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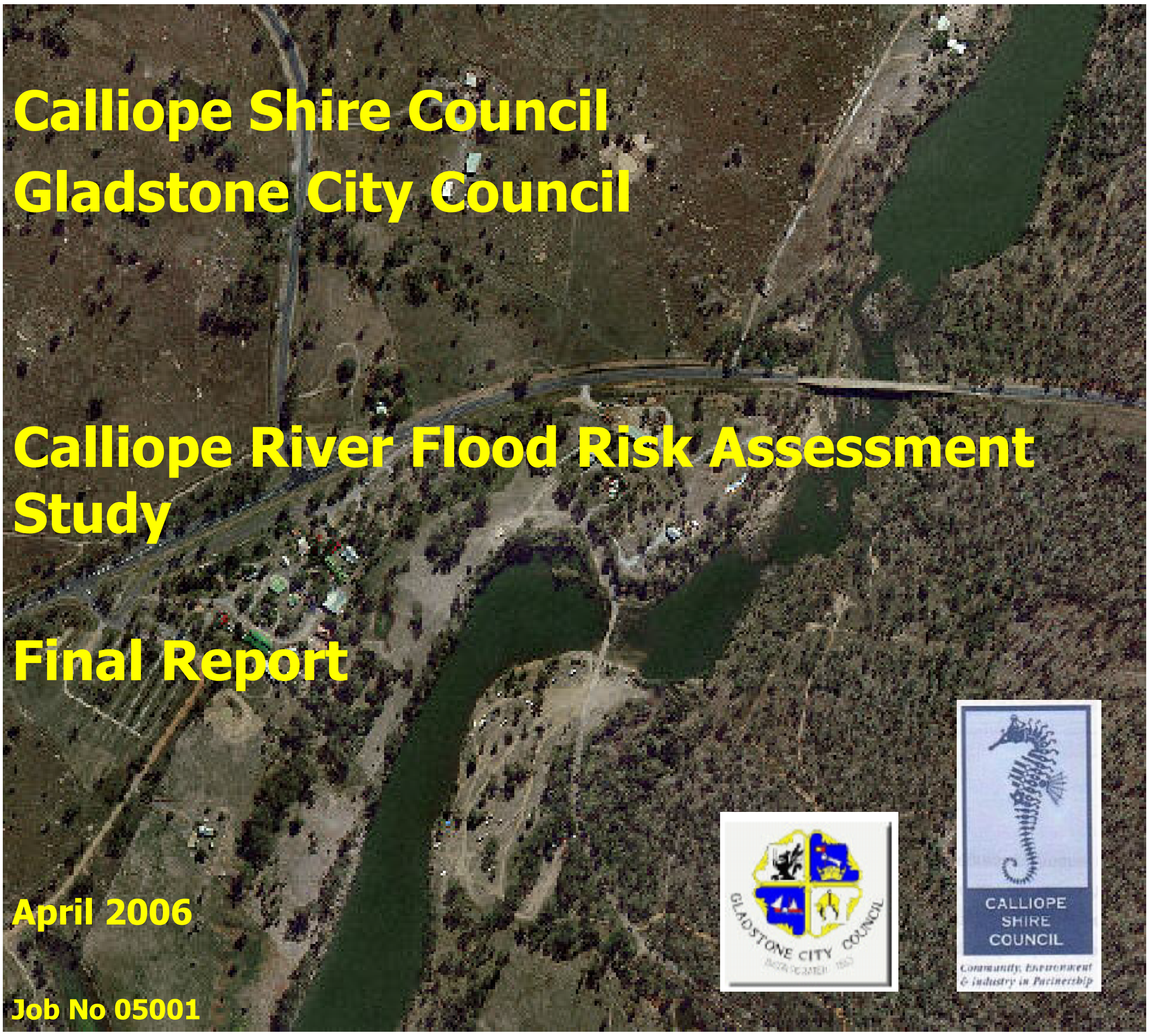

Calliope Shire Council
Gladstone City Council

Calliope River Flood Risk Assessment Study

Final Report

April 2006

Job No 05001

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Executive Summary

Study Structure

Calliope Shire Council (CSC) appointed Sargent Consulting (SC) to undertake the Calliope River Flood Risk Assessment Study in February 2005.

The study has been conducted in a number of stages with a Milestone Report being submitted for review at the completion of each stage.

These stages and their accompanying reports are:

Milestone 1	*Completion of Survey, Model Setup and Calibration*
Milestone 2	*Completion of Hydrologic and Hydraulic Analyses and 100 year inundation plan*
Milestone 3	*Completion of assessment of mitigation measures*
Milestone 4	*Submission of Draft Study Report*
Milestone 5	***Submission of Final Study Report and other deliverables***

Final Report

*This report is the **Final Report** (Milestone 5). It includes minor changes from the Draft Final Report (Milestone 4) resulting from the SAG's review. Key points from the report are outlined in this Executive Summary.*

The Calliope River Catchment

For the hydrologic components of the study, the Study Area comprised the whole of the catchment of the Calliope River, a catchment area of 1,860 km^2. The hydraulic modelling was limited to the reach of the Calliope River from the gauging station at Castlehope (AMTD 32.8km) to its discharge into the ocean at Gladstone, together with The Anabranch and nominated reaches of Leixlip Creek and Clyde Creek.

The Calliope River rises in the Calliope Range (which forms the western boundary of the catchment) to the southwest of Gladstone. The river flows firstly south easterly, and then generally easterly in its mid-reaches before turning north easterly to reach the coast at Gladstone, where it discharges into Port Curtis (Main Channel). The northern boundaries of the catchment are the Mount Alma and Mount Larcom Ranges, whilst the southern boundary is the Boyne Range. Elevations in the catchment range from only marginally above sea level near the river mouth to over 800m AHD on the catchment divide.

The catchment experiences a semi-tropical maritime climate with orographic influences due to its high elevation boundary. This climate is dominated by summer rainfalls with heavy falls likely from severe thunderstorms and occasionally from tropical cyclones. Heavy rainfall is most likely to occur between November and April, with most flood events occurring in the months January to March.

The mean annual rainfalls over the catchment show some reduction with distance from the coast i.e. 980mm at Gladstone, 936mm at Calliope, 900mm at Mount Larcom, 862mm at Calliope Station, 871mm at Manersley and 691mm at Biloela, with the latter being west of the catchment divide.

There is significant variation between years with Calliope having a highest recorded annual rainfall of 2,317mm and a highest monthly fall of 686mm (January) compared to the January *mean of 148 mm. The corresponding lowest recorded falls are 352mm annually, and zero in each month except January for which the lowest recorded was 8mm.*

Flood History

*Streamflow records in the Calliope River commenced in October 1938 when the gauging station at Castlehope was opened. The flood of record is **4,040m^3/s** on 12th February 1947. The second highest flood in this record is **3,860 m^3/s** on 20th December 1973. The most recent significant flood occurred on 6th February 2003 when a peak flow of **2,770 m^3/s** was recorded (5th highest on record).*

Hydrologic Modelling

*The report describes in some detail the setting up and calibration of a hydrologic model for the catchment using the widely used **RORB** model.*

The model was successfully calibrated for three flood events for which good or reasonably good rainfall and streamflow data were available. These events were: February 2003, December 1990 and January 1978.

The December 1973 flood was then used to validate the model. Running the model for this event with parameters determined from the three calibration events replicated the recorded peak flow at Castlehope within 8%, which is satisfactory.

*Instead of adopting the default value of 0.8 for the model's non-linearity parameter (**m**), this was allowed to vary within the range 0.6 to 1.0 and corresponding values of the model storage parameter k_c determined. This procedure enabled the parameter interaction curve (a graph of k_c versus **m**) to be drawn, which clearly indicated that the best model fit was obtained with an **m** value of 0.88 and a corresponding k_c of 44.5.*

*The **RORB** model was then used to produce flow hydrographs for input to the calibration runs of the hydraulic model, by exporting hydrographs for the Calliope River at Castlehope together with a further 51 locations representing tributary and local runoff inputs.*

Hydraulic Modelling

*The hydraulic model used in this study is **MIKE 11** which is a "state of the art" numerical model based on one-dimensional unsteady flow conditions in open channels. **MIKE 11** was developed by the Danish Hydraulics Institute (DHI) and is widely used in Australia and many other countries for the modelling of flood behaviour in natural river systems.*

Application to the Calliope River and Tributaries

Model Setup

*In **MIKE 11** the geometry of the river system and its floodplain is defined by first defining the relevant flow paths and then a number of cross sections along each flow path, together with that of any floodplain structures such as roads, bridges and culverts.*

Survey

In this study, new survey was undertaken over that part of the study area within Calliope Shire for which a digital elevation model (DEM) was not previously available. Gladstone City Council provided a DEM for that part of the study area within its area.

There were two components of the survey, namely: aerial survey to produce the DEM and digital ortho-imagery; and a hydrographic survey of the rivers and creeks to define the underwater parts of the channel sections.

The aerial survey was undertaken by Fugro Spatial Solutions (FSS) using the "state of the art" airborne laser survey (ALS) techniques. This produced a dense sampling of ground spot levels, which were then processed into both a DEM and contour maps.

Digital photography was taken concurrently with the ALS, producing rectified images (ortho-imagery), which was provided in a tiled format, combined into a single seamless image in MapInfo format.

The hydrographic survey was undertaken by Ken McDonald Surveys using "state of the art" echo sounding equipment linked to kinematic GPS.

Geometry

The model structure comprises a total of 27 flowpaths, made up of 5 primary flowpaths (Calliope River, The Anabranch, Clyde Creek and Leixlip Creek and a meander cut off), 2 additional tributary flowpaths (Deep Creek, Double Creek), 6 flood breakout flow paths, 5 bridge flowpaths and 9 link channels.

In all a total of 426 river and creek cross sections were extracted from the DEM and converted to MIKE 11 cross-section format. This was done by selecting cross-section locations, then using GIS/Cad software to drape these locations over the DEM, sampling levels at 2m intervals, leading to very detailed cross-sections.

In addition, there are a total of 26 structures in the model comprising 12 bridges, 7 culverts, 4 weirs representing over road flows at culverts and a further 3 weirs representing other roads acting as hydraulic controls.

Hydraulic Roughness

A key element of models of this type is their representation of hydraulic roughness.

In this case, detailed information regarding the vegetation at each of the cross sections was obtained from the new ortho-imagery, and the 'relative roughness' across each section was varied to account for the effects of vegetation changes.

Initial values of hydraulic roughness (Manning's ***n****) were selected based on field inspections, aerial photographs and previous experience. These were subsequently modified during the calibration phase.*

Boundary Conditions

The required boundary conditions are hydrographs of streamflow at the upstream end of each of the open flow paths (ie those with no upstream connection), and a downstream water level or stage-discharge rating curve. In addition, intermediate flow inputs can be applied to represent tributary or local runoff inflows. The streamflow hydrographs required for input to the Calliope River model were produced from the ***RORB*** *hydrologic model, at a total of 52 locations.*

The downstream boundary condition was the tide level at Gladstone Harbour. Tide level time series for the duration of the calibration events were obtained from the Maritime Services Office of the Queensland Department of Transport. For the events from December 1990 to date, the data are recorded values, and for events prior to that date are predicted values.

Model Calibration

The principal source of historic flood levels for the study are those at the DNRM gauging station on the Calliope River at Castlehope, at which there is an automatic stage recorder. In addition to the above, Calliope Shire Council has a few records of flood levels from a number of locations within the Calliope River floodplain.

Given that there were four flood events, essentially with a single flood level each, it was decided to use all of the available events to calibrate the model and to evaluate the relative model performance for each event.

Model roughness parameters were selected initially based on field inspections, survey notes, aerial photographs and experience from previous studies. Roughness values were then modified by an iterative trial and error *process to obtain as good a match as possible between recorded and modelled peak water levels.*

Whilst every effort was made to effect a calibration which was satisfactory for all of the flood events, it did not prove possible to achieve this. The results of these runs compared to the recorded flood levels together with the model roughness parameters used are given in ***Table ES1.***

Table ES1 Summary of Peak Flood Levels at Key Points – Calibration Events

Flowpath	Chainage m	Location	Peak Flood Level (m AHD) in Event			
			February 2003	**December 1990**	**January 1978**	**December 1973**
	n		0.0573	0.057	0.065	0.072
Calliope River	33	Castlehope GS (observed)	16.27	14.01	16.64	19.23
	33	Castlehope GS (Mike 11)	16.26	14.08	16.63	19.24
	2556	D/s Deep Ck	14.87	12.53	14.92	17.48
	6000	D/s Double Ck	13.79	10.88	13.75	16.42
	7250	D/s Leixlip Ck	13.37	10.37	13.29	15.95
	9413	U/s Old Bruce Highway Crc	12.89	9.78	12.74	15.48
	12800	D/s LBO2 re-entry	9.06	6.59	9.02	10.75
	14250	D/s LBO3 re-entry	8.59	6.11	8.48	10.16
	20417	U/s Clyde Ck	6.29	4.15	6.11	7.39
	20750	D/s Clyde Ck	6.12	4.00	5.96	7.22
	23256	U/s Meander Cutoff	3.81	2.52	3.65	4.54
	27246	D/s Meander Cutoff	3.65	2.52	3.50	4.39
	31750	D/s Anabranch Re-entry	2.22	2.47	1.85	2.60
	34000	D/sWiggins Is flowpath	2.01	2.45	1.54	2.00
Trbutaries						
Deep Creek	0	Dawson Highway	19.02	18.08	20.13	21.11
Double Ck	-460	Dawson Highway	18.16	16.83	18.46	20.06
Leixlip Ck	0	U/s Model Boundary	32.90	32.76	32.86	33.08
	1062	Dawson Highway	30.32	30.13	30.17	30.44
	2493	Stowe Rd	26.48	26.20	26.37	26.86
	4167	Rail Crossing	22.09	21.31	21.68	22.59
Clyde Ck	0	U/s Model Boundary	20.48	19.19	19.96	21.52
	953	Dawson Highway	19.24	17.91	18.51	20.45
	3800	Wyndham Rd	11.11		10.79	
	6090	Jefferis Road	6.65	4.90	6.30	7.69
The Anabranch	2590	Port Curtis Way	3.02	2.50	2.83	3.68
Wiggins Island Flowpath	364	Adj. Wiggins Island	2.01\	2.45	1.54	1.89

*It can be seen from **Table ES1**, for example, that the best fit to the observed water level at Castlehope for the 2003 event was obtained with a Manning's **n** of 0.0573, whilst to give the same outcome for the 1973 flood, a value of 0.072 was required.*

*Using the **n** value which gave the best fit for the 2003 flood (0.0573) with the 1973 event underestimated the latter by almost a metre. Conversely, using the value which best fitted the 1973 event (0.072) overestimated the 2003 flood by over a metre. These results were clearly unsatisfactory necessitating a review of physical changes in the Calliope River as outlined in the next section.*

Further inspection of these results shows that similar results were obtained for the 2 most recent events (2003 and 1990) and for the earlier events (1978 and 1973).

Further details of peak flood levels, peak flows and longitudinal profiles from these model runs are given in the body of the report.

Brief Assessment of Physical Changes in the Calliope River

It was considered that the degree of discrepancy in the calibration results could indicate that a physical change has occurred since the earlier series of floods. A number of occurrences could have resulted in enlargement of the channel cross-section, for example:

- *Significant erosion (channel deepening/widening) following the floods in the 1970's;*
- *Dredging in the lower reaches of the river since the 1970's for navigational purposes; or*
- *If the cut-off of the large meander upstream of the start of the Anabranch occurred in that period, this would have initiated an episode of headwards erosion.*

*It was decided at the SAG meeting to discuss the **Milestone 1 Report** (Sargent Consulting 2005a) that it would be prudent to undertake a brief assessment of the evidence for such a change as part of the Study. This was undertaken and subsequently reported on in **Working Paper No 1** (Sargent Consulting 2005b).*

The hypothesis that there may have been sufficient physical change to the channel characteristics of the Calliope River over recent years to result in the above inconsistency in modelled roughness between historic events, when it was assumed that there was no such change, was tested based on information from aerial photographs, mapping and cross section surveys..

The following conclusions were drawn from this brief investigation of physical changes to the channel of the Calliope River over the last 100 years:

- *There has been significant widening of the channel cutting across the neck of the large meander which contains the entry to the Anabranch over this period, from about 15m in 1892 to 50m in 1941 and to 200m today, with the rate of widening increasing since 1961 to 2.7 m/annum. This is consistent with the recent flood history;*
- *There has been a slower but still significant rate of widening at each of 3 other locations, namely: Devil's Elbow, immediately upstream of Farmers Island and immediately upstream of the Calliope River/Leixlip Creek confluence. The rate of widening at these sites has also increased in the last 50 years and is currently about 0.5m per annum. Due to the consistency of these changes, it is reasonable to assume that these locations are typical of the whole of the study reach;*

- *The meander cutoff has shortened the river course by about 3.8 km resulting in an increased the gradient upstream. An increased gradient results in greater flow energy and erosion potential. As the rock control at the Bruce Highway should prevent any significant lowering there and upstream, when this deepening process is completed there would be a bed lowering of from zero to 1m though this reach, or an average of about 0.5m; and*

- *A comparison of cross sections between the 2005 mapping and the 1980 contour mapping at 12 locations (including sites upstream of the rock control at the Bruce Highway crossing) showed a lowering of levels within the higher parts of the channel which contain flow only during flood events. Whilst not of high accuracy due to the 1980 mapping having only 5m contours (i.e. possible errors of ± 2.5m), the consistency of these differences and with some being up to 5m suggests that these differences are not due to possible map error alone. This type of change is consistent with erosion during high flows. The hydraulic modelling has shown that average velocities in the major floods are of the order of 3m/s which is quite sufficient to cause significant erosion.*

Hence, this investigation demonstrated that there has been quite significant change to the hydraulic capacity of the Calliope River as a result on ongoing fluvial geomorphologic change, the rate of which has increased post 1961.

Taken together, the channel changes indicated above are believed to be consistent with the difference in hydraulic roughness required to calibrate the 1973 and 2003 floods assuming that there had been no change in geometry.

Hence, it was concluded that the appropriate hydraulic roughness is that which gives the best fit to the flood which most resembles the current conditions, i.e. the February 2003 event. Using the higher roughness indicated by the 1973 flood calibration is not justified, as it is now clear that in 1973, the river cross section was smaller than at present, resulting in a higher than appropriate roughness being needed to compensate for the channel changes not being taken into account.

*On the basis of this assessment, it was determined that there has been significant channel change over the last 50 – 100 years, and that the appropriate choice of hydraulic roughness was that which satisfactorily fitted the more recent flood events. This is a base Manning's **n** value of **0.057**, but this is increased by the relative roughness across each cross section**,** so that overall value at a given cross section is in the range of 0.034 to 0.114 (i.e. relative roughness from 0.6 to 2). These values are within the typical range with values at the low end representing the smooth sand/silt bed in the estuary reaches, and the higher values representing typical floodplain conditions.*

Flow Distribution in Lower Calliope River

*The flow distribution between the Calliope River, The Anabranch and the meander cut off channel is of interest. These were estimated from the four calibration events as a proportion of the maximum peak flow in the river, and the proportions were found to not vary greatly. These proportions are given in **Table ES2.***

Table ES 2 Flow Distributions Lower Calliope River

Reach/ Flowpath	Mike 11 Chanage m	Peak flows and Percent Peak flows in event									
		2003		1990		1978		1973		Mean	SD
		Peak Flow (Cumecs)	%of Peak Flow	Peak Flow (Cumecs)	%of Peak Flow	Peak Flow (Cumecs)	%of Peak Flow	Peak Flow (Cumecs)	%of Peak Flow		
Calliope R u/s of cutoff	u/s of 23250	4550	102%	2640	99%	3800	101%	4880	101%	101%	1.4%
Calliope R d/s of cutoff, u/s of Anabranch	d/s 23250 - u/s25750	675	15%	370	14%	540	14%	690	14%	14%	0.4%
Anabranch	0 - 4750	980	22%	490	18%	800	21%	1090	23%	21%	1.8%
Calliope R d/s of Anabranch, u/s of Cutoff re-entry	d/s 25750 - u/s 27246	270	6%	60	2%	15	0.4%	35	0.7%	2%	2.5%
Cutoff	0 - 220	3870	85%	2270	85%	3255	87%	4190	87%	86%	1.1%
Calliope R d/s of Cutoff re-entry u/s of Anabranch	d/s 27246 - 31750	3480	76%	2150	80%	2965	79%	3765	78%	78%	1.6%
Calliope R d/s Anabranch re-entry to Wiggins Island	d/s 31750 to 34000	4480	100%	2680	100%	3760	100%	4825	100%	100%	0.0%
Wiggins Island flowpath	0 - 2492	1630	36%	860	32%	1100	29%	1600	33%	33%	2.7%
Calliope R d/s Wiggins Island to Mouth	d/s 34000 - 36500	3060	67%	2100	78%	2670	71%	3240	67%	71%	5.3%

Design Flows

*Design flows were estimated from direct flood frequency analysis of peak flows at Castlehope and from the **RORB** model. The adopted flood magnitude - frequency relationship derived from the direct frequency analysis is summarised in **Table ES3**.*

Table ES3 Calliope River at Castlehope
Adopted Flood Frequency Curve

Average Recurrence Interval (ARI) Years	Estimated Instantaneous Peak Flow m^3/s		
	Central Estimate	90% Confidence Band	
5	1,500	1,100	1,900
10	2,200	1,750	2,900
20	3,000	2,350	3,900
50	3,900	3,050	5,550
100	4,700	3,500	6,800
200	5,600	3,800	8,200
500	6,700	4,100	10,000

*The **RORB** model parameters were subsequently refined in order that these were consistent with those determined from the direct frequency analysis.*

*The **RORB** model was then used to estimate design flood hydrographs for the 52 inflow locations in the hydraulic model for a range of flood ARIs for a range of storm durations.*

*The probable maximum flood (PMF) was estimated by firstly estimating the probable maximum precipitation (PMP), using techniques prepared by the Bureau of Meteorology for a range of storm durations, and secondly by applying these rainfalls to the fitted **RORB** model. The estimate PMFs were: 20,000m^3/s for the Calliope River at Castlehope; 1,200m^3/s for Leixlip Creek, and 1,900m^3/s for Clyde Creek.*

Design Flood Levels

The design flood levels were obtained by running the hydraulic model with the inflows for each flood frequency and PMF for a range of storm durations, with the maximum for each ARI (i.e. over the range of durations) taken as the design flood level for that location and event.

The SAG, at its meeting of 15th December 2005, determined that the appropriate downstream boundary condition for all but PMF was the Highest Astronomical Tide (HAT) which at Gladstone Harbour is 2.42m AHD. This is consistent with the boundary condition used in the concurrent Auckland Creek Flood Study being undertaken by Gladstone City Council, and previous flood studies for the Boyne River.

For the PMF, the boundary condition was varied to the 1,000 year ARI storm surge level for Gladstone of 3.80m AHD as determined by the recent comprehensive investigation of storm surge levels along the east coast of Queensland (Systems Engineering Australia et al, 2003).

*Design flood levels for ARIs of 10, 20, 50 and 100 years and for PMF are given in **Table ES4**. Flood inundation maps and longitudinal flood profiles for the main flow paths were prepared for this range of floods and are included in the body of the report.*

Sensitivity testing for the 100 year ARI only allowing for a reasonable error band in both hydraulic roughness and design flows, indicated that an appropriate freeboard to add to these values for town planning purposes would be 1.0m.

A map of "Development Levels" was prepared based on the estimated 100 Year ARI flood levels plus 1m.

Flood Immunity of Road and Rail Crossings

*The hydraulic model results were used to estimate the current flood immunity of the road and rail crossings within the modelled area. These are summarised in **Table ES5.***

Table ES4 Design Flood Levels at Key locations

Flowpath	Location	MIKE 11 Chainage	Peak Flood Level (m AHD) for ARI (Years)						
			10	20	50	100	200	500	PMF
Calliope River	Castlehope GS	33	14.8	16.1	17.9	19.1	20.1	21.4	27.5
	Deep Ck	2184	13.3	14.7	16.4	17.6	18.9	20.0	27.0
	Double Ck	6000	11.4	13.0	15.1	16.5	17.3	18.5	26.9
	Leixlip Ck	7250	10.9	12.5	14.6	16.1	16.8	17.4	26.6
	Old Bruce Highway Crossing	9413	10.4	12.0	14.2	15.7	16.4	16.9	26.6
	Devil's Elbow	17250	5.9	6.9	8.2	8.9	10.0	10.9	21.1
	Clyde Creek	20750	4.9	5.7	6.7	7.2	8.2	9.4	20.7
	Meander Cutoff Upstream	23256	3.4	3.8	4.4	4.8	5.3	6.0	10.4
	Anabranch Entry	25750	3.3	3.7	4.2	4.6	5.2	5.8	10.3
	Meander Cutoff Downstream	27246	3.3	3.7	4.3	4.7	5.2	5.8	10.3
	Anabranch Re-entry	31750	2.7	2.8	3.1	3.2	3.5	3.8	6.3
	River Mouth	36500	2.4	2.4	2.4	2.4	2.4	2.4	3.8
Leixlip Creek	Model Boundary	0	32.9	33.1	33.1	33.2	33.4	33.5	34.3
	Dawson Highway	1062	30.4	30.6	30.8	30.9	31.1	31.3	32.7
	Stowe Rd	2946	25.5	25.7	25.8	25.9	26.2	26.4	27.6
	Hookes Rd	4466	21.5	22.1	22.4	22.8	23.2	23.8	27.0
	Rail Crossing	4813	21.5	22.1	22.4	22.8	23.1	23.6	27.0
	Schilling Lane	6332	15.3	15.7	16.1	16.5	17.2	17.7	25.9
	Calliope River	9261	10.9	12.5	14.6	16.1	16.8	17.4	26.6
Clyde Creek	Model Boundary	0	20.3	21.0	21.6	22.0	22.4	22.7	24.4
	Dawson Highway	953	19.0	19.8	20.8	21.1	21.4	21.6	22.8
	Rail Crossing	973	17.8	18.7	19.2	19.6	20.1	20.4	22.0
	Wyndham Rd	3820	11.6	11.9	12.2	12.5	13.0	13.5	20.6
	Jefferis Rd	6100	5.4	6.1	7.0	7.7	8.8	10.1	20.9
	Calliope River	8667	4.9	5.7	6.7	7.2	8.2	9.4	20.7

Road Upgrade Requirements

Table ES6 *lists road upgrades which would increase the flood immunity for Council roads to 10 year ARI (5 locations) and to 50 year ARI flood immunity for highways (i.e. roads under the control of the Department of Main Roads) (2 locations).*

There are two low level crossings on the Calliope River, namely, the Old Bruce Highway Crossing and the ford between Blackgate Road and Ferguson Road at Castlehope. Both of these crossings represent a high risk during even relatively low flows, especially for visitors to the area who are unaware of local conditions. It is recommended, therefore, that at the minimum, flood depth markers and appropriate warnings signs be erected at these crossings. Furthermore, as these crossings are not required for access i.e. both are accessible from both sides), it is further recommended that consideration be given to permanent closure of these crossings.

