash flooding - flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

Flood - relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage (refer Section 1.9) before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

Flood education, awareness and readiness

- **Flood education** seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
- **Flood awareness** is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
- **Flood readiness** is an ability to react within the effective warning time.

Flood fringe areas - the remaining area of flood prone land after floodway and flood storage areas have been defined.

Flood liable land - is synonymous with flood prone land (ie) land susceptible to flooding by the Probable Maximum Flood (PMF) event. Note that the term flood liable land now covers the whole of the floodplain, not just that part below the flood planning level, as indicated in the 1986 Floodplain Development Manual (see flood planning area).

Flood mitigation standard - the average recurrence interval of the flood, selected as part of the floodplain risk management process, that forms the basis for physical works to modify the impacts of flooding.

Floodplain - area of land which is subject to inundation by floods up to and including the Probable Maximum Flood event, that is, flood prone land.

Floodplain risk management options - the measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.

Floodplain Risk Management Plan - a management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

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

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

Flood planning levels (FPL) - are the combinations of flood levels and freeboards selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans. The concept of flood planning levels supersedes the "standard flood event" of the first edition of the Floodplain Development Manual.

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

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

Flood risk - potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in the Floodplain Development Manual is divided into 3 types, existing, future and continuing risks; these are described below.

- **Existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain.
- **Future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain.
- **Continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

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

Floodway areas - those areas of the floodplain where a significant discharge of water occurs during floods; they are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

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

Hazard - a source of potential harm or a situation with a potential to cause loss. In relation to this report the hazard is flooding which has the potential to cause damage to the community.

Isohyetal – refers to an isohyet or isohyetal line which joins points of equal precipitation on a map. A map with isohyets is called an isohyetal map.

Isopleth -

Local overland flooding - inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

Local drainage - are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

Mainstream flooding - inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

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

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

- **Minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.
- **Moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.
- **Major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

Modification measures - measures that modify either the flood, the property or the response to flooding.

Peak discharge - the maximum discharge occurring during a flood event.

Pluviograph - a self-registering rain gauge typically measuring and recording hourly rainfall depths

Probable Maximum Flood (PMF) - the largest flood that could conceivably occur at a particular location, usually estimated from Probable Maximum Precipitation. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP) - the theoretical greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to the estimation of the Probable Maximum Flood.

Probability - a statistical measure of the expected chance of flooding (see Annual Exceedance Probability).

Risk - chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this report it is the likelihood of consequences arising from the interaction of floods, communities and the environment. The risk of such an event occurring over a longer period is much higher.

Probability of Experiencing a Given Size Flood One or More Times in a Lifetime (70 Years)

Likelihood of Occurrence in any Year (AEP)	Percentage Probability of Experiencing in a 70 Year Period	
	At least Once	**At Least Twice**
10% (1 chance in 10)	99.9%	99.3%
5%(1 chance in 20)	97.0%	86.4%
2%(1 chance in 50)	75.3%	40.8%
1%(1 chance in 100)	50.3%	15.6%
0.5% (1 chance in 200)	29.5%	4.9%

Risk management - the systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring flood risk. Flood risk management is undertaken as part of a Floodplain Risk Management Study. The Floodplain Risk Management Plan reflects the adopted means of managing flood risk.

Runoff - the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

Stage - equivalent to "water level". Both are measured with reference to a specified datum.

Stage hydrograph - a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.

Temporal pattern – refers to the overall pattern of the rainfall event over time and is specific to spatial location and storm duration.

11 REFERENCES

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APPENDICES

A. Flood Heights for Historical Events (MIKE11)

B. Flood Heights and Velocities for Design Events (MIKE11)

C. MIKE 11 Results (graphical)

1. a. Historical events flood profiles
   b. Historical events hydrograph comparison

2. Design events flood profiles

D. Summary of Roughness Coefficients

E. Sensitivity Analysis

F. Comments by NSW Department of Natural Resources

Appendix A: Flood heights for historical events (MIKE11)

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
BARRENGARRY	0	68.72	72.48	72.55	74.11	73.55
BARRENGARRY	1	68.72	72.48	72.55	74.11	73.55
BARRENGARRY	212	68.26	72.10	71.98	74.05	73.21
BARRENGARRY	265	68.25	72.10	71.97	74.04	73.20
BARRENGARRY	600	68.01	71.82	71.37	73.96	72.59
BARRENGARRY	888	67.91	71.62	70.94	73.89	72.18
BARRENGARRY	1400	67.84	71.43	70.48	73.85	71.92

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
JARRETTS	0	84.76	84.39	84.96	85.37	85.25
JARRETTS	61	83.44	84.24	84.35	83.99	84.72
JARRETTS	77	80.93	80.95	80.95	80.94	80.96
JARRETTS	200	77.95	78.00	77.99	78.01	78.02
JARRETTS	400	74.43	74.61	74.54	74.85	74.64
JARRETTS	600	71.22	73.85	72.92	74.85	73.80

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
KANGAROO	0.00	79.90	81.18	80.10	80.46	80.76
KANGAROO	509.00	79.02	80.13	79.20	79.45	79.73
KANGAROO	733.00	78.61	79.76	78.80	79.07	79.35
KANGAROO	1179.00	77.83	78.88	78.10	78.27	78.53
KANGAROO	1578.00	77.00	77.95	77.30	77.47	77.68
KANGAROO	2039.16	75.56	76.44	75.90	76.13	76.23
KANGAROO	2682.00	74.02	76.21	75.10	75.87	75.87
KANGAROO	3385.52	72.46	74.96	73.90	75.18	74.72
KANGAROO	3446.00	72.36	74.89	73.80	75.15	74.65
KANGAROO	4095.36	71.22	73.85	72.90	74.85	73.80
KANGAROO	4227.00	71.00	73.58	72.70	74.70	73.60
KANGAROO	4269.00	70.93	73.48	72.70	74.61	73.52
KANGAROO	4500.00	70.45	73.06	72.20	74.27	73.18
KANGAROO	4592.98	70.22	72.89	72.10	74.20	73.03
KANGAROO	4990.00	68.94	72.04	71.10	73.89	72.34
KANGAROO	4991.71	68.93	72.04	71.10	73.89	72.33
KANGAROO	5398.76	67.83	71.38	70.40	73.77	71.85
KANGAROO	5405.00	67.82	71.37	70.40	73.76	71.84
KANGAROO	5505.31	67.60	71.14	70.20	73.50	71.61
KANGAROO	5779.00	66.88	70.32	69.40	72.55	70.78
KANGAROO	5948.00	66.25	69.51	68.70	71.58	69.94
KANGAROO	6069.00	66.10	69.38	68.50	71.47	69.81

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
NUGENTS	0	81.47	82.10	82.18	82.28	82.08
NUGENTS	61	81.29	81.80	81.87	81.96	81.79
NUGENTS	77	81.24	81.72	81.78	81.86	81.70
NUGENTS	96	81.10	81.51	81.56	81.63	81.49
NUGENTS	113	80.50	81.07	81.13	81.21	81.06
NUGENTS	166	79.74	80.27	80.31	80.38	80.27
NUGENTS	400	77.72	78.29	78.39	78.49	78.34
NUGENTS	600	75.21	75.90	76.14	76.24	76.13
NUGENTS	840	72.49	74.98	73.87	75.19	74.74
NUGENTS	1000	72.46	74.97	73.86	75.19	74.72
NUGENTS	1160	72.46	74.97	73.86	75.18	74.72
NUGENTS	1400	72.46	74.96	73.86	75.18	74.72

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
MYRTLE1	0	85.70	86.86	86.76	86.58	86.86
MYRTLE1	125.71	85.70	86.85	86.75	86.57	86.85
MYRTLE1	126	85.69	86.85	86.75	86.57	86.85
MYRTLE1	147.16	84.69	85.01	84.98	84.96	85.02
MYRTLE1	148	84.67	84.99	84.96	84.94	85.00
MYRTLE1	313	80.54	80.76	80.74	80.73	80.79
MYRTLE1	388.68	79.57	79.85	79.88	79.85	79.92
MYRTLE1	400	79.30	79.57	79.59	79.57	79.64
MYRTLE1	550.36	74.26	74.63	74.54	74.52	74.62
MYRTLE1	600	72.81	74.07	73.76	73.72	74.05
MYRTLE1	719	72.55	74.03	73.71	73.71	74.00
MYRTLE1	721.68	72.55	74.03	73.70	73.70	74.00
MYRTLE1	740	70.10	71.15	70.50	73.50	71.61
MYRTLE1	800	68.31	71.14	70.19	73.50	71.61
MYRTLE1	960	67.60	71.14	70.18	73.50	71.61
MYRTLE1	1031.91	67.60	71.14	70.18	73.50	71.61

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
MYRTLE 2	0	87.24	88.40	87.33	87.29	87.32
MYRTLE 2	64.5	86.42	88.40	86.98	86.78	86.92
MYRTLE 2	79.5	85.69	85.91	85.79	85.76	85.78
MYRTLE 2	167	79.91	80.08	80.00	79.98	80.00
MYRTLE 2	326.14	74.26	74.63	74.54	74.52	74.62

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
MYRTLE 3	0	86.74	86.73	86.93	86.85	86.90
MYRTLE 3	67	85.81	85.80	86.48	86.24	86.40
MYRTLE 3	83	84.71	84.71	84.95	84.87	84.90
MYRTLE 3	173	81.12	81.13	81.23	81.20	81.20
MYRTLE 3	217.65	79.57	79.85	79.88	79.85	79.90

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
TOWN1	0	75.07	75.28	76.72	77.06	75.65
TOWN1	46.5	73.41	74.58	75.30	74.73	74.75
TOWN1	64.5	72.00	72.89	75.13	74.20	73.03
TOWN1	192.27	70.22	72.89	72.07	74.20	73.03
TOWN1	200	70.22	72.89	72.07	74.20	73.03

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
TOWN2	0	73.70	74.76	74.62	74.90	74.27
TOWN2	41	73.45	74.76	74.62	74.90	74.27
TOWN2	63.5	72.14	72.89	72.28	74.20	73.03
TOWN2	150	70.22	72.89	72.07	74.20	73.03

		Water Level				
Branch	Chainage	2005	1999	1990	1978	1975
TOWN3	0	86.95	87.01	87.14	87.05	87.09
TOWN3	53	81.32	81.39	81.50	81.43	81.46
TOWN3	83	79.26	80.02	80.31	80.11	80.19
TOWN3	118	77.82	77.87	77.93	77.88	77.90
TOWN3	215	74.12	74.29	74.49	74.72	74.51

Appendix B: Hydraulic Modelling Results for Design Events

1. **Water Levels**
2. **Velocities**
3. **Flows**

Appendix B1 – Water Levels

Branch	Chainage	Water Levels (mAHD)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
KANGAROO	0	87.06	83.89	83.42	82.79	81.80	81.12	80.27
KANGAROO	509	85.87	82.75	82.30	81.70	80.73	80.07	79.32
KANGAROO	733	85.48	82.35	81.91	81.32	80.35	79.70	78.93
KANGAROO	1179	84.61	81.25	80.83	80.29	79.41	78.82	78.14
KANGAROO	1578	84.17	80.15	79.72	79.20	78.42	77.92	77.31
KANGAROO	2039.16	83.80	78.96	78.39	77.73	76.92	76.42	75.87
KANGAROO	2039.16	83.80	78.96	78.39	77.73	76.92	76.42	75.87
KANGAROO	2682	83.73	78.91	78.34	77.64	76.80	76.19	74.96
KANGAROO	2682	83.73	78.91	78.34	77.64	76.80	76.19	74.96
KANGAROO	3385.52	83.58	78.42	77.69	76.64	75.54	74.96	73.69
KANGAROO	3385.52	83.58	78.42	77.69	76.64	75.54	74.96	73.69
KANGAROO	3446	83.57	78.39	77.65	76.58	75.46	74.89	73.61
KANGAROO	3446	83.57	78.39	77.65	76.58	75.46	74.89	73.61
KANGAROO	4095.36	83.45	78.05	77.24	75.98	74.40	73.91	72.62
KANGAROO	4095.36	83.45	78.05	77.24	75.98	74.40	73.91	72.62
KANGAROO	4227	83.42	77.97	77.16	75.85	74.19	73.67	72.40
KANGAROO	4227	83.42	77.97	77.16	75.85	74.19	73.67	72.40
KANGAROO	4269	83.41	77.95	77.13	75.81	74.12	73.58	72.33
KANGAROO	4269	83.41	77.95	77.13	75.81	74.12	73.58	72.33
KANGAROO	4500	83.36	77.84	77.01	75.65	73.85	73.17	71.89
KANGAROO	4500	83.36	77.84	77.01	75.65	73.85	73.17	71.89
KANGAROO	4592.98	83.35	77.82	76.98	75.61	73.78	73.01	71.68
KANGAROO	4592.98	83.35	77.82	76.98	75.61	73.78	73.01	71.68
KANGAROO	4990	83.28	77.71	76.86	75.45	73.46	72.26	70.61
KANGAROO	4991.71	83.28	77.71	76.86	75.45	73.46	72.25	70.61
KANGAROO	4991.71	83.28	77.71	76.86	75.45	73.46	72.25	70.61
KANGAROO	5398.76	83.25	77.65	76.79	75.37	73.32	71.70	69.74
KANGAROO	5398.76	83.25	77.65	76.79	75.37	73.32	71.70	69.74
KANGAROO	5405	83.25	77.65	76.79	75.37	73.31	71.69	69.73
KANGAROO	5405	83.25	77.65	76.79	75.37	73.31	71.69	69.73
KANGAROO	5505.31	83.14	77.46	76.58	75.13	73.05	71.46	69.52
KANGAROO	5505.31	83.14	77.46	76.58	75.13	73.05	71.46	69.52
KANGAROO	5779	82.50	76.55	75.62	74.10	72.13	70.63	68.77
KANGAROO	5948	81.31	75.22	74.37	72.98	71.19	69.79	68.04
KANGAROO	5948	81.31	75.22	74.37	72.98	71.19	69.79	68.04
KANGAROO	6069	79.32	75.10	74.26	72.88	71.08	69.67	67.90
KANGAROO	6069	79.32	75.10	74.26	72.88	71.08	69.67	67.90
KANGAROO	6554	76.45	72.80	72.04	70.78	69.13	67.80	66.17
BARRENGARRY	0	83.36	77.84	77.01	75.65	74.19	72.99	71.57
BARRENGARRY	1	83.36	77.84	77.01	75.65	74.19	72.99	71.56
BARRENGARRY	1	83.36	77.84	77.01	75.65	74.19	72.99	71.56
BARRENGARRY	212	83.36	77.83	76.99	75.61	74.04	72.54	70.96
BARRENGARRY	265	83.28	77.73	76.89	75.53	74.02	72.53	70.95
BARRENGARRY	600	83.28	77.72	76.87	75.48	73.75	72.19	70.39
BARRENGARRY	600	83.28	77.72	76.87	75.48	73.75	72.19	70.39
BARRENGARRY	888	83.28	77.71	76.86	75.45	73.55	71.97	70.06
BARRENGARRY	888	83.28	77.71	76.86	75.45	73.55	71.97	70.06
BARRENGARRY	1400	83.27	77.69	76.83	75.42	73.41	71.76	69.77
BARRENGARRY	1400	83.27	77.69	76.83	75.42	73.41	71.76	69.77
BARRENGARRY	1490.08	83.25	77.65	76.79	75.37	73.32	71.70	69.74
MYRILA2	0	88.71	88.09	87.99	87.74	87.45	87.36	87.63
MYRILA2	64.5	88.70	88.08	87.98	87.71	87.34	87.09	87.58
MYRILA2	64.5	88.70	88.08	87.98	87.71	87.34	87.09	87.58
MYRILA2	79.5	86.67	85.89	85.88	85.87	85.84	85.81	85.86
MYRILA2	79.5	86.67	85.89	85.88	85.87	85.84	85.81	85.86
MYRILA2	167	83.18	80.07	80.07	80.06	80.04	80.01	80.05
MYRILA2	326.14	83.14	77.47	76.59	75.15	74.80	74.59	74.45
MYRILA3	0	87.25	87.59	87.54	87.30	87.14	87.01	86.88
MYRILA3	67	87.15	87.54	87.49	87.22	86.93	86.67	86.33
MYRILA3	67	87.15	87.54	87.49	87.22	86.93	86.67	86.33
MYRILA3	83	85.13	85.31	85.25	85.16	85.09	85.01	84.90

Branch	Chainage	Water Levels (mAHD)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
MYRILA3	83	85.13	85.31	85.25	85.16	85.09	85.01	84.90
MYRILA3	173	83.14	81.42	81.40	81.34	81.30	81.25	81.20
MYRILA3	217.65	83.14	80.55	80.51	80.33	80.12	79.92	79.74
MYRILA1	0	88.50	87.92	87.92	87.74	87.50	86.69	86.16
MYRILA1	125.71	88.47	87.91	87.91	87.73	87.49	86.69	86.16
MYRILA1	125.71	88.47	87.91	87.91	87.73	87.49	86.69	86.16
MYRILA1	126	88.47	87.91	87.91	87.73	87.49	86.68	86.15
MYRILA1	147.16	86.15	85.52	85.52	85.35	85.18	84.99	84.84
MYRILA1	147.16	86.15	85.52	85.52	85.35	85.18	84.99	84.84
MYRILA1	148	86.13	85.50	85.50	85.33	85.16	84.97	84.82
MYRILA1	313	83.14	81.23	81.21	81.07	80.92	80.76	80.64
MYRILA1	388.68	83.14	80.55	80.51	80.33	80.12	79.92	79.74
MYRILA1	388.68	83.14	80.55	80.51	80.33	80.12	79.92	79.74
MYRILA1	400	83.14	80.24	80.20	80.02	79.82	79.63	79.47
MYRILA1	550.36	83.14	77.47	76.59	75.15	74.80	74.59	74.45
MYRILA1	550.36	83.14	77.47	76.59	75.15	74.80	74.59	74.45
MYRILA1	600	83.14	77.47	76.59	75.14	74.32	73.95	73.48
MYRILA1	719	83.14	77.47	76.59	75.13	74.28	73.90	73.41
MYRILA1	721.68	83.14	77.47	76.59	75.13	74.27	73.89	73.40
MYRILA1	721.68	83.14	77.47	76.59	75.13	74.27	73.89	73.40
MYRILA1	740	83.14	77.46	76.58	75.13	73.05	71.46	70.27
MYRILA1	740	83.14	77.46	76.58	75.13	73.05	71.46	70.27
MYRILA1	800	83.14	77.46	76.58	75.13	73.05	71.46	69.53
MYRILA1	960	83.14	77.46	76.58	75.13	73.05	71.46	69.52
MYRILA1	1031.91	83.14	77.46	76.58	75.13	73.05	71.46	69.52
JARRETTS	0	84.84	85.39	84.56	84.90	84.54	84.75	85.00
JARRETTS	61	84.04	83.96	83.94	83.89	83.80	83.35	83.25
JARRETTS	61	84.04	83.96	83.94	83.89	83.80	83.35	83.25
JARRETTS	77	83.45	81.18	81.15	81.08	80.97	80.93	80.92
JARRETTS	77	83.45	81.18	81.15	81.08	80.97	80.93	80.92
JARRETTS	200	83.45	78.37	78.33	78.22	78.03	77.97	77.93
JARRETTS	400	83.45	78.05	77.24	75.98	74.70	74.53	74.42
JARRETTS	600	83.45	78.05	77.24	75.98	74.40	73.91	72.62
JARRETTS	714.91	83.45	78.05	77.24	75.98	74.40	73.91	72.62
NUGENTS	0	84.96	83.48	83.40	82.99	82.65	82.22	81.69
NUGENTS	77	84.92	82.87	82.85	82.59	82.14	81.81	81.41
NUGENTS	96	84.83	82.65	82.61	82.32	81.89	81.59	81.24
NUGENTS	113	83.58	82.25	82.09	81.77	81.49	81.16	80.71
NUGENTS	166	83.58	80.91	80.83	80.73	80.59	80.33	80.07
NUGENTS	400	83.58	79.04	78.96	78.86	78.69	78.42	77.90
NUGENTS	600	83.58	78.43	77.71	76.71	76.35	76.17	75.49
NUGENTS	840	83.58	78.42	77.70	76.64	75.56	74.97	73.70
NUGENTS	1000	83.58	78.42	77.70	76.64	75.55	74.96	73.69
NUGENTS	1160	83.58	78.42	77.70	76.64	75.55	74.96	73.69
NUGENTS	1400	83.58	78.42	77.69	76.64	75.54	74.96	73.69
NUGENTS	1501.8	83.58	78.42	77.69	76.64	75.54	74.96	73.69
TOWN1	0	83.35	77.82	76.98	75.95	75.33	75.27	75.38
TOWN1	46.5	83.35	77.82	76.98	75.61	74.76	74.59	74.78
TOWN1	46.5	83.35	77.82	76.98	75.61	74.76	74.59	74.78
TOWN1	64.5	83.35	77.82	76.98	75.61	73.78	73.07	72.37
TOWN1	64.5	83.35	77.82	76.98	75.61	73.78	73.07	72.37
TOWN1	192.27	83.35	77.82	76.98	75.61	73.78	73.01	71.68
TOWN1	192.27	83.35	77.82	76.98	75.61	73.78	73.01	71.68
TOWN1	200	83.35	77.82	76.98	75.61	73.78	73.01	71.68
TOWN1	260.24	83.35	77.82	76.98	75.61	73.78	73.01	71.68
TOWN2	0	83.35	77.82	76.98	75.95	75.39	74.76	73.70
TOWN2	41	83.35	77.82	76.98	75.95	75.39	74.75	73.45
TOWN2	41	83.35	77.82	76.98	75.95	75.39	74.75	73.45
TOWN2	63.5	83.35	77.82	76.98	75.61	73.78	73.01	72.21
TOWN2	63.5	83.35	77.82	76.98	75.61	73.78	73.01	72.21
TOWN2	150	83.35	77.82	76.98	75.61	73.78	73.01	71.68

Branch	Chainage	Water Levels (mAHD)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
TOWN2	180.64	83.35	77.82	76.98	75.61	73.78	73.01	71.68
MCUL1	0	88.47	87.91	87.91	87.73	87.49	86.69	86.16
MCUL1	8	86.15	85.52	85.52	85.35	85.18	84.99	84.84
MCUL3	0	87.15	87.54	87.49	87.22	86.93	86.67	86.33
MCUL3	22	85.13	85.31	85.25	85.16	85.09	85.01	84.90
MCUL2	0	88.70	88.08	87.98	87.71	87.34	87.09	87.58
MCUL2	14	86.67	85.89	85.88	85.87	85.84	85.81	85.86
MCUL12	0	83.14	77.47	76.59	75.13	74.27	73.89	73.40
MCUL12	14	83.14	77.46	76.58	75.13	73.05	71.46	70.27
TCUL1	0	83.35	77.82	76.98	75.61	74.76	74.59	74.78
TCUL1	19	83.35	77.82	76.98	75.61	73.78	73.07	72.37
TCUL2	0	83.35	77.82	76.98	75.95	75.39	74.75	73.45
TCUL2	20	83.35	77.82	76.98	75.61	73.78	73.01	72.21
NCUL1	0	84.04	83.96	83.94	83.89	83.80	83.35	83.25
NCUL1	14	83.45	81.18	81.15	81.08	80.97	80.93	80.92
BARRENGARRY_OF	0	83.36	77.84	77.01	75.65	74.19	72.99	71.56
BARRENGARRY_OF	300	83.36	77.84	77.00	75.64	73.72	72.24	71.03
SHOALHAVEN_R	-3530	69.63	67.35	67.07	66.69	66.29	66.03	65.72
SHOALHAVEN_R	-2130	69.30	66.43	65.95	65.21	64.37	63.95	63.44
SHOALHAVEN_R	-1049	68.84	65.63	65.01	63.95	62.50	61.65	60.58
SHOALHAVEN_R	330	68.23	65.00	64.36	63.27	61.79	60.94	59.82
SHOALHAVEN_R	3084	66.59	63.73	63.13	62.12	60.83	60.12	59.19
SHOALHAVEN_R	4256	65.80	63.34	62.78	61.84	60.65	60.00	59.14
SHOALHAVEN_R	8784	64.05	62.71	62.23	61.44	60.43	59.85	59.07
SHOALHAVEN_R	9589	63.88	62.68	62.20	61.41	60.42	59.84	59.07
SHOALHAVEN_R	10666	63.76	62.65	62.18	61.40	60.41	59.84	59.07
SHOALHAVEN_R	11745	63.72	62.65	62.18	61.40	60.41	59.84	59.07
SHOALHAVEN_R	12405	63.68	62.64	62.17	61.40	60.41	59.84	59.07
SHOALHAVEN_R	12700	63.65	62.64	62.17	61.40	60.41	59.84	59.07
SHOALHAVEN_R	12700	63.65	62.64	62.17	61.40	60.41	59.84	59.07
SHOALHAVEN_R	12900	63.63	62.62	62.16	61.39	60.40	59.83	59.06
SHOALHAVEN_R	12950	63.62	62.62	62.16	61.39	60.40	59.83	59.06
KANGROOV_R	-1587	76.45	72.80	72.04	70.78	69.13	67.80	66.17
KANGROOV_R	0	70.38	68.43	67.95	67.02	65.73	64.68	63.23
KANGROOV_R	997	68.85	66.91	66.34	65.39	64.25	63.33	62.10
KANGROOV_R	1982	68.30	66.36	65.78	64.86	63.68	62.79	61.52
KANGROOV_R	3153	67.98	66.08	65.48	64.51	63.19	62.28	60.96
KANGROOV_R	3921	67.58	65.74	65.12	64.10	62.75	61.89	60.63
KANGROOV_R	4564	67.25	65.46	64.83	63.79	62.47	61.65	60.43
KANGROOV_R	5903	66.59	64.96	64.31	63.24	61.94	61.14	60.00
KANGROOV_R	8486	65.09	63.92	63.31	62.30	61.06	60.34	59.39
KANGROOV_R	10798	64.47	63.50	62.92	61.97	60.79	60.12	59.24
KANGROOV_R	13292	64.34	63.40	62.83	61.89	60.73	60.07	59.21
KANGROOV_R	14476	64.25	63.35	62.78	61.85	60.70	60.05	59.19
KANGROOV_R	17222	63.96	63.17	62.62	61.73	60.61	59.99	59.15
KANGROOV_R	18108.45	63.90	63.12	62.58	61.70	60.59	59.97	59.14
KANGROOV_R	18108.45	63.90	63.12	62.58	61.70	60.59	59.97	59.14
KANGROOV_R	18969	63.85	63.04	62.51	61.65	60.56	59.95	59.13
KANGROOV_R	21096	63.74	62.89	62.39	61.55	60.50	59.91	59.10
KANGROOV_R	22216	63.70	62.80	62.31	61.49	60.47	59.88	59.09
KANGROOV_R	22216	63.70	62.80	62.31	61.49	60.47	59.88	59.09
KANGROOV_R	22936	63.68	62.75	62.27	61.47	60.45	59.87	59.08
KANGROOV_R	24416	63.63	62.64	62.17	61.40	60.41	59.84	59.07
KANGROOV_R	24800	63.65	62.64	62.17	61.40	60.41	59.84	59.07
EXT-SHOALHAVEN	0	69.50	69.63	69.63	69.63	69.63	69.63	69.63
EXT-SHOALHAVEN	8333.33	68.74	68.02	68.02	68.02	68.02	68.02	68.03
EXT-SHOALHAVEN	16666.67	69.10	67.18	67.01	66.78	66.59	66.59	66.59
EXT-SHOALHAVEN	25000	69.63	67.35	67.07	66.69	66.29	66.03	65.72
YARRUNGA	0	63.90	63.13	62.60	61.91	61.78	61.72	61.72
YARRUNGA	1850	63.90	63.12	62.58	61.70	60.60	59.97	59.14
YARRUNGA	3670	63.90	63.12	62.58	61.70	60.60	59.97	59.14

Branch	Chainage	Water Levels (mAHD)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
YARRUNGA	5030	63.90	63.12	62.58	61.70	60.59	59.97	59.14
BUNDANOON	0	63.70	62.80	62.31	61.49	60.47	59.88	59.09
BUNDANOON	945	63.70	62.80	62.31	61.49	60.47	59.88	59.09
BUNDANOON	1120	63.70	62.80	62.31	61.49	60.47	59.88	59.09
HAMPDENOF	0	81.31	75.22	74.37	72.98	71.19	69.79	68.04
HAMPDENOF	121	79.32	75.10	74.26	72.88	71.08	69.67	67.90
BARRENGARRY_OF1	0	83.28	77.72	76.87	75.48	73.75	72.19	70.39
BARRENGARRY_OF1	5	83.29	77.71	76.86	75.45	73.45	71.77	69.76
BARRENGARRY_OF2	0	83.28	77.71	76.86	75.45	73.55	71.97	70.06
BARRENGARRY_OF2	5	83.29	77.71	76.86	75.45	73.45	71.77	69.76
BARRENGARRY_OF3	0	83.27	77.69	76.83	75.42	73.41	71.76	69.77
BARRENGARRY_OF3	5	83.29	77.71	76.86	75.45	73.45	71.77	69.76
KANGAROOOF	0	83.80	78.96	78.39	77.73	76.92	76.42	75.87
KANGAROOOF	2	83.74	78.95	78.39	77.71	76.91	76.41	75.84
KANGAROOOF	2	83.74	78.95	78.39	77.71	76.91	76.41	75.84
KANGAROOOF	385	83.57	78.39	77.65	76.58	75.46	74.90	74.53
KANGAROOOF	385	83.57	78.39	77.65	76.58	75.46	74.90	74.53
KANGAROOOF	1020	83.40	77.94	77.12	75.81	74.09	73.26	72.31
KANGAROOOF	1020	83.40	77.94	77.12	75.81	74.09	73.26	72.31
KANGAROOOF	1415	83.36	77.84	77.00	75.64	73.72	72.24	71.03
KANGAROOOF	1415	83.36	77.84	77.00	75.64	73.72	72.24	71.03
KANGAROOOF	1660	83.29	77.71	76.86	75.45	73.45	71.77	69.76
KANGAROOOF	1660	83.29	77.71	76.86	75.45	73.45	71.77	69.76
KANGAROOOF	1995.5	83.25	77.65	76.79	75.37	73.31	71.69	69.73
KVOF1	0	83.73	78.91	78.34	77.64	76.80	76.19	74.96
KVOF1	5	83.74	78.95	78.39	77.71	76.91	76.41	75.84
KVOF2	0	83.57	78.39	77.65	76.58	75.46	74.89	73.61
KVOF2	5	83.57	78.39	77.65	76.58	75.46	74.90	74.53
KVOF3	0	83.41	77.95	77.13	75.81	74.12	73.58	72.33
KVOF3	5	83.40	77.94	77.12	75.81	74.09	73.26	72.31
KVOF4	0	83.36	77.84	77.01	75.65	73.85	73.17	71.89
KVOF4	5	83.36	77.84	77.00	75.64	73.72	72.24	71.03
KVOF5	0	83.28	77.71	76.86	75.45	73.46	72.25	70.61
KVOF5	5	83.29	77.71	76.86	75.45	73.45	71.77	69.76
TOWN3	0	94.11	87.39	87.35	87.31	87.26	87.19	86.94
TOWN3	53	85.15	81.74	81.70	81.66	81.60	81.55	81.32
TOWN3	83	84.95	80.67	80.61	80.54	80.47	80.38	79.19
TOWN3	83	84.95	80.67	80.61	80.54	80.47	80.38	79.19
TOWN3	118	83.42	78.07	78.05	78.03	78.00	77.96	77.82
TOWN3	118	83.42	78.07	78.05	78.03	78.00	77.96	77.82
TOWN3	215	83.42	77.97	77.16	75.86	74.53	74.42	74.01
TOWN3	397.97	83.42	77.97	77.16	75.85	74.19	73.67	72.40
TOWN3OF	0	84.95	80.67	80.61	80.54	80.47	80.38	79.19
TOWN3OF	30	83.42	78.07	78.05	78.03	78.00	77.96	77.82

Appendix B2 – Velocities

Branch	Chainage	Average Velocity (m/s)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
KANGAROO	0	2.30	1.66	1.56	1.44	1.23	1.12	1.16
KANGAROO	509	1.53	1.19	1.20	1.16	1.11	1.09	1.11
KANGAROO	733	2.55	1.26	1.26	1.22	1.18	1.16	1.18
KANGAROO	1179	2.11	1.60	1.51	1.41	1.20	1.04	0.88
KANGAROO	1578	1.47	1.28	1.28	1.26	1.24	1.23	1.24
KANGAROO	2039.16	2.51	2.16	2.07	2.03	1.98	1.80	1.54
KANGAROO	2039.16	1.69	1.62	1.60	1.55	1.54	1.52	1.46
KANGAROO	2682	1.41	1.46	1.45	1.44	1.43	1.42	1.38
KANGAROO	2682	2.04	1.98	1.94	1.90	1.91	1.84	1.64
KANGAROO	3385.52	1.18	1.33	1.29	1.23	1.28	1.24	1.15
KANGAROO	3385.52	1.55	1.41	1.38	1.36	1.33	1.26	1.19
KANGAROO	3446	1.47	1.35	1.31	1.30	1.27	1.24	1.21
KANGAROO	3446	1.57	1.43	1.39	1.37	1.34	1.25	1.21
KANGAROO	4095.36	1.77	1.49	1.46	1.44	1.46	1.38	1.30
KANGAROO	4095.36	1.75	1.50	1.46	1.44	1.45	1.37	1.30
KANGAROO	4227	2.07	1.76	1.71	1.67	1.54	1.43	1.25
KANGAROO	4227	2.07	1.76	1.71	1.68	1.54	1.44	1.25
KANGAROO	4269	2.22	1.88	1.82	1.79	1.62	1.46	1.24
KANGAROO	4269	1.68	1.58	1.53	1.55	1.56	1.45	1.24
KANGAROO	4500	1.80	1.64	1.58	1.61	1.65	1.54	1.49
KANGAROO	4500	1.73	1.64	1.58	1.61	1.65	1.54	1.49
KANGAROO	4592.98	1.71	1.63	1.57	1.61	1.66	1.55	1.49
KANGAROO	4592.98	1.66	1.59	1.54	1.58	1.63	1.53	1.47
KANGAROO	4990	1.68	1.64	1.56	1.65	1.76	1.66	1.55
KANGAROO	4991.71	3.08	1.65	1.56	1.66	1.77	1.66	1.55
KANGAROO	4991.71	3.08	1.65	1.56	1.66	1.77	1.66	1.55
KANGAROO	5398.76	1.26	1.24	1.18	1.26	1.35	1.27	1.12
KANGAROO	5398.76	1.91	1.84	1.77	1.81	1.74	1.66	1.46
KANGAROO	5405	1.90	1.83	1.76	1.80	1.73	1.65	1.46
KANGAROO	5405	1.80	1.76	1.74	1.73	1.68	1.63	1.45
KANGAROO	5505.31	2.09	1.93	1.91	1.85	1.63	1.47	1.29
KANGAROO	5505.31	2.05	1.91	1.89	1.85	1.64	1.47	1.30
KANGAROO	5779	2.86	2.29	2.16	1.93	1.65	1.47	1.27
KANGAROO	5948	3.83	3.23	3.03	2.70	2.28	2.02	1.74
KANGAROO	5948	3.55	3.23	3.03	2.70	2.28	2.02	1.74
KANGAROO	6069	3.78	3.40	3.25	3.01	2.74	2.60	2.26
KANGAROO	6069	4.28	3.40	3.25	3.01	2.74	2.60	2.26
KANGAROO	6554	5.22	4.11	3.93	3.65	3.31	2.95	2.54
BARRENGARRY	0	1.91	1.74	1.73	1.69	1.61	1.63	1.53
BARRENGARRY	1	1.91	1.74	1.73	1.69	1.61	1.63	1.54
BARRENGARRY	1	1.70	1.61	1.61	1.59	1.54	1.56	1.50
BARRENGARRY	212	2.89	2.58	2.56	2.44	2.07	2.03	1.60
BARRENGARRY	265	2.16	1.99	1.98	1.90	1.64	2.00	1.47
BARRENGARRY	600	1.90	1.81	1.83	1.70	1.39	1.49	1.16
BARRENGARRY	600	1.89	1.81	1.82	1.70	1.39	1.49	1.16
BARRENGARRY	888	2.49	2.35	2.39	2.16	2.07	2.32	1.97
BARRENGARRY	888	2.47	2.33	2.37	2.15	2.06	2.31	1.95
BARRENGARRY	1400	1.78	1.57	1.66	1.35	0.89	1.04	0.69
BARRENGARRY	1400	1.78	1.57	1.66	1.35	0.96	1.04	0.69
BARRENGARRY	1490.08	1.78	1.57	1.67	1.35	0.98	1.04	0.68
MYRILA2	0	0.97	1.04	1.03	1.07	1.04	1.01	1.04
MYRILA2	64.5	0.26	0.20	0.20	0.20	0.20	0.19	0.20
MYRILA2	64.5	0.20	0.19	0.19	0.19	0.19	0.18	0.19
MYRILA2	79.5	5.28	1.21	1.20	1.16	1.10	1.01	1.14
MYRILA2	79.5	7.37	1.21	1.20	1.20	1.10	1.01	1.14
MYRILA2	167	1.53	1.36	0.91	0.86	1.20	0.66	0.73
MYRILA2	326.14	13.39	4.87	3.72	4.27	5.22	3.23	3.36
MYRILA3	0	0.91	0.87	0.86	0.86	0.86	0.86	0.84
MYRILA3	67	0.69	0.69	0.69	0.69	0.69	0.68	0.59
MYRILA3	67	0.68	0.68	0.68	0.68	0.68	0.68	0.59
MYRILA3	83	2.39	2.51	2.52	2.39	2.20	2.01	1.73
MYRILA3	83	2.39	2.74	2.62	2.39	2.20	2.01	1.73
MYRILA3	173	1.04	1.21	1.16	1.12	1.10	1.08	0.98
MYRILA3	217.65	5.54	8.01	7.24	6.26	5.78	5.37	4.52
MYRILA1	0	0.21	0.12	0.12	0.10	0.09	0.07	0.05
MYRILA1	125.71	0.67	0.48	0.48	0.48	0.48	0.48	0.40