We understand from Council that alternative routes provide adequate access/egress to areas served by Schilling Lane and by Hookes Road and hence upgrading the flood immunity of these roads is of low priority. Council is also considering a higher immunity road into the area served by Wyndham Road. If the crossings on these roads are not to be upgraded, it is recommended that appropriate warning signs be installed.

Table ES5 Flood Immunity of Road and Rail Crossings

Flowpath	Road/Rail Crossing	MIKE 11 Chainage m	Crossing Level	Flood Immunity	Approx. closure duration in 10 Year ARI event	Peak Flood Level (m AHD) for ARI (Years)			
			m AHD	Years	Hours	10	20	50	100
Calliope River	Blackgate Rd/ Ferguson Rd	324	2.5	<<10	>72	14.6	16.0	17.7	18.9
	Old Bruce Highway Crossing	9413	2.0	<<10	>72	10.4	12.0	14.2	15.7
	Bruce Highway Bridge	9907	15.24	>100	N/A	9.0	10.3	11.7	12.5
	Rail Bridge 1	22576	8.35 abutments ~6	50	N/A	4.4	5.2	6.1	6.7
	Rail Bridge 2	22770	9 abutments ~8	>100	N/A	4.0	4.6	5.4	5.9
	Port Curtis Way	30721	8.32 abutment ~6	>100	N/A	2.8	3.0	3.3	3.5
Leixlip Creek	Dawson Highway	1062	29.5	<10	3	30.4	30.6	30.8	30.9
	Stowe Rd	2924	25.0	<10	12	25.8	26.0	26.2	26.3
	Hookes Rd	4466	18.5	<10	24	21.5	22.1	22.4	22.8
	Rail Crossing	4813	22	20	N/A	21.5	22.1	22.4	22.8
	Schilling Lane	6332	12.7	<10	27	15.3	15.7	16.1	16.5
Clyde Creek	Dawson Highway	953	20.82	50	N/A	19.0	19.8	20.8	21.1
	Rail Crossing	973	20.5	>100	N/A	17.8	18.7	19.2	19.6
	Wyndham Rd	3820	10.4	<10	15	11.6	11.9	12.2	12.5
	Jefferis Rd	6100	4	<10	26	5.4	6.1	7.0	7.7
Deep Ck	Dawson Highway	47	16.15	10	N/A	15.9	18.0	18.5	18.9
Double Ck	Railway Crossing	3100	15.9	50	N/A	11.6	13.1	15.2	16.6
	Dawson Highway	-440	14	<<10	24	16.6	17.1	17.6	18.0
Anabranch	Port Curtis Way	2630	5.17	>100	N/A	3.0	3.3	3.7	4.0

Table ES6 Road Upgrade Requirements

Flowpath	MIKE 11 Chainage m	Road Crossing	Structure	Current Crossing Level m AHD	Approx Current Immunity Level ARI (Years)	Proposed Immunity (Years)	Proposed Upgrade or Comment	Min Road/Deck Level Required m AHD (assume deck 0.8 m above soffit)
Calliope River	324	Blackgate Rd/ Ferguson Rd	Ford	2.5	<<10	<<10	No proposed change High risk crossing Upgrade impractical Recommend closure or as min. warning signs	-
	9413	Old Bruce Highway Crossing	Low level Causeway	2.0	<<10	<<10	No proposed change High risk crossing Upgrade impractical Recommend closure or as min. warning signs	-
Leixlip Creek	1062	Dawson Highway	Culverts	29.5	<10	50	Raise min road level to 31.2m Increase main culvert from 5 to 15 cells (3.0w x 2.4h)	31.20
	2924	Stowe Rd	Culvert	25.0	<10	10	Raise min road level to 26.8m Increase main culvert from 5 to 10 cells (3.6w x 3.0h)	26.80
	4466	Hookes Rd	Ford	18.5	<<10	10	Raise min road level to 22.1m New 10 cell culvert (3.6w x 2.1h) Low priority as alternative access/egress route available. Warning signs recommended.	22.10
	6332	Schilling Lane	Causeway with low flow culvert	12.7	<10	10	Raise min road level to 16.0m New 10 cell culvert (3.6w x 3.0h) Low priority as alternative access/egress route available. Warning signs recommended.	16.00
Clyde Creek	3820	Wyndham Rd	Proposed Bridge	10.4	<10	10	Increase bridge deck level and approaches to 12.2m. An alternative high immunity acess route is being considered. Warning signs recommended.	12.20
	6100	Jefferis Rd	Culvert	4	<10	10	Raise min road level to 7.1m Additional 5 cells to culvert (3.6w x 2.1h)	7.10
Deep Ck	47	Dawson Highway	Bridge	16.15	10	50	Increase bridge deck level and approaches to 18.5m	18.50
Double Ck	-440	Dawson Highway	Bridge	14	<<10	50	Increase bridge deck level and approaches to 18.1m	18.10

Physical Flood Mitigation Measures

From the flood extent maps it can be seen that only a small number of properties are subject to inundation or isolation by floodwaters in a 100 year ARI event, as listed below:

- *There are some 15 properties liable to property and/or over-floor flooding from Leixlip Creek. These properties are in Calliope Township along the right bank of Leixlip Creek, comprising 14 properties on Sutherland Street and adjacent streets, and 1 on Stowe Road;*

- *One property fronting Clyde Creek immediately upstream of the Dawson Highway bridge which is flooded at 10 year ARI and above and one property fronting Clyde Creek immediately upstream of Wyndham Road; and*

- *Two areas adjacent to Calliope River, one near the confluence with Clyde Creek (ch 18386 – ch 19926) and another further south (ch 15750 – ch 16793) become isolated (flood islands) in floods of 100 year ARI or greater. Any future development on these areas may be subject to isolation for periods of several days, unless the access provided is to a high level. The appropriate access provision should be considered if and when development in these areas is proposed.*

This study considered a range of potential flood mitigation measures in broad terms only. It is beyond the scope of this study to propose works in detail, and works will require further investigation in respect of their detail, economics (eg cost/benefit performance) and sustainability.

The following options were considered to have potential merit.

a) Levee Leixlip Creek

This possible levee would extend along the right bank of Leixlip Creek between the Dawson Highway and Stowe Road in order to provide protection to houses along Sutherland Street and adjacent streets.

In order to provide protection against the 100 year flood plus 1m freeboard, this levee would vary in height from about 2m to 4m.

Hydraulic modelling demonstrated that the levee would have little impact on flood levels and would have no significant impact on properties outside the levee.

It appears from this preliminary evaluation that the levee would not have significant adverse impacts on flood levels elsewhere, and is worthy of further consideration. It is outside the scope of the current study to consider aspects other than the hydraulic impacts of possible flood mitigation works.

However, as with any levee scheme the issue of drainage of the area behind the levee would be an issue which would need to be considered.

Although economic considerations are outside the scope of this report, it is considered unlikely that the levee would have a sufficiently high benefit/cost ratio to be considered favourably for subsidised funding under the Natural Disaster Mitigation Program.

b) Detention Basins Leixlip Creek and Clyde Creek

The reduction of flood flow rates requires the introduction of storage. Possible storage locations on the Calliope River and its tributaries were investigated on the basis of topography, hydrology and hydraulics only.

Whilst no major site was identified on the Calliope River, a number of potential flood detention basin sites were identified on Leixlip Creek and Clyde Creek.

*The potential for these schemes to reduce flood flows was estimated using the **RORB** model which was modified to include the potential detention basins. The **MIKE 11** hydraulic model was then run, for the 100 year ARI only, with input hydrographs modified to represent the outflows with the detention basins in place. The resulting peak flood levels were then compared with those under current conditions.*

It was determined that, although the detention basins had the potential to substantially reduce flows from their respective upstream catchments, this reduction would not be sufficient to obviate the need for culvert upgrades as the road crossings downstream, nor that of the levee to protect properties in the Sutherland Road area of Calliope Township.

It was concluded, therefore, that there was no significant flood mitigation benefit to be gained from the construction of any of the identified detention basins.

Summary of Conclusions and Recommendations

Hydrologic and Hydraulic Model Calibration

The following conclusions were reached in respect of the setup and calibration phases of the hydrologic and hydraulic modelling components of the study which form the content of this Milestone Report:

- *The calibrated **RORB** hydrologic model satisfactorily represented both the quantum of flood flows and their distribution from the Calliope River catchment into the reaches of the lower Calliope River represented in the hydraulic model;*
- *There were inconsistencies in the hydraulic model calibration between the more recent flood events (2003, 1990) and those from the 1970s (1978, 1973);*
- *These inconsistencies were resolved by the brief assessment of physical changes to the channel capacity of the Calliope River which concluded that there has been significant channel widening/deepening occurring over recent years, and hence the hydraulic model parameters should be estimated from the most recent flood events only; and*
- *Whilst the data available for calibration of the hydrologic model were reasonable, there were too few historic flood level data in respect of the hydraulic model to obtain a reach by reach calibration, and even less to calibrate the tributaries.*

Design Flood Estimation - Conclusions

The following conclusions were reached in respect of the design flood estimation component of the study:

- *The flood extent or footprint is not very sensitive to the assumed downstream boundary condition (within an appropriate range);*

- *That the likely accuracy of the estimated 100 year ARI flood levels is of the order of ±1m, and hence that an appropriate freeboard allowance when using these estimates for town planning purposes is 1m; and*

- *The likely accuracy of the PMF is of the order of ±2m.*

Design Flood Estimation - Recommendations
The following recommendations are made in respect of design flood estimation:

- *Flood maps should carry a suitable disclaimer regarding their being based on the best available information but that these maps should not be relied upon to define the extent of flooding on any particular property;*

- *Given the relatively poor accuracy associated with the estimated flood levels, we recommend that Council considers the installation of peak level indicators through the hydraulic model extent. These are of relatively low cost, and will allow the collection of improved flood level data over time, which can then be used to refine the calibration of the hydraulic model and thereby, to reduce the uncertainty inherent in the estimated flood levels; and*

- *Due to the findings that there is ongoing channel widening and deepening occurring in the Calliope River, that a number of monitoring sites be established to better quantify this.*

Physical Flood Mitigation Measures - Conclusions
The following conclusions were reached in respect of physical flood mitigation measures:

Flood Immunity of Road Crossings

- *The flood immunity of a number of road crossings within the study area for which Calliope Shire Council is responsible is less than 10 year ARI and the measures required to upgrade these crossings have been determined to a preliminary design level;*

- *The flood immunity of the Dawson Highway crossings of Leixlip Creek and Double Creek are 10 year ARI or less;*

- *Where these crossings are low priority for raising of their flood immunity due to the availability (or planned availability) of alternative means of access/egress during flood that appropriate warning signs be installed; and*

- *There are two low level crossings on the Calliope River, namely, the Old Bruce Highway Crossing and the ford between Blackgate Road and Ferguson Road at Castlehope, which represent a high risk during even relatively low flows, especially for visitors to the area who are unaware of local conditions.*

Flood Mitigation Measures

- *There is the potential to construct a levee to prevent flooding up to 100 year ARI to about 15 properties along Leixlip Creek without unduly impacting on flood levels; and*

- *Potential detention storage sites within the Leixlip Creek and Clyde Creek catchments were identified and found to have some potential to reduce flood levels downstream. However, this potential was found to be insufficient to obviate the need for the upgrade of road crossings.*

Physical Flood Mitigation Measures Recommendations

The following recommendations are made in respect of road upgrading and physical flood mitigation measures:

Low Level Crossings

- *That at the minimum, Calliope Shire Council considers the installation of flood depth markers and appropriate warnings signs at these crossings; and*

- *As these crossings are not required for access i.e. both are accessible from both sides), it is further recommended that consideration be given to permanent closure of these crossings.*

Flood Immunity of Road Crossings

- *That Calliope Shire Council considers the upgrade of the flood liable roads in the study area which are under its control to achieve a flood immunity of 10 year ARI;*

- *Where these crossings are low priority for raising of their flood immunity due to the availability (or planned availability) of alternative means of access/egress during flood that appropriate warning signs be installed; and*

- *That Calliope Shire Council lobbies the Queensland Government to upgrade the flood immunity of the Dawson Highway at Leixlip Creek and Double Creek to 50 year ARI.*

Flood Mitigation Measures

a) Levees

The construction of a levee to mitigate flooding from Leixlip Creek in the Sutherland Street area of Calliope Township would be possible without adverse impacts on flooding elsewhere.

Although economic considerations are outside the scope of this report, it is considered unlikely that the levee would have a sufficiently high benefit/cost ratio to be considered favourably for subsidised funding under the Natural Disaster Mitigation Program. Hence, further work on this is not considered to be warranted at this time.

b) Detention Basins

As it was concluded that there was no significant flood mitigation benefit to be gained from the construction of the identified detention basins on Leixlip Creek and Clyde Creek, it is recommended that no further work on these possible schemes be undertaken.

1. Introduction

1.1. Study Structure

Calliope Shire Council (CSC) appointed Sargent Consulting (SC) to undertake the Calliope River Flood Study in November 2003.

The study has been conducted in a number of stages with a *Milestone Report* being submitted for review at the completion of each stage. These stages and their accompanying reports are:

Milestone 1	Completion of Model Setup and Calibration
Milestone 2	Completion of Hydrologic and Hydraulic Analyses and 100 year inundation plan
Milestone 3	Completion of assessment of mitigation measures
Milestone 4	Submission of Draft Study Report
Milestone 5	**Submission of Final Study Report and other deliverables**

1.2. Milestone 5 Report – Final Study Report

This report is the Milestone 5 report which is the **Final Study Report**. It consolidates and updates the information in **Milestone Reports 1** to **3** and from **Working Paper 1**, taking account of discussions and decisions made in meetings of the Study Advisory Group (SAG).

The report comprises the following sections:

Catchment Description;

Flood History;

Survey;

Hydrologic Model – Description, setup and calibration;

Hydraulic Model – Description, survey undertaken, setup and calibration;

Brief Assessment of Physical Changes in the Calliope River;

Design Flows;

Design Flood Levels;

Flood Mapping;

Assessment of Physical Flood Mitigation Measures;

Conclusions; and

Recommendations.

Further details of the modelling results are given in the ***Appendices.***

1.3. Study Area

For the hydrologic components of the study, the Study Area comprises the whole of the catchment of the Calliope River, a catchment area of **1,860** km^2. The hydraulic modelling is limited to the reach of the Calliope River from the gauging station at

Castlehope (AMTD 32.8km) to its discharge into the ocean at Gladstone, together with the Anabranch and nominated reaches of Leixlip Creek and Clyde Creek.

Figure 1 shows the general location of the Study Area, while **Figure 2** shows the location of the Calliope River catchment. **Section 2** contains a more detailed description of the catchment.

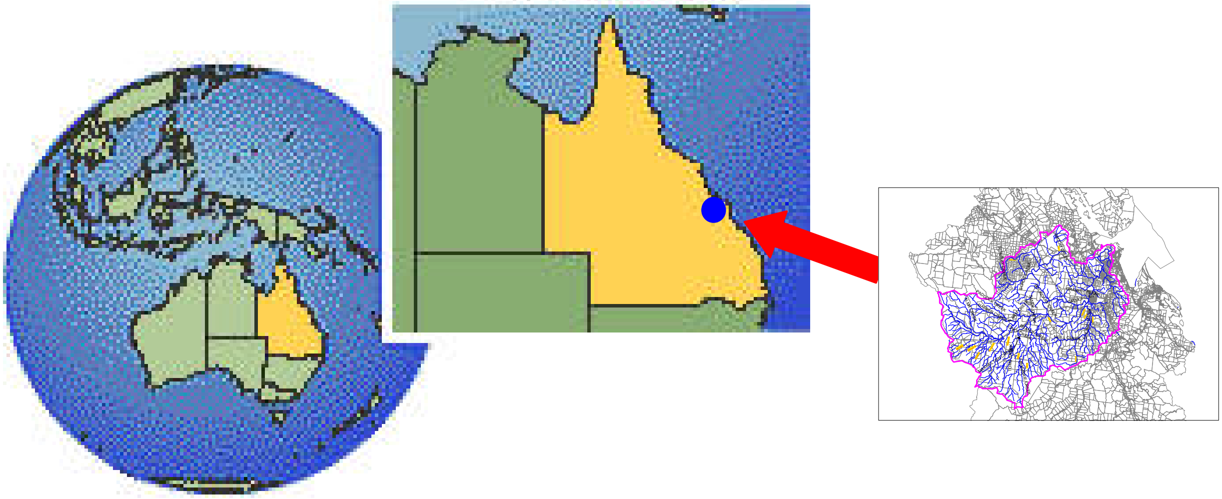


Figure 1 **General Location of Calliope River Catchment**

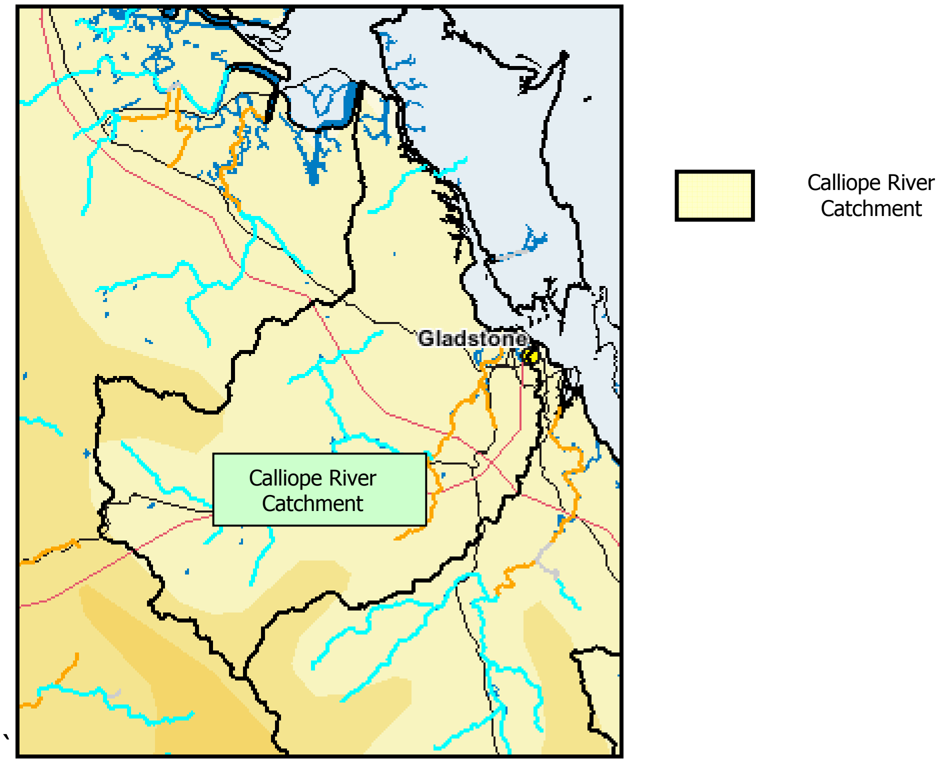


Figure 2 **Calliope River Catchment (Outline)**

Source: Commonwealth of Australia (Natural Water Resources Audit 2001)

2. Catchment Description

2.1. General

The general location of the Calliope River is shown in **Figure 2.** The catchment area of the Calliope River is shown in more detail in **Figure 3.**

The Calliope River rises in the Calliope Range (which forms the western boundary of the catchment) to the southwest of Gladstone. The river flows firstly south easterly, then generally easterly in its mid-reaches before turning north easterly to reach the coast at Gladstone, where it discharges into Port Curtis (Main Channel). The northern boundaries of the catchment are the Mount Alma and Mount Larcom Ranges, whilst the southern boundary is the Boyne Range.

Including coastal streams directly draining to the ocean, the catchment area of the Calliope Basin is 2,255 km^2. However, the catchment area of the Calliope River itself (excluding the minor coastal catchments) was estimated to be 1,860 km^2.

The main tributaries of the Calliope River are Alma Creek, Harper Creek, Paddock Creek and Larcom Creek on the left bank (looking downstream) and Lost Spring Creek, Tom Creek, Double Creek (also known as Middle Creek), Leixlip Creek and Clyde Creek on the right bank. The latter two creeks are of particular interest in this study as they pass through some of the more developed parts of Calliope Shire.

Elevations in the catchment range from only marginally above sea level near the river mouth to over 800m AHD on the catchment divide.

From the strategic plan and zoning maps it was estimated that 85% of the catchment is zoned rural, with 5% forest, 6% Gladstone State Development Area (GSDA), and about 2% major infrastructure, 1% rural residential, 0.3% village and 0.2% residential.

2.2. Climate

The catchment is situated between latitudes of 23° 45′ and 24° 10′ south, about 100km south of the Tropic of Capricorn. The western boundary of the catchment is about 60km from the Pacific Ocean coast at Gladstone. As a result, the catchment experiences a semi-tropical maritime climate with orographic influences due to its high elevation boundary.

This climate is dominated by summer rainfalls with heavy falls likely from severe thunderstorms and occasionally from tropical cyclones. Heavy rainfall is most likely to occur between November and April, with most flood events occurring in the months December to March.

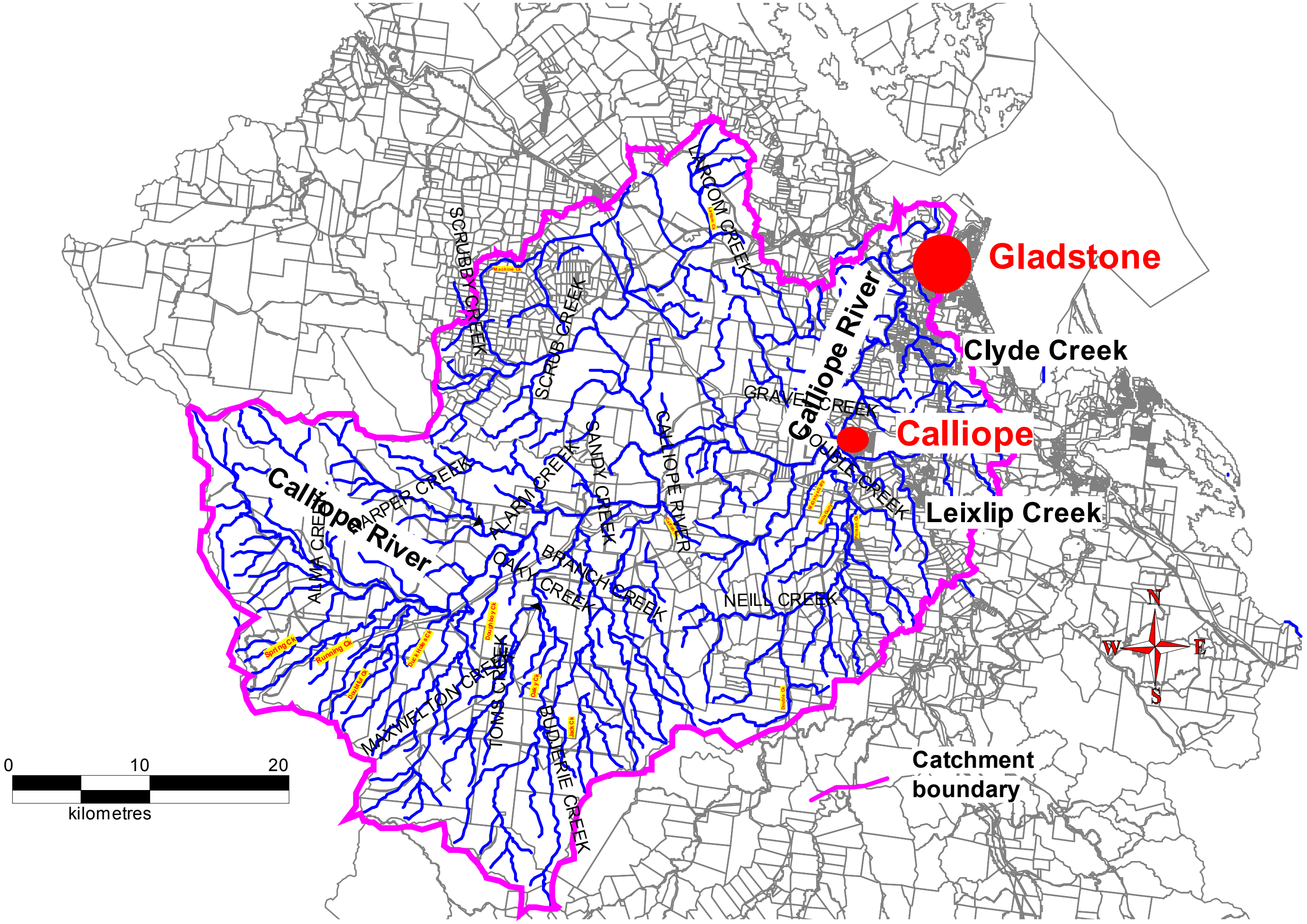


Figure 3 **Calliope River Catchment (Detail)**

2.3. Rainfall

Average rainfalls vary across the catchment due to the variation in elevation and orographic influences with higher rainfalls occurring around the catchment rim.

Figure 4 shows the location of rainfall stations in or adjacent to the Calliope River catchment with long term records. Monthly rainfall statistics for these stations are given in **Figure 5** and in **Table 1.**

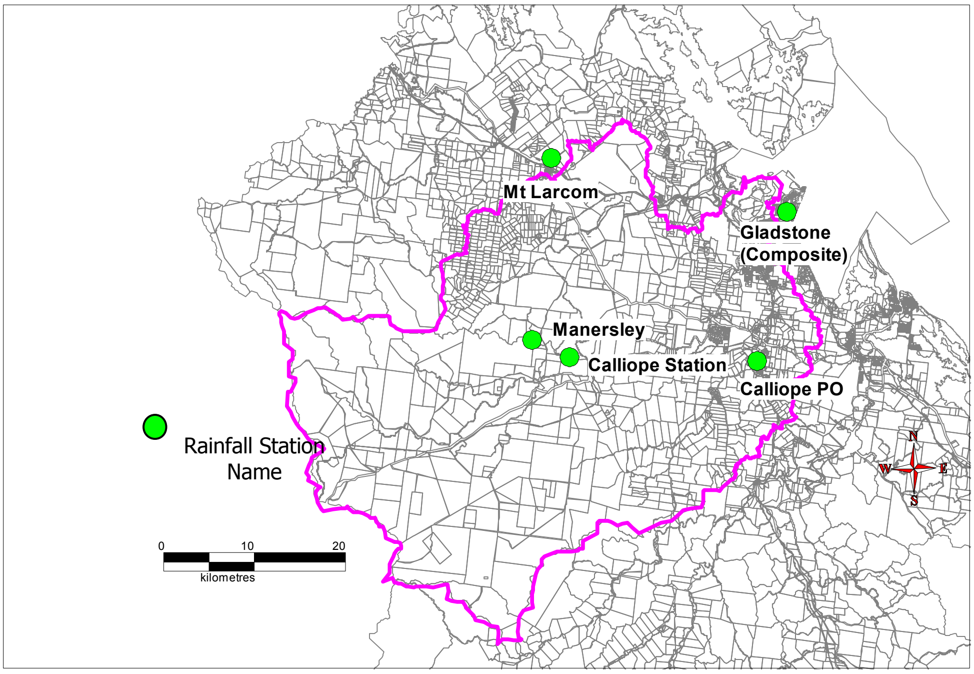


Figure 4 **Location of Rainfall Stations for which statistics are given**

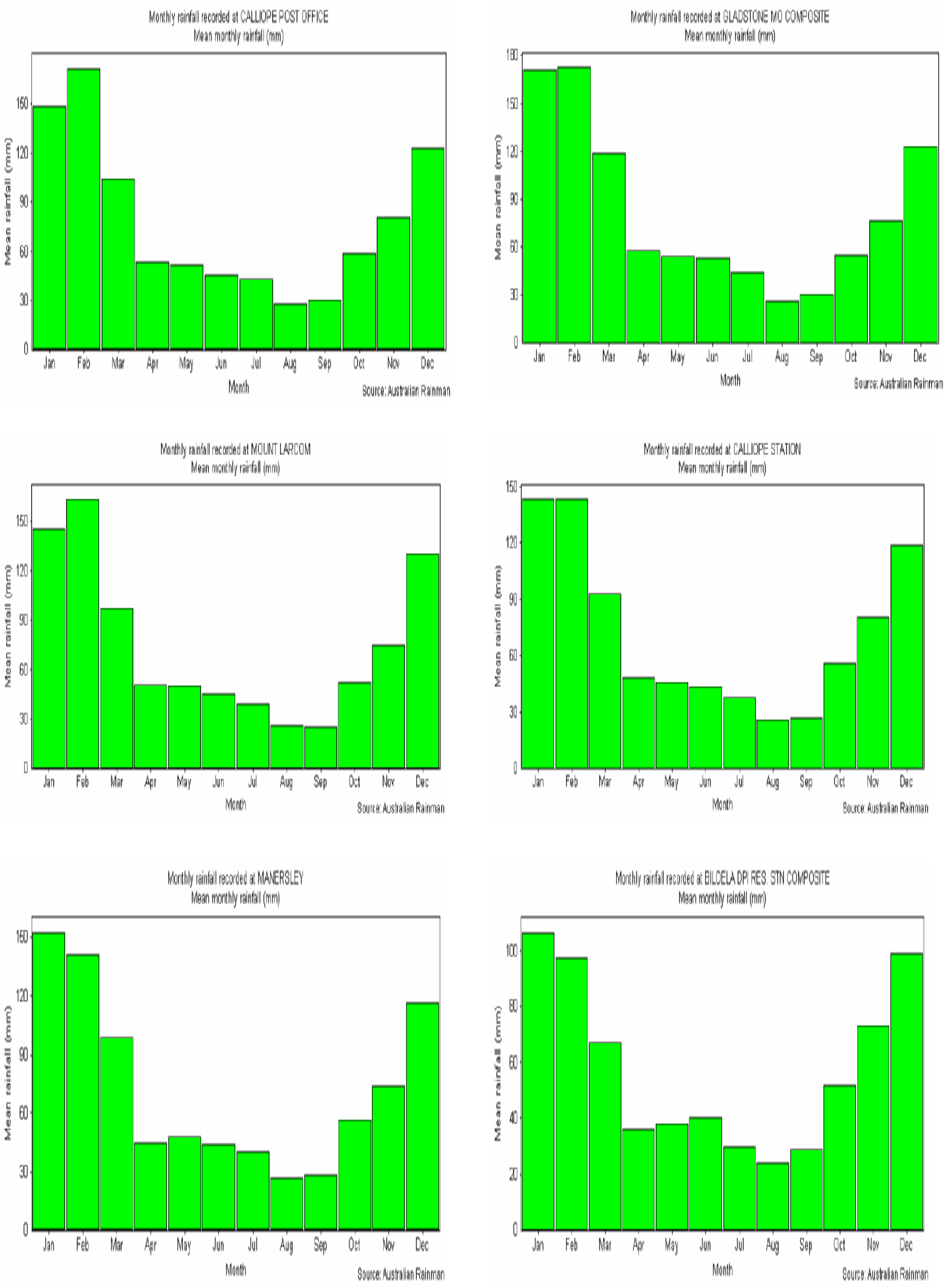
Calliope and Gladstone are situated in the lower reaches of the catchment; and Calliope Station and Manersley in mid-catchment. There are no stations in the upper western catchment although Mt Larcom is near the northern catchment boundary. Records for Biloela about 50km west of the catchment boundary are included due to the absence of records in the upper western catchment.

The information contained in **Figure 5** and **Table 1** shows:

The mean annual rainfalls at these locations show some reduction with distance from the coast i.e. 980mm at Gladstone, 936mm at Calliope, 900mm at Mount Larcom, 862mm at Calliope Station, 871mm at Manersley and 691mm at Biloela with the latter being west of the catchment divide;

The clear seasonal pattern with rainfall concentrated in the summer months with mean monthly rainfalls in the catchment in the range 116mm to 172mm; and

The significant variation between years with Calliope having a highest recorded annual rainfall of 2,317mm and a highest monthly fall of 686mm (January) compared to the January mean of 148 mm. The corresponding lowest recorded falls are 352mm annually, and zero in each month except January for which the lowest recorded was 8mm.



Monthly rainfall recorded at CALLIOPE POST OFFICE
Mean monthly rainfall (mm)
Source: Australian Rainman

Monthly rainfall recorded at GLADSTONE MO COMPOSITE
Mean monthly rainfall (mm)
Source: Australian Rainman

Monthly rainfall recorded at MOUNT LARCOM
Mean monthly rainfall (mm)
Source: Australian Rainman

Monthly rainfall recorded at CALLIOPE STATION
Mean monthly rainfall (mm)
Source: Australian Rainman

Monthly rainfall recorded at MANERSLEY
Mean monthly rainfall (mm)
Source: Australian Rainman

Monthly rainfall recorded at BILOELA DPI RES. STN COMPOSITE
Mean monthly rainfall (mm)
Source: Australian Rainman

Figure 5 **Mean Monthly Rainfalls at Selected Stations**

Source: Australian Rainman

Table 1 Monthly Rainfall Statistics at Selected Stations

Source: Australian Rainman

Monthly rainfall recorded at CALLIOPE POST OFFICE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	148	171	104	53	52	45	43	28	30	58	81	123	936
Median	113	112	70	37	36	29	21	20	19	40	63	89	890
Standard deviation	130	157	103	57	59	50	54	28	32	51	62	108	328
Highest on record	686	605	424	325	325	245	300	134	117	332	279	636	2,317
Lowest on record	8	0	0	0	0	0	0	0	0	0	0	0	352
Mean raindays	9	8	7	5	4	3	3	3	3	5	6	7	63
No. of years	86	86	85	85	85	85	85	85	85	85	85	85	85

Monthly rainfall recorded at GLADSTONE MO COMPOSITE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	171	172	118	58	54	53	44	26	30	55	76	123	980
Median	120	102	94	38	35	31	28	17	26	41	61	98	958
Standard deviation	145	174	110	60	56	63	59	27	28	51	59	103	323
Highest on record	682	769	586	312	316	343	378	142	152	277	345	668	2,212
Lowest on record	6	3	0	0	0	0	0	0	0	0	0	3	355
Mean raindays	11	11	10	6	6	5	5	4	4	6	7	9	84
No. of years	129	129	128	128	128	128	128	128	128	128	128	128	128

Monthly rainfall recorded at MOUNT LARCOM

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	145	163	97	51	50	45	39	26	25	52	75	130	900
Median	106	124	60	35	30	28	22	18	19	38	64	101	853
Standard deviation	125	144	92	56	54	47	53	29	26	45	56	124	298
Highest on record	617	667	406	386	254	244	335	133	120	186	244	851	2,046
Lowest on record	0	0	0	0	0	0	0	0	0	0	0	0	293
Mean raindays	9	9	7	5	5	4	4	3	3	5	6	8	68
No. of years	88	88	87	87	87	87	87	87	87	87	87	87	87

Table 1 (Contd) Monthly Rainfall Statistics at Selected Stations

Source: Australian Rainman

Monthly rainfall recorded at CALLIOPE STATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	143	143	93	48	46	43	38	26	27	56	80	119	862
Median	105	107	65	29	24	25	21	22	13	49	70	92	824
Standard deviation	123	125	88	60	52	49	47	25	30	43	62	112	265
Highest on record	592	601	416	416	275	294	267	109	162	195	293	718	1,803
Lowest on record	3	0	0	0	0	0	0	0	0	0	0	0	281
Mean raindays	9	7	6	4	4	3	3	3	3	5	6	7	60
No. of years	94	94	93	93	93	93	93	93	93	93	93	93	93

Monthly rainfall recorded at MANERSLEY

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	152	141	99	45	48	44	40	27	28	56	74	116	871
Median	119	99	75	31	35	26	25	20	21	45	71	92	845
Standard deviation	130	124	88	52	52	52	50	27	28	45	49	111	267
Highest on record	630	688	355	322	290	317	281	110	109	215	212	771	1,736
Lowest on record	2	0	0	0	0	0	0	0	0	0	0	3	326
Mean raindays	9	8	7	4	4	4	4	3	3	5	6	8	65
No. of years	92	92	91	91	91	91	91	91	91	91	91	91	91

Monthly rainfall recorded at BILOELA DPI RES. STN COMPOSITE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	106	97	67	36	38	40	30	24	29	52	73	99	691
Median	88	74	60	23	28	27	20	18	17	46	68	96	681
Standard deviation	68	75	54	38	39	42	31	24	32	38	45	61	175
Highest on record	370	331	295	238	196	267	158	116	172	165	240	299	1,157
Lowest on record	3	0	0	0	0	0	0	0	0	0	0	5	295
Mean raindays	9	8	6	4	4	4	4	4	3	6	6	8	66
No. of years	110	110	109	109	109	109	109	109	109	109	109	109	109

3. Flood History

Streamflow records in the Calliope River commenced in October 1938 when the gauging station at Castlehope was opened. The flood of record is **4,040m^3/s** on 12th February 1947. The second highest flood in this record is **3,860 m^3/s** on 20th December 1973. The most recent significant flood occurred on 6th February 2003 when a peak flow of **2,770 m^3/s** was recorded (5th highest on record). A summary of the 20 highest recorded flood flows at Castlehope (including those mentioned above) is given in **Table 2.**

There are shorter flow records (1968 -1988) for Calliope River at Mount Alma where the catchment area is only 165 km^2 compared to 1310 km^2 at Castlehope. A summary of the 10 highest recorded flood flows at Mount Alma is given in **Table 3.**

Table 2 **Calliope River at Castlehope**
Highest 20 Recorded Flood Flows

Source: Department of Natural Resources and Mines

Rank	Date	Peak Flow Cumecs
1	12/02/1947	4040
2	20/12/1973	3860
3	31/01/1978	2900
4	10/02/1942	2830
5	6/02/2003	2765
6	1/03/1947	2710
7	3/03/1949	2590
8	31/01/1971	2155
9	21/12/1956	2100
10	29/12/1990	1910
11	9/01/1996	1905
12	18/03/1940	1600
13	8/03/1955	1530
14	9/02/1956	1420
15	26/03/1963	1410
16	8/02/1981	1385
17	11/03/1977	1335
18	25/05/1955	1320
19	3/05/1983	1230
20	12/02/1954	1205

Table 3 Calliope River at Mount Alma
Highest 20 Recorded Flood Flows

Source: Department of Natural Resources and Mines

Rank	Date	Peak Flow Cumecs
1	20/12/1973	660
2	31/01/1978	600
3	10/03/1977	404
4	3/05/1983	313
5	31/01/1971	278
6	7/02/1981	211
7	26/02/1975	208
8	8/02/1971	197
9	29/01/1987	175
10	24/01/1979	175

Additional anecdotal information was obtained from the Bureau of Meteorology web site and is reproduced in **Table 4.** Very few of these reference the Calliope River specifically, so those referring to the general region have also been included.

Table 4 Notes on Historic Floods

Source: Bureau of Meteorology web site

1862 29th March to 1st April	Heavy rain at Gladstone. The **Calliope and Boyne Rivers** rose exceedingly high and flooded a large portion of the district. Several farmers compelled to leave their head stations and seek shelter as best they could. Great numbers of sheep swept away, and a man lost his life whilst attempting to swim across a creek.
1910 March:	On the 18th, a well-defined tropical storm was central in the neighbourhood of Townsville, and was causing further rain over the eastern districts of the central and southern divisions of the State, and the rain area again extended inland. Exceptionally heavy falls occurred in the central districts. For the 48 hours ending 9 a.m., 21st, Blackall recorded 494 points, Rolleston 405, Tambo 773, Rockhampton 851, and Gladstone 627. As a result of the heavy rain that fell over the central and southern portions of the State during the greater part of the first three weeks of the month, stations situated on or in the neighbourhood of almost every river or stream south from latitude 20 deg. and east from longitude 142 deg., reported floods. In many instances the flooding was serious and attained record heights. Heavy losses occurred in stock; railway traffic was suspended; and the mail service was entirely disorganized.
1913 13th to 17th January:	A tropical disturbance caused very heavy rain south from Townsville, especially heavy on and near coast between the Tropic and Wide Bay. Record flood occurred in Baffle Creek, near Rosedale.
1918	Disastrous and most severe flood on record at Mackay (associated

19th to 22nd January	with intense cyclone), where 24.70 inches rain fell in 24 hours. Twenty lives lost; enormous damage to property. All rivers between Townsville and Gladstone affected. Unprecedented floods in the Burdekin and Fitzroy Rivers. Highest flood on record at Rockhampton (31 ft. 11 in.) ; two or three lives lost. Man drowned at Townsville. Portion of Don River Bridge at Bowen washed away. High floods experienced in all tributaries of Fitzroy and Burdekin Rivers, especially the Dawson, Mackenzie, Comet and Nogoa Rivers.
1921 April	From 1st to 6th some heavy flooding occurred in rivers flowing into south-eastern and southern sections of the Gulf of Carpentaria. Between 6th and 8th most of the coastal rivers south from Gladstone flooded. Bundaberg, Maryborough, Gympie and other centres were temporarily submerged, but no very serious inundations were reported.
1933 July	Between 10th and 12th there was minor flooding in many localities in coastal districts from Bowen to Gladstone, over a greater part of the Central division and adjacent portions of the Warrego and Maranoa districts.
1937 February	On 12th there was flooding in the Rockhampton-Mt. Larcom-Mt. Morgan districts and between Emerald and Clermont. Local floods also occurred in isolated parts, chiefly Dirranbandi, Taroom and Collinsville districts (girl drowned in the latter).
1947 February	At the end of the month another flood rain depression was operating over the Port Curtis and Moreton districts.
1952 December	The **Calliope River** rose sharply after the 250mm rains of 23rd and 24th. Some stock were washed away.
1953 October	The heavy 125 to 275mm rains on the coastal strip between Bundaberg and Gladstone on 26th and 27th caused railway wash-outs south of Gladstone, and temporarily dislocated traffic.
1972 April	During the first week of the month heavy rains in south-east Queensland , associated with **Cyclone "Emily"** , caused moderate flooding in the **Mary** , **Calliope** and upper **Brisbane** rivers. Flooding also occurred in the **Kolan** and **Curtis Coast** streams.
1973 December	Heavy flood rains during the latter part of the month , resulting from **Cyclone "Una"**, caused major flooding and extensive traffic disabilities in coastal streams between Gladstone and Rockhampton. Moderate to major flooding occurred inland throughout the central and northern reaches of the **Fitzroy River** catchment and upper reaches of the **Burnett River**. Flooding also occurred during the month in some far Western and Peninsula rivers.

1983 March	Rainfall associated with **Cyclone "Elinor"** caused very minor flooding in the Northern Curtis and Southern Central coast districts at the beginning of the period.
1991 January	Continued heavy rainfalls caused by ex **Cyclone "Joy"** along coastal areas caused minor to moderate flooding to develop in all coastal streams between Cairns and Gladstone during January.
2003 February	Heavy rainfall and flash flooding in coastal streams between Gladstone and Rockhampton from 4th to 7th February.

Based on historic rainfalls, it is possible that a flood in February 1911 was greater than that in 1947. Daily rainfall records for this period are only available for Gladstone, the 4 day rainfall total for 1st to 4th February 1911 being 641mm compared to 361mm in February 1947. If this heavy rainfall has also occurred further inland, this could have given rise to a higher flood in the Calliope River but there is no other information available in this regard.

4. Hydrologic Model Calibration

4.1. Model Description

The hydrologic model used in this study is RORBWIN, the Windows version of the widely used RORB model which comprises PCRORB version 4.2 with WINDOWS interface (Laurenson & Mein 1997).

The RORB model represents the rainfall runoff process occurring in a catchment by:

- Conceptualising the catchment as a linked series of sub-catchments represented in the model by catchment storages and river reach storages;
- Applying rainfall excess (rainfall minus losses) to each sub-catchment (rainfalls are assumed to enter the sub-catchment at its centroid);
- Calculating the resulting runoff from each sub-catchment storage;
- Routing this through the catchment system, adding further flows at channel junctions; and
- Outputting flow hydrographs at points of interest in the catchment.

The model represents only the rapid flow or surface runoff component of streamflow, and the slow response or baseflow component has to be treated outside the model.

Setting up the model comprises:

- Determining the catchment boundary and subdividing the catchment into sub-catchments;
- Calculating the area contributing to each sub catchment;
- Placing model nodes at sub-catchment inflows and junctions;
- Placing reach storages between nodes; and
- Measuring the length of channel between adjacent nodes.

The catchment sub division was undertaken on the basis of the stream network shown on 1:250,000 digital mapping obtained from Geoscience Australia (Map Sheets Rockhampton and Monto). The catchment boundary and sub areas were determined on the basis of the contours provided by Calliope Shire Council and Gladstone City Council (in GIS form). The sub catchments were labelled alphabetically and the GIS used to determine the area of each sub-catchment.

Model storages were numbered numerically and reach lengths between model nodes measured using the GIS.

The model has 130 sub areas and 215 storages. The resulting layout of sub areas, nodes and reach storages is shown in **Figure 6.**

The RORB model has two main parameters known as k_c and m as well as two rainfall loss parameters.

The parameter k_c represents the model storage functions, whilst m is a non-linearity parameter.

Sub area storage is related to flow by the equation:

$$S = k_c Q^m$$

Where:

S is the volume of water in storage;
Q is outflow rate from the model storage;
$\mathbf{k_c}$ is an empirical coefficient representing the model storage parameter; and
m is a dimensionless exponent representing the non-linearity of catchment response. m varies in the range 0.6 to 1.0 with a value of 1 representing a linear response. Many studies adopt a default value of 0.8 for m.

In respect of reach storages, the model becomes:

$$S = k_r k_c Q^m$$

In which $\mathbf{k_r}$ is a dimensionless ratio called the relative time delay and is a function of reach length.

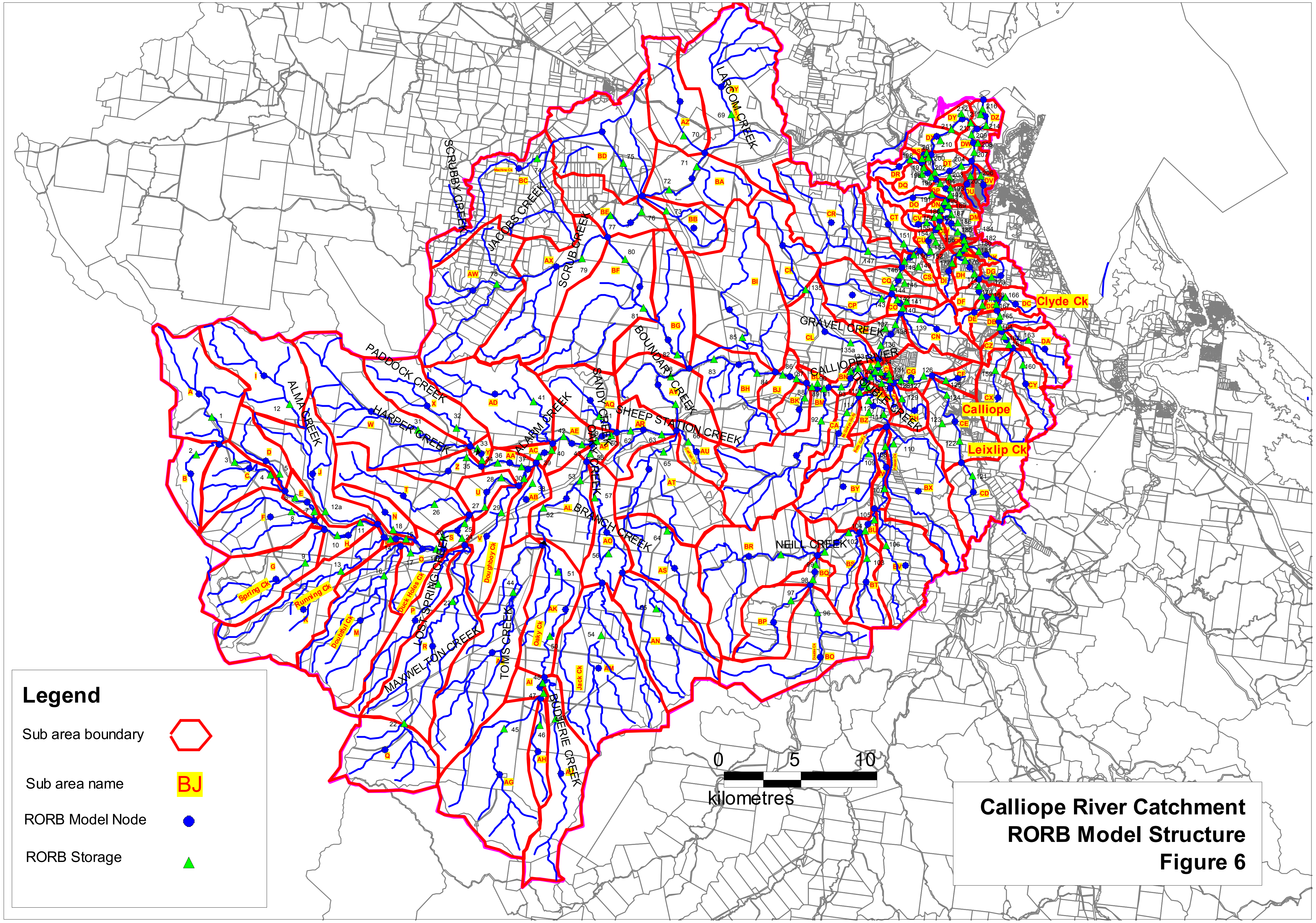
The two rainfall loss parameters are known as initial loss and continuing loss. Initial loss is that rainfall at the start of a storm which fills soil and groundwater storage and does not contribute to runoff. Continuing loss is the ongoing portion of total rainfall not producing surface runoff due to deep soil storage, plant interception or evaporation. The loss rates described above are storm and catchment specific.

4.2. Data Available for Model Calibration

Data available for model calibration comprised the following:

- Streamflow data in the form of discharge and water level measurements;
- Flood level records used in hydraulic model calibration but not directly in calibration of the hydrologic model;
- Daily rainfall records for a number of rainfall stations in or close to the catchment;

Rainfall intensity data at pluviograph stations within or near the catchment.



Calliope River Catchment
RORB Model Structure
Figure 6

a) Streamflow Data

The only streamflow recording station in the Calliope River catchment now operating is Station No 132001A Calliope River at Castlehope for which records exist for the period 1938 to present. The catchment area at this station is 1310 km^2. Streamflow records also exist for the period 1968 to 1988 only for Calliope River at Mount Alma (Station No 132002A) for which the catchment area is 165 km^2. The location of these stations is shown in **Figure 6**.

Daily records of streamflow for the station at Castlehope were obtained from DNRM together with sub daily flows (known as all points data) during selected storm periods.

b) Daily Rainfalls

Total storm rainfall (as obtained from daily rainfall stations for the duration of a storm) is used in the hydrologic model to estimate the spatial pattern of rainfall over the catchment during a storm event. The more stations for which data are available, the better can this spatial pattern and its variation across the catchment be defined.

There are a number of daily read rainfall stations within or close to the Calliope River catchment, the principal ones within the catchment and relevant to this study are at Calliope, Gladstone, Mount Larcom, Mount Alma and Calliope (Fig Tree). Records from other stations around the catchment periphery were also used where available for specific events. The location of rainfall stations whose records were used in respect of specific events are shown in **Section 4.3.**

Daily rainfall data for appropriate stations were obtained from the Bureau of Meteorology and rainfall totals for the relevant storm rainfalls extracted from these records.

b) Pluviograph Records

Pluviograph data is used in the hydrologic model to estimate the temporal pattern of rainfall over the catchment during a storm event. The more stations for which data are available, the better can this temporal pattern and its variation across the catchment be defined.

The Bureau of Meteorology operates a number of such stations as part of its automatic weather station (AWS) network, but most of these have been operating for a few years only. The only stations for which pluviograph data are available for the major storm events for which there are streamflow records are Gladstone and Biloela.

Pluviograph data were obtained from the Bureau of Meteorology for these stations for selected flood periods corresponding to significant flood events and were provided in the form of hourly rainfalls.

Whilst the Gladstone records are expected to be reasonably representative of the lower catchment, Biloela is about 50km west of the western catchment boundary and may not be representative of rainfall even in the upper reaches of the Calliope River catchment. This lack of pluviograph data from within the body of the catchment makes it difficult to obtain a robust model calibration.

Furthermore, in some flood events, pluviograph data is available at only one of the pluviographs, adding further uncertainty to the calibration process.

4.3. Model Calibration

4.3.1. Events Selected

Following inspection of the streamflow and flood level data, a number of flood events were provisionally selected for calibration of both the hydrologic and hydraulic models. Whilst more recent events are preferable in that they have more extensive data available, some earlier major events have also been included. The selected events are listed in **Table 5,** in reverse chronologic order, together with their peak flow at Castlehope to provide a guide as to their relative magnitude.

Table 5 Flood Events selected for Model Calibration

Date	Peak Flow Rate (m^3/s)	Pluviograph data available
February 2003	2,765	Gladstone only
December 1990	1,910	Gladstone Biloela
January 1978	2,900	Gladstone Biloela
December 1973/ January 1974	3,860	Gladstone only

The flood of February 1947 was not included in the calibration events as there were insufficient daily rainfall station data available to adequately represent the spatial distribution of rainfall across the catchment, and the only pluviograph data available was for Biloela. Taking both of these data inadequacies into account, this event was rejected from that used for model calibration and/or validation.