Branch	Chainage	Average Velocity (m/s)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
MYRILA1	125.71	0.48	0.48	0.48	0.48	0.48	0.48	0.40
MYRILA1	126	0.51	0.51	0.51	0.51	0.51	0.51	0.43
MYRILA1	147.16	1.67	1.64	1.64	1.63	1.64	1.41	1.17
MYRILA1	147.16	2.98	2.20	2.20	1.97	1.72	1.41	1.17
MYRILA1	148	3.24	2.41	2.39	2.15	1.89	1.57	1.30
MYRILA1	313	1.59	1.20	1.21	1.14	1.07	1.00	0.94
MYRILA1	388.68	2.05	1.65	1.65	1.46	1.26	1.01	0.74
MYRILA1	388.68	2.39	2.29	2.25	2.05	1.81	1.58	1.37
MYRILA1	400	3.13	2.59	2.55	2.33	2.08	1.83	1.60
MYRILA1	550.36	1.60	1.40	1.37	1.24	1.12	1.05	0.89
MYRILA1	550.36	2.07	1.56	1.53	1.43	1.36	1.34	1.28
MYRILA1	600	1.32	0.79	0.77	0.73	0.73	0.72	0.71
MYRILA1	719	0.64	0.42	0.41	0.41	0.41	0.41	0.41
MYRILA1	721.68	0.78	0.60	0.60	0.60	0.60	0.60	0.60
MYRILA1	721.68	0.60	0.60	0.60	0.60	0.60	0.60	0.60
MYRILA1	740	2.51	2.52	2.52	2.52	2.52	2.49	2.30
MYRILA1	740	4.61	2.89	3.03	3.05	2.82	2.49	2.30
MYRILA1	800	3.04	1.95	1.93	1.71	1.91	1.76	1.67
MYRILA1	960	1.20	0.47	0.47	0.47	0.47	0.47	0.47
MYRILA1	1031.91	10.50	1.96	1.82	2.08	1.72	1.72	1.93
JARRETTS	0	2.25	1.55	1.47	1.42	1.41	1.38	1.11
JARRETTS	61	69.51	2.72	5.83	1.67	1.04	6.26	0.96
JARRETTS	61	0.06	0.05	0.05	0.05	0.05	0.05	0.06
JARRETTS	77	0.62	0.50	0.48	0.48	0.49	0.48	0.48
JARRETTS	77	1.10	0.90	0.85	0.75	0.56	0.48	0.48
JARRETTS	200	12.88	2.39	2.36	2.26	1.31	1.46	1.37
JARRETTS	400	1.53	1.62	1.71	1.73	1.31	1.24	1.19
JARRETTS	600	1.28	0.92	0.88	0.84	0.76	0.79	0.82
JARRETTS	714.91	162.98	49.85	40.83	31.75	43.29	37.45	28.93
NUGENTS	0	2.71	2.64	2.65	2.60	2.23	1.81	1.32
NUGENTS	77	2.05	2.19	2.08	2.08	2.04	1.64	1.15
NUGENTS	96	3.32	4.43	3.06	3.02	2.99	2.62	2.09
NUGENTS	113	3.61	3.61	3.61	3.58	3.31	3.04	2.72
NUGENTS	166	1.77	1.74	1.73	1.70	1.74	1.74	1.68
NUGENTS	400	2.70	2.23	2.12	2.20	2.06	2.03	1.85
NUGENTS	600	2.65	2.62	2.62	2.60	2.62	2.61	2.25
NUGENTS	840	2.60	2.02	1.85	1.98	1.95	1.71	1.43
NUGENTS	1000	2.83	2.00	1.86	1.68	1.90	1.78	1.58
NUGENTS	1160	3.23	1.64	1.41	1.15	1.47	1.27	1.12
NUGENTS	1400	2.85	1.14	0.98	0.66	0.81	0.89	0.73
NUGENTS	1501.8	20.84	1.18	0.95	0.62	0.81	0.88	0.74
TOWN1	0	2.03	1.74	1.67	1.52	1.50	1.40	1.21
TOWN1	46.5	0.52	0.31	0.31	0.59	0.37	0.36	0.31
TOWN1	46.5	0.22	0.24	0.24	0.24	0.28	0.30	0.27
TOWN1	64.5	10.63	28.27	2.08	6.33	2.59	2.61	13.03
TOWN1	64.5	3.86	3.14	3.26	3.11	3.27	2.61	14.46
TOWN1	192.27	1.36	1.25	1.52	1.31	2.93	2.65	1.22
TOWN1	192.27	2.00	1.60	1.75	1.55	3.13	2.68	1.53
TOWN1	200	1.63	1.22	1.46	1.27	3.24	2.12	1.18
TOWN1	260.24	105.71	34.34	34.55	31.05	49.24	209.35	26.79
TOWN2	0	0.92	0.79	0.91	0.77	0.99	0.92	1.02
TOWN2	41	0.23	0.20	0.20	0.20	0.20	0.20	0.17
TOWN2	41	0.19	0.19	0.19	0.19	0.19	0.19	0.17
TOWN2	63.5	1.28	2.04	2.04	1.84	2.00	1.77	9.01
TOWN2	63.5	2.28	2.04	2.04	2.03	2.00	1.77	12.92
TOWN2	150	1.88	1.14	1.06	0.99	1.10	1.05	0.70
TOWN2	180.64	35.91	10.88	9.12	7.67	10.14	8.84	3.30
MCUL1	0	0.46	0.18	0.18	0.10	0.02	0.02	0.01
MCUL1	8	1.98	0.87	0.86	0.49	0.10	0.00	0.00
MCUL3	0	0.21	0.15	0.09	0.05	0.05	0.09	0.09
MCUL3	22	0.05	0.36	0.15	0.03	0.03	0.03	0.03
MCUL2	0	0.13	0.02	0.02	0.01	0.02	0.02	0.02
MCUL2	14	2.38	0.08	0.12	0.07	0.09	0.14	0.11
MCUL12	0	0.53	0.24	0.22	0.17	0.07	0.01	0.00
MCUL12	14	3.12	1.08	1.21	0.95	0.47	0.00	0.00
TCUL1	0	0.38	0.14	0.14	0.44	0.14	0.14	0.19

Branch	Chainage	Average Velocity (m/s)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
TCUL1	19	3.04	1.69	1.92	1.73	2.26	0.57	11.13
TCUL2	0	0.15	0.06	0.05	0.04	0.03	0.04	0.03
TCUL2	20	1.45	0.43	0.59	0.27	0.03	0.02	3.91
NCUL1	0	0.80	0.01	0.01	0.00	0.00	0.00	0.00
NCUL1	14	0.95	0.69	0.63	0.47	0.13	0.01	0.00
BARRENGARRY_OF	0	0.47	0.24	0.22	0.14	0.12	0.10	0.07
BARRENGARRY_OF	300	0.35	0.12	0.16	0.04	0.03	0.02	0.01
SHOALHAVEN_R	-3530	1.38	1.20	1.18	1.14	1.04	0.94	0.81
SHOALHAVEN_R	-2130	1.51	1.49	1.49	1.49	1.49	1.49	1.47
SHOALHAVEN_R	-1049	1.68	1.41	1.40	1.37	1.29	1.20	1.07
SHOALHAVEN_R	330	1.84	1.66	1.63	1.57	1.44	1.34	1.20
SHOALHAVEN_R	3084	2.32	1.80	1.70	1.51	1.21	1.01	0.77
SHOALHAVEN_R	4256	2.45	1.79	1.68	1.49	1.17	0.96	0.71
SHOALHAVEN_R	8784	2.35	1.15	1.04	0.87	0.63	0.49	0.35
SHOALHAVEN_R	9589	2.25	1.04	0.94	0.78	0.56	0.44	0.32
SHOALHAVEN_R	10666	1.75	0.84	0.75	0.62	0.44	0.34	0.24
SHOALHAVEN_R	11745	1.39	0.60	0.54	0.43	0.31	0.24	0.17
SHOALHAVEN_R	12405	1.63	0.61	0.55	0.44	0.31	0.24	0.17
SHOALHAVEN_R	12700	1.70	0.63	0.56	0.45	0.32	0.25	0.17
SHOALHAVEN_R	12700	1.79	1.48	1.33	1.09	0.81	0.66	0.46
SHOALHAVEN_R	12900	1.77	1.46	1.31	1.08	0.80	0.65	0.46
SHOALHAVEN_R	12950	1.77	1.46	1.31	1.08	0.80	0.65	0.46
KANGROOV_R	-1587	8.06	6.16	5.78	5.16	4.40	3.94	3.42
KANGROOV_R	0	4.97	3.82	3.63	3.35	3.02	2.66	2.32
KANGROOV_R	997	3.79	3.32	3.25	3.14	2.86	2.65	2.16
KANGROOV_R	1982	1.92	1.63	1.63	1.61	1.56	1.61	1.47
KANGROOV_R	3153	1.49	1.20	1.22	1.22	1.23	1.29	1.21
KANGROOV_R	3921	2.70	1.93	1.95	1.98	1.86	1.71	1.41
KANGROOV_R	4564	2.29	1.62	1.63	1.64	1.59	1.45	1.29
KANGROOV_R	5903	2.08	1.51	1.49	1.46	1.43	1.40	1.26
KANGROOV_R	8486	2.81	1.99	1.90	1.75	1.53	1.34	1.10
KANGROOV_R	10798	1.54	1.13	1.06	0.94	0.78	0.65	0.50
KANGROOV_R	13292	0.68	0.59	0.56	0.51	0.43	0.35	0.27
KANGROOV_R	14476	1.23	0.94	0.87	0.76	0.61	0.50	0.38
KANGROOV_R	17222	1.84	1.34	1.22	1.05	0.83	0.66	0.50
KANGROOV_R	18108.45	1.92	1.23	1.12	0.96	0.75	0.60	0.45
KANGROOV_R	18108.45	3.15	1.28	1.17	1.00	0.78	0.62	0.47
KANGROOV_R	18969	2.67	1.30	1.19	1.00	0.77	0.62	0.46
KANGROOV_R	21096	3.35	1.27	1.16	0.97	0.74	0.60	0.44
KANGROOV_R	22216	2.42	1.25	1.14	0.96	0.73	0.60	0.43
KANGROOV_R	22216	2.16	1.26	1.15	0.96	0.73	0.60	0.44
KANGROOV_R	22936	1.28	1.19	1.08	0.90	0.68	0.56	0.40
KANGROOV_R	24416	1.51	1.28	1.16	0.96	0.73	0.60	0.43
KANGROOV_R	24800	1.03	0.98	0.89	0.74	0.55	0.46	0.33
EXT-SHOALHAVEN	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EXT-SHOALHAVEN	8333.33	0.99	0.20	0.20	0.20	0.19	0.19	0.19
EXT-SHOALHAVEN	16666.67	0.23	0.19	0.19	0.19	0.19	0.19	0.19
EXT-SHOALHAVEN	25000	1.38	1.20	1.18	1.14	1.04	0.94	0.81
YARRUNGA	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
YARRUNGA	1850	1.44	0.04	0.04	0.04	0.04	0.04	0.04
YARRUNGA	3670	1.37	0.04	0.04	0.03	0.03	0.03	0.02
YARRUNGA	5030	35.98	0.16	0.16	0.16	0.15	0.14	0.13
BUNDANOON	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BUNDANOON	945	2.79	0.01	0.01	0.01	0.01	0.01	0.01
BUNDANOON	1120	2.39	0.01	0.01	0.01	0.01	0.01	0.01
HAMPDENOF	0	0.45	0.03	0.02	0.03	0.02	0.02	0.02
HAMPDENOF	121	0.53	0.01	0.01	0.01	0.01	0.01	0.01
BARRENGARRY_OF1	0	0.10	0.09	0.09	0.08	0.00	0.00	0.00
BARRENGARRY_OF1	5	0.13	0.04	0.04	0.03	0.00	0.00	0.00
BARRENGARRY_OF2	0	0.50	0.43	0.42	0.32	0.24	0.02	0.01
BARRENGARRY_OF2	5	0.15	0.12	0.12	0.09	0.07	0.00	0.00
BARRENGARRY_OF3	0	0.43	0.45	0.44	0.42	0.24	0.21	0.00
BARRENGARRY_OF3	5	0.76	0.68	0.72	0.59	0.41	0.41	0.00
KANGAROOOF	0	1.82	1.62	1.58	1.58	1.50	1.31	0.73
KANGAROOOF	2	7.02	5.97	4.89	5.44	4.66	4.24	3.25
KANGAROOOF	2	6.91	5.88	4.81	5.36	4.59	4.17	3.20

Branch	Chainage	Average Velocity (m/s)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
KANGAROOOF	385	3.72	2.66	2.45	2.19	2.19	1.93	1.33
KANGAROOOF	385	3.69	2.63	2.43	2.17	2.17	1.92	1.32
KANGAROOOF	1020	1.45	1.00	0.92	0.85	0.84	0.71	0.51
KANGAROOOF	1020	1.43	0.99	0.91	0.83	0.83	0.70	0.50
KANGAROOOF	1415	17.22	1.08	0.36	1.44	1.63	1.36	0.99
KANGAROOOF	1415	1.27	0.58	0.56	0.46	0.51	0.30	0.28
KANGAROOOF	1660	5.51	0.67	0.66	0.65	0.62	0.61	0.54
KANGAROOOF	1660	6.05	0.68	0.67	0.66	0.63	0.62	0.54
KANGAROOOF	1995.5	0.34	0.30	0.29	0.29	0.29	0.14	0.06
KVOF1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
KVOF1	5	0.01	0.01	0.01	0.01	0.01	0.01	0.01
KVOF2	0	0.04	0.03	0.02	0.00	0.00	0.00	0.00
KVOF2	5	0.06	0.04	0.03	0.00	0.00	0.00	0.00
KVOF3	0	0.77	0.55	0.52	0.47	0.33	0.19	0.00
KVOF3	5	0.95	0.64	0.65	0.59	0.47	0.33	0.00
KVOF4	0	0.38	0.36	0.34	0.35	0.22	0.03	0.00
KVOF4	5	0.26	0.27	0.16	0.48	0.31	0.05	0.00
KVOF5	0	0.24	0.25	0.23	0.26	0.23	0.01	0.00
KVOF5	5	0.13	0.13	0.12	0.13	0.12	0.01	0.00
TOWN3	0	9.36	3.08	2.98	2.88	2.75	2.59	1.85
TOWN3	53	15.32	2.51	2.38	2.25	2.10	1.94	1.38
TOWN3	83	0.93	0.44	0.43	0.41	0.42	0.43	0.38
TOWN3	83	0.58	0.41	0.40	0.40	0.40	0.41	0.38
TOWN3	118	0.46	3.78	4.07	3.34	0.75	0.70	0.57
TOWN3	118	3.67	6.86	7.04	5.71	1.01	0.90	0.57
TOWN3	215	5.70	1.71	1.53	1.43	1.60	1.53	0.98
TOWN3	397.97	343.65	31.26	27.16	24.41	27.91	26.44	21.79
TOWN3OF	0	0.43	0.13	0.12	0.12	0.11	0.09	0.01
TOWN3OF	30	3.85	3.08	3.06	2.37	0.60	0.43	0.01