It was decided to use the three more recent events, ie those in 1978, 1990 and 2003 for model calibration and that of 1973 (the largest event for which adequate data existed for model validation. Model validation is discussed further in **Section 4.3.2**.

In all cases, it has been assumed that the streamflow records provided by DNRM are of acceptable accuracy.

4.3.2. Calibration and Validation Procedure

The calibration procedure comprised running the model with historic storm rainfall data, and varying the model parameters to obtain the best possible match between estimated flow hydrographs and observed flow hydrographs. By this means, the most suitable model parameter values are selected. As outlined above, calibration was undertaken using the 1978, 1990 and 2003 events.

The model validation procedure comprises running the model for one or more additional events, for which streamflow and rainfall data exist, but which were not used for model calibration, using the model parameters derived form the calibration process. If the modelled flows compare well with the recorded flows for the validation event(s), this provides confidence in use of the model for events other than those used in calibration. Conversely, poor replication of these events indicates that further model calibration is required. As indicated above, the December 1973 flood event was used to validate the calibrated model.

The remainder of this section outlines the calibration process in greater detail:

- Rainfall totals were estimated for each event for each sub area using the GIS to interpolate between recorded rainfall values and then selecting the rainfall at the centroid of each sub area as representative of that area. This process produces a more realistic rainfall variation across the catchment than the traditional approach of Thiessen weighting.

- The temporal pattern for each sub area is given by allocating one of the pluviographs records to that sub-catchment.

- The model is then run with the rainfall totals and temporal patterns and rainfall loss rates and model parameters varied until the estimated streamflow hydrograph fits well with the recorded hydrograph in terms of peak flow, time to peak and other indicators of hydrograph shape.

The rainfall losses will vary between individual storm events as a result of antecedent catchment wetness, but, ideally, the model parameters should be the same across all events.

However, this rarely occurs due to a combination of model error and data error. Model error is the systemic error introduced by the model not fully representing catchment behaviour in its translation of incident rainfall into runoff. This includes the need to separate the rapid runoff response from the slow runoff response (baseflow), as the hydrologic model does not deal with the latter flow component.

The principal data error is usually the inability to adequately represent the temporal and spatial variability of rainfall across the catchment which results from rainfall being sampled and measured at only a few points across a broad area. This type of error is expected to be substantial in this case due to the lack of pluviograph data within the catchment.

There are also errors in the streamflow data due to the inexact nature of the process in which water levels are continuously monitored and a rating curve applied to convert water level to discharge i.e. discharge is not itself continuously monitored.

The following paragraphs outline the data available for each of the selected flood events, whilst the next section discusses the variation in model parameters resulting from the various events.

In this study, the model parameter $\boldsymbol{m}$ has not been fixed at its default value of 0.8, but has been allowed to vary between 0.6 and 1. This results in pairs of model parameters $\boldsymbol{k_c}$ and $\boldsymbol{m}$, (as these parameters are interdependent) which all adequately replicate the peak flow but may not all adequately replicate other hydrograph characteristics. The value of adopting this approach is discussed in **Section 4.4**.

4.3.3. Event Calibration

a) February 2003 Flood Event

The streamflow hydrograph as recorded at Castlehope for this event is given in **Figure 7.**

In this event pluviograph records were available for Gladstone only. Hourly rainfalls at Gladstone for this event are shown in **Figure 8** and cumulative rainfall in **Figure 9**.

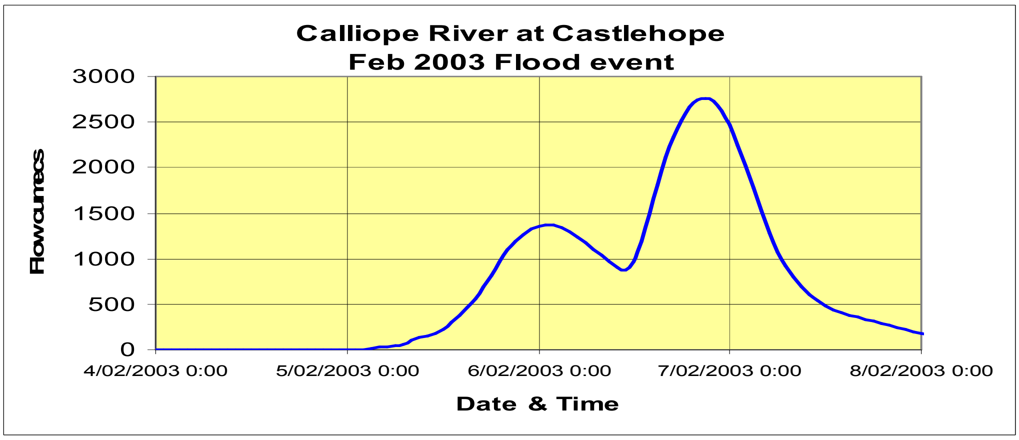


Figure 7 **Streamflow Hydrograph Calliope River at Castlehope 4th – 8th February 2003**

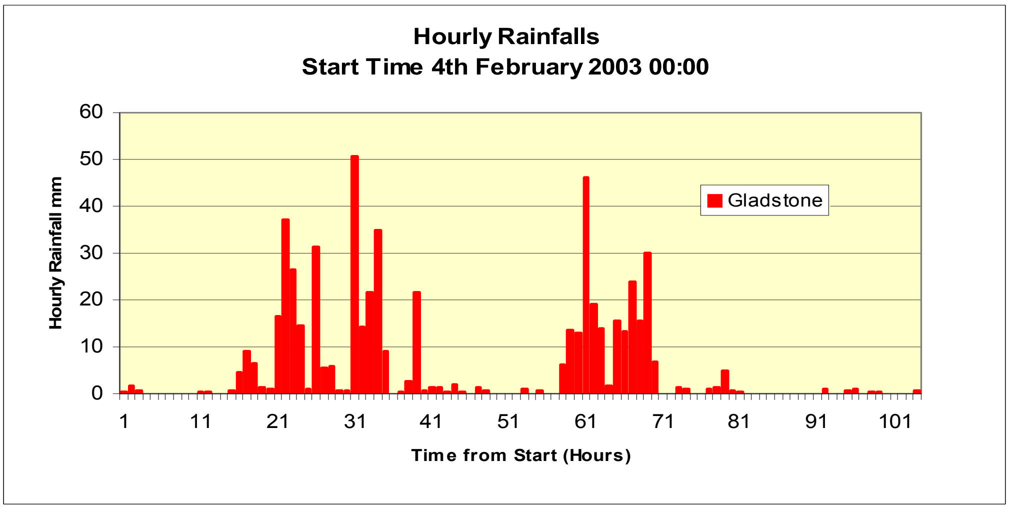


Figure 8 **Hourly Rainfalls at Gladstone from 4th -7th February 2003**

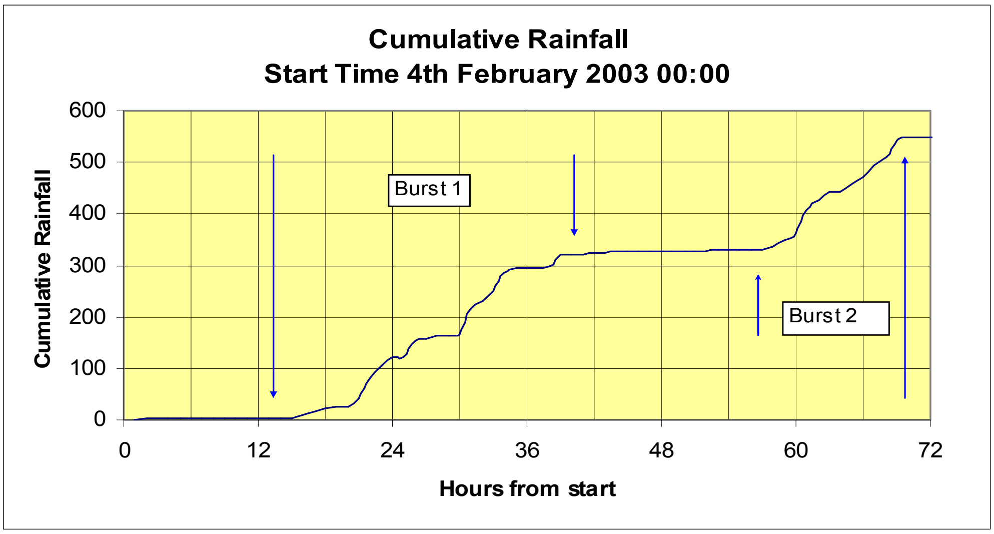


Figure 9 Cumulative Rainfalls at Gladstone from 4th -7th February 2003

In the Gladstone rainfall record there are two rainfall bursts, the first of which peaked at 4 am on 5th February (peak intensity 50.5 mm/hr) and the second at 8 am on 6th February (peak intensity 46 mm/hr). The streamflow hydrograph has two peaks corresponding to two rainfall bursts, at 1 am and 9 pm on 6th February, so the lag between peak rainfall and peak runoff, on this basis, was 21 hours and 13 hours respectively. This could be reasonable, as the response time could be less with the catchment already wet and streamflow already occurring, or the relative timing of the rainfall could have varied significantly across the catchment.

Figure 10 shows the recorded rainfall totals for this event together with the fitted rainfall variation as shown by thematic mapping. Rainfalls varied from over 500mm at Gladstone and in the Calliope River headwaters to about 400mm at Mount Larcom.

The baseflow component of the streamflow hydrograph was very small, so no baseflow separation was applied to this event.

Figure 11 shows observed and estimated hydrographs at Castlehope for this event together with estimated hydrographs at the river mouth for the RORB model with ***m*** = 0.8. It can be seen from **Figure 11** that the computed hydrograph is double peaked as is the observed hydrograph and that both peaks replicate the recorded peaks well. There are some timing errors, with the first peak being about 3 hours early and the second, higher peak about 3 hours late. These timing errors are not surprising given that the temporal rainfall pattern is only available at Gladstone, and are considered to be secondary.

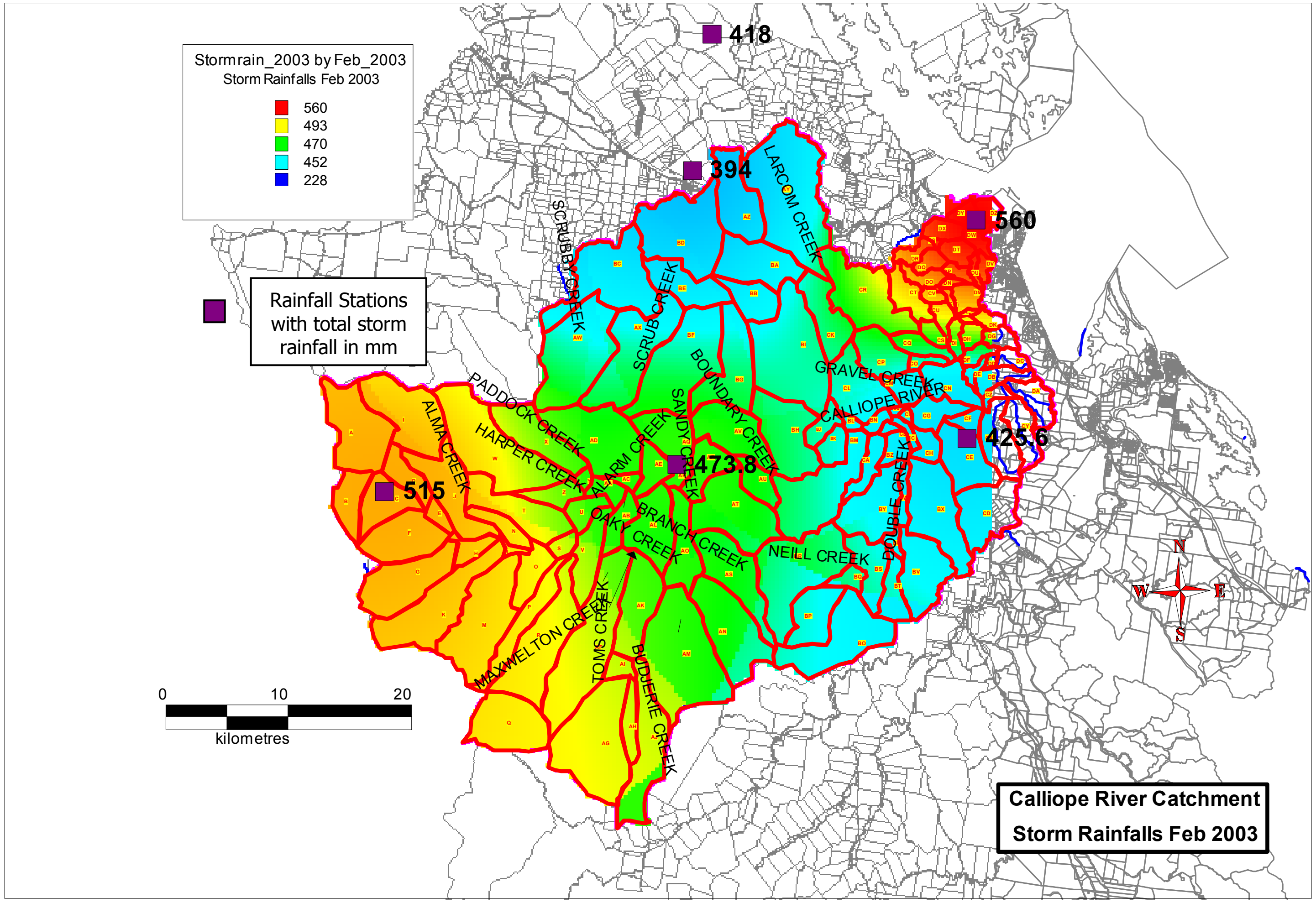


Figure 10 Catchment Rainfall Totals –4th to 7th February 2003

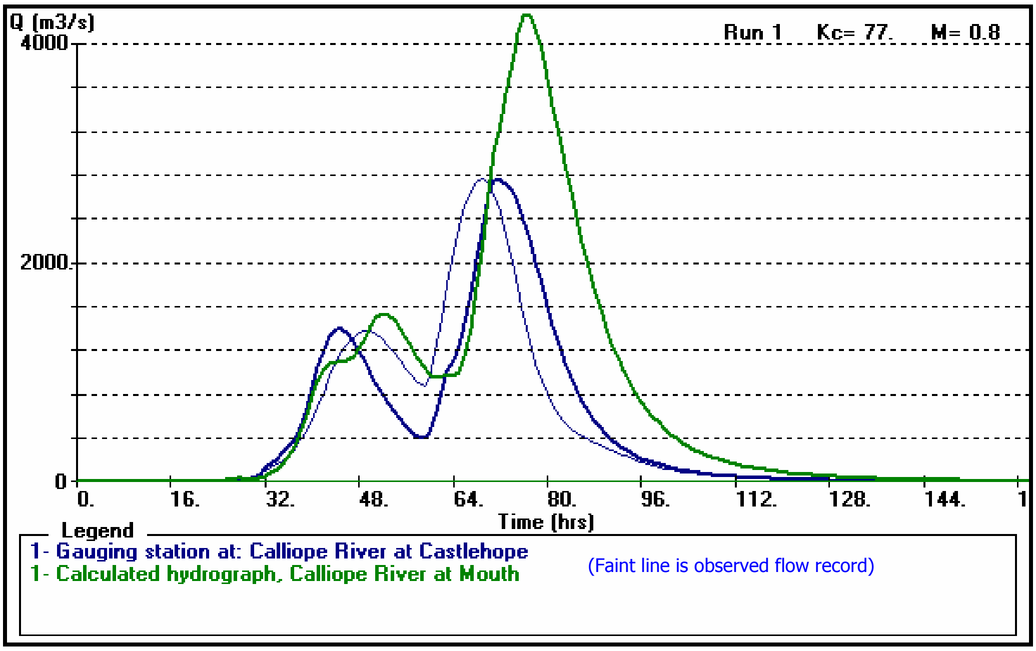


Figure 11 **Observed and Estimated Hydrographs – February 2003**

The estimated peak flow at the river mouth is 4,270m^3/s compared to 2,765 m^3/s at Castlehope.

b) December 1990 Flood Event

The streamflow hydrograph as recorded at Castlehope for the December 1990 flood event is given in **Figure 12.** As with the other events, no baseflow separation was warranted.

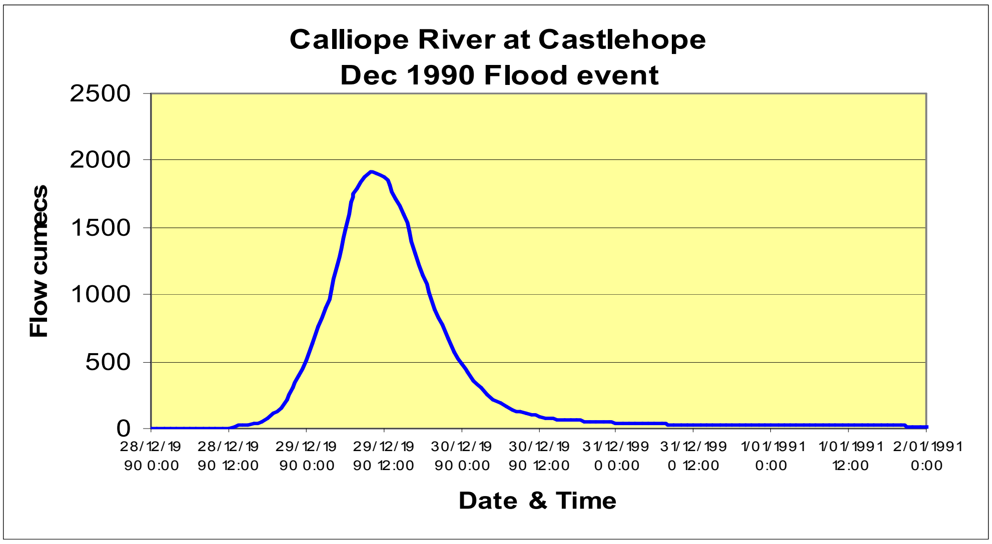


Figure 12 **Streamflow Hydrograph Calliope River at Castlehope 29th December 1990 – 2nd January 1991**

Hourly rainfalls for this event were available for both Gladstone and Biloela and are shown in **Figure 13**. The corresponding cumulative rainfalls are shown in **Figure 14.**

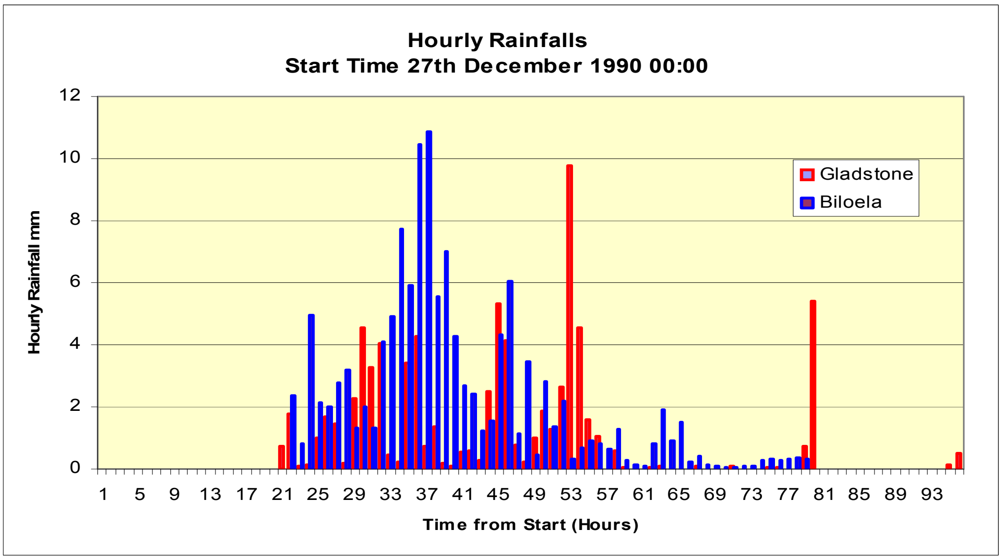


Figure 13 Hourly Rainfalls for December 1990 Flood Event

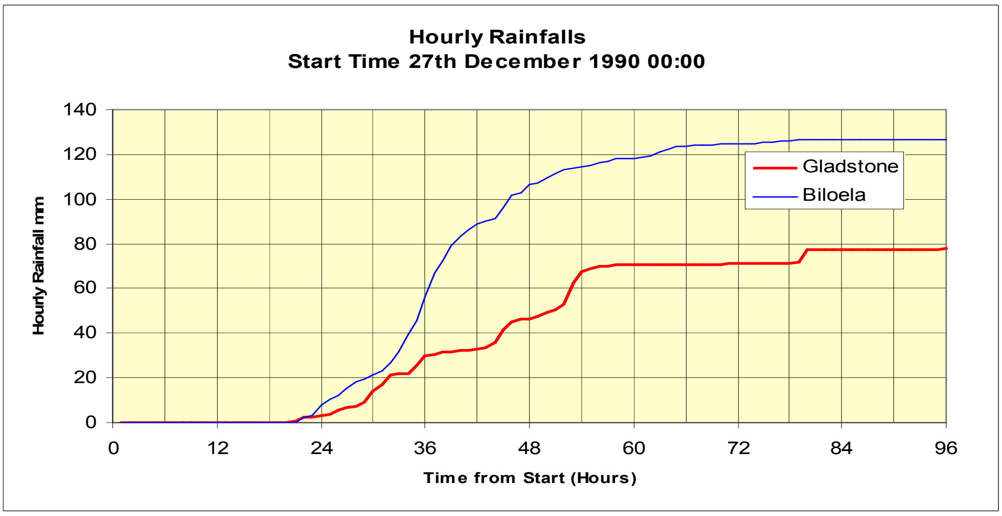


Figure 14 Cumulative Rainfalls for December 1990 Flood Event

The rainfalls for this event show a single burst of about 48 hours duration, which is consistent with the streamflow hydrograph being single peaked.

The catchment rainfall for this event and its variation over the catchment is shown in **Figure 15**. This varied from 400mm in the centre of the catchment to less than 80mm at Gladstone, with the highest rainfalls around and south of Mount Alma.

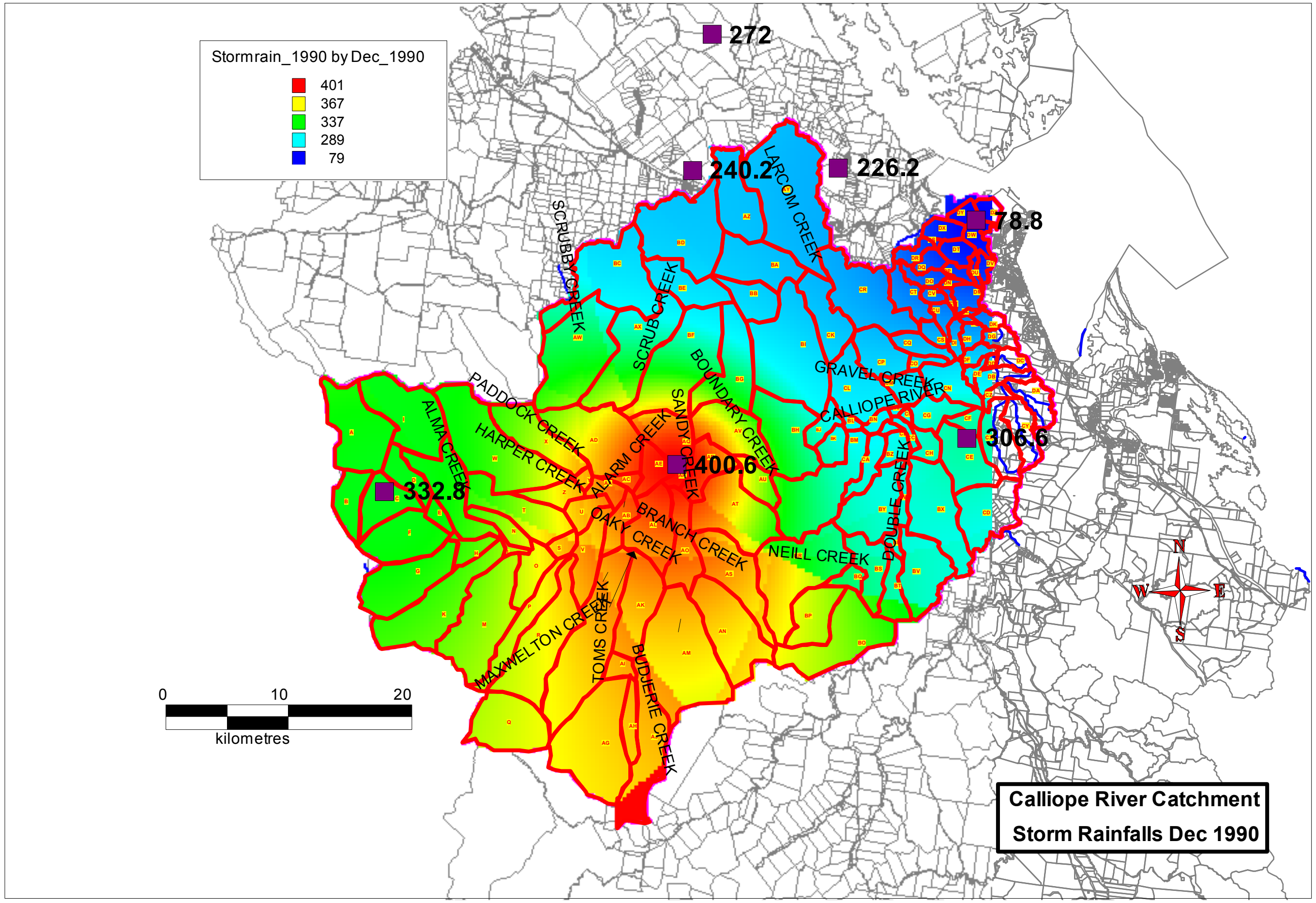


Figure 15 Catchment Rainfalls 27th – 30th December 1990

Figure 16 shows observed and estimated hydrographs at Castlehope for this event together with that at the mouth of the Calliope River for the RORB model with m = 0.8.

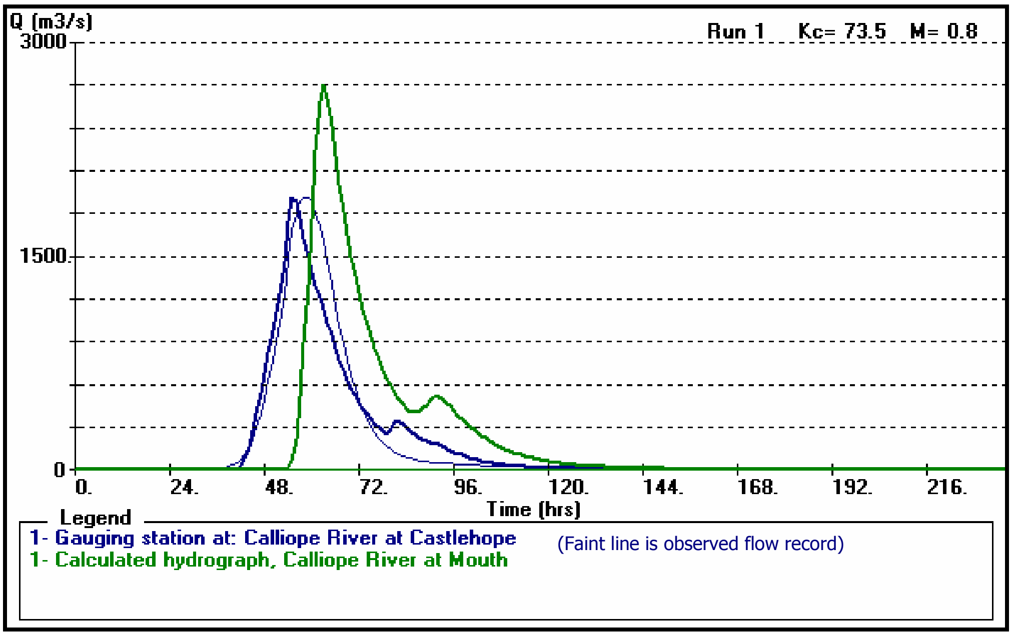


Figure 16 Observed and Estimated Hydrographs – December 1990

In this event, the peak flow is well replicated, but occurs 3 hours earlier than the recorded peak. This is due to the necessity to assign the temporal pattern for either Biloela or Gladstone raingauges to individual sub areas, whereas there would in reality be a gradual variation in timing. It can be seen from **Figures 13** and **14** that peak rainfall intensities occurred earlier at Gladstone than at Biloela. The estimated peak flow at the river mouth was 2,700m^3/s compared to 1,910m^3/s at Castlehope.

c) January/February 1978 Flood Event

The streamflow hydrograph as recorded at Castlehope for the January/February 1978 flood event is given in **Figure 17.** As with the other events, no baseflow separation was warranted. As can be seen from **Figure 17**, the streamflow has two peaks.

Hourly rainfalls at Gladstone and Biloela for this event are shown in **Figure 18** with cumulative rainfalls in **Figure 19**. The rainfall at Gladstone was in 3 bursts for this event with 2 bursts at Biloela. In RORB, rainfall bursts have to be concurrent so the rainfall at both pluviographs was split into 3 bursts for input to the model.

The catchment rainfall distribution in this event is shown in **Figure 20** from which it can be seen that rainfalls were much higher in the upper catchment than closer to the coast varying from about 530mm in the headwaters to about 240mm at Gladstone.

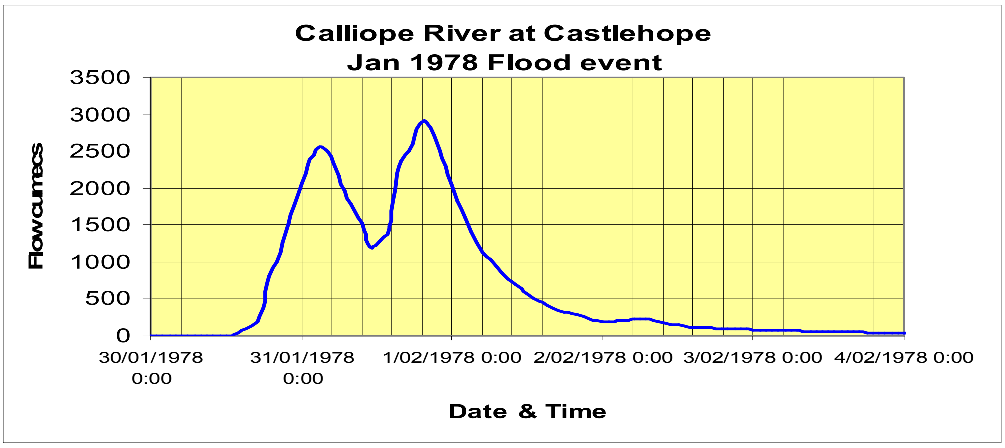


Figure 17 Streamflow Hydrograph Calliope River at Castlehope 30th January – 4th February 1978

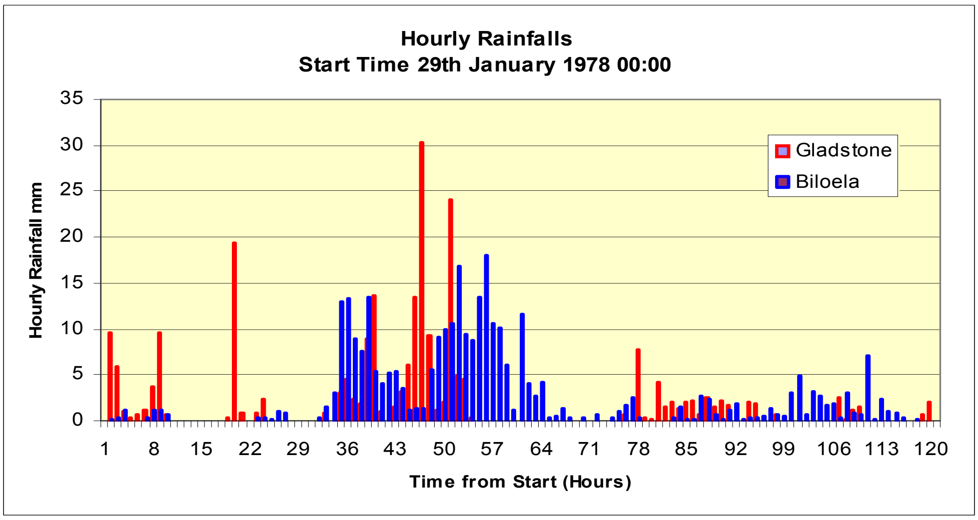


Figure 18 Hourly Rainfalls for January/February 1978 Flood

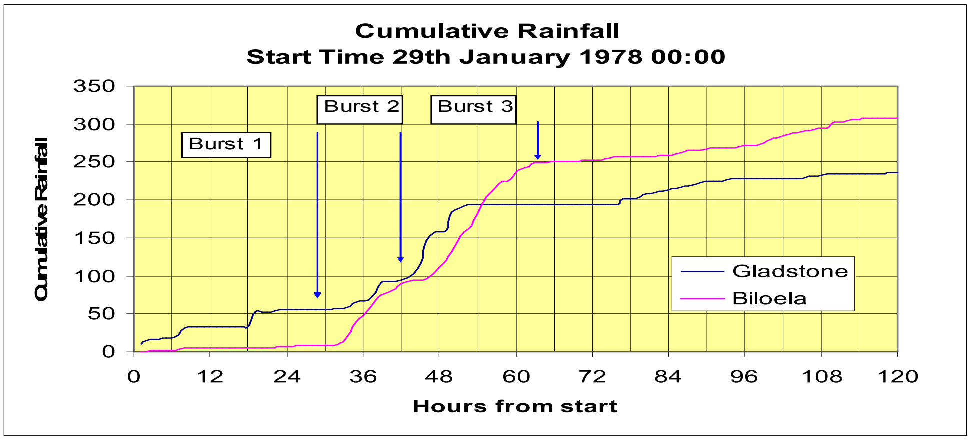


Figure 19 Cumulative Rainfalls for January/February 1978 Flood

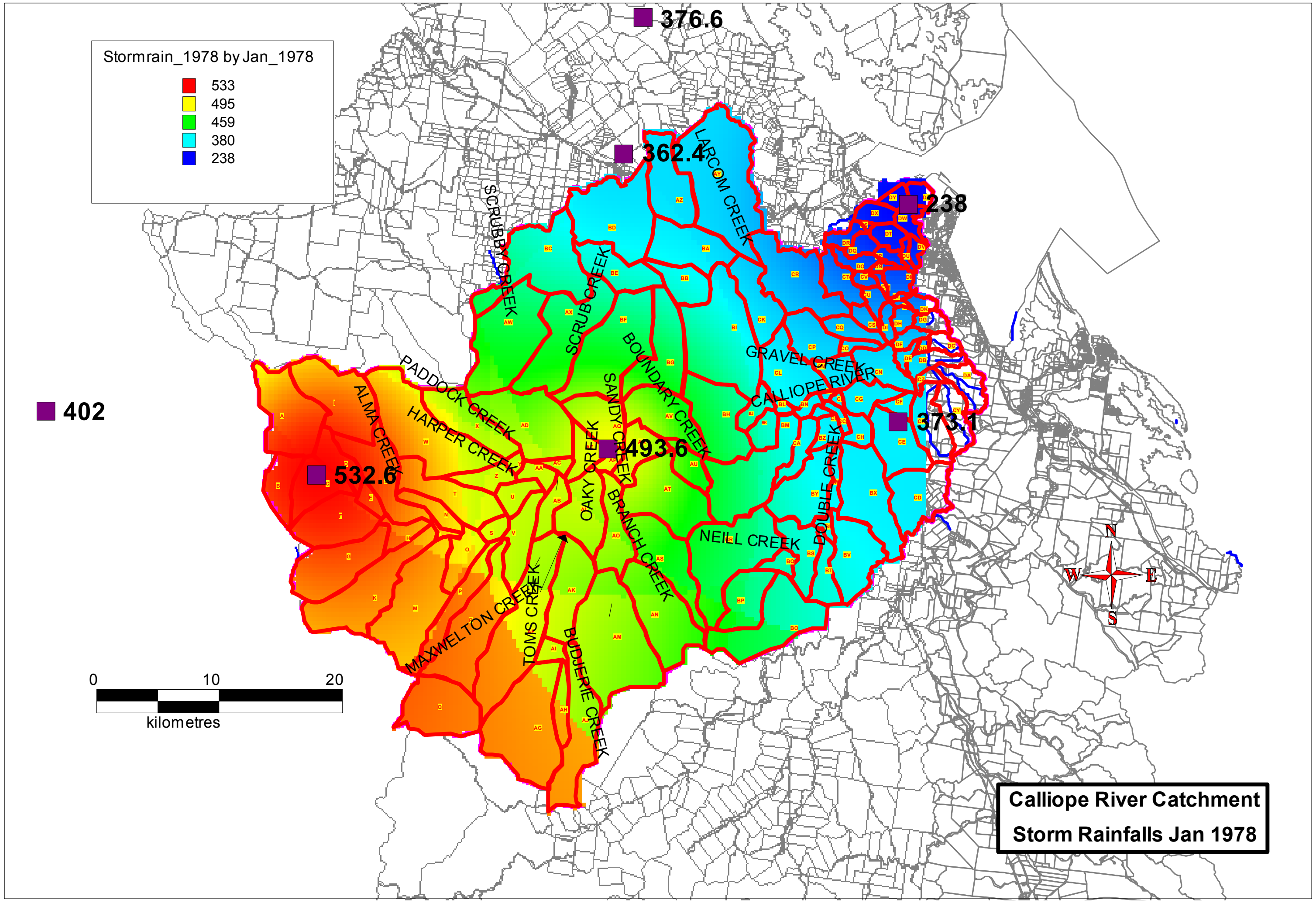


Figure 20 Catchment Rainfalls 29th January to 2nd February 1978

Figure 21 shows observed and estimated hydrographs at Castlehope for this event together with estimated hydrographs at the mouth of Calliope River for the RORB model with m = 0.8.

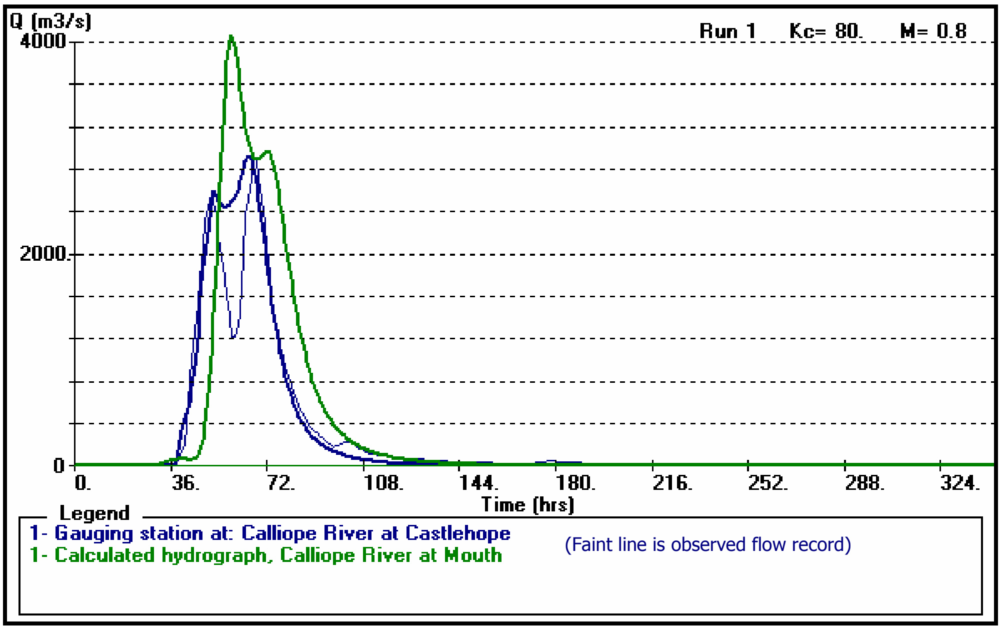


Figure 21 **Observed and Estimated Hydrographs – January/February 1978**

Whilst both peaks of the hydrograph are well replicated in magnitude, the flow reduction between peaks is poorly modelled. The timing of the first peak is accurate but the second peak is 3 hours early. Again, these discrepancies are secondary, and the model fit is regarded as acceptable. The estimated peak flow at the river mouth was 4,060m^3/s compared to 2,900m^3/s at Castlehope.

4.4. Model Parameters

As mentioned in **Section 4.3.2**, in this study the model parameter ***m*** has not been fixed at its default value of 0.8, but has been allowed to vary between 0.6 and 1 and corresponding values of k_c to best fit the peak flow determined. This procedure enables the parameter interaction curve which is a graph of k_c versus ***m***, to be prepared. The resulting curve is given in **Figure 22**.

Ideally, the curve for individual events all cross at the same point giving a unique pair of k_c and ***m*** values which is valid for all of the events tested.

However, more typically this does not occur due to various data errors and in particular, the difficulty of adequately representing both spatial and temporal rainfall variation across the catchment.

Figure 22 shows that this intersection occurs between ***m*** values of 0.85 and 0.9. Further modelling was undertaken to more fully define the parameter interaction curve between ***m*** values of 0.8 and 0.9 and this is shown in **Figure 23.** The detailed results from the model calibration process are given in **Appendix A.**

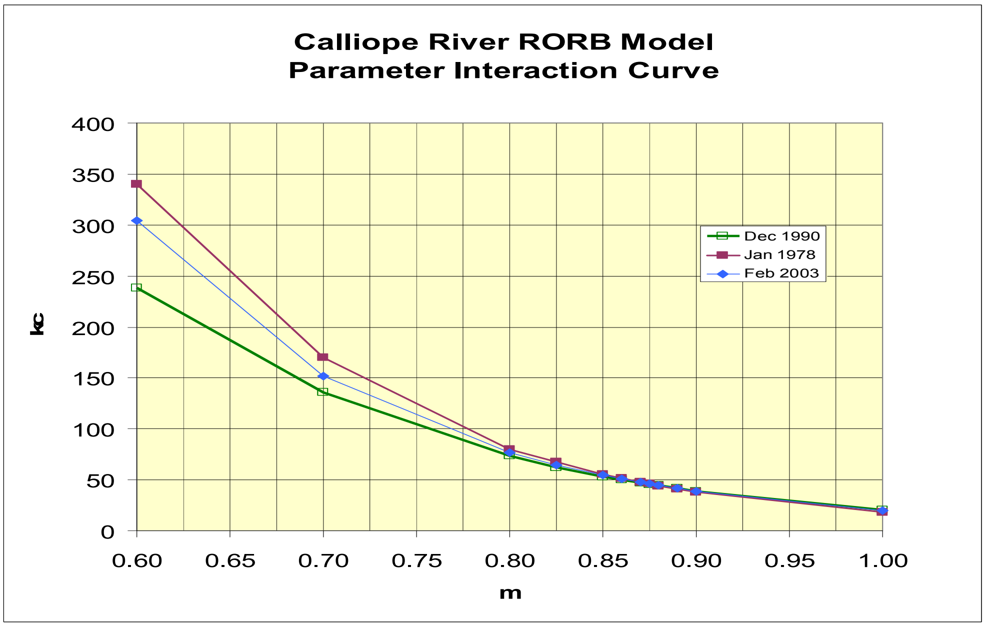


Figure 22 **RORB Model – Overall Parameter Interaction Curves**

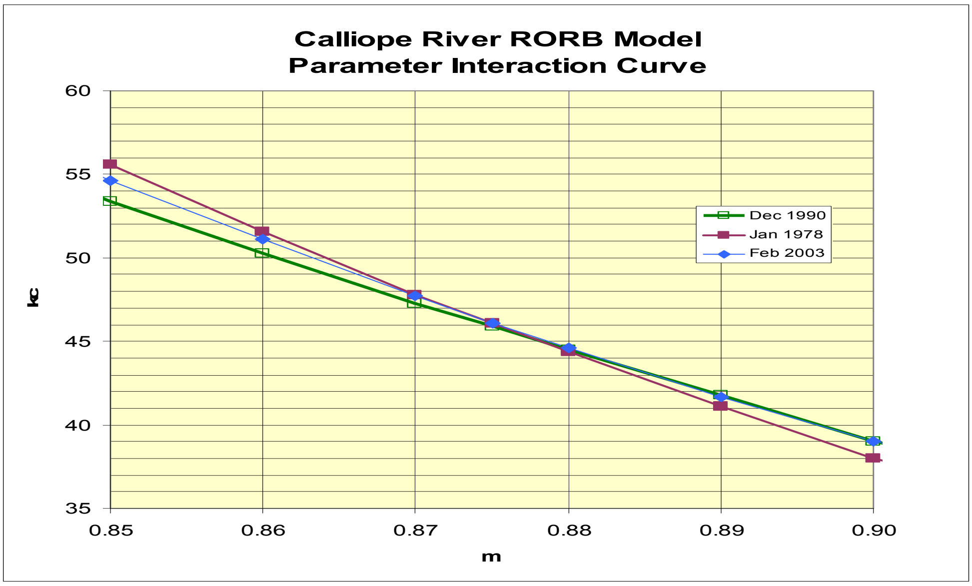


Figure 23 **RORB Model – Detail Parameter Interaction Curve**
m range 0.8 to 0.9

It can be seen from **Figure 23** that the intersection point occurs where ***m* = 0.88** and **k_c = 44.5**.

This pair of model parameters should be optimal for all flood events.

This ***m*** value is greater than the default value of 0.8 which is commonly adopted, but should be more reliable in this instance as it has been derived from three events fitted to catchment data.

In addition, the modelling had shown that using ***m*** values of 0.8 to 0.9 gave improved hydrograph shape compared to that obtained using smaller m values.

Given the above, the model parameter values selected for the estimation of design floods are:

k_c = 44.5
and
m = 0.88

At the design flood estimation stage, the sensitivity of the estimated flows to the parameter selection will be tested.

4.5. Model Validation

Validation of the model was undertaken using the catchment data for the December 1973 flood, which is the second largest recorded flood, and the largest for which there is adequate rainfall data.

The streamflow hydrograph as recorded at Castlehope for the December 1973 flood event is given in **Figure 24.** As with the other events, no baseflow separation was warranted.

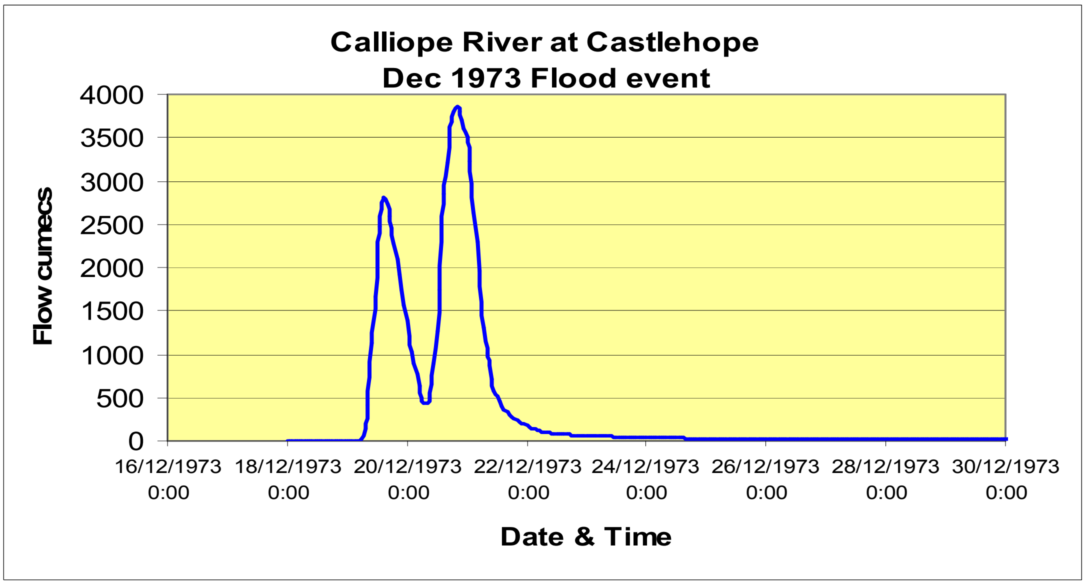


Figure 24 **Streamflow Hydrograph Calliope River at Castlehope 16th – 30th December 1973**

The only pluviograph record in the region for this event was at Gladstone, so this had to be assumed to be representative of the temporal pattern on the catchment. Hourly rainfalls for this event are shown in **Figure 25** and cumulative rainfalls in **Figure 26.**

There are two distinct rainfall bursts and also two peaks to the streamflow hydrograph so the hydrologic model was run with two rainfall bursts.

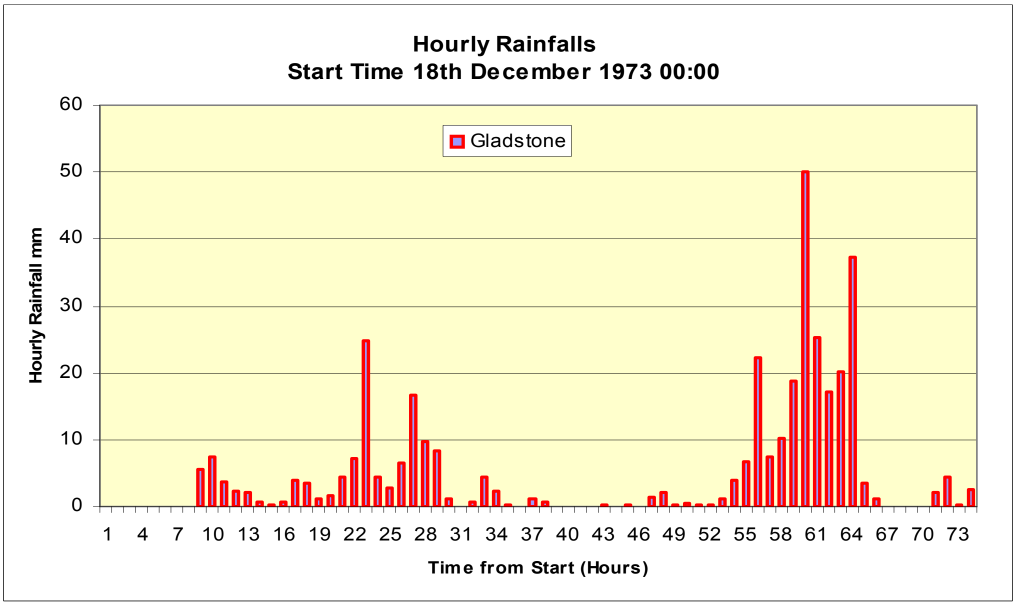


Figure 25 Hourly Rainfalls from 18th December 1973

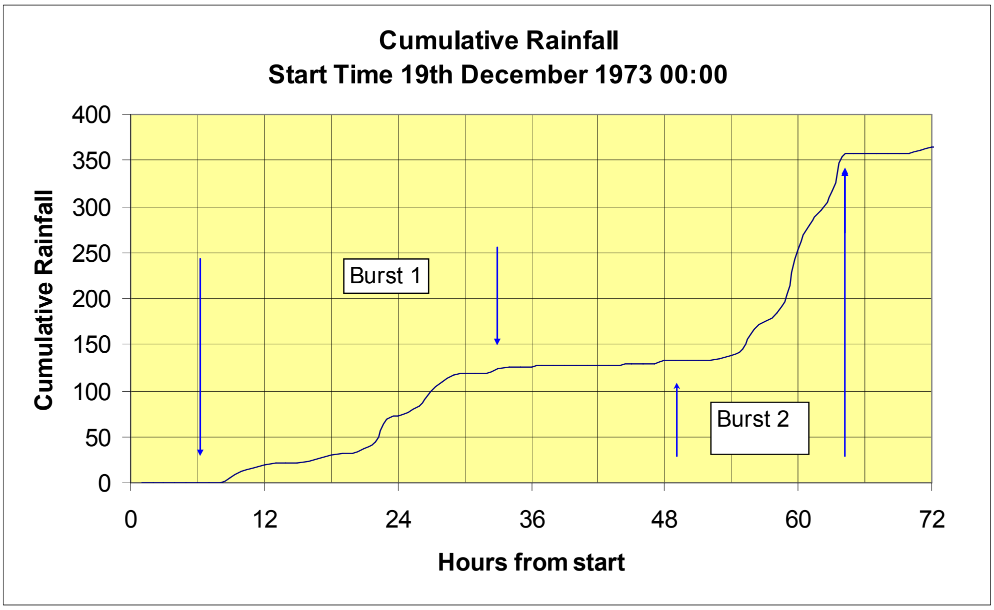


Figure 26 Cumulative Rainfalls for Gladstone from 18th December 1973

The catchment rainfall distribution in this event is shown in **Figure 27** from which it can be seen that 4 day rainfalls varied from nearly 650mm in the mid and upper catchment, to over 500mm at Calliope and Mount Larcom, to 370mm at Gladstone.