Appendix B3 – Flows

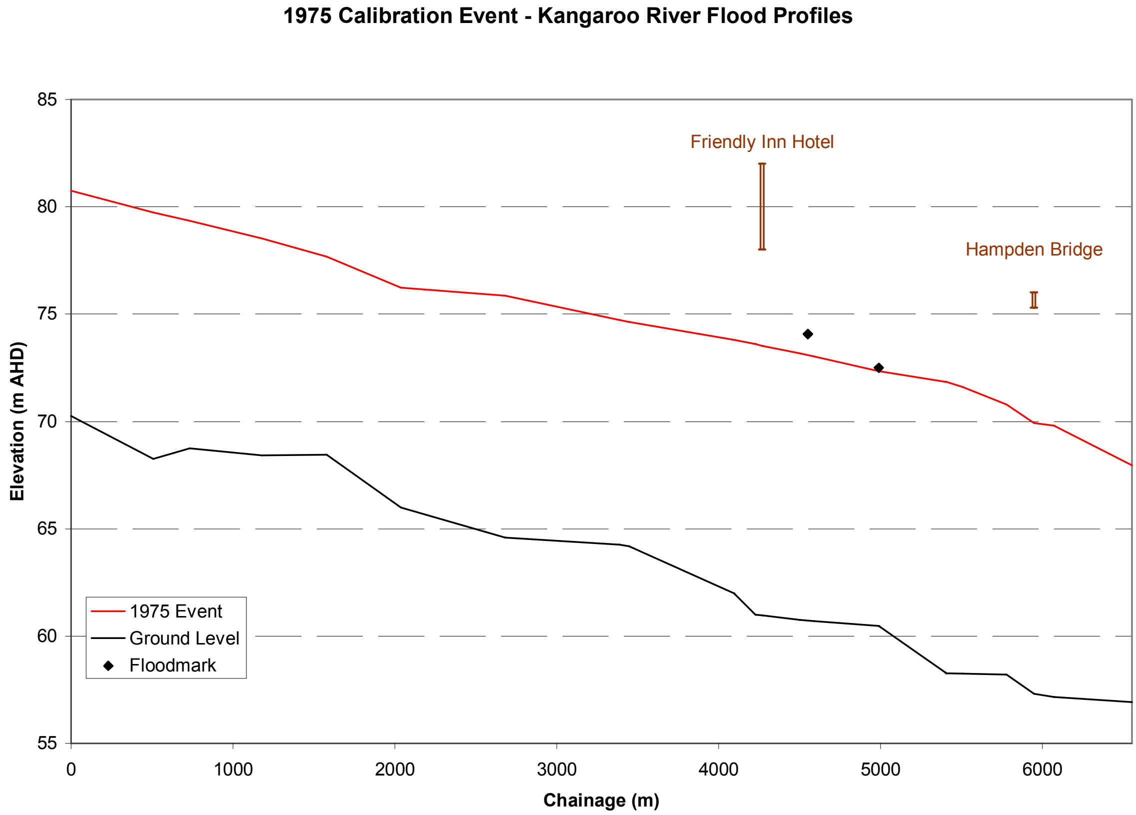
Branch	Chainage	Peak Discharge (m3/s)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
KANGAROO	254.5	8219.5	4086.1	3597.2	2987.1	2132.2	1621.8	1132.2
KANGAROO	621	8198.6	4084.8	3595.3	2978.8	2129.5	1620.4	1129.3
KANGAROO	956	8179.1	4088.5	3595.3	2979.4	2129.2	1620.7	1128.0
KANGAROO	1378.5	8127.9	4089.8	3592.7	2980.7	2129.1	1621.8	1126.6
KANGAROO	1808.58	8014.8	4080.7	3583.5	2978.4	2125.5	1621.0	1122.1
KANGAROO	2360.58	1980.1	817.0	805.6	786.9	784.5	770.1	731.7
KANGAROO	3033.76	4063.5	2470.1	2250.2	2011.0	1593.9	1288.5	983.5
KANGAROO	3415.76	3941.8	2493.0	2280.3	2078.0	1672.5	1335.2	976.7
KANGAROO	3770.68	3729.4	2514.7	2364.2	2197.3	1802.0	1476.9	1040.8
KANGAROO	4161.18	3463.8	2412.5	2280.2	2167.7	1804.2	1475.5	1028.1
KANGAROO	4248	3337.5	2377.2	2254.1	2161.3	1805.8	1476.1	1026.7
KANGAROO	4384.5	2389.3	1832.0	1728.3	1702.0	1448.6	1305.8	1023.4
KANGAROO	4546.49	1942.9	1435.6	1381.6	1409.5	1396.1	1297.7	1020.7
KANGAROO	4791.49	1799.5	1411.1	1362.4	1385.6	1373.4	1284.6	1015.6
KANGAROO	4990.85	1767.6	1389.7	1341.5	1369.4	1356.9	1275.7	1012.8
KANGAROO	5195.23	2056.7	1329.7	1286.5	1333.7	1341.7	1266.5	1010.5
KANGAROO	5401.88	4473.2	2843.9	2590.1	2205.5	1793.3	1652.0	1317.1
KANGAROO	5455.15	7098.4	4181.5	3726.6	3043.4	2272.0	1798.8	1318.3
KANGAROO	5642.15	7068.4	4186.0	3736.6	3050.7	2279.0	1806.1	1323.4
KANGAROO	5863.5	7064.4	4184.1	3736.0	3049.4	2277.1	1805.1	1320.9
KANGAROO	5998	6186.4	4183.5	3735.8	3049.1	2276.2	1804.5	1320.1
KANGAROO	6311.5	7062.4	4182.8	3734.9	3048.4	2274.7	1803.1	1319.3
BARRENGARRY	0.5	3178.0	1493.0	1400.0	1030.0	660.0	546.9	359.2
BARRENGARRY	106.5	1266.4	1023.3	1261.8	892.7	630.1	523.3	345.2
BARRENGARRY	235	1469.6	1019.3	1019.9	887.9	627.3	521.5	343.4
BARRENGARRY	432.5	1219.8	1009.3	1011.5	880.0	621.2	516.4	340.1
BARRENGARRY	744	1162.8	947.7	951.5	835.2	589.4	494.8	331.5
BARRENGARRY	1144	985.4	899.0	914.1	809.1	564.9	484.2	320.7
BARRENGARRY	1445.04	2470.1	1572.0	1427.7	1204.3	984.4	530.3	311.5
MYRILA2	32.25	17.3	3.3	3.0	2.5	2.1	1.6	2.4
MYRILA2	65.5	2.6	2.2	2.2	2.0	1.7	1.4	1.9
MYRILA2	123.25	17.3	2.2	2.2	2.0	1.7	1.9	1.9
MYRILA2	246.57	17.3	6.8	2.2	2.3	4.9	4.0	4.3
MYRILA3	33.5	7.0	10.1	9.2	7.6	6.3	4.9	3.4
MYRILA3	68	6.9	8.6	8.4	7.3	6.0	4.9	3.4
MYRILA3	128	6.9	9.9	8.9	7.3	6.0	4.9	3.4
MYRILA3	195.33	6.9	9.9	8.9	7.2	6.0	4.9	3.4
MYRILA1	62.86	37.5	18.4	18.3	14.1	10.3	6.4	4.2
MYRILA1	125.86	12.8	11.7	11.7	11.2	10.3	6.9	4.5
MYRILA1	126.5	12.8	11.7	11.7	11.2	10.3	6.9	4.5
MYRILA1	147.58	40.9	20.0	19.8	15.3	11.1	7.1	4.6
MYRILA1	230.5	44.2	21.5	21.3	16.5	12.0	7.7	4.9
MYRILA1	350.84	49.0	23.7	23.3	18.2	13.3	8.7	5.5
MYRILA1	394.34	57.6	34.4	33.0	26.5	20.1	14.6	10.6
MYRILA1	475.18	60.8	35.8	34.4	27.7	20.9	15.2	10.9
MYRILA1	575.18	82.6	41.4	39.9	32.8	25.7	19.6	15.7
MYRILA1	659.5	82.6	41.3	39.8	32.7	25.6	19.1	15.6
MYRILA1	720.34	82.6	41.2	39.7	32.7	25.5	18.7	15.5
MYRILA1	725	26.6	23.4	23.3	22.4	21.3	18.7	15.5
MYRILA1	770	82.5	41.0	39.5	32.7	25.5	18.7	15.5
MYRILA1	880	227.7	37.3	36.6	32.3	25.4	18.7	15.5
MYRILA1	995.95	100.2	32.4	29.6	23.3	20.3	14.1	12.7
JARRETTS	30.5	20.4	61.9	15.9	66.7	33.1	39.6	46.9
JARRETTS	62	2.6	2.6	2.6	2.5	2.5	2.2	2.1
JARRETTS	138.5	20.9	12.0	10.4	7.4	3.4	2.4	2.2
JARRETTS	300	24.0	13.6	11.8	8.5	4.0	2.9	2.3
JARRETTS	500	44.4	18.6	16.2	11.1	4.7	3.8	2.8
JARRETTS	657.45	52.3	22.4	19.5	13.5	6.4	4.8	3.6
NUGENTS	38.5	446.7	222.8	195.6	167.0	127.7	89.3	51.3
NUGENTS	86.5	446.1	264.3	197.9	166.1	127.5	89.3	51.3
NUGENTS	103	446.2	265.1	199.5	166.2	127.6	89.3	51.3
NUGENTS	139.5	447.4	246.1	196.8	166.6	127.8	89.4	51.4
NUGENTS	283	451.8	230.6	196.2	167.4	127.5	89.8	52.0
NUGENTS	500	459.0	224.8	199.0	169.4	128.3	90.6	52.9
NUGENTS	720	466.7	225.2	200.2	170.9	129.2	91.4	53.8
NUGENTS	920	471.1	217.1	185.5	162.7	130.1	92.3	54.5
NUGENTS	1080	471.6	213.5	178.3	152.2	129.9	92.5	53.3
NUGENTS	1280	467.8	205.9	164.8	138.7	127.8	91.4	50.5
NUGENTS	1450.9	454.3	199.5	154.2	114.1	119.7	86.2	46.1
TOWN1	23.25	11.7	62.3	6.0	19.8	4.6	3.5	4.1

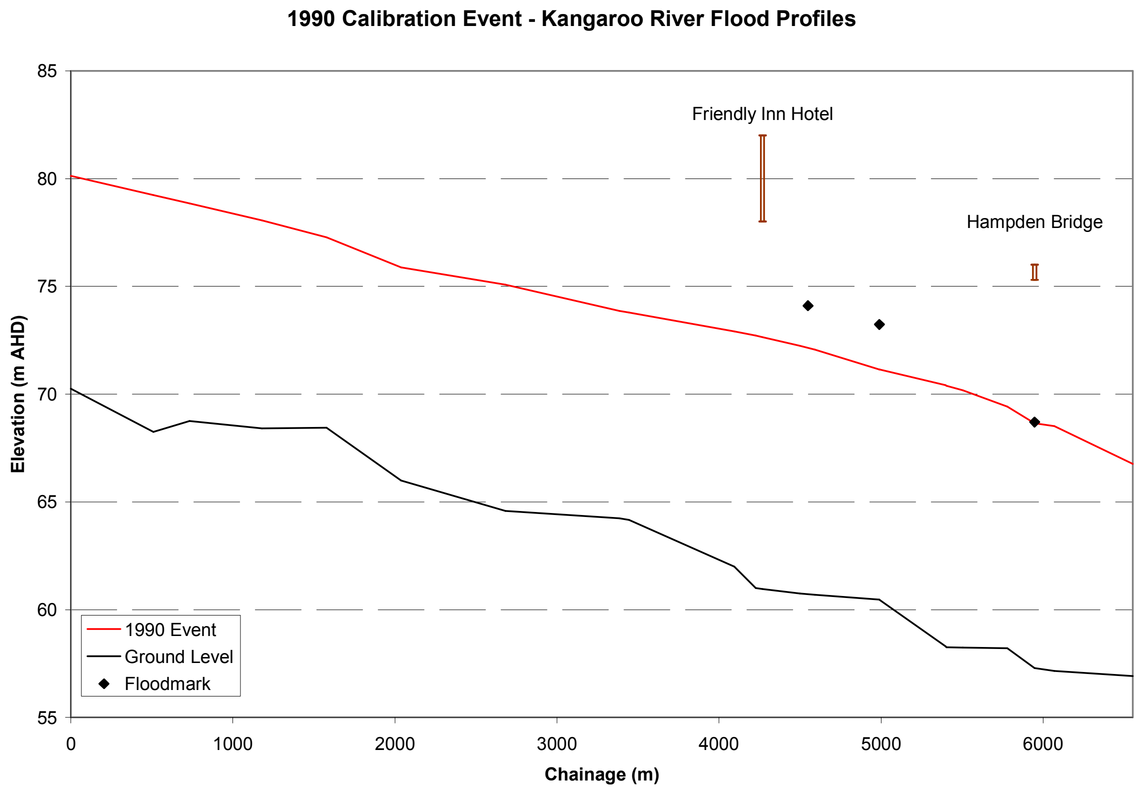
Branch	Chainage	Peak Discharge (m3/s)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
TOWN1	47	1.7	1.7	1.7	1.7	1.7	1.6	1.7
TOWN1	128.39	9.8	4.7	4.7	3.8	6.1	10.9	2.7
TOWN1	196.14	27.1	12.1	10.1	9.1	6.2	14.9	3.4
TOWN1	230.12	30.9	15.3	11.8	11.5	8.1	32.3	4.2
TOWN2	20.5	9.0	5.0	4.3	3.3	2.7	2.2	0.7
TOWN2	41.5	3.0	2.9	2.9	2.8	2.5	2.1	0.6
TOWN2	106.75	9.0	4.4	4.2	3.2	2.5	2.1	1.7
TOWN2	165.32	9.3	4.5	3.4	3.4	2.4	2.1	1.2
MCUL1	5	27.2	7.9	7.7	3.8	0.6	0.0	0.0
MCUL3	10	0.0	1.3	0.5	0.0	0.0	0.0	0.0
MCUL2	7.5	14.7	0.0	0.0	0.0	0.0	0.0	0.0
MCUL12	10	55.9	17.8	16.4	12.0	4.2	0.0	0.0
TCUL1	10	7.3	3.3	2.9	2.1	3.2	0.8	3.9
TCUL2	10	6.1	2.1	1.7	0.4	0.0	0.0	0.0
NCUL1	7.5	17.1	8.8	7.3	4.5	0.8	0.0	0.0
BARRENGARRY_OF	150	2273.7	674.2	608.9	291.3	22.5	0.0	0.0
SHOALHAVEN_R	-2830	349.4	203.0	185.7	155.9	115.8	89.7	62.3
SHOALHAVEN_R	-1589.5	1006.3	615.6	556.4	457.7	326.5	251.9	174.1
SHOALHAVEN_R	-359.5	1715.0	1025.4	920.8	750.8	530.8	409.6	282.1
SHOALHAVEN_R	1707	2913.0	1706.1	1523.0	1229.2	860.0	660.3	452.8
SHOALHAVEN_R	3670	4054.2	2337.5	2080.7	1668.1	1158.5	884.1	606.7
SHOALHAVEN_R	6520	5712.2	3220.6	2856.2	2267.8	1562.8	1182.3	811.8
SHOALHAVEN_R	9186.5	7266.7	3970.6	3516.2	2765.7	1889.3	1424.7	977.9
SHOALHAVEN_R	10127.5	7816.1	4218.7	3731.9	2929.4	1990.6	1505.3	1027.1
SHOALHAVEN_R	11205.5	8446.3	4491.0	3967.4	3108.7	2099.9	1592.8	1076.3
SHOALHAVEN_R	12075	8955.6	4696.0	4145.2	3244.3	2186.1	1658.5	1107.5
SHOALHAVEN_R	12552.5	9235.3	4806.3	4240.7	3317.6	2237.2	1694.6	1124.0
SHOALHAVEN_R	12800	14690.4	11571.8	10222.3	8109.3	5731.6	4542.5	3067.7
SHOALHAVEN_R	12925	14690.4	11571.8	10222.3	8109.3	5731.5	4542.5	3067.7
KANGROOV_R	-793.5	7063.1	4181.3	3733.4	3047.1	2272.0	1800.4	1316.9
KANGROOV_R	498.5	7047.1	4177.7	3723.1	3038.1	2262.6	1792.9	1306.8
KANGROOV_R	1489.5	6941.5	4132.7	3680.4	3015.5	2252.9	1784.6	1298.1
KANGROOV_R	2567.5	6804.4	4086.3	3640.9	2973.9	2220.2	1756.0	1275.1
KANGROOV_R	3537	6661.4	4060.3	3620.0	2950.3	2193.6	1734.2	1257.8
KANGROOV_R	4242.5	6606.7	4057.5	3618.1	2947.7	2190.9	1731.8	1254.3
KANGROOV_R	5233.5	6505.6	4062.4	3623.0	2950.8	2190.6	1729.5	1249.6
KANGROOV_R	7194.5	6350.0	4097.3	3656.0	2975.9	2206.5	1738.4	1249.7
KANGROOV_R	9642	6180.4	4158.8	3712.0	3021.9	2238.2	1762.1	1261.0
KANGROOV_R	12045	5927.8	4271.6	3817.6	3112.4	2304.2	1811.1	1291.0
KANGROOV_R	13884	5666.0	4453.9	3984.3	3254.1	2413.1	1887.9	1351.3
KANGROOV_R	15849	5551.9	4571.8	4089.5	3345.1	2487.8	1941.1	1396.7
KANGROOV_R	17665.22	5510.3	4624.5	4136.2	3386.5	2522.6	1966.0	1418.1
KANGROOV_R	18538.72	7794.1	4906.8	4386.0	3589.8	2673.3	2089.4	1508.7
KANGROOV_R	20032.5	7716.2	5440.1	4859.7	3952.9	2908.4	2302.2	1638.3
KANGROOV_R	21656	13881.0	6115.6	5452.7	4401.6	3215.6	2561.5	1798.3
KANGROOV_R	22576	8044.4	6560.3	5843.6	4708.1	3428.0	2735.7	1913.4
KANGROOV_R	23676	6333.6	7068.2	6288.0	5055.3	3660.2	2924.9	2034.8
KANGROOV_R	24608	6575.8	7523.0	6679.7	5359.8	3865.9	3091.4	2142.0
EXT-SHOALHAVEN	4166.67	5.0	5.3	5.3	5.3	5.3	5.3	5.3
EXT-SHOALHAVEN	12500	12.3	5.9	5.9	5.7	5.2	5.2	5.2
EXT-SHOALHAVEN	20833.33	43.5	14.2	11.9	9.1	6.7	6.7	6.7
YARRUNGA	925	16.9	18.8	18.8	18.8	18.8	18.8	18.8
YARRUNGA	2760	705.0	40.0	35.9	30.6	24.6	23.4	21.8
YARRUNGA	4350	2860.5	126.2	113.8	94.9	74.8	67.9	52.3
BUNDANOON	472.5	9393.4	33.7	30.9	27.0	22.8	21.2	17.4
BUNDANOON	1032.5	8735.0	57.9	52.7	45.3	37.6	34.6	27.6
HAMPDENOF	60	876.8	0.0	0.0	0.0	0.0	0.0	0.0
BARRENGARRY_OF1	2	178.7	180.9	186.8	141.1	0.0	0.0	0.0
BARRENGARRY_OF2	2	404.0	347.9	337.4	243.3	162.4	0.0	0.0
BARRENGARRY_OF3	2	289.6	307.5	300.8	286.9	155.9	124.7	0.0
KANGAROOOF	1	6230.6	3483.4	3020.7	2495.9	1723.2	1185.0	532.9
KANGAROOOF	193.5	3557.0	1546.2	1287.3	947.7	520.3	312.0	122.2
KANGAROOOF	702.5	3311.6	1460.6	1195.9	819.8	391.1	178.5	55.1
KANGAROOOF	1217.5	3458.2	1762.5	1473.9	1094.0	679.0	327.6	42.5
KANGAROOOF	1537.5	5390.0	2625.4	2227.1	1638.0	801.4	312.7	34.3
KANGAROOOF	1827.75	2665.0	1346.2	1148.9	846.1	500.4	160.2	37.3
KVOF1	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KVOF2	2	281.2	99.9	63.6	4.4	0.0	0.0	0.0
KVOF3	2	1224.2	672.9	637.4	561.3	376.2	190.1	0.0
KVOF4	2	451.3	437.8	412.7	413.5	228.2	25.9	0.0