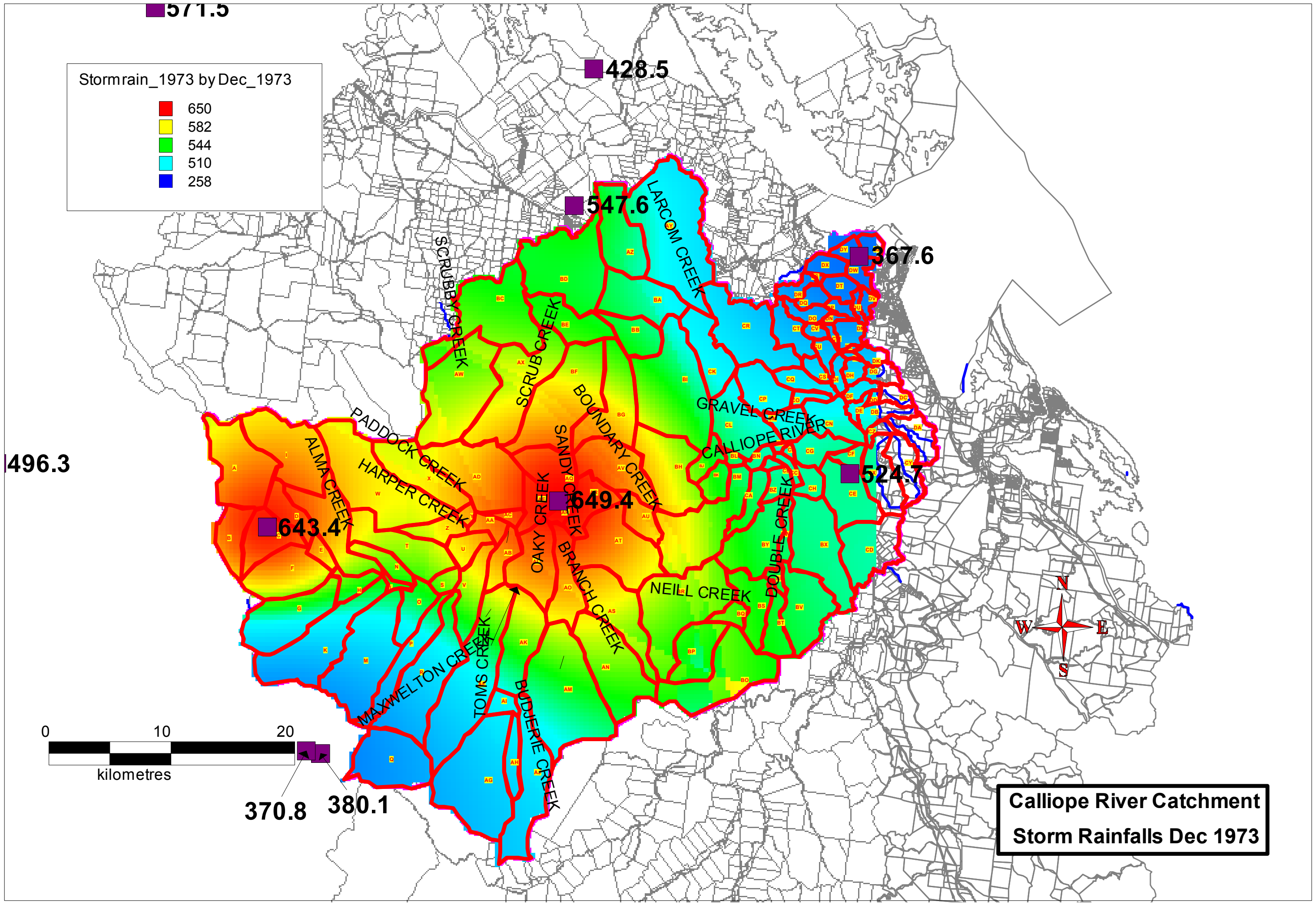


Figure 27 Catchment Rainfalls 18th – 21st December 1973

The estimated and observed flow hydrographs for this event using the selected ***m*** and ***k_c*** values are given in **Figure 28.**

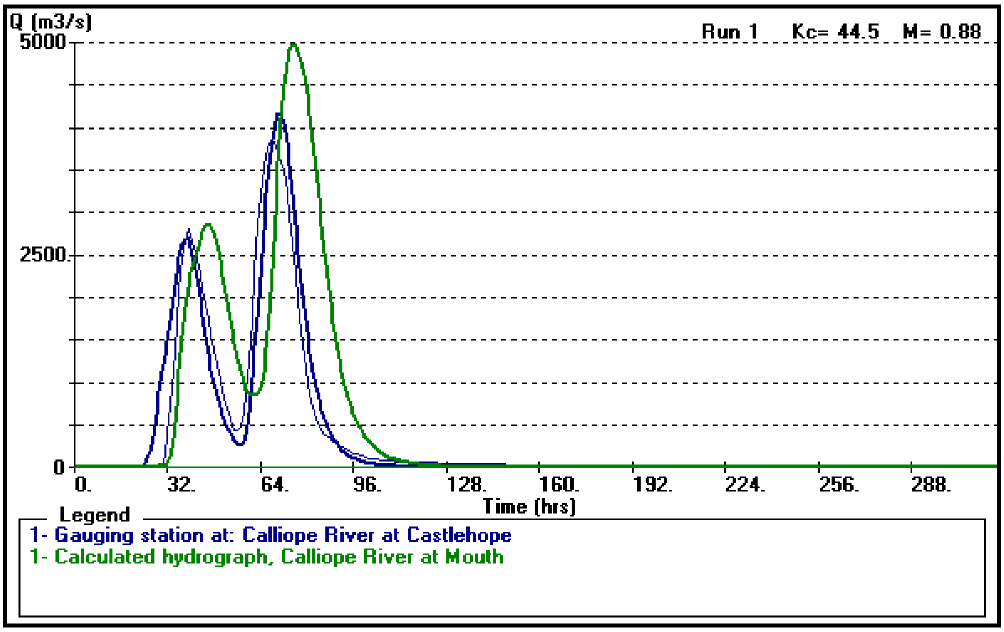


Figure 28 Observed and Estimated Flow Hydrographs – December 1973 Flood

The peak estimated flow at Castlehope was 4,170m^3/s compared to the recorded flow of 3,865m^3/s, an overestimate of 8%. This overestimation occurred only on the second peak, with the first peak being well modelled. Also the timing of the first peak was accurate, with the second peak only 2 hours late. As there was only one set of pluviograph data for this event, this is very acceptable. The estimated peak flow at the river mouth in this event was 5,000m^3/s.

When **m = 1**, the catchment response is linear, that twice the peak rainfall excess will result in twice the peak flow. When **m** is less than **1**, the response in non-linear and the flow increase for a given rainfall increase is higher than under linear conditions. One argument regarding using an **m** value of more than 0.8, is that the non-linearity may be underestimated and peak flows may be under-estimated for the more extreme events. The overestimation found in the validation run is actually encouraging in this case, as it shows that extrapolation beyond the range of calibration floods is not underestimating flows.

Given the uncertainties in flood modelling, it is prudent to retain some conservatism in design flood estimates.

Given the above, we believe this validation result to be acceptable and to indicate that the RORB model with these parameters can be used with confidence to estimate design flows.

4.6 Flow Hydrographs for Hydraulic Model

These fitted RORB models were then rerun to produce the flow hydrographs required for the calibration of the hydraulic model. Key points at which these hydrographs were produced and the peak flows for each of the calibration runs are given in **Table 6**. Further details of the hydrographs to be used in the hydraulic model calibration are given in **Appendix A**.

The consistency of the downstream hydrographs between the hydrologic and hydraulic models will be checked subsequent to the calibration of the latter.

Table 6 **RORB Calibration Runs**
Summary of Peak Flows at Key Locations

Location	RORB Sub	February 2003	December 1990	January 1978	December 1973
Calliope River at Castlehope	BJ	2772	1910	2894	3864
Double Ck u/s Calliope R	CB	887	522	829	1206
Leixlip Ck at hydraulic model boundary	CD	193	144	145	200
Gravel Creek	CL	172	65	169	242
Vulcan Ck	CN	97	62	74	113
Clyde Ck at hydraulic model boundary	DD	299	178	214	347
Calliope River at Mouth	DZ	4080	2645	4090	4980

5. Hydraulic Model Description and Calibration

5.1. Model Area

As outlined in **Section 1.3** hereof, the hydraulic modelling is limited to the reach of the Calliope River from the gauging station at Castlehope (AMTD 32.8km) to its discharge into the ocean at Gladstone, together with the Anabranch and nominated reaches of Leixlip Creek and Clyde Creek.

Figure 29 shows the approximate extent of the hydraulic model.

The main stream length modelled (excluding overbank flow areas) is about 60 km comprising 36.5 km along the Calliope River, 4.8 km along the Anabranch, 8.7 km along Clyde Creek and 9.3 km along Leixlip Creek. In addition the downstream reaches of Deep Creek and Double Creek were modelled in order to give flood levels at major road crossings, and a number of flood breakout paths were added. In all the flowpath length modelled was over 80 km.

5.2. Outline of the MIKE 11 Model

The hydraulic model used in this study is **MIKE 11** which is a "state of the art" numerical model based on one-dimensional unsteady flow conditions in open channels. **MIKE 11** was developed by the Danish Hydraulics Institute (DHI) and is widely used in Australia and many other countries for the modelling of flood behaviour in natural river systems.

The one-dimensional basis of the numerical solution scheme relates to the flow being in essentially one direction, that is, along the main axis of the watercourse in predetermined flow paths. It is possible to model several linked flow paths, and in this way flood channels and breakouts can be modelled to form a quasi two-dimensional flow network.

The model can also include floodplain structures such as bridges and culverts, and hydraulic structures such as weirs and gates.

The numerical scheme used to solve the differential equations of flow uses an implicit finite difference scheme which solves the complete equations of flow based on the conservation of mass and momentum, known as the Saint Venant equations (DHI).

The model is constructed by setting up its geometry, flows, boundary conditions and hydraulic roughness.

The model is then calibrated against historically recorded flood data to refine its structure and parameters to replicate historic flood behaviour as closely and possible.

Once the model has been satisfactorily calibrated, it can be used in conjunction with estimates of design flows in the river system to predict corresponding water levels throughout the modelled system.

The application of this model to the Calliope River system is described in the following paragraphs.

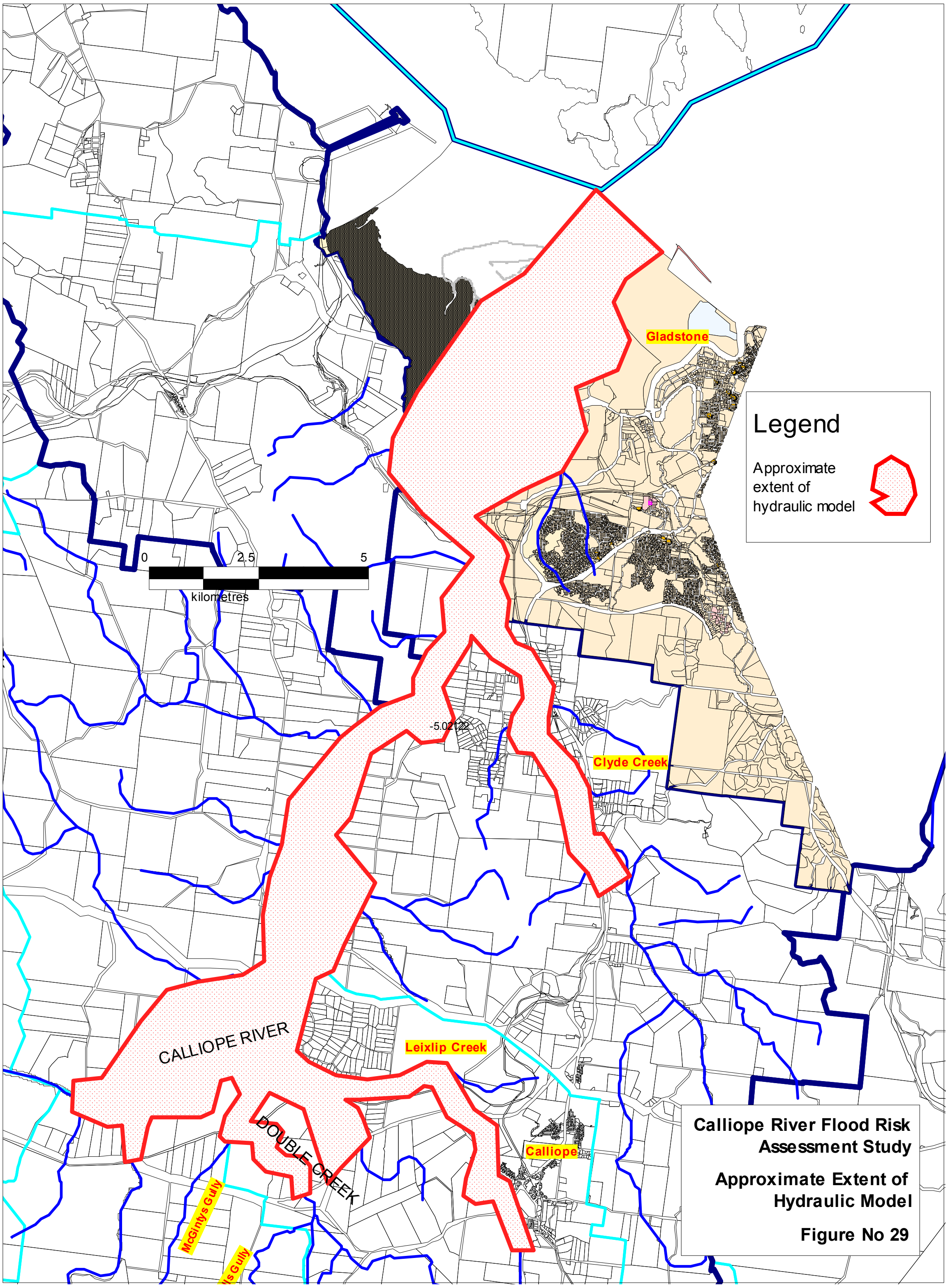


Figure 29 Extent of Calliope River Hydraulic Model

5.3. Calliope River Model

In **MIKE 11** the geometry of the river system and its floodplain is defined by first defining the relevant flow paths and then a number of cross sections along each flow path, together with that of any floodplain structures such as roads, bridges and culverts.

Cross section information can be obtained by ground survey or from topographic maps where these are of sufficient precision and reliability. In this study, new survey was undertaken as outlined in Section **5.3.1**. over that part of the study area within Calliope Shire for which a digital elevation model (DEM) was not available. Gladstone City Council provided a DEM for that part of the study area within its area.

5.3.1. Survey

There were two components of the survey, namely: aerial survey to produce the DEM and digital orthoimagery, and a hydrographic survey of the rivers and creeks to define the underwater parts of the channel sections. These are outlined below.

a) Aerial Survey

The aerial survey was undertaken by Fugro Spatial Solutions (FSS) using the "state of the art" airborne laser survey (ALS) techniques. This produced a dense sampling of ground spot levels, which were then processed into both a DEM and contour maps.

Digital photography was taken concurrently with the ALS, producing rectified images (ortho-imagery), which was provided in a tiled format of tiles, combined into a single seamless image in MapInfo format.

The specification of the ALS and ortho-imagery are given below:

ALS Equipment used	Leica ALS50
Flying height	1200m
Nominal swath width	1040m
Positioning	DGPS
Point density	1 point per 2m^2
Vertical accuracy	± 0.2 m
Horizontal accuracy	± 0.6 m
Image pixel size	0.3 m

This specification was a variation from FSS normal procedures in order to limit the cost to the budget available. Whilst 0.5m contours were produced from the DEM, these do not fully comply with the normally accepted accuracy of ± half a contour interval (± 0.25m in this case). This is because with a ± 0.2 m point accuracy, about 67% of points (1 standard deviation) are expected to be within this limit, with 90% of points (2 standard deviation) are expected to be twice this limit (i.e. ± 0.4m in this case).

This limitation is countered by the much higher point density than is available from conventional photogrammetry with the result that we are confident that the information obtained is sufficiently accurate to meet the requirements for hydraulic modelling of the Calliope River and its floodplain. However, Council are advised to be mindful of this limitation when using the contours for other purposes.

The extent of the ALS and digital ortho-imagery are shown in **Figure 30**.

b) River Survey

The hydrographic survey was undertaken by Ken McDonald Surveys using "state of the art" echo sounding equipment linked to kinematic GPS. The survey was undertaken along the whole of the Calliope River within the study area except for the following areas which were inaccessible:

- Area between the Bruce Highway bridge and the Old Bruce Highway causeway;

- The first 4km downstream of Castlehope where the water was too shallow for boat access.

At the former location hydraulics in the area are controlled by the causeway and rock bars. In respect of the latter, the below water channel capacity is nominal and has been estimated. In neither case does this limit the ability to realistically model the flow hydraulics.

Boat access was only possible in the lower reaches of Clyde Creek and Leixlip Creek but in these cases, the creek bed upstream was essentially dry and is picked up by the aerial survey.

5.3.2. Geometry

The model structure comprises a total of 27 flowpaths, made up of 5 primary flowpaths (Calliope River, The Anabranch, Clyde Creek and Leixlip Creek and a meander cut off), 2 additional tributary flowpaths (Deep Creek, Double Creek), 6 flood breakout flow paths, 5 bridge flowpaths and 9 link channels.

The model structure outline is shown in **Figure 31** and in more detail in **Figures 32** to **35.**

In all a total of 426 river and creek cross sections were extracted from the DEM and converted to MIKE 11 cross-section format. This was done by selecting cross-section locations, then using GIS/Cad software to drape these locations over the DEM, sampling levels at 2m intervals, leading to very detailed cross-sections.

There are also a total of 9 *link* channels which provide cross linkage between other flowpaths. Two of these are of sufficient length to warrant use of conventional flowpaths (links 1 and 7), with the others being specified by the simplified link channel procedure in MIKE 11 which is based on weir flow across the link. These short link channels are not included in **Table 7,** neither are additional flowpaths used to model over road flow at culvert locations.

Table 7 lists the flow paths in the model together with the number of cross sections in each flowpath, and their average spacing. The overall average spacing is 196m with only 2 flowpath links exceeding the 250m maximum specified in the study brief.

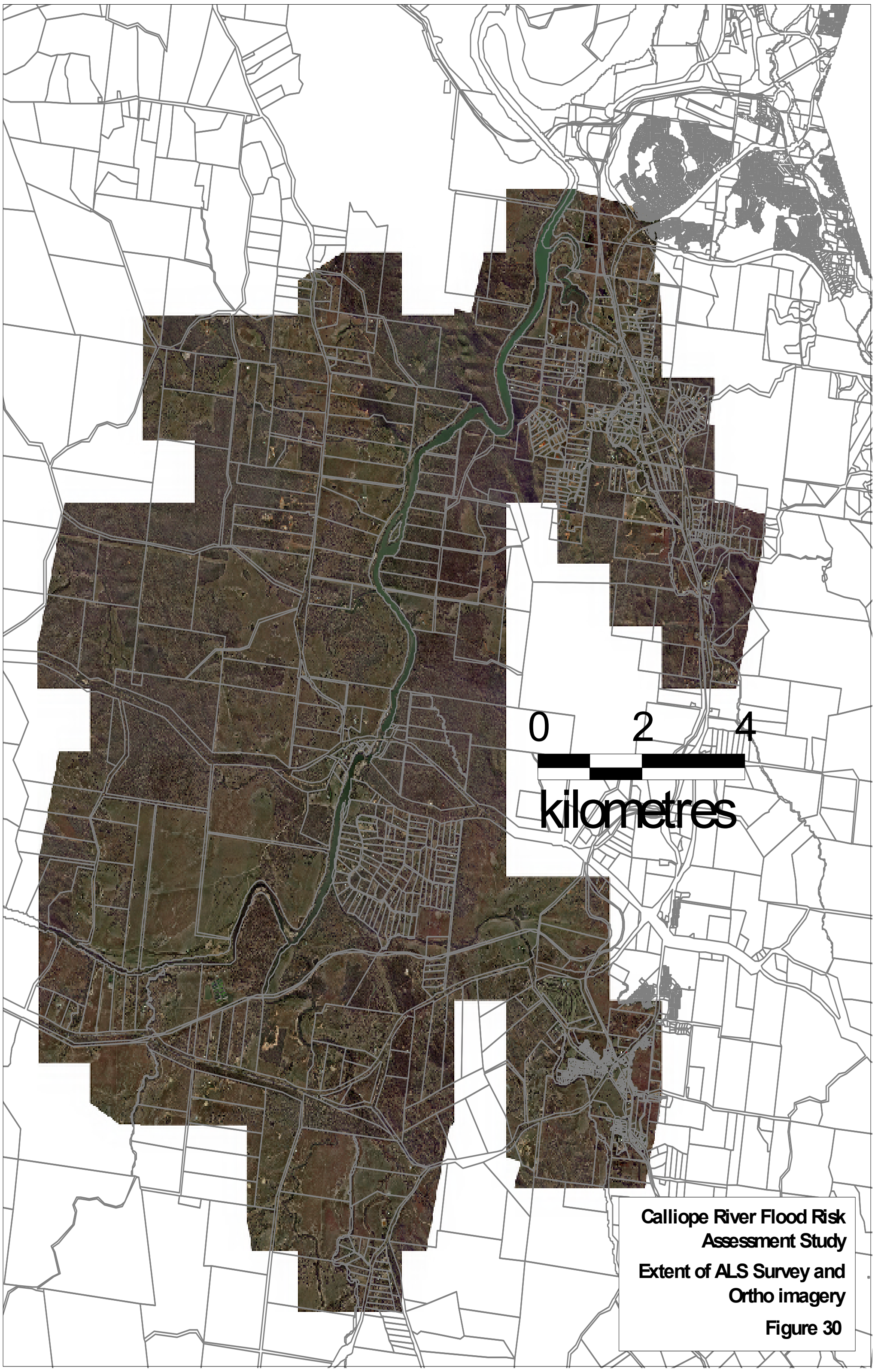


Figure 30 **Extent of ALS Survey**

Table 7 Calliope River Model – Flowpath Summary

Flowpath	Upstream chainage m	Downstream chainage m	Number of cross sections	Average distance between cross sections m	Comments
a) Main Flowpaths					
Calliope River	0	36300	165	220	
Anabranch	0	4750	20	238	
Clyde Creek	0	8667	51	170	
Cutoff	0	220	2	110	Cutoff across large meander in downstream reach
Deep Creek	0	1144	9	127	Added to give flood levels at Dawson Highway
Double Creek	-460	4048	20	225	Added to give flood levels at Dawson Highway
Leixlip Creek	0	9261	66	140	
b) Breakouts and Links					
Double BO	0	3085	20	154	Breakout from Double Creek towardsthen parallel to Leixlip Creek
Double BO2	0	1638	11	149	Breakout from Double Creek to Leixlip Creek
LB01	0	4460	22	203	High level flood breakout on left bank
LB02	-130	3196	17	196	High level flood breakout on left bank
LB03	0	1706	9	190	High level flood breakout on left bank
Wiggins	0	2492	7	356	Flow to south of Wiggins Island
Link1	0	570	2	285	High level flow across bend on CalliopeRiver
Link 7	45	1800	5	351	Potential flood breakout from Anabranch direct to ocean
Totals and averages		**83422**	**426**	**196**	

For the Calliope River flowpath only, although the river and floodplain are contained in a single flowpath, the computational option allowing conveyance to be separately computed in the channel and the left and right bank floodplains was utilised as this is more realistic. This is not necessary in the tributary, breakout and link flowpaths.

There are a total of 26 structures in the model comprising 12 bridges, 7 culverts, 4 weirs representing over road flows at culverts and a further 3 weirs representing other roads acting as hydraulic controls. This excludes weirs on link flowpaths and breakout thresholds. The locations of these structures are listed in **Table 8**.

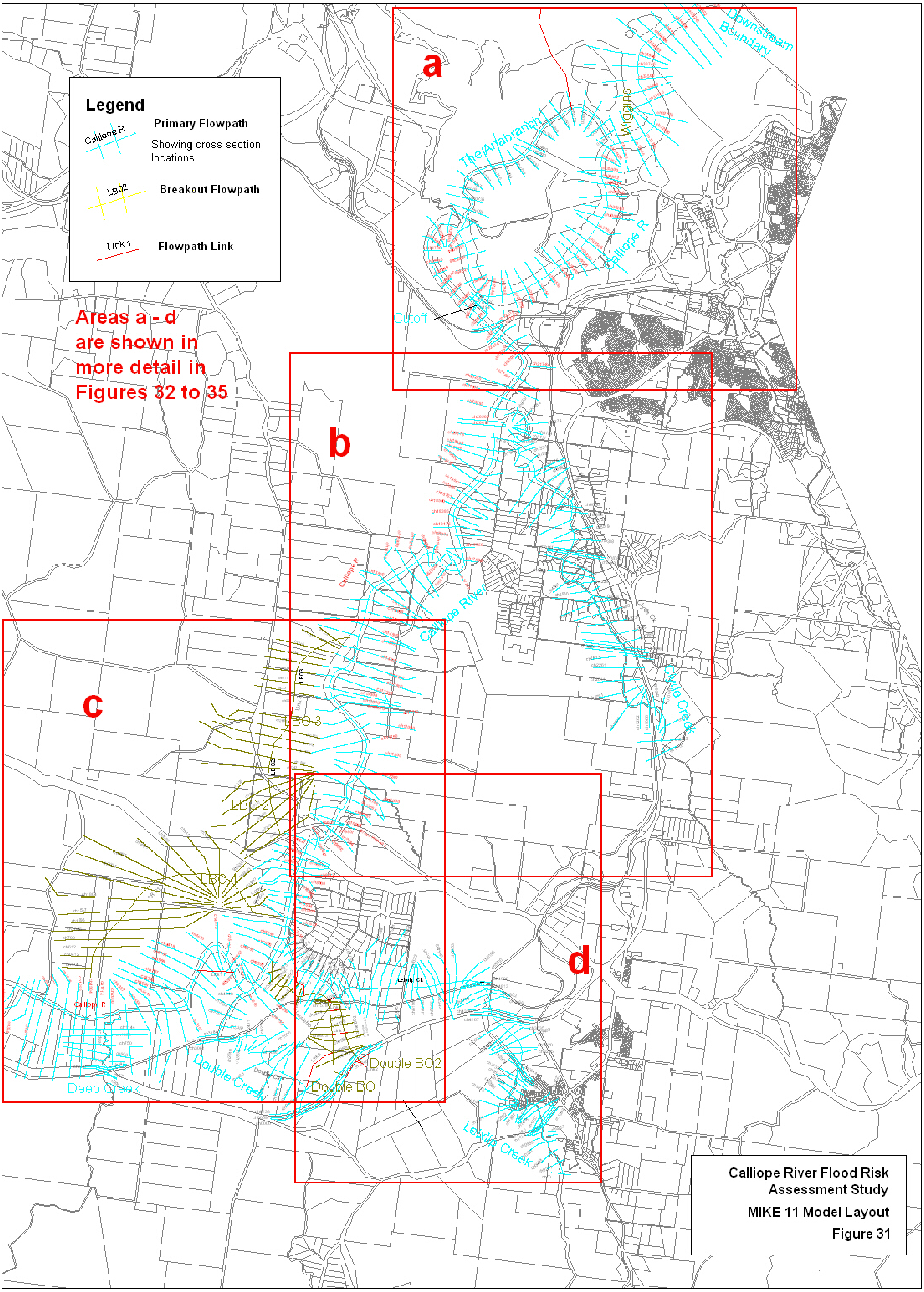


Figure 31 Mike 11 Model Layout (Outline)

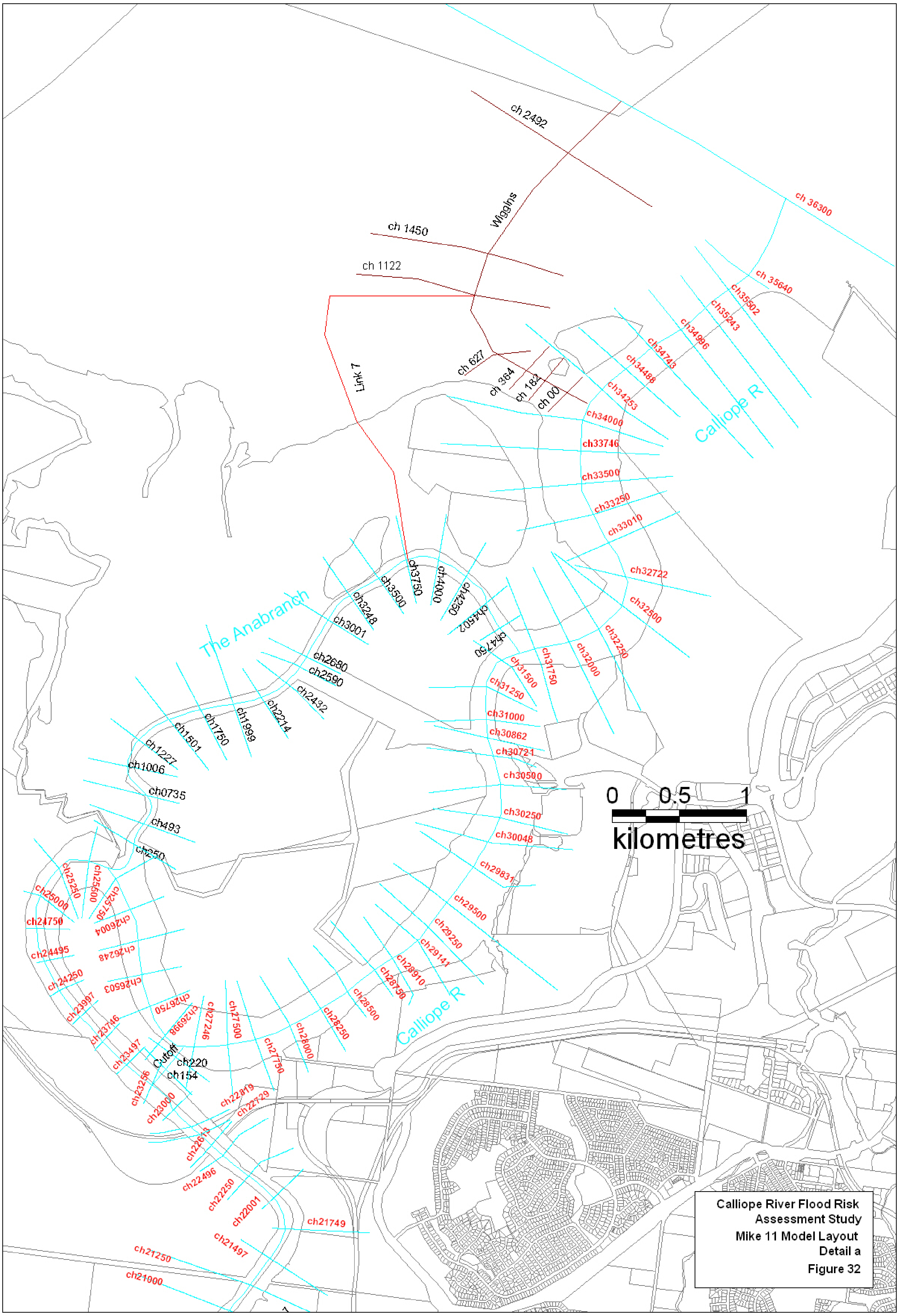


Figure 32 Mike 11 Model Layout - Detail a

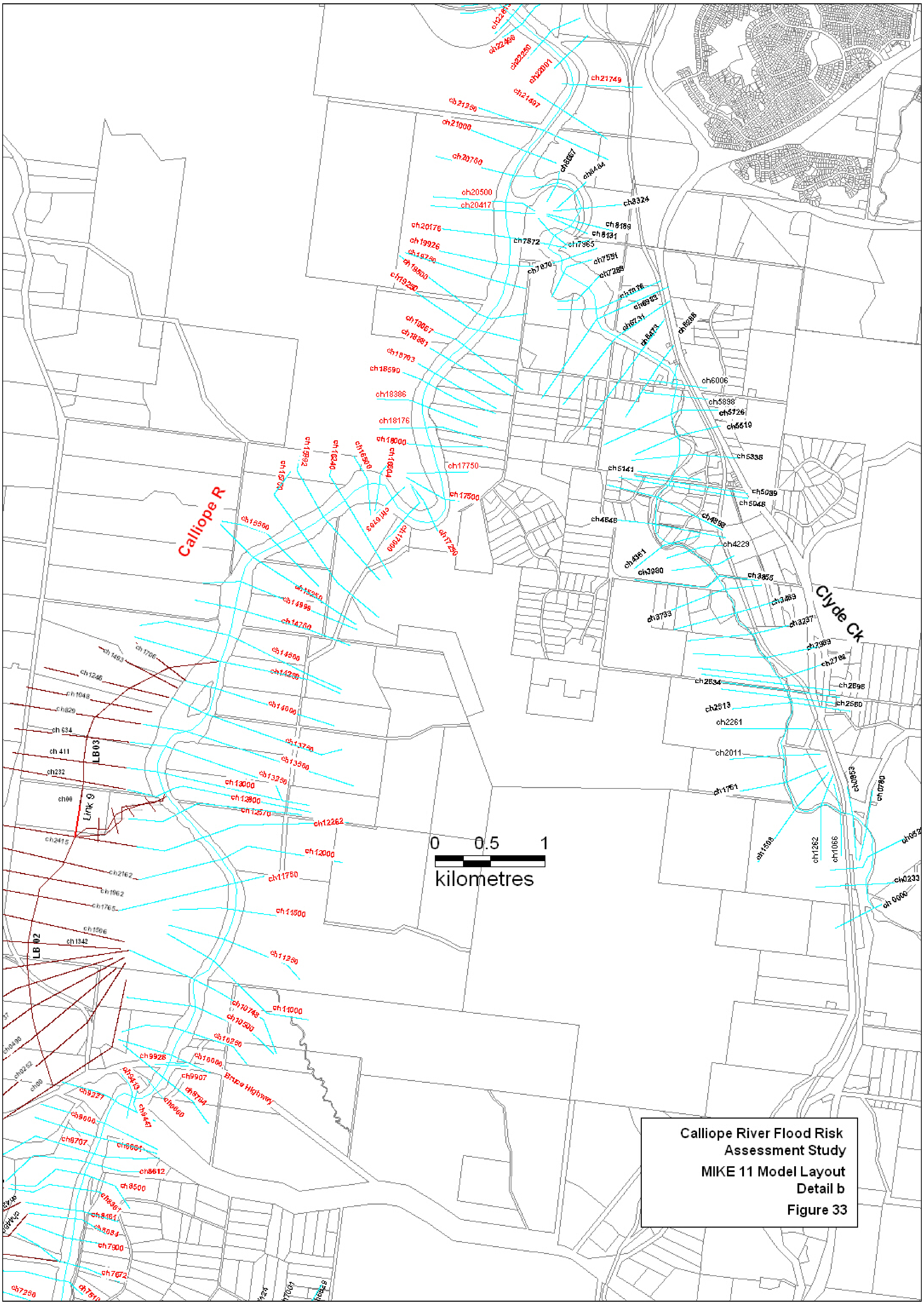


Figure 33 **Mike 11 Model Layout - Detail b**

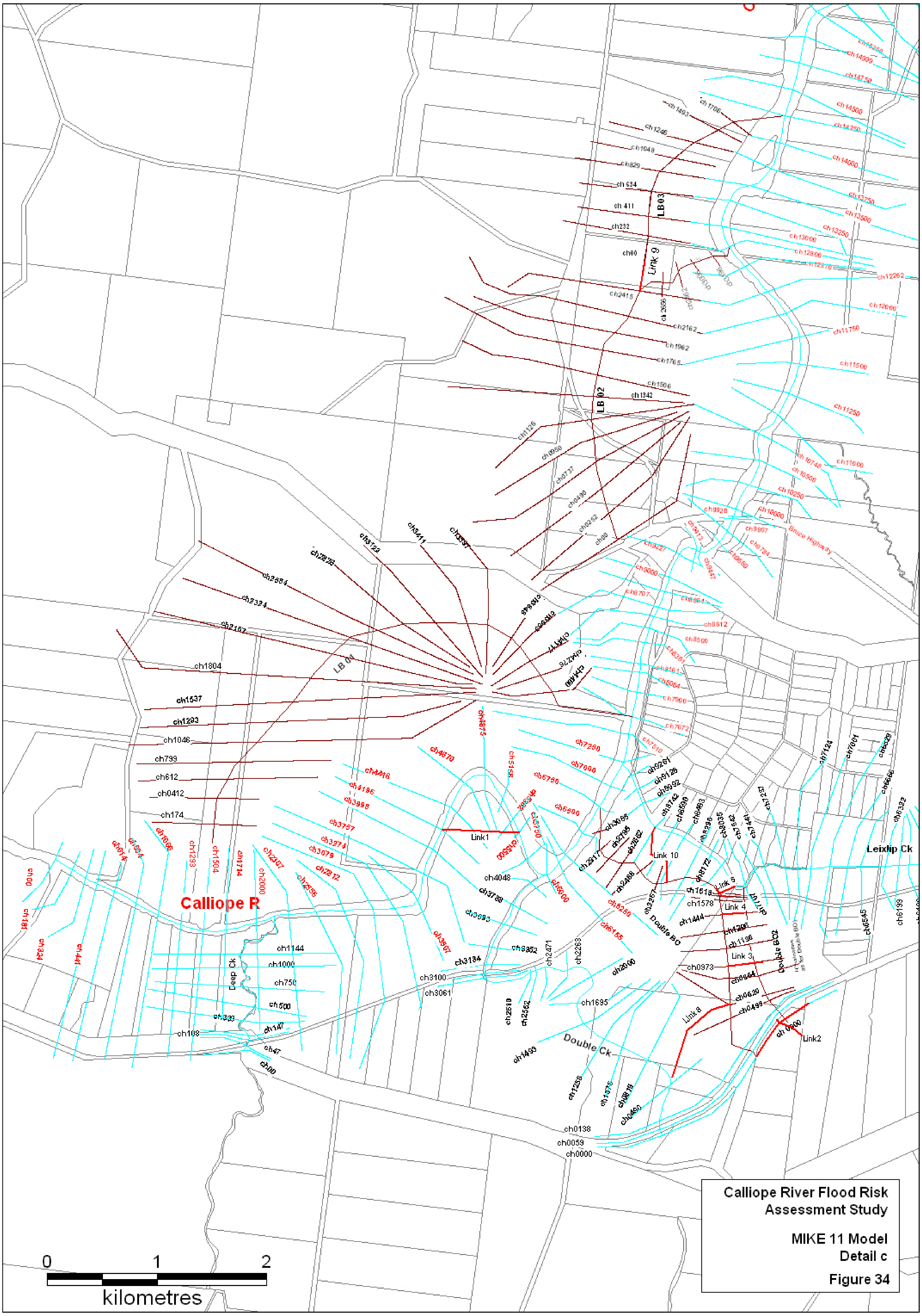


Figure 34 Mike 11 Model Layout - Detail c

Figure 35 Mike 11 Model Layout - Detail d

Table 8 Structure List

Flowpath	Chainage	Location
Bridges		
Clyde_Ck	963	Dawson Hwy (Clyde Ck)
Double_Ck	20	Dawson Hwy (Double Ck)
Deep_Ck	63	Dawson Hwy (Deep Ck)
CalliopeR	22770	Railway Br 2 (d/s)
CalliopeR	22576	Railway Br 1 (u/s)
Leixlip_Ck	4870	Railway Br (Leixlip Ck)
Double_Ck	3100	Railway Br (Double Ck)
Clyde_Ck	980	Railway Br (Clyde Ck)
Jefferis Rd	35	Jefferis Rd (Clyde Ck)
CalliopeR	30800	Port Curtis Way (Calliope R)
Anabranch	2630	Port Curtis Way (Anabr)
CalliopeR	9918	Bruce Hwy Br
Culverts		
Leixlip_Ck	4380	Stowe Road.
Leixlip_Ck	1110	Dawson Hwy Culvert (Leixlip Ck)
Leixlip_Ck	2924	Hookes Road culvert
CalliopeR	9426	Old Bruce Highway Causeway
Double_BO	1600	rail culvert
Double_BO2	1600	rail culverts
Double_Ck	20	culvert
Weirs		
CalliopeR	9426	Old Bruce Hwy Crossing
LBO2	-65	Bruce Hwy
LBO2	970	road
Leixlip_Ck	6380	Causeway
Dawson Hwy (overroad)	43	Dawson overroad (leixlip)
Hookes Rd (overroad)	30	Hookes Rd (Leixlip)
Stowe Rd (overroad)	40	Stowe Rd (Leixlip)

Road overflows were represented as broad-crested weirs, and road and rail bridges by the appropriate MIKE 11 formulations using geometry obtained from the bridge drawings. Details of road culverts were provided by Calliope Shire Council. There are two rail culverts in breakout flow paths for which no detailed information was available, and their sizes have been assumed at this time, subject to later confirmation in the field. These are unlikely to have any significant effect on the modelled results.

5.3.2. Hydraulic Roughness

Hydraulic roughness is represented in the model by Manning's ***n*** in three ways:

- Firstly, a global or default value of Manning's ***n***. In the absence of any further specification, this is applied to the entire model;

- Secondly, the global value can be varied for any flowpath reach by specifying upstream and downstream changes and the ***n*** value to apply at those chainages. If different values are given at the two ends of a reach, the intermediate values are determined by linear interpolation; and

- Thirdly, the roughness can be varied across model cross sections to take account of varying vegetation cover. This is applied as a relative roughness resulting in the actual roughness applied to a vertical strip in the cross section being the product of the ***n*** value and the relative roughness.

In MIKE 11, the roughness parameter includes all elements which make up the composite roughness, which according to Chow (1973) comprises:

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)\, m_5$$

where: ***n*** is the composite roughness;
n_0 is the basic roughness for a straight uniform channel;
n_1 is an addition to n_0 to correct for surface irregularities;
n_2 is an additional amount to account for variations in cross section shape and size;
n_3 is an additional amount to account for obstructions;
n_4 is a value for vegetation and flow conditions; and
m_5 is a correction factor for channel meandering.

The relative roughness values were varied with vegetation cover as obtained from the aerial photography. The values adopted are given in **Table 9**. Once applied, these were not varied as part of the calibration process in which only the reach values of ***n*** were varied.

Initial values of reach roughness were selected based on field inspections, aerial photographs and previous experience. These were subsequently modified during the calibration phase.

Table 9 Adopted Relative Roughness Values

Surface type	Relative Roughness
Sand/silt channel	0.6
Rock channel	0.8
Open floodplain (grass/light scrub)	1.0
Mangroves, dense scrub	2.0

5.3.3. Boundary Conditions

The required boundary conditions are hydrographs of streamflow at the upstream end of each of the open flow paths (ie those with no upstream connection), and a downstream water level or stage-discharge rating curve.

In addition, intermediate flow inputs can be applied to represent tributary or local runoff inflows.

The streamflow hydrographs required for input to the Calliope River model were produced from the RORB hydrologic model as described in Section 4 hereof. There were a total of 52 flow hydrograph inputs, as listed in **Table 10**.

The downstream boundary condition was the tide level at Gladstone Harbour. Tide level time series for the duration of the calibration events were obtained from the Maritime Services Office of the Queensland Department of Transport. For the events from December 1990 to date, the data are recorded values, and for events prior to that date are predicted values.

5.4. Hydraulic Model Calibration

5.4.1. Selected Events

The events utilised in the calibration of the hydrologic model, as listed in **Table 5** in **Section 4.3.1** hereof were also used in the calibration of the hydraulic model. These events were December 1973, January 1978, December 1990 and February 2003.

5.4.2. Historic Flood Levels

The principal source of historic flood levels for the study are those at the DNRM gauging station on the Calliope River at Castlehope, at which there is an automatic stage recorder. These records were obtained from the DNRM Rockhampton Hydrography unit. The datum for these records is Queensland State Datum (QSD) and advice from DNRM and Council was that the adjustment at Calliope between QSD and Australian Height Datum (AHD) is +0.23m. This adjustment was assumed to be valid at Castlehope. The Department of Main Roads has recently surveyed this station and advised that the adjustment is 0.284m. The values used were adjusted to take this into account.

In addition to the above, Calliope Shire Council has a few records of flood levels from a number of locations within the Calliope River floodplain.

Only recorded or observed flood levels have been used for calibration with those based on various study estimates excluded. The resulting flood level data available for calibration are listed in **Table 11.** As can be seen from **Table 11**, there is very little useful data for calibration apart from the recorded levels at Castlehope.

5.4.3. Calibration Procedure

Given that there were four flood events essentially with a single flood level each, it was decided to use all of the available events to calibrate the model and to evaluate the relative model performance for each event.

Model roughness parameters were selected initially based on field inspections, survey notes, aerial photographs and experience from previous studies. Roughness values were then modified by an iterative *trial and error* process to obtain as good a match as possible between recorded and modelled peak water levels.

As the only flood level information was at the upstream end of the model, there was no opportunity to objectively vary the roughness on a reach basis within the model.

The calibration results and model performance for each event are set out in the following paragraphs.

When modifying the model roughness to match the observed flood levels, it must be recognised that the sample of flood levels available are also subject to error and that this error varies with the type of record. For example, the levels at Castlehope are from a fixed measuring stations and should be accurate within ± 0.1m (with the possibility of a further small error being introduced by the assumed conversion from QSD to AHD), say ± 0.2m overall.

Table 10 Flow Hydrograph Inputs

Flowpath	Chainage	RORB sub area Desrcription
CalliopeR	0	BJ Castlehope
CalliopeR	441	BK Calliope local
CalliopeR	614	BL Calliopelocal
Deep_Ck	0	BM Deep Ck
CalliopeR	3998	BN Calliopelocal
Double_Ck	-346	BY Double Ck at Dawson Hwy
Double_Ck	1258	BZ Double Ck local
Double_Ck	2994	CA McGintys Ck
Double_Ck	3593	CB Double Ck local
Double_BO	0	CC Calliope local
Leixlip_Ck	0	CD Leixlip Ck u/s
Leixlip_Ck	1062	CE Leixlip Ck local
Leixlip_Ck	5198	CF Leixlip Ck trib
Leixlip_Ck	6545	CG Leixlip Ck local
Double_BO2	0	CH Leixlip Ck trib
Leixlip_Ck	8463	CI Leixlip Ck local
CalliopeR	7250	CJ Calliope local
LBO1	3122	CL Gravel Ck
CalliopeR	9227	CM Calliope local
CalliopeR	11250	CN Vulcan Ck
CalliopeR	12000	CO Calliope local
CalliopeR	12800	CP Calliope trib
CalliopeR	13750	CQ Calliope local
CalliopeR	14750	CR Oakey Ck
CalliopeR	15500	CS Calliope local
CalliopeR	16500	CT Calliope trib
CalliopeR	18176	CU Calliope local
CalliopeR	19500	CV Calliope trib
CalliopeR	19750	CW Calliope local
Clyde_Ck	0	DD Clyde Ck u/s
Clyde_Ck	1066	DE Clyde Ck trib
Clyde_Ck	1761	DF Clyde Ck local
Clyde_Ck	2696	DG Clyde Ck trib
Clyde_Ck	3733	DH Clyde Ck local
Clyde_Ck	4646	DI Clyde Ck trib
Clyde_Ck	5048	DJ Clyde Ck local
Clyde_Ck	5338	DK Clyde Ck trib
Clyde_Ck	5726	DL Clyde Ck local
Clyde_Ck	7288	DM Clyde Ck local
CalliopeR	21000	DN Calliope local
CalliopeR	21250	DO Call trib
CalliopeR	22250	DP Calliope local
CalliopeR	23497	DQ Calliope local
CalliopeR	24750	DR Calliope trib
CalliopeR	25250	DS Calliope local
CalliopeR	28000	DT Calliope local
CalliopeR	29250	DU Calliope trib
CalliopeR	29500	DV Calliope trib
CalliopeR	30500	DW Calliope local
CalliopeR	33250	DZ Calliope local
Anabranch	1501	DX Anabranch local
Anabranch	3750	DY Anabranch local

Table 11 Recorded Flood Level Data

Location (Source)	Flowpath/ Chainage	Peak Flood Levels in m AHD						Reference to CSC Historic Flood Level Plan
		1947	1973/4	1978	1990	2003	Other	
Calliope River at Castlehope (DNRM)	Calliope R 52m	19.67	19.23	16.64	14.01	16.27		Location A
Calliope R u/s Bruce Highway bridge (	Calliope R 9928m	15.0						Location B
Leixlip Creek at Pump Station (CSC)	Leixlip Ck 2493m		27.0					Location H
Leixlip Creek at Dawson Hwy (DMR)	Leixlip Ck 1062m						date unknown 30.0	Location J
Clyde Ck at Dawson Highway Bridge (DMR)	Clyde Ck 0953m						1911 20.6	Location M

The few other levels available were probably surveyed after the event from debris marks. These can be in error by up to about ± 0.3m or more depending on whether they were measured at the top or bottom of the debris line, whether the level was in a slow or non-moving storage area or in the main flow, whether there was wave set up and possibly superelevation at bends, plus datum errors. This range of likely error was taken into account in fitting the model.

5.4.4. Calibration Results

The model was run with the boundary conditions for the appropriate flood event which comprised the 52 inflow hydrographs (at the locations listed in **Table 10**) plus the downstream tidal records.

Whilst every effort was made to effect a calibration which was satisfactory for all of the flood events, it did not prove possible to achieve this. The results of these runs compared to the recorded flood levels together with the model roughness parameters used and the estimated flood levels at other key locations are given in **Table 12.**

Reference to **Table 12** shows that using the ***n*** value which gave the best fit for the calibration event varies from 0.057 for the 2003 and 1990 floods to 0.075 for the 1978 event and 0.072 for the 1973 event. These results are clearly unsatisfactory. Possible reasons for this discrepancy are discussed in **Section 5.5.**

In respect of the tributaries, there was only a single flood level on Leixlip Creek at the pump station at Calliope for the December 1973 event of 27.0 m AHD. This was fitted with an ***n*** value of 0.057 for Leixlip Creek. In the absence of any other tributary data, this roughness was adopted for the remaining tributaries and breakout flow paths in the model. It is reasonable that the tributaries have a higher roughness than the Calliope River, as they have little or no permanent water and hence vegetation spreads across a greater proportion of the channel and also generally occupies a greater proportion of the floodplain.

Table 13 lists the corresponding peak flood discharges to the flood levels given in **Table 12** for the four flood events modelled.

Table 12 Summary of Peak Flood Levels at Key Points – Calibration Events

Flowpath	Chainage m	Location	Peak Flood Level (m AHD) in Event			
			February 2003	December 1990	January 1978	December 1973
	n		0.0573	0.057	0.065	0.072
Calliope River	33	Castlehope GS (observed)	16.27	14.01	16.64	19.23
	33	Castlehope GS (Mike 11)	16.26	14.08	16.63	19.24
	2556	D/s Deep Ck	14.87	12.53	14.92	17.48
	6000	D/s Double Ck	13.79	10.88	13.75	16.42
	7250	D/s Leixlip Ck	13.37	10.37	13.29	15.95
	9413	U/s Old Bruce Highway Cros	12.89	9.78	12.74	15.48
	12800	D/s LBO2 re-entry	9.06	6.59	9.02	10.75
	14250	D/s LBO3 re-entry	8.59	6.11	8.48	10.16
	20417	U/s Clyde Ck	6.29	4.15	6.11	7.39
	20750	D/s Clyde Ck	6.12	4.00	5.96	7.22
	23256	U/s Meander Cutoff	3.81	2.52	3.65	4.54
	27246	D/s Meander Cutoff	3.65	2.52	3.50	4.39
	31750	D/s Anabranch Re-entry	2.22	2.47	1.85	2.60
	34000	D/sWiggins Is flowpath	2.01	2.45	1.54	2.00
Trbutaries						
Deep Creek	0	Dawson Highway	19.02	18.08	20.13	21.11
Double Ck	-460	Dawson Highway	18.16	16.83	18.46	20.06
Leixlip Ck	0	U/s Model Boundary	32.90	32.76	32.86	33.08
	1062	Dawson Highway	30.32	30.13	30.17	30.44
	2493	Stowe Rd	26.48	26.20	26.37	26.86
	4167	Rail Crossing	22.09	21.31	21.68	22.59
Clyde Ck	0	U/s Model Boundary	20.48	19.19	19.96	21.52
	953	Dawson Highway	19.24	17.91	18.51	20.45
	3800	Wyndham Rd	11.11	11.02	10.79	13.31
	6090	Jefferis Road	6.65	4.90	6.30	7.69
The Anabranch	2590	Port Curtis Way	3.02	2.50	2.83	3.68
Wiggins Island Flowpath	364	Adj. Wiggins Island	2.01\	2.45	1.54	1.89

Table 13 Summary of Peak Discharges at Key Points – Calibration Events

Flowpath	Chainage m	Location	Peak Flow (Cumecs) in Event			
			February 2003	December 1990	January 1978	December 1973
	n		0.057	0.057	0.065	0.072
Calliope River	33	Castlehope GS (observed)	2,765	1,910	2,900	3,860
	33	Castlehope GS (Mike 11)	2,765	1,910	2,900	3,865
	2684	D/s Deep Ck	2,920	1,950	2,895	3,900
	6077	D/s Double Ck	3,670	2,440	3,335	4,675
	7380	D/s Leixlip Ck	3,930	2,550	3,525	4,760
	9320	U/s Old Bruce Highway Cros	4,080	2,550	3,610	4,655
	12900	D/s LBO2 re-entry	4,150	2,540	3,620	4,650
	14375	D/s LBO3 re-entry	4,160	2,540	3,610	4,645
	20458	U/s Clyde Ck	4,280	2,520	3,625	4,675
	20875	D/s Clyde Ck	4,550	2,640	3,810	4,885
	23128	U/s Meander Cutoff	4,550	2,640	3,800	4,880
	27373	D/s Meander Cutoff	3,530	2,150	2,965	3,765
	31875	D/s Anabranch Re-entry	4,470	2,650	3,760	4,825
	34370	D/sWiggins Is flowpath	3,020	2,100	2,670	3,240
Trbutaries						
Deep Creek	63	Dawson Highway	175	133	205	245
Double Ck	-440	Dawson Highway	835	533	810	1,200
Leixlip Ck	0	U/s Model Boundary	190	142	150	225
Leixlip Ck	1010	Dawson Highway	182	142	150	225
Leixlip Ck	2430	Stowe Rd	350	255	265	400
Leixlip Ck	4046	Rail Crossing	335	235	245	385
Clyde Ck	0	U/s Model Boundary	300	177	215	345
Clyde Ck	963	Dawson Highway	285	171	205	325
Clyde Ck	6100	Jefferis Road	295	130	205	370
The Anabranch	2511	Port Curtis Way	970	490	800	1,090
Wiggins Island Flowpath	273	Adj. Wiggins Island	1,630	860	1,100	1,585

The mean peak discharge in the Calliope River at its mouth from the hydraulic model compared to the corresponding figures from the RORB model was 101% with individual values ranging from 92% to 110%. Such discrepancies are expected as the MIKE 11 model allows for the temporary flood storage effects in detail whereas RORB does this only in a very broad fashion, and MIKE 11 includes the tidal flow components in the lower reaches, where RORB does not.