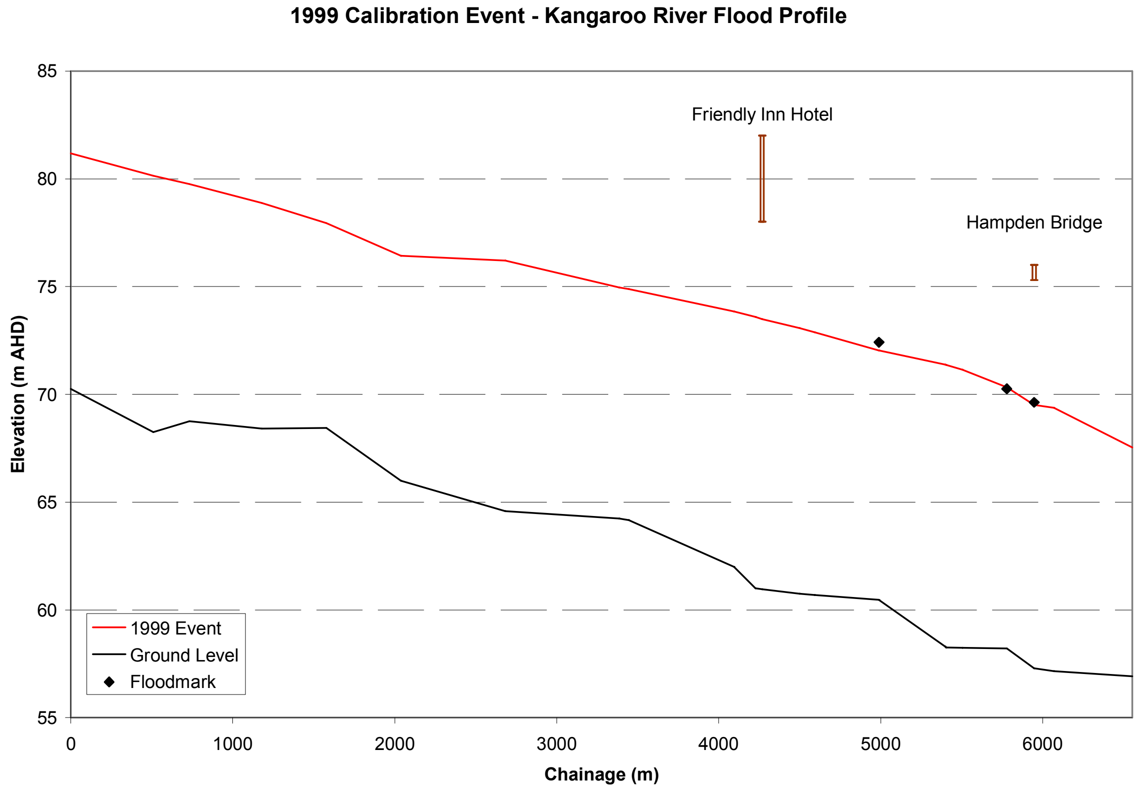
Branch	Chainage	Peak Discharge (m3/s)						
		PMF	0.5%AEP	1%AEP	2%AEP	5%AEP	10%AEP	20%AEP
KVOF5	2	256.1	269.0	250.7	278.7	240.9	11.5	0.0
TOWN3	26.5	74.1	9.3	8.1	7.1	5.9	4.8	1.3
TOWN3	68	176.6	9.2	8.1	7.1	5.9	4.8	1.3
TOWN3	100	4.2	2.4	2.4	2.3	2.3	2.2	1.3
TOWN3	166.5	145.4	8.7	7.7	6.7	5.6	4.3	1.3
TOWN3	306.48	121.7	10.9	8.4	6.6	5.6	4.2	1.3
TOWN3OF	15	145.8	6.3	5.3	4.4	3.3	2.1	0.0

Appendix C: Flood Level Profiles

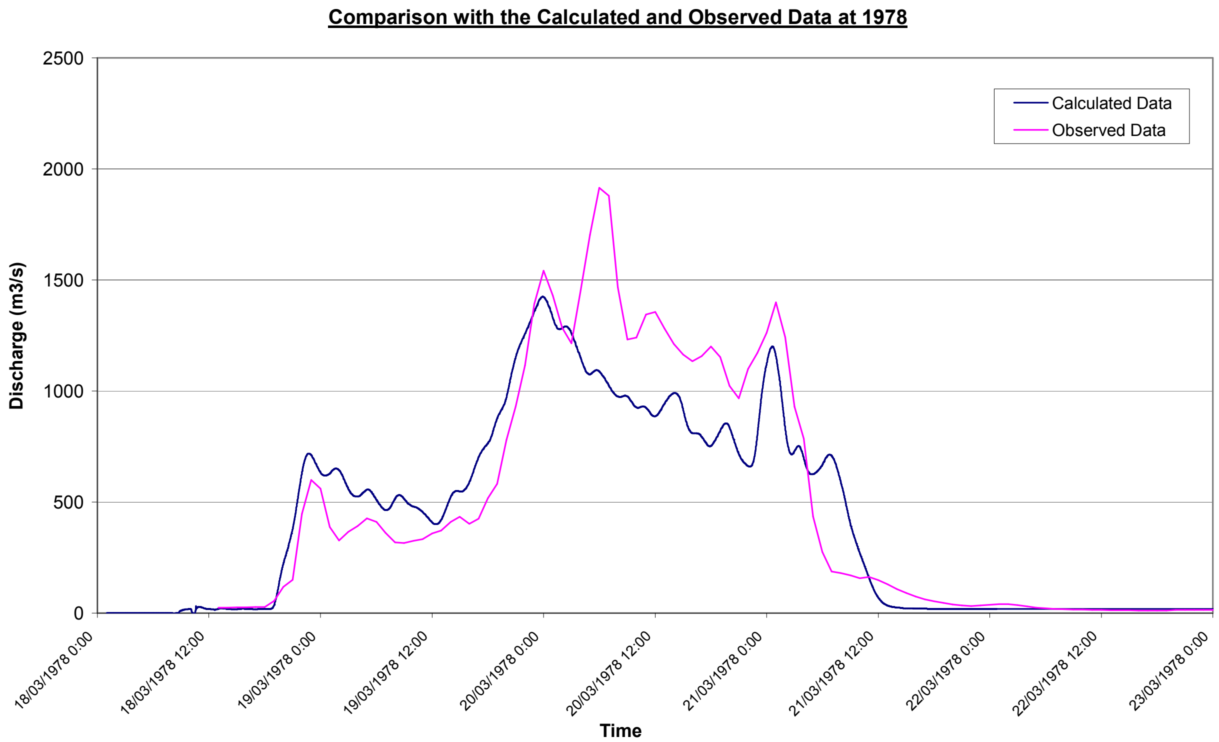
Part 1a – 1975 & 1999 Flood Profiles

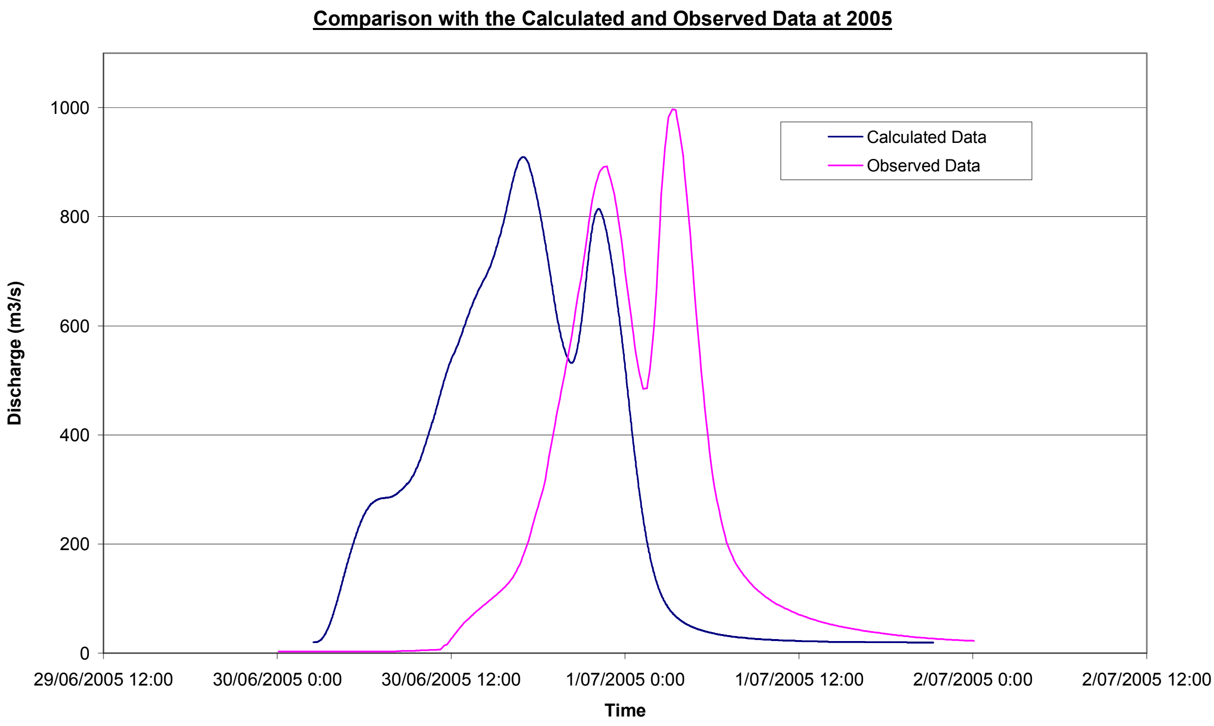




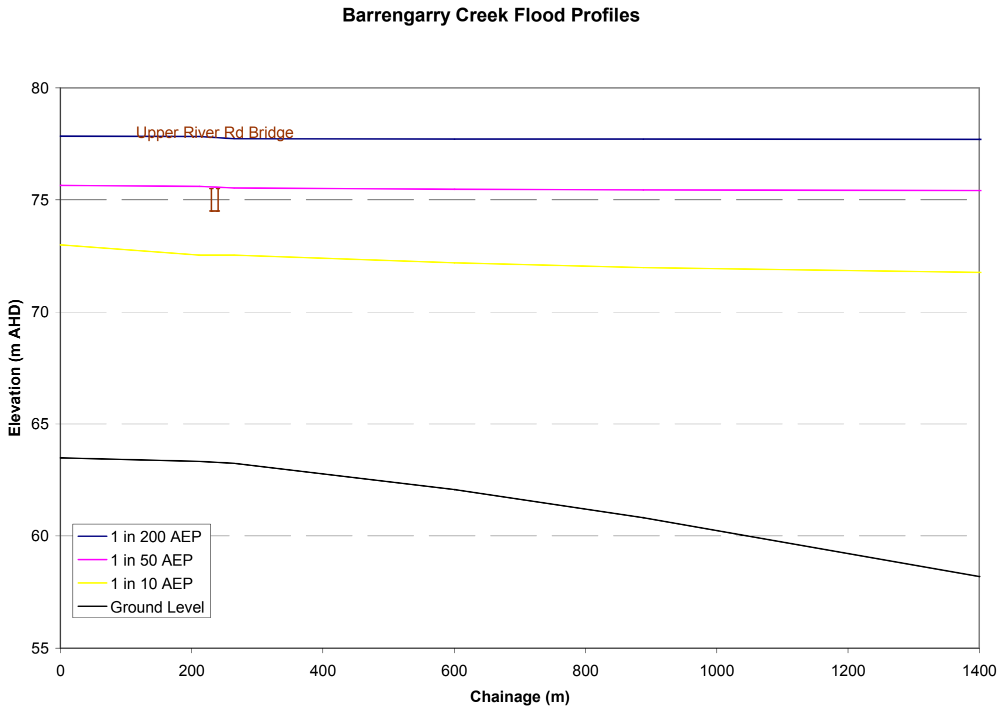


Part 1b – Historical Event Hydrographs (1978 & 2005)

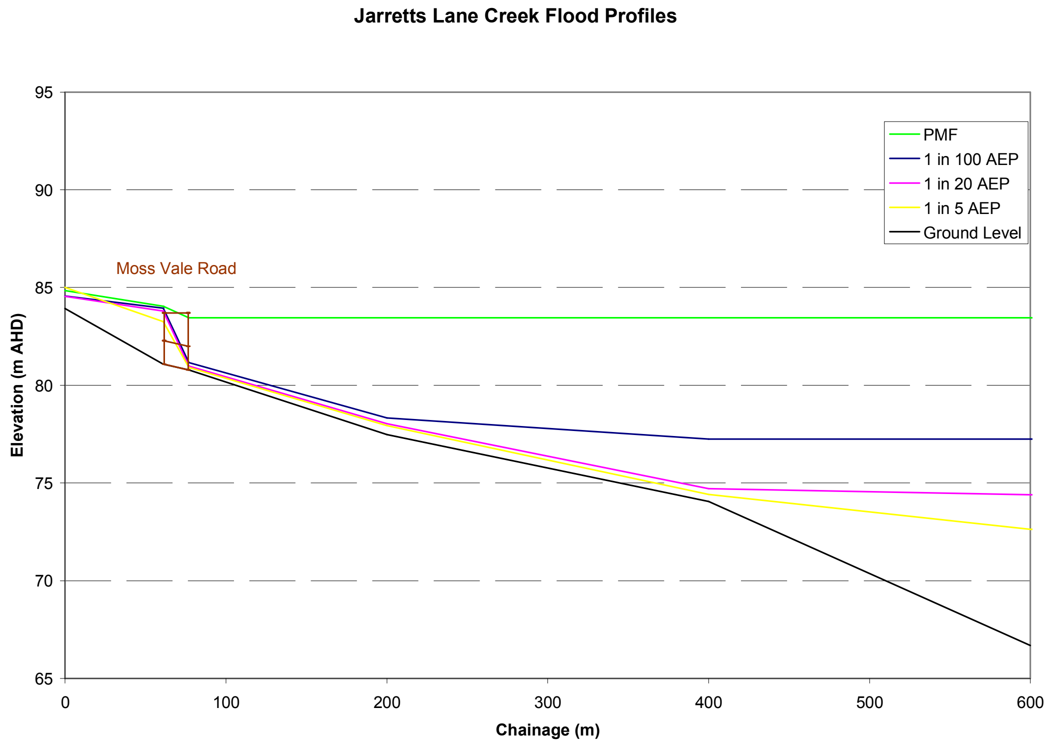


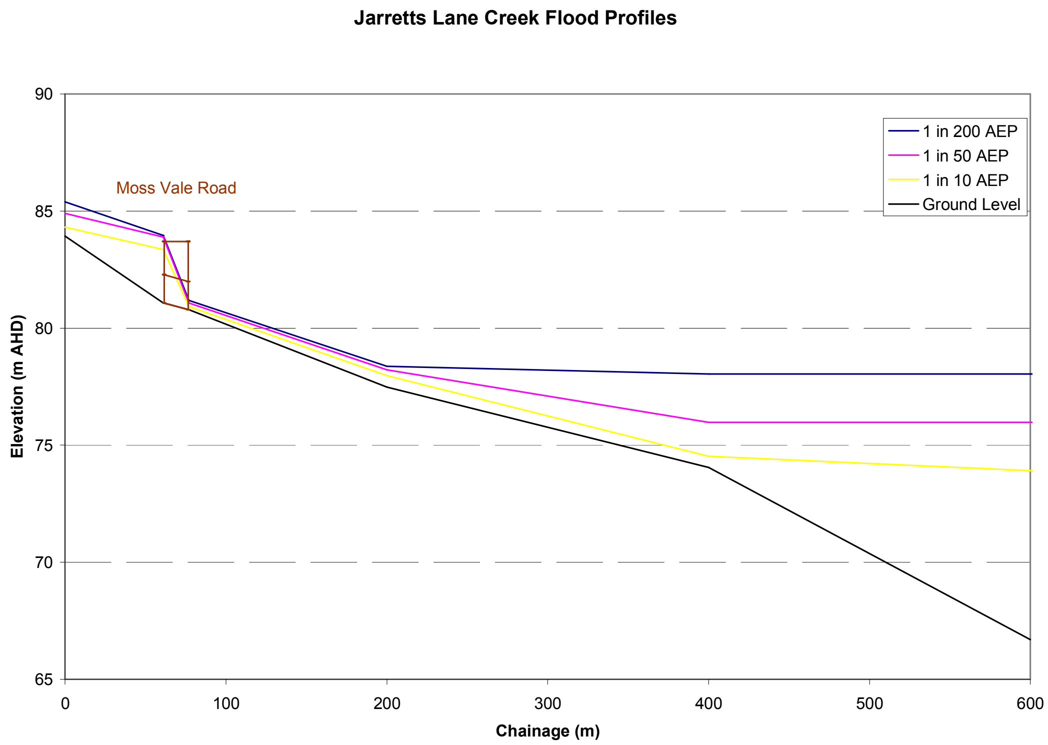

Comparison with the Calculated and Observed Data at 2005
Discharge (m3/s)
1000
800
600
400
200
0
Calculated Data
Observed Data
29/06/2005 12:00
30/06/2005 0:00
30/06/2005 12:00
1/07/2005 0:00
1/07/2005 12:00
2/07/2005 0:00
2/07/2005 12:00
Time