Figures 36 to **41** show modelled longitudinal profiles along the Calliope River, the Anabranch, Leixlip Creek and Clyde Creek for the February 2003 flood event, and along Calliope River and Leixlip Creek for the December 1973 event.

Discharge and water level hydrographs at various points for this event are shown in **Figures 42** and **43**, for the Calliope River and tributaries respectively**.** The corresponding flood level and discharge hydrographs for the other floods are given in **Appendix B.**

The flow distribution between the Calliope River and The Anabranch and the meander cut off channel is of interest, and is shown in **Figure 44** which shows the peak flows in each flowpath as a proportion of the maximum peak flow in the river. These figures were estimated from the four calibration events, and the proportions were found to not vary greatly. The details of this analysis are given in **Table 14.** These proportions may not be valid outside of the range of flows experienced in these events, namely, approximately 3,200m^3/s to 6,000m^3/s.

Table 14 Flow Distributions Lower Calliope River

Reach/ Flowpath	Mike 11 Chanage m	Peak flows and Percent Peak flows in event									
		2003		1990		1978		1973			
		Peak Flow (Cumecs)	% of Peak Flow	Peak Flow (Cumecs)	% of Peak Flow	Peak Flow (Cumecs)	% of Peak Flow	Peak Flow (Cumecs)	% of Peak Flow	Mean	SD
Calliope R u/s of cutoff	u/s of 23250	4550	102%	2640	99%	3800	101%	4880	101%	101%	1.4%
Calliope R d/s of cutoff, u/s of Anabranch	d/s 23250 - u/s25750	675	15%	370	14%	540	14%	690	14%	14%	0.4%
Anabranch	0 - 4750	980	22%	490	18%	800	21%	1090	23%	21%	1.8%
Calliope R d/s of Anabranch, u/s of Cutoff re-entry	d/s 25750 - u/s 27246	270	6%	60	2%	15	0.4%	35	0.7%	2%	2.5%
Cutoff	0 - 220	3870	85%	2270	85%	3255	87%	4190	87%	86%	1.1%
Calliope R d/s of Cutoff re-entry u/s of Anabranch	d/s 27246 - 31750	3480	76%	2150	80%	2965	79%	3765	78%	78%	1.6%
Calliope R d/s Anabranch re-entry to Wiggins Island	d/s 31750 to 34000	4480	100%	2680	100%	3760	100%	4825	100%	100%	0.0%
Wiggins Island flowpath	0 - 2492	1630	36%	860	32%	1100	29%	1600	33%	33%	2.7%
Calliope R d/s Wiggins Island to Mouth	d/s 34000 - 36500	3060	67%	2100	78%	2670	71%	3240	67%	71%	5.3%

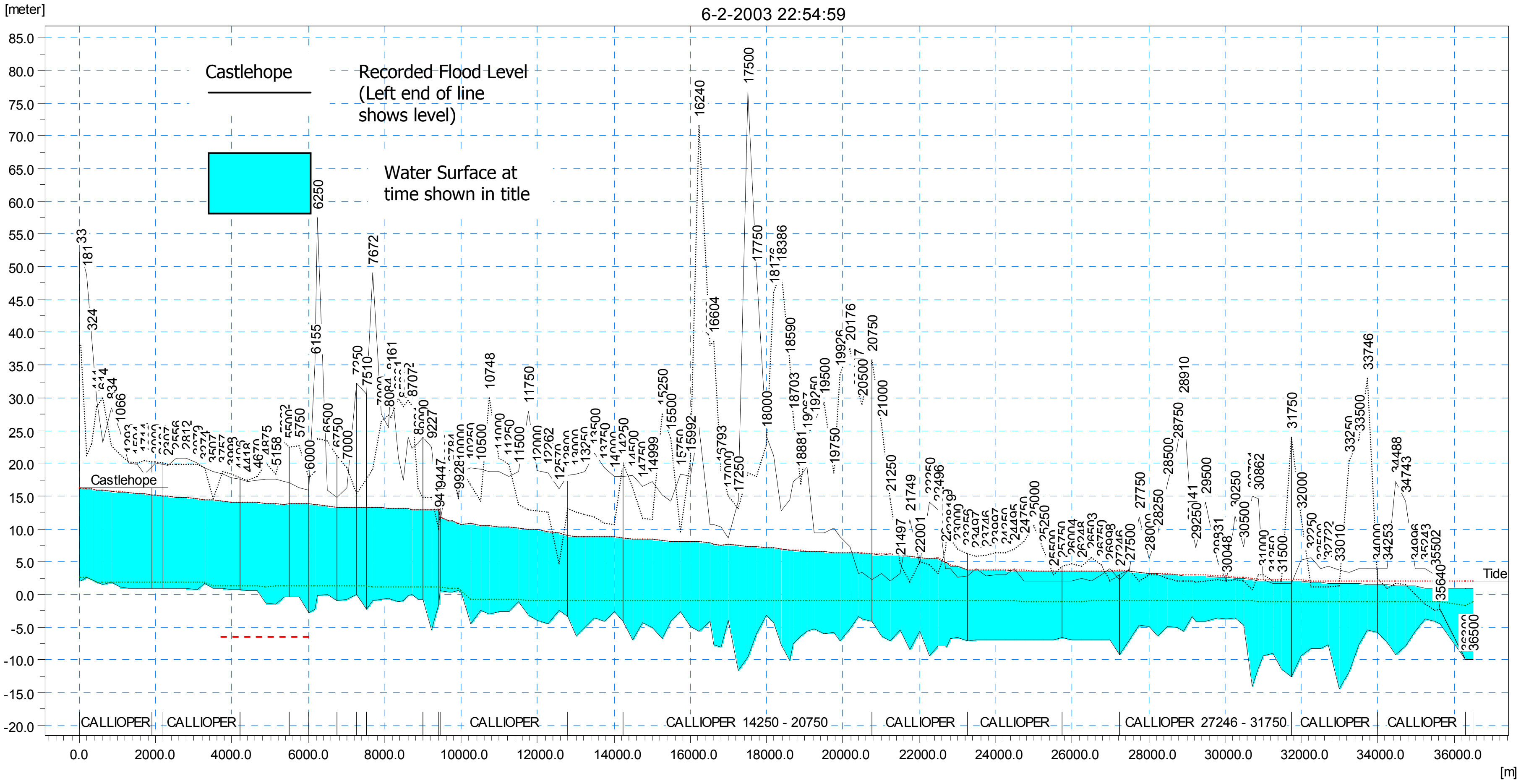


Figure 36 Longitudinal Profile Calliope River– 2003 Flood Event

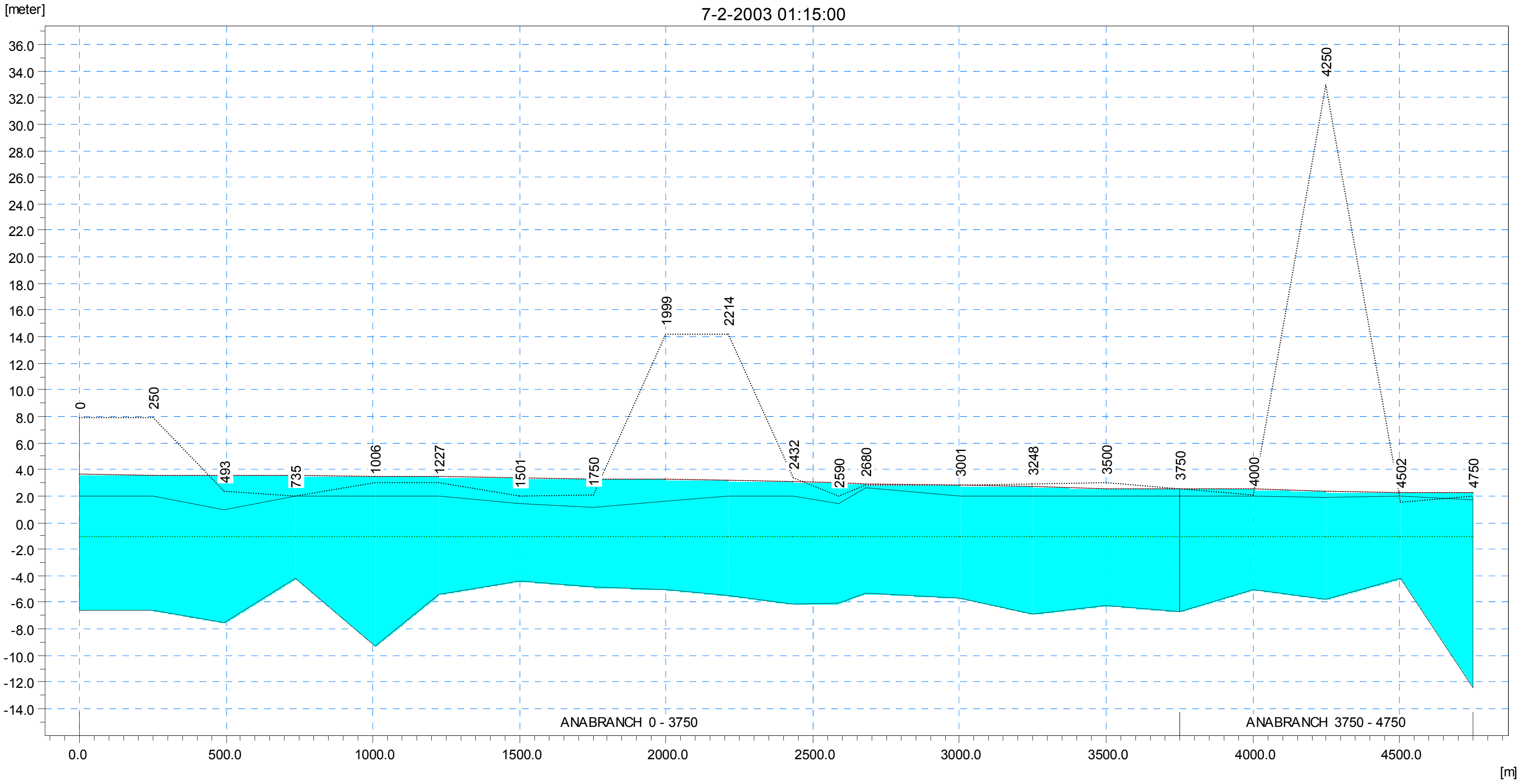


Figure 37 **Longitudinal Profile along The Anabranch – 2003 Flood**

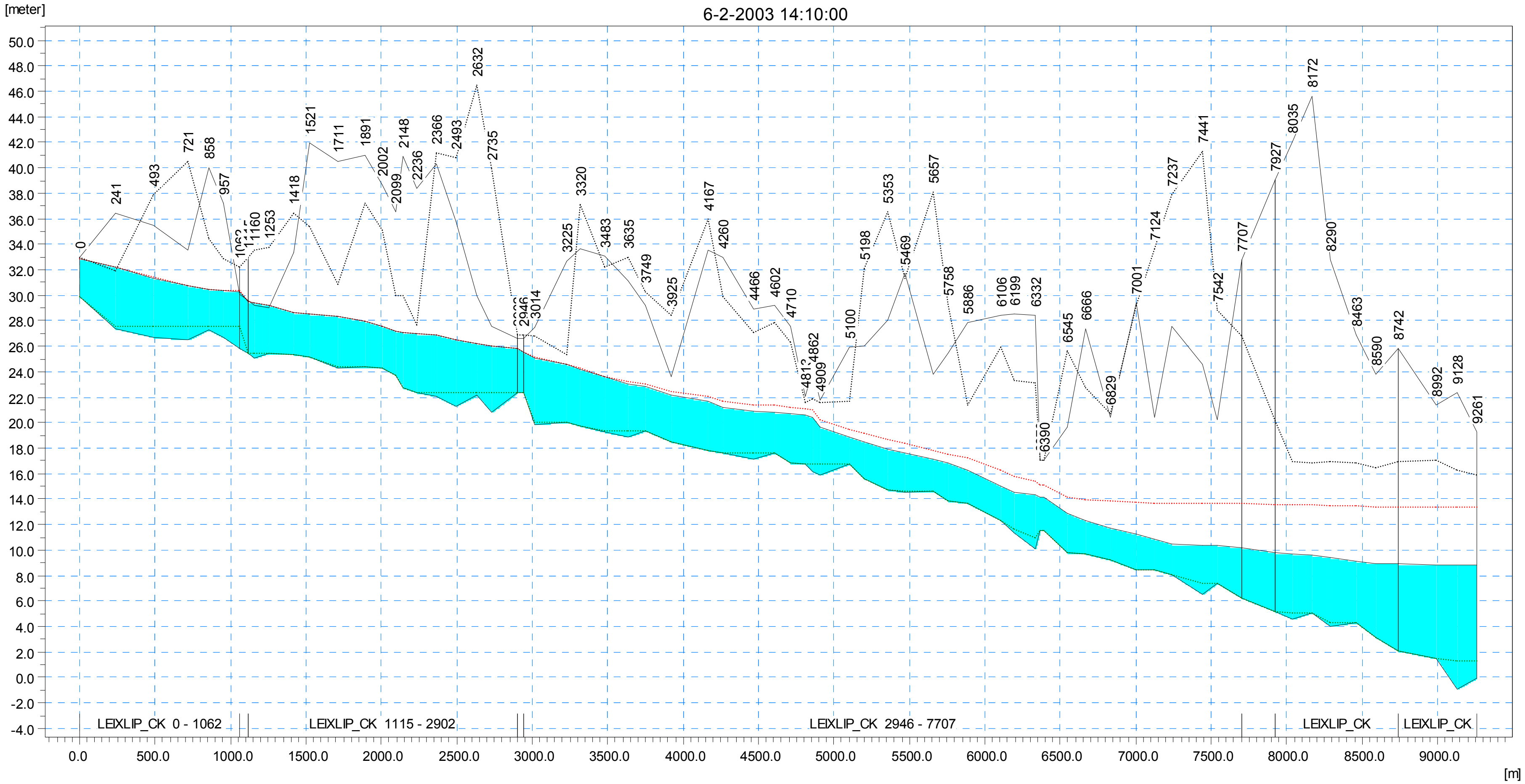


Figure 38 **Longitudinal Profile Leixlip Creek – 2003 Flood**
(Shown at peak of flood in upper reaches)

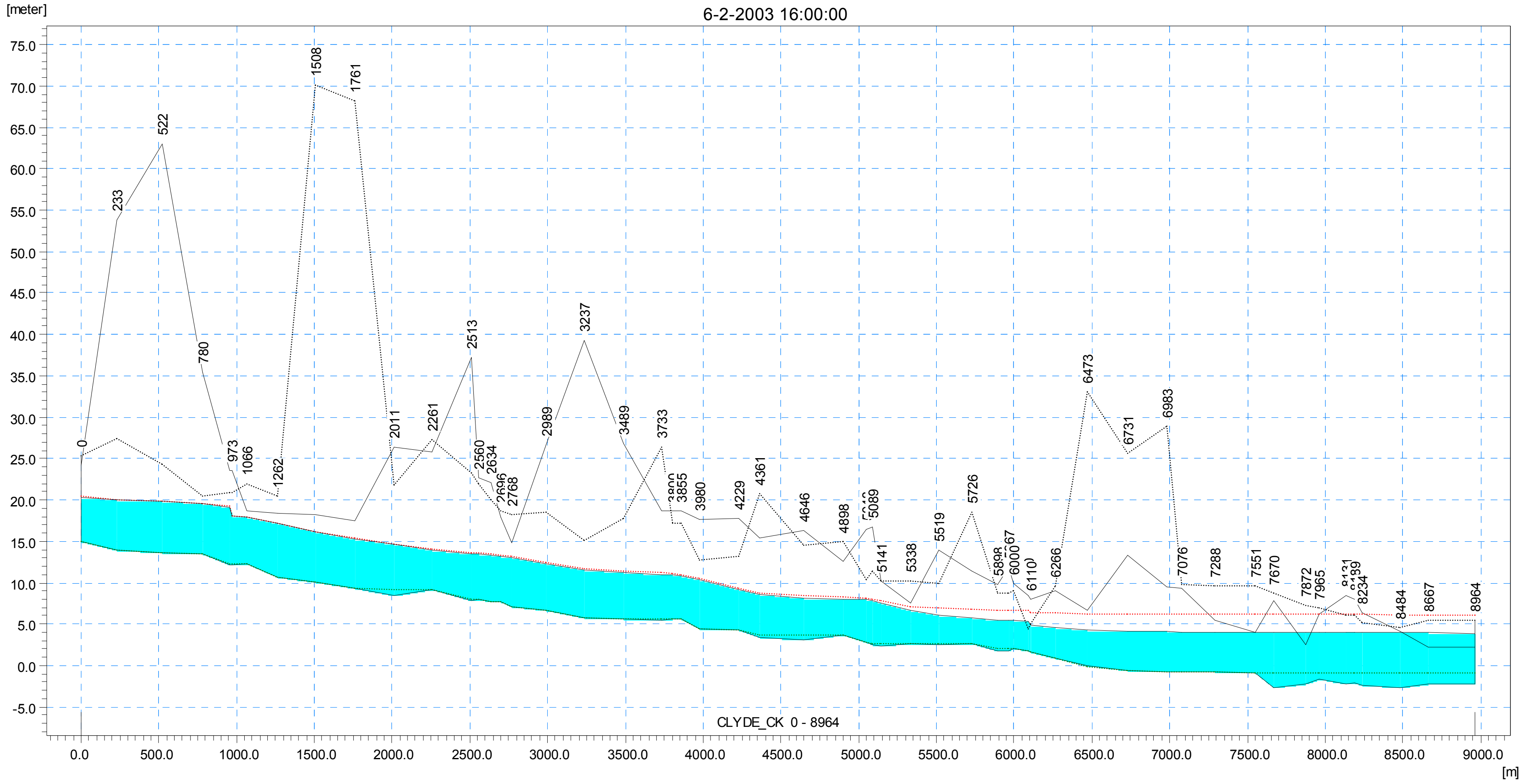


Figure 39 **Longitudinal Profile Clyde Creek - 2003 Event**

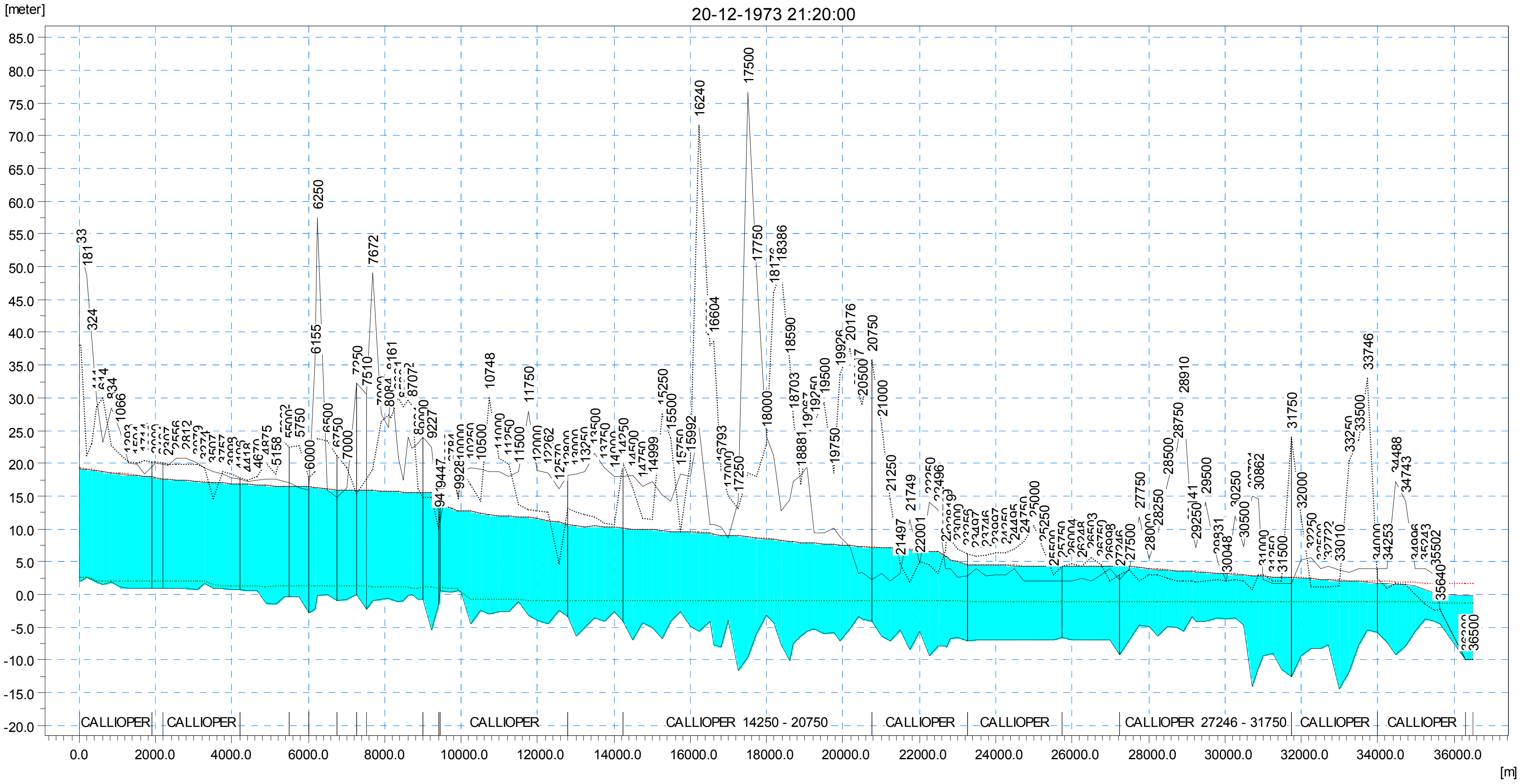


Figure 40 Longitudinal Profile Calliope River – 1973 Flood

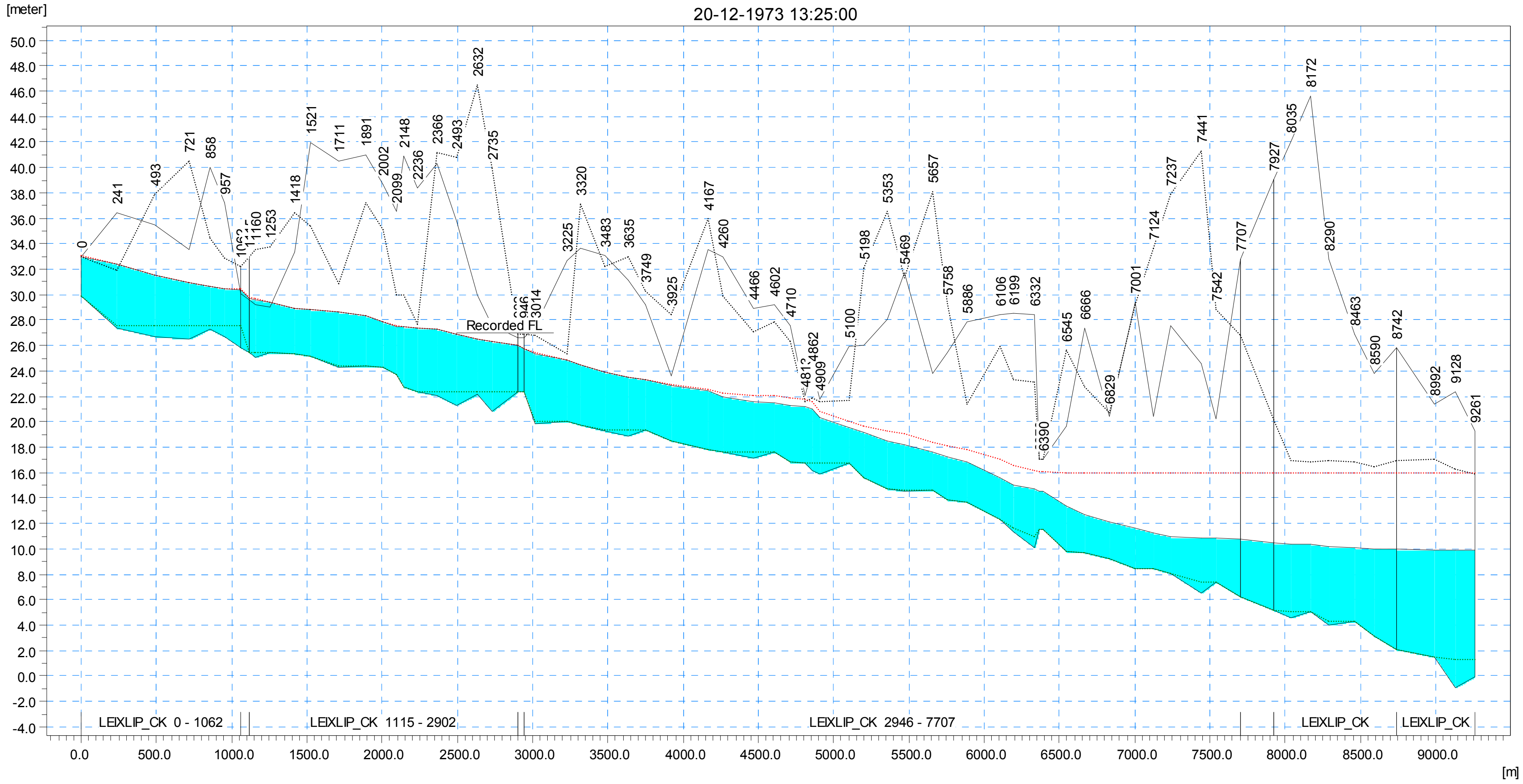