Part 2 – Design Event Flood Profiles
Barrengarry Creek

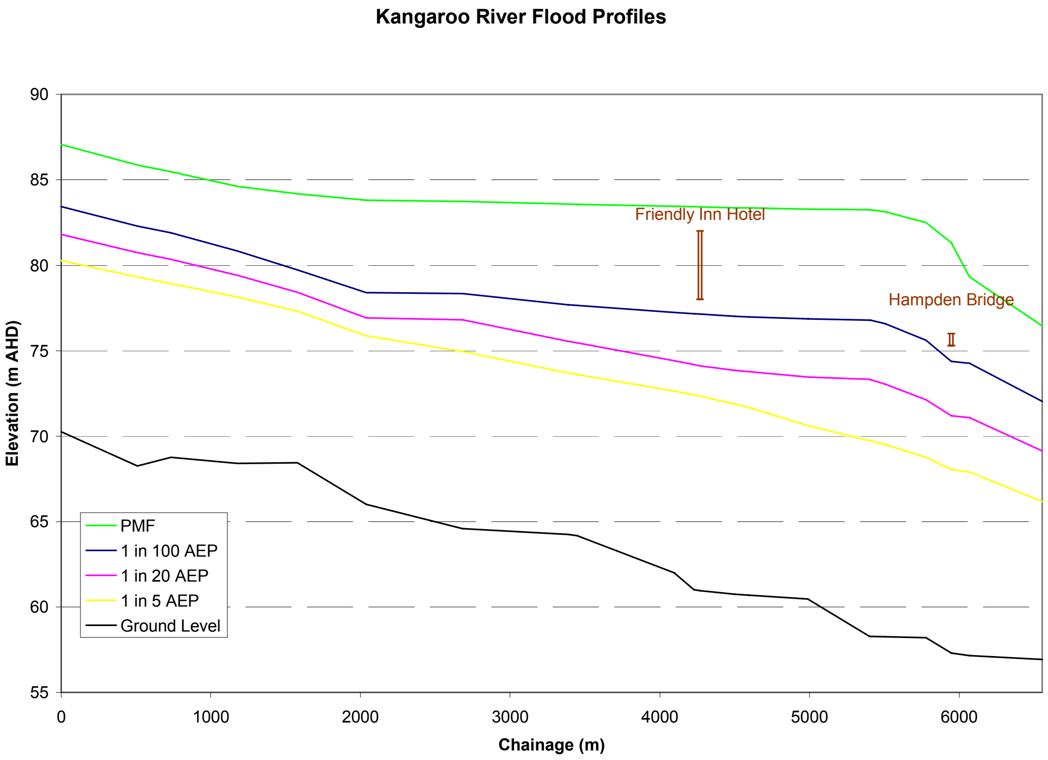


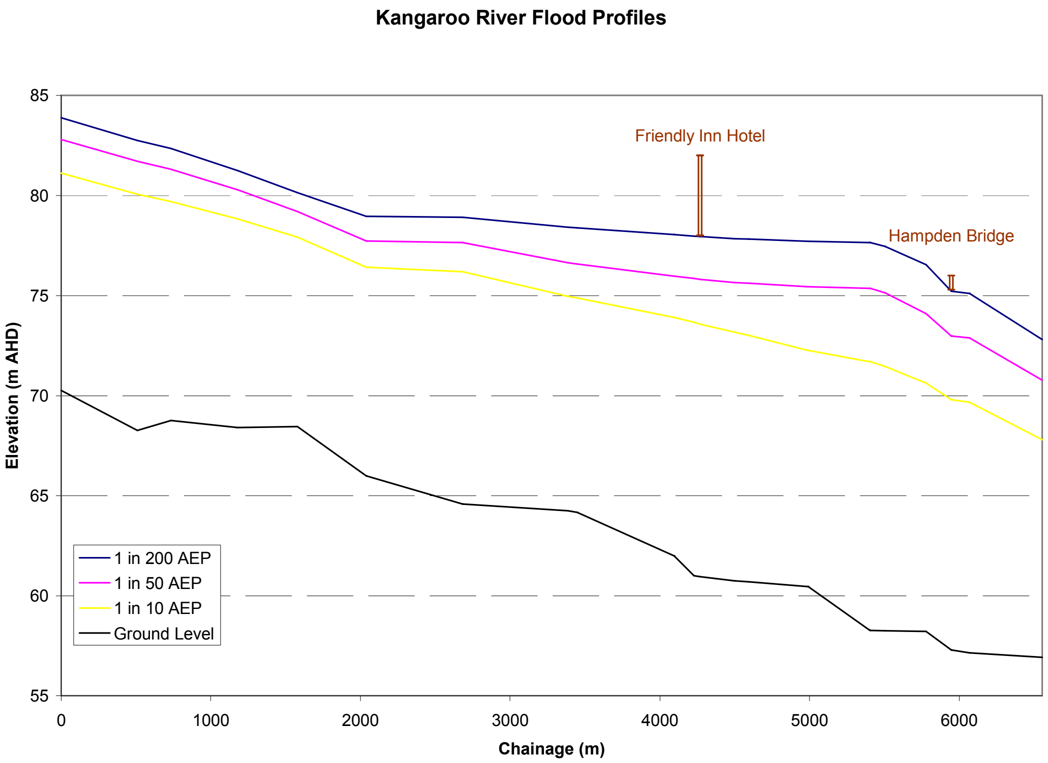
Jarretts Lane Creek



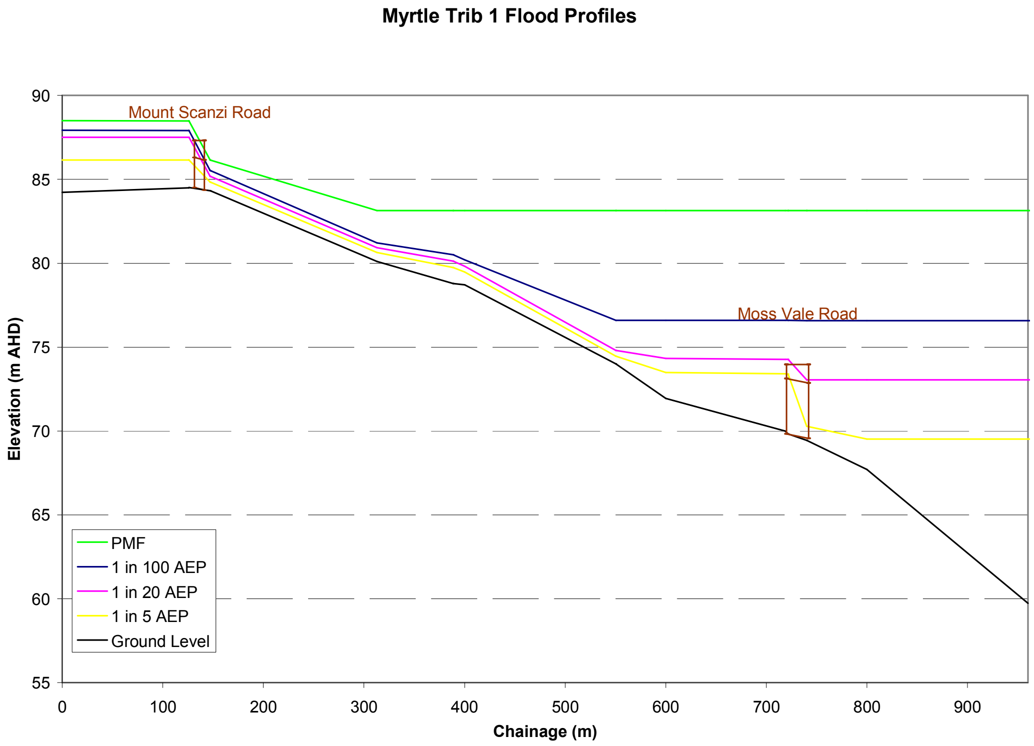


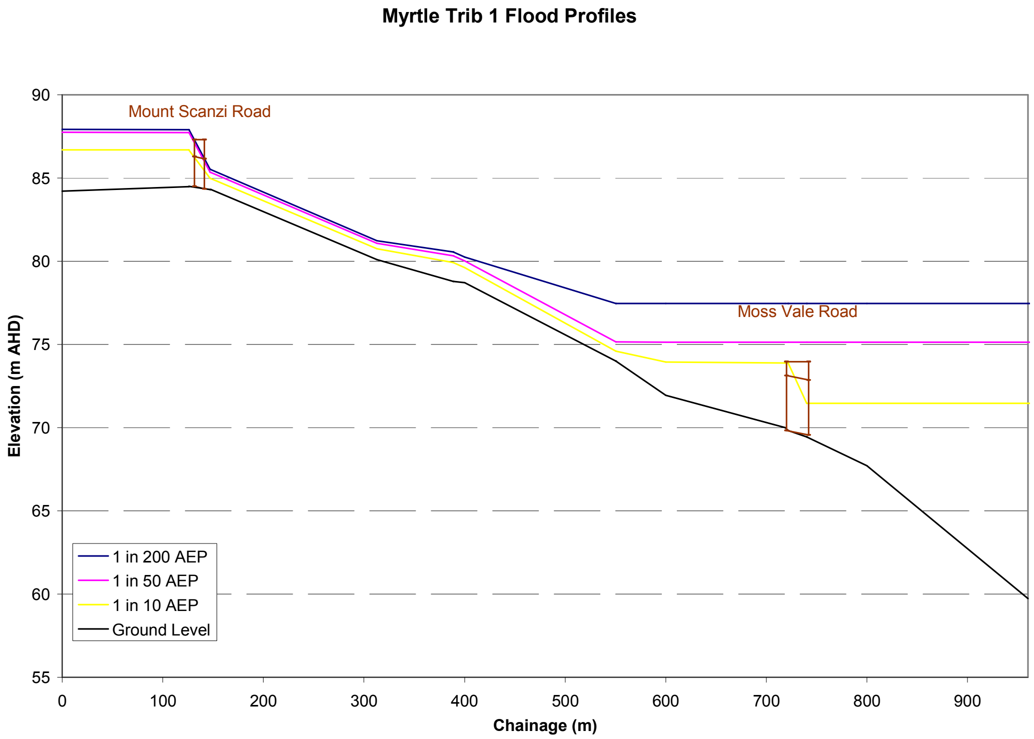
Kangaroo River





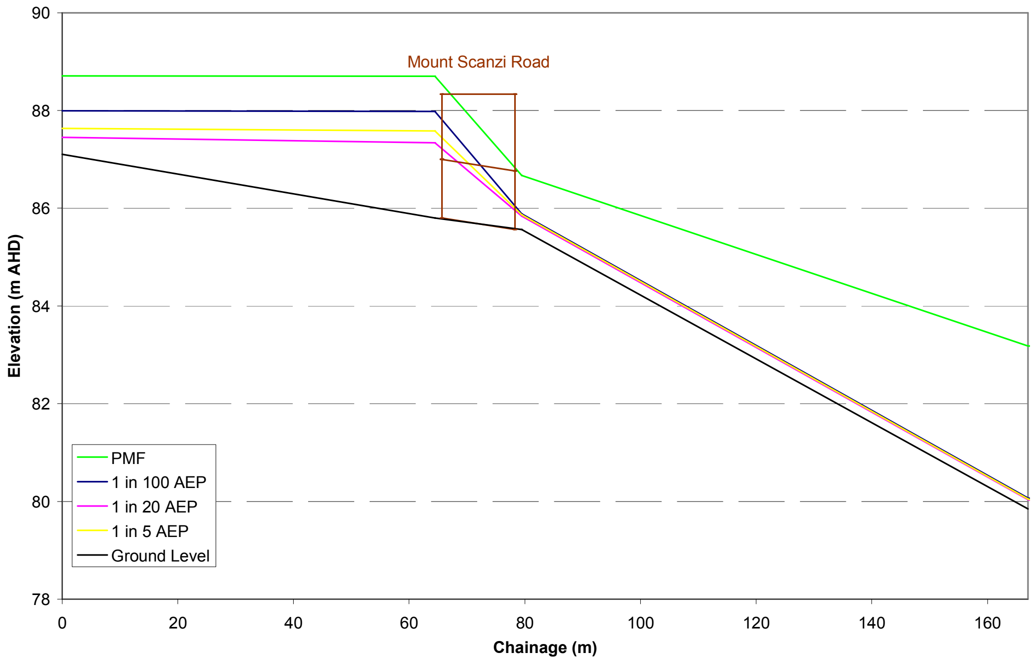
Myrtle Tributary 1



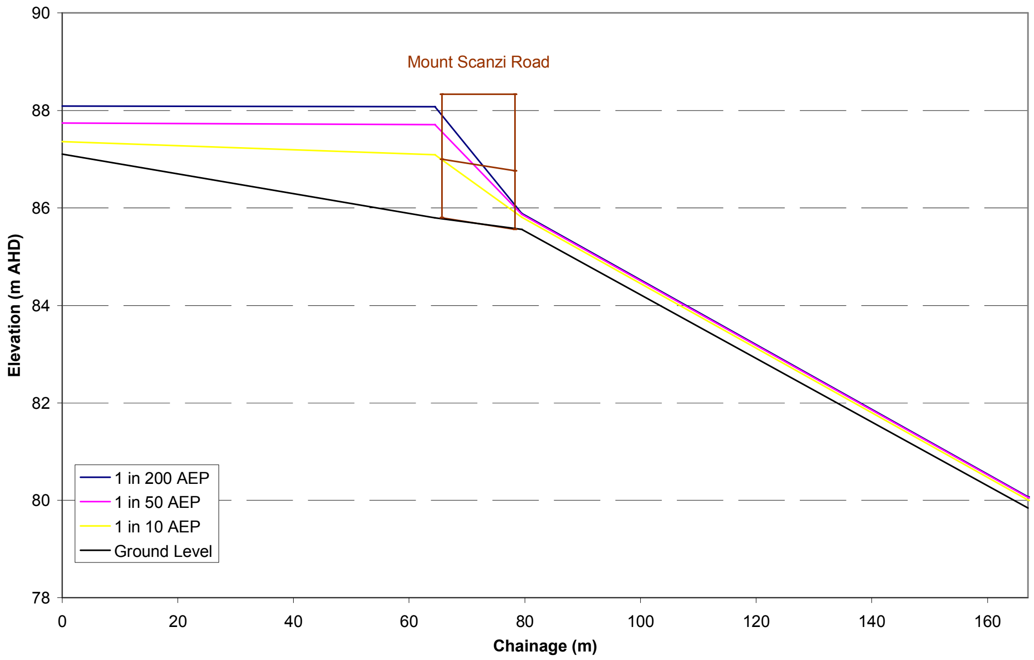


Myrtle Tributary 2

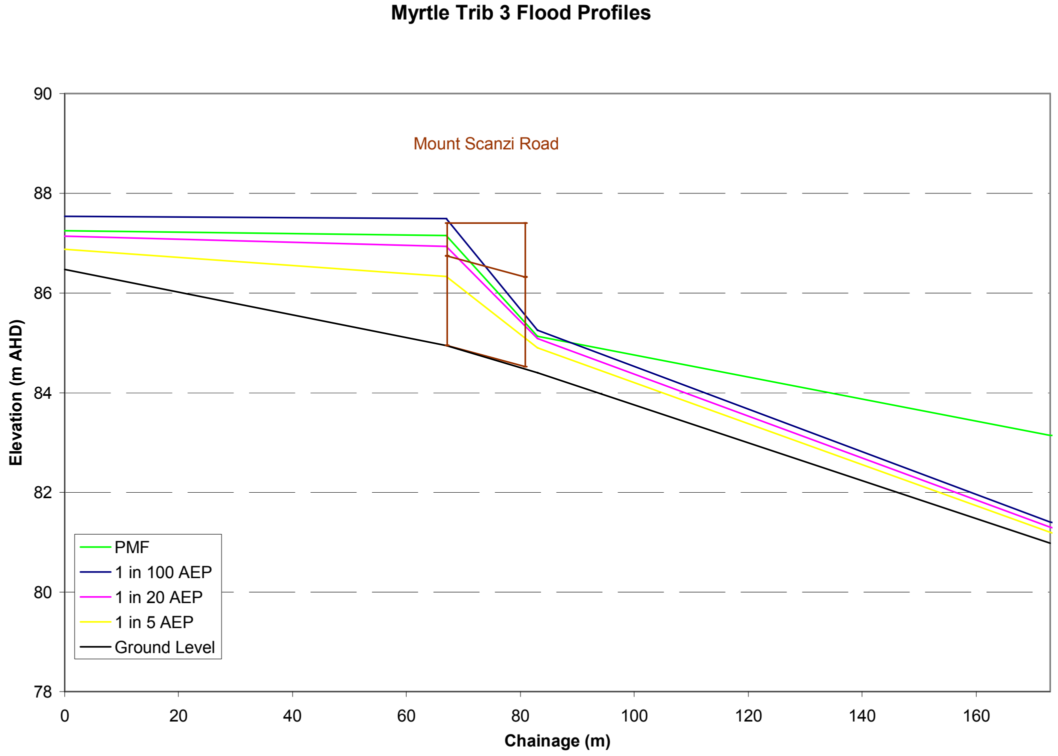
Myrtle Trib 2 Flood Profiles

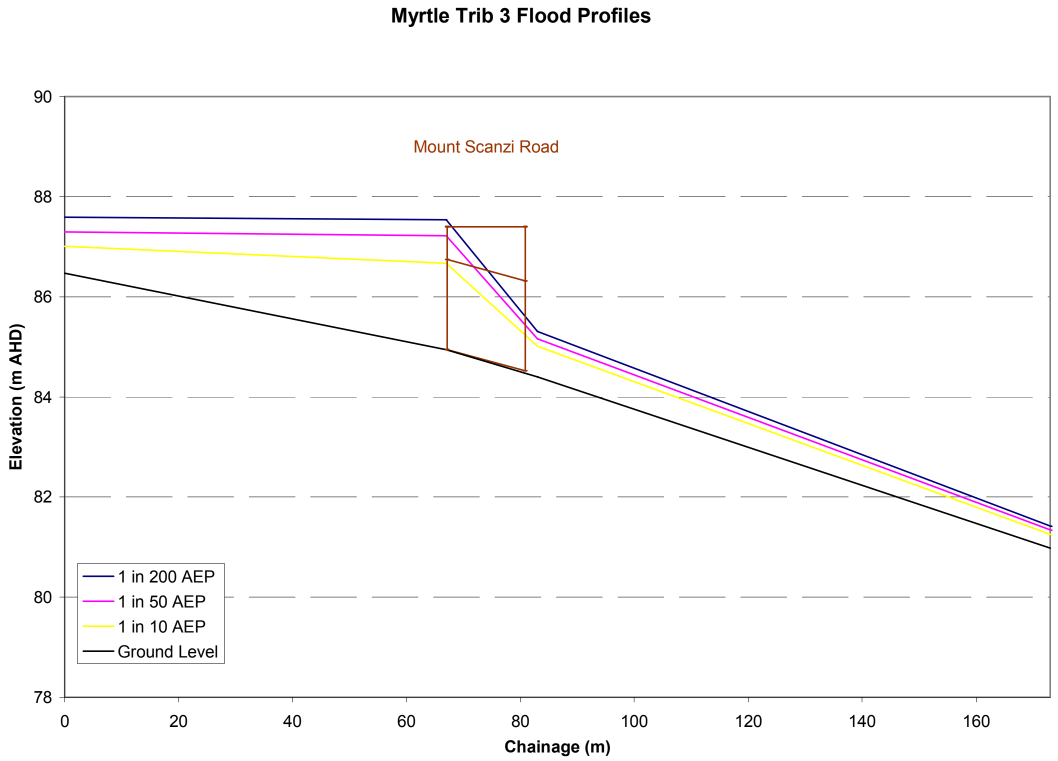


Myrtle Trib 2 Flood Profiles

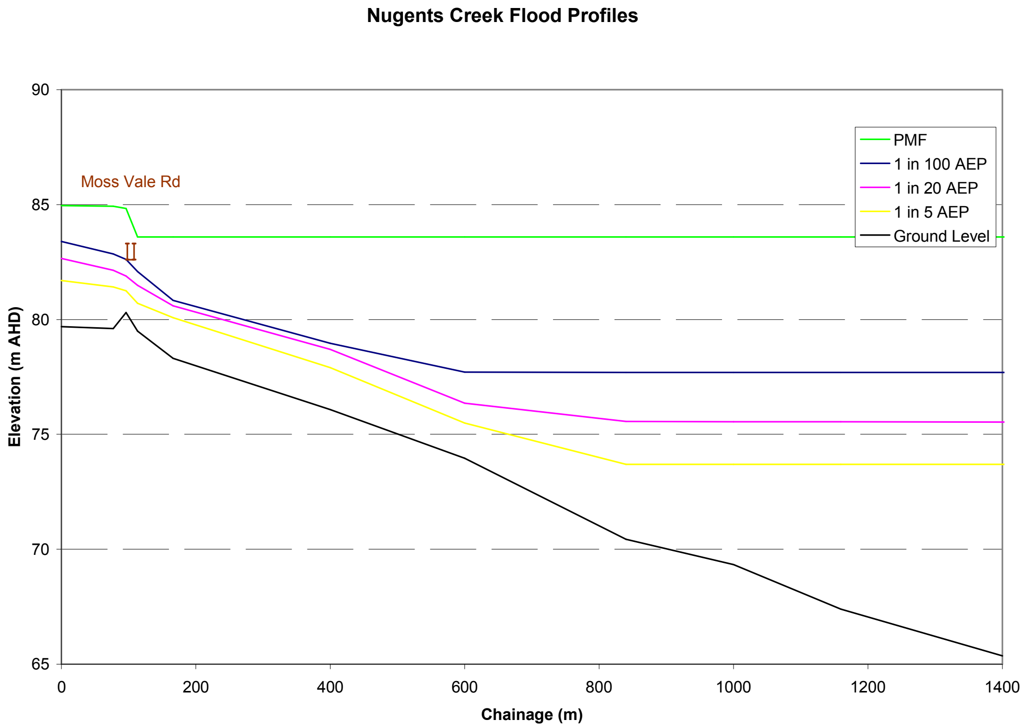


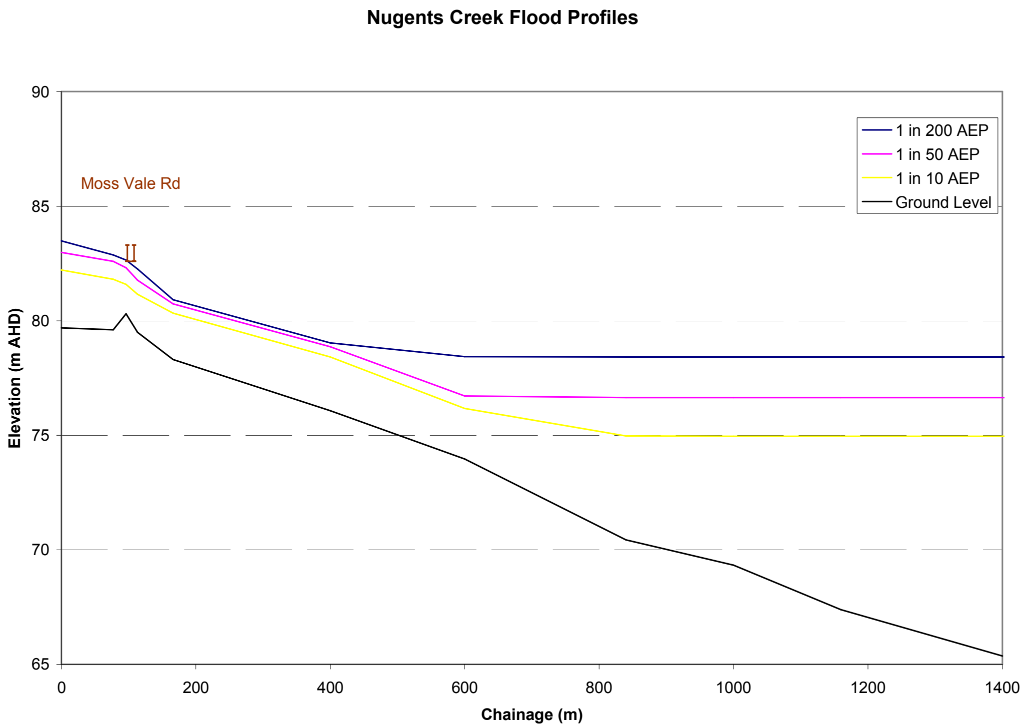
Myrtle Tributary 3



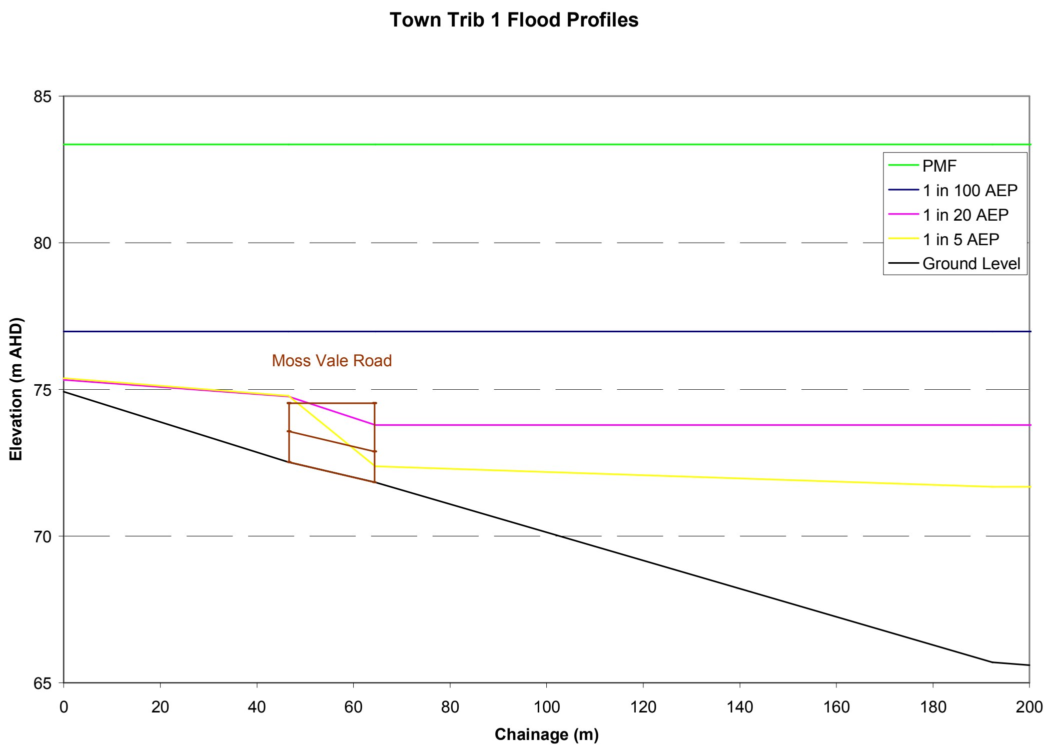


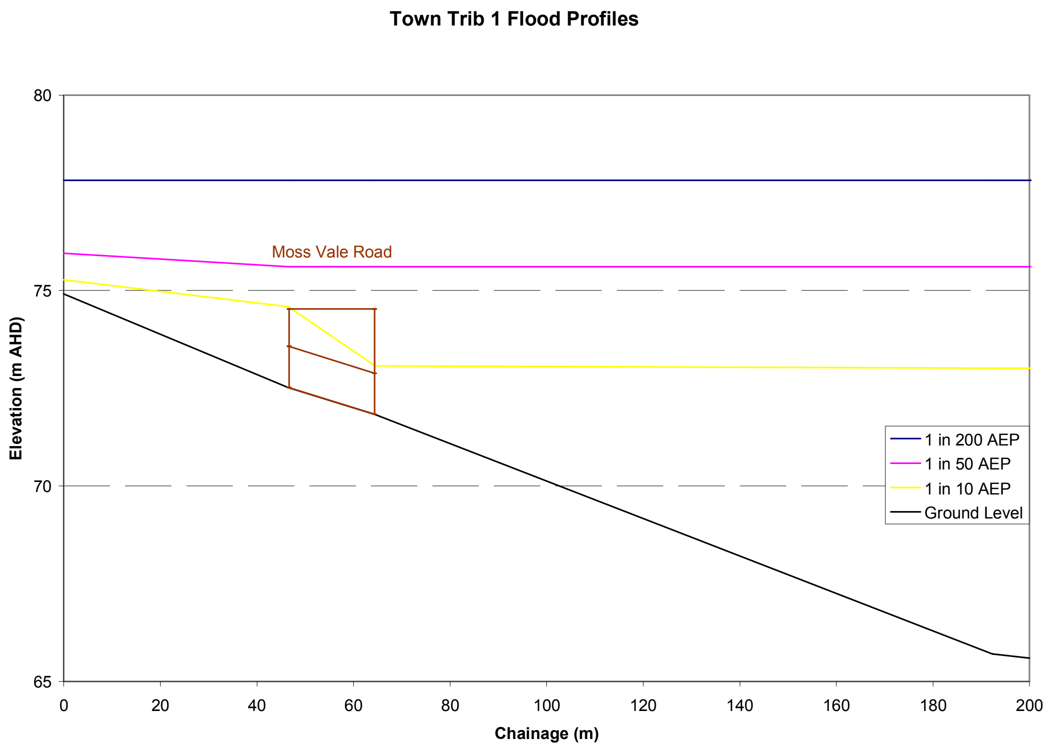
Nugents Creek



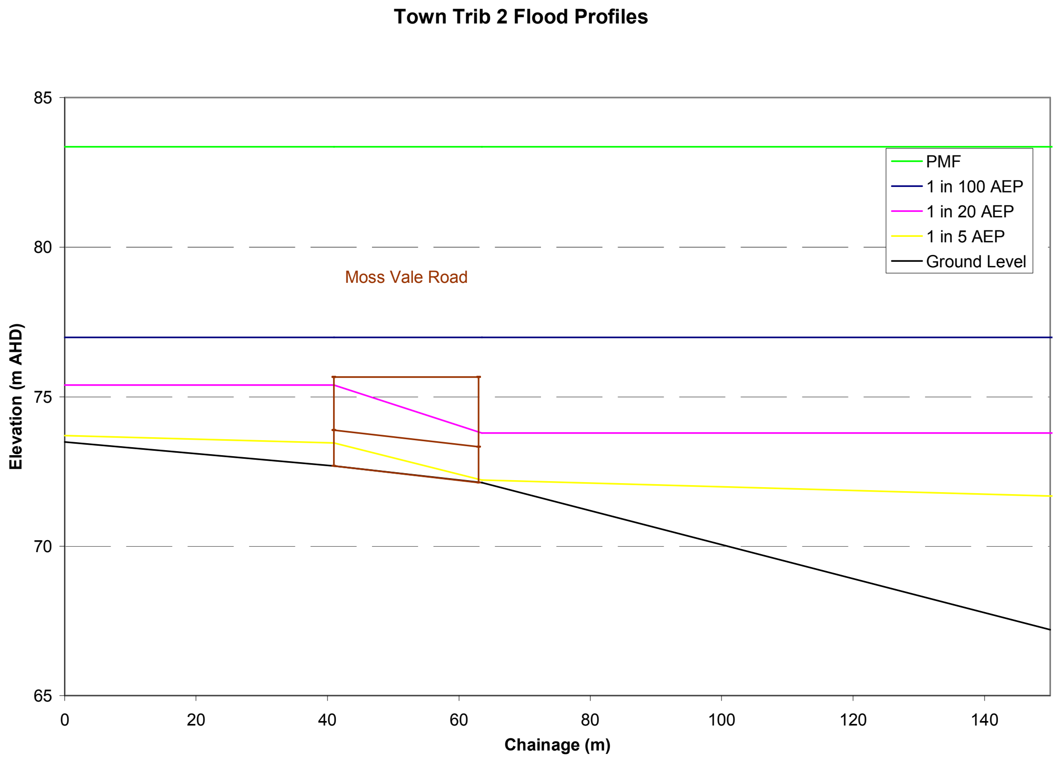


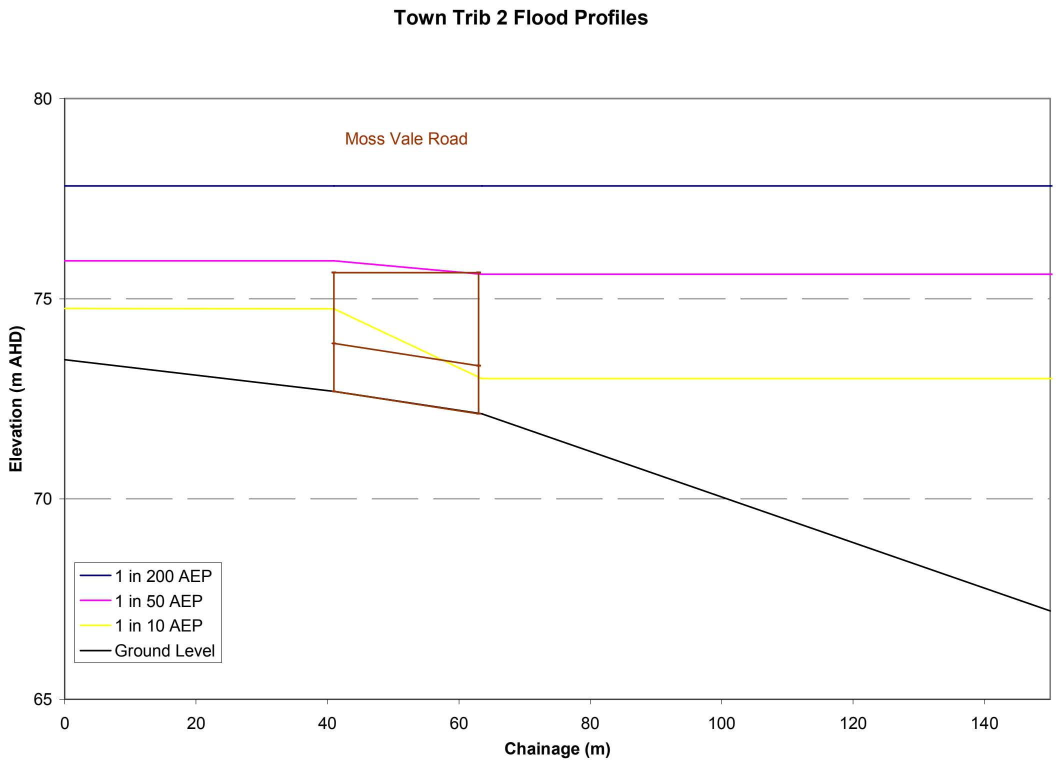
Town Tributary 1



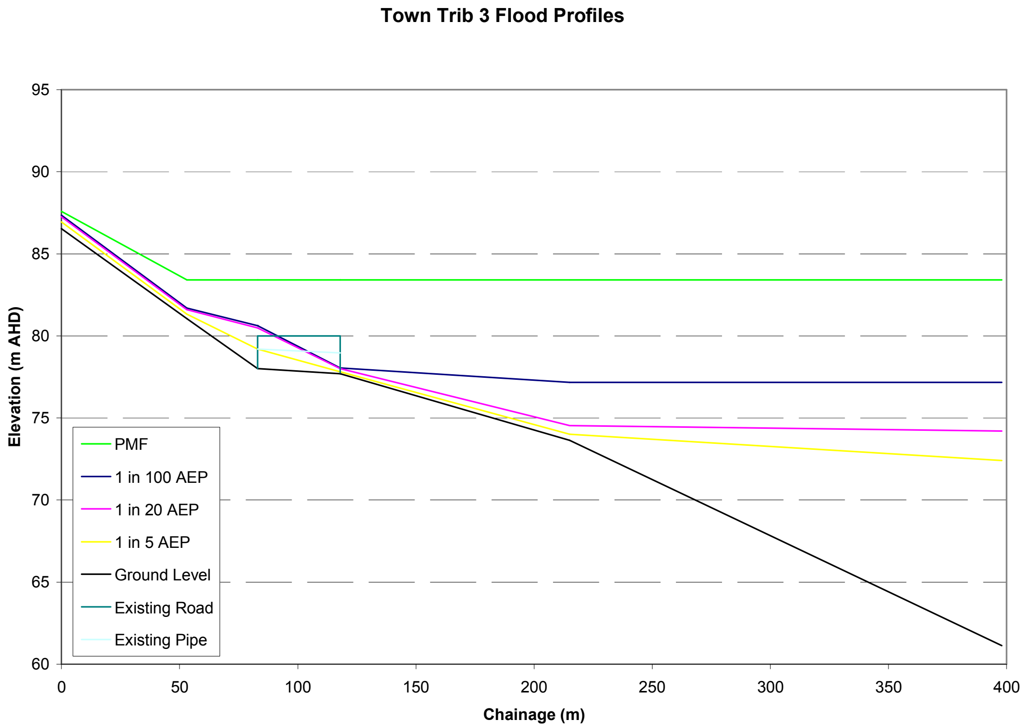


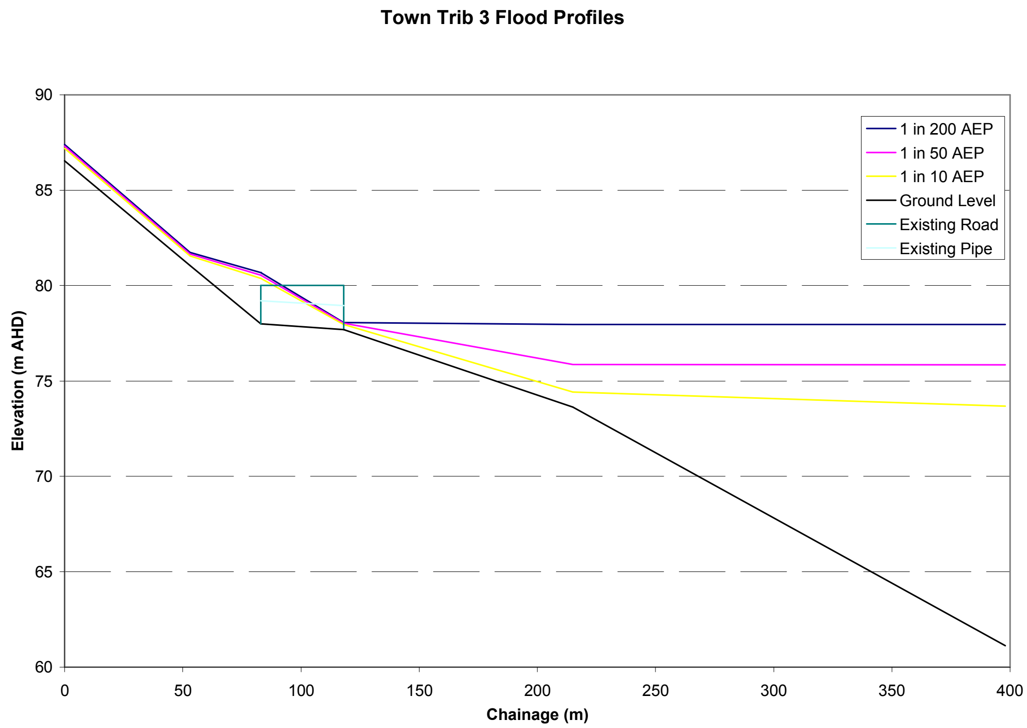
Town Tributary 2





Town Tributary 3





Appendix D: Summary of Roughness Coefficients

Branch	Chainage Extent (m)		Roughness Coefficients		
	Start	End	Left FP	Channel	Right FP
Kangaroo	0	1578	0.120	0.120	0.120
	2682	5948	0.105	0.070	0.105
	6069	6554	0.070	0.053	0.070
Myrtle1	0	600	0.070	0.053	0.070
	715	960	0.053	0.053	0.053
Myrtle2	0	326	0.075	0.075	0.075
Myrtle3	0	217	0.075	0.075	0.075
Jarrets	0	714	0.075	0.075	0.075
Nuggents	0	600	0.050	0.050	0.050
	840	1400	0.072	0.072	0.072
Barrengarry	0	1400	0.120	0.120	0.120
Town1	0	-	0.120	0.060	0.180
	46	200	0.120	0.060	0.120
Town2	0	150	0.120	0.060	0.120
Shoalhaven_R	-3530	12950	0.060	0.060	0.060
Kangaroo_V	-1587	-	0.120	0.090	0.120
	0	24800	0.060	0.060	0.060
Ext_Shoalhaven	0	25000	0.060	0.060	0.060
Yarrunga	0	5030	0.060	0.060	0.060
Bundanoon	0	1120	0.060	0.060	0.060
KangarooOF	0	1995	0.200	0.200	0.200
Town3	0	398	0.060	0.060	0.060

Appendix E: SENSITIVITY ANALYSIS

Sensitivity Analysis of Tailwaters

The proposed raising of the Tallowa Dam spillway was analysed to consider the sensitivity that the proposal has at Kangaroo Valley. A previous report prepared by SMEC for the Department of Commerce and Sydney Catchment Authority, titled *Kangaroo River – Tallowa Dam Flood Investigations* indicated that the proposed changes to Tallowa Dam would have an insignificant effect on flood levels upstream of Kangaroo Valley @ Hampden Bridge for events up to the 2%AEP event (SMEC, 2006). For events larger than the 2%AEP event the model was run to review the affluxes just upstream of Hampden Bridge along the Kangaroo Valley. These are shown in Table E.1 below. Note that there is a negligible afflux (increase in levels) during the PMF with a maximum afflux of 0.5m for the 0.5%AEP event.

Table E.1: Flood levels - Kangaroo River @ Hampden Bridge

Condition	Units	Event				Initial Condition
		2%AEP	1%AEP	0.5%AEP	PMF	
Existing (old spillway)	mAHD	72.98	74.37	75.22	81.31	Existing FSL 56.34
Proposed (raised spillway)	mAHD	73.05	74.46	75.31	81.35	Existing FSL 56.34
	mAHD	73.28	74.63	75.70	81.32	Proposed FSL 63.34
Max Afflux	**(m)**	**0.3**	**0.3**	**0.5**	**0.0**	

Sensitivity Analysis of Roughness Coefficients

The roughness coefficients were varied in an attempt to assess the sensitivity of changes to channel conditions such as debris and vegetation. The results indicate that the model is relatively sensitive to these conditions. A 20 percent change in roughness coefficient caused a maximum change to the 1%AEP flood levels of about 1m. The average change in the 1%AEP flood levels was approximately 0.6m. However it is envisaged that these change in flood levels will have a relatively minor (but non zero) impact on the flood extents.

Branch	Chainage	Water Level (mAHD)			Water Level Difference (m)		
		Base Case	20%increase	20%decrease	Base Case	20%increase	20%decrease
KANGAROO	0	83.42	84.09	82.68	0.00	0.67	-0.74
KANGAROO	1179	80.83	81.38	80.20	0.00	0.55	-0.63
KANGAROO	2039.16	78.39	78.95	77.76	0.00	0.56	-0.63
KANGAROO	2682	78.34	78.91	77.67	0.00	0.57	-0.67
KANGAROO	2682	78.34	78.91	77.67	0.00	0.57	-0.67
KANGAROO	3446	77.65	78.35	76.82	0.00	0.70	-0.83
KANGAROO	4269	77.13	77.90	76.17	0.00	0.77	-0.96
KANGAROO	4592.98	76.98	77.77	76.00	0.00	0.79	-0.98
KANGAROO	5398.76	76.79	77.61	75.77	0.00	0.82	-1.02
KANGAROO	5405	76.79	77.60	75.77	0.00	0.81	-1.02
KANGAROO	5505.31	76.58	77.43	75.51	0.00	0.85	-1.07
KANGAROO	5948	74.37	75.20	73.33	0.00	0.83	-1.04
KANGAROO	6069	74.26	75.09	73.21	0.00	0.83	-1.05
BARRENGARRY	0	77.01	77.80	76.03	0.00	0.79	-0.98
BARRENGARRY	1	77.01	77.80	76.03	0.00	0.79	-0.98
BARRENGARRY	265	76.89	77.69	75.89	0.00	0.80	-1.00
BARRENGARRY	600	76.87	77.67	75.86	0.00	0.80	-1.01
BARRENGARRY	1400	76.83	77.64	75.81	0.00	0.81	-1.02
BARRENGARRY	1490.08	76.79	77.61	75.77	0.00	0.82	-1.02
MYRILA2	0	87.99	87.99	87.99	0.00	0.00	0.00
MYRILA2	64.5	87.98	87.98	87.98	0.00	0.00	0.00
MYRILA2	79.5	85.88	85.92	85.84	0.00	0.04	-0.04
MYRILA2	326.14	76.59	77.44	75.52	0.00	0.85	-1.07
MYRILA3	0	87.54	87.56	87.52	0.00	0.02	-0.02
MYRILA3	67	87.49	87.49	87.49	0.00	0.00	0.00
MYRILA3	217.65	80.51	80.68	80.33	0.00	0.17	-0.18
MYRILA1	125.71	87.91	87.91	87.91	0.00	0.00	0.00
MYRILA1	147.16	85.52	85.65	85.37	0.00	0.13	-0.15
MYRILA1	388.68	80.51	80.68	80.33	0.00	0.17	-0.18
MYRILA1	550.36	76.59	77.44	75.52	0.00	0.85	-1.07
MYRILA1	600	76.59	77.44	75.52	0.00	0.85	-1.07
MYRILA1	740	76.58	77.43	75.51	0.00	0.85	-1.07
MYRILA1	1031.91	76.58	77.43	75.51	0.00	0.85	-1.07
JARRETTS	0	84.56	84.62	84.48	0.00	0.06	-0.08

JARRETTS	61	83.94	83.94	83.94	0.00	0.00	0.00
JARRETTS	200	78.33	78.41	78.25	0.00	0.08	-0.08
JARRETTS	714.91	77.24	78.00	76.31	0.00	0.76	-0.93
NUGENTS	0	83.40	83.55	83.05	0.00	0.15	-0.35
NUGENTS	113	82.09	82.16	81.70	0.00	0.07	-0.39
NUGENTS	400	78.96	79.11	78.80	0.00	0.15	-0.16
NUGENTS	600	77.71	78.38	76.92	0.00	0.67	-0.79
NUGENTS	840	77.70	78.38	76.88	0.00	0.68	-0.82
NUGENTS	1501.8	77.69	78.38	76.87	0.00	0.69	-0.82
TOWN1	0	76.98	77.77	76.00	0.00	0.79	-0.98
TOWN1	64.5	76.98	77.77	76.00	0.00	0.79	-0.98
TOWN1	260.24	76.98	77.77	76.00	0.00	0.79	-0.98
TOWN2	41	76.98	77.77	76.06	0.00	0.79	-0.92
TOWN2	180.64	76.98	77.77	76.00	0.00	0.79	-0.98
BARRENGARRY_OF1	0	76.87	77.67	75.86	0.00	0.80	-1.01
BARRENGARRY_OF1	5	76.86	77.67	75.85	0.00	0.81	-1.01
BARRENGARRY_OF2	0	76.86	77.66	75.85	0.00	0.80	-1.01
BARRENGARRY_OF2	5	76.86	77.67	75.85	0.00	0.81	-1.01
BARRENGARRY_OF3	0	76.83	77.64	75.81	0.00	0.81	-1.02
BARRENGARRY_OF3	5	76.86	77.67	75.85	0.00	0.81	-1.01
KANGAROOOF	0	78.39	78.95	77.76	0.00	0.56	-0.63
KANGAROOOF	2	78.39	78.94	77.75	0.00	0.55	-0.64
KANGAROOOF	1020	77.12	77.90	76.17	0.00	0.78	-0.95
KANGAROOOF	1415	77.00	77.79	76.02	0.00	0.79	-0.98
KANGAROOOF	1660	76.86	77.67	75.85	0.00	0.81	-1.01
KANGAROOOF	1995.5	76.79	77.60	75.77	0.00	0.81	-1.02
KVOF1	0	78.34	78.91	77.67	0.00	0.57	-0.67
KVOF1	5	78.39	78.94	77.75	0.00	0.55	-0.64
KVOF2	0	77.65	78.35	76.82	0.00	0.70	-0.83
KVOF2	5	77.65	78.34	76.82	0.00	0.69	-0.83
KVOF3	0	77.13	77.90	76.17	0.00	0.77	-0.96
KVOF3	5	77.12	77.90	76.17	0.00	0.78	-0.95
KVOF4	0	77.01	77.80	76.03	0.00	0.79	-0.98
KVOF4	5	77.00	77.79	76.02	0.00	0.79	-0.98
KVOF5	0	76.86	77.66	75.85	0.00	0.80	-1.01
KVOF5	5	76.86	77.67	75.85	0.00	0.81	-1.01
TOWN3	0	87.35	87.41	87.29	0.00	0.06	-0.06
TOWN3	53	81.70	81.77	81.62	0.00	0.07	-0.08
TOWN3	83	80.61	80.61	80.61	0.00	0.00	0.00
TOWN3	118	78.05	78.08	78.02	0.00	0.03	-0.03
TOWN3	215	77.16	77.93	76.21	0.00	0.77	-0.95
TOWN3	397.97	77.16	77.93	76.21	0.00	0.77	-0.95
TOWN3OF	0	80.61	80.61	80.61	0.00	0.00	0.00
TOWN3OF	30	78.05	78.08	78.02	0.00	0.03	-0.03

Sensitivity Analysis of Storage Factor Bx – PMF

Results of the sensitivity analysis on the storage factor Bx indicate that peak flows can vary by up to 26% at the outlet (at Hampden Bridge) for the PMF

Label	Peak Local Flow (m3/s)			Difference (%)	
	calibrated **LOW**	base **MED**	**HIGH**	**LOW**	**HIGH**
	Bx=0.6	**Bx=1.0**	**Bx=1.5**		
KV_BG1	942	742	528	27	-29
KV_BG2	922	777	593	19	-24
KV_BG3	927	758	557	22	-27
KV_BG4	346	267	183	30	-31
KV_BY1	1120	851	579	32	-32
KV_BY2	875	678	472	29	-30
KV_BY3	337	227	139	48	-39
KV_BY4	136	97	61	40	-37
KV_CV1	20	20	19	0	-5
KV_DB1	556	480	396	16	-18
KV_GG1	1444	1065	689	36	-35
KV_KR1	1101	845	582	30	-31
KV_KR2	970	819	641	18	-22
KV_KR3	993	837	648	19	-23
KV_KR4	767	613	437	25	-29
KV_KR5	238	186	130	28	-30
KV_KR6	57	45	31	27	-31
KV_KR7	11	10	9	10	-10
KV_KR8	5	5	4	0	-20
KV_KR9	4	3	3	33	0
KV_KR10	52	29	17	79	-41
KV_KR11	18	17	16	6	-6
KV_MG1	35	34	31	3	-9
KV_MG2	22	21	19	5	-10
KV_MGTRIB1	17	17	16	0	-6
KV_MGTRIB2	7	7	7	0	0
KV_ML1	371	259	165	43	-36
KV_ML2	668	571	465	17	-19
KV_NG1	114	111	104	3	-6
KV_NG2	236	218	191	8	-12
KV_NGTRIB	100	95	86	5	-9
KV_SY1	776	587	392	32	-33
KV_TTRIB1	16	16	15	0	-6
KV_TTRIB2	18	18	17	0	-6
Total Flow @ Outlet	**11947**	**9675**	**7207**	23	-26

Appendix F: Comments from NSW Department of Natural Resources

This question of effective roughness is turning out to be a very interesting issue irrespective of whether a 1D or 2D model is used. The 2D models should explicitly calculate diverging & converging flow fields so that the losses & viscosity effects associated with those should be handled in those calculations. The practical upshot of which seems to be that the numerical value of the "effective roughness" parameter is lower in a 2D model of a given location than a 1D model of the same location to achieve similar calibration.

The adoption of a fixed or erodible bed & banks in the model also seems to be important. Some recent sensitivity testing of models of an ICOLL with an erodible entrance has shown that increasing roughness in the floodplain while maintaining the same roughness in the channel can actually lower flood levels in both the channel and floodplains. The explanation appears to be that the increased floodplain roughness increased the proportion of flow conveyed within the channel throughout all stages of the flood so that there was greater flow energy to scour the entrance more & earlier so there is less need to store water in the floodplains so the levels don't rise as high.

All fascinating, but not necessarily relevant to KV where I understand we are using a fixed bed model. My intuition is that increasing either or both stream &/or floodplain roughness in a fixed bed model may still change the proportion of flow in each by redistributing flows, but that since the cross sections remain constant the levels should go up.

I would expect that increasing the floodplain roughness would increase the proportion of flow conveyed in the relatively less rough channel. Given more water in the channel & a fixed bed, I would expect the water levels in the channel to increase.

Referring back to my old mates Arcement & Schneider I note that their pictures of n=0.18 & indeed n=0.20 floodplains look like places I would have little difficulty traversing on foot at normal walking pace. I therefore tend to the view that they do not necessarily represent particularly high effective roughness values for vegetated floodplains.

Further as your email indicates, the macro topography in your area of interest (ie the confluence of two streams in a floodplain contracting into a gorge) may be exerting some note worthy influence on the effective roughness.

So looking at your model results, I note there is significant variability in "Goodness of fit" in modelled & recorded peak flood levels between events. Since the macro topography wouldn't have varied much between events that suggests that some more variable factor such as riparian vegetation may be significant to the variability between events.

You may be able to form a more informed view on that if you established how much either or both roughness values need to increase to better match the peaks of the events with the higher differences & whether or not there is any evidence of riparian vegetation changes to suggest such roughness variations between events are explainable. I neither request nor recommend the additional analysis, I simply observe that it may assist your decision making.

Bottom line, on the basis of the information supplied & for the reasons discussed above, I therefore think that 0.12 channel roughness & 0.18 floodplain roughness may well be at or about the lower bound of reasonable.

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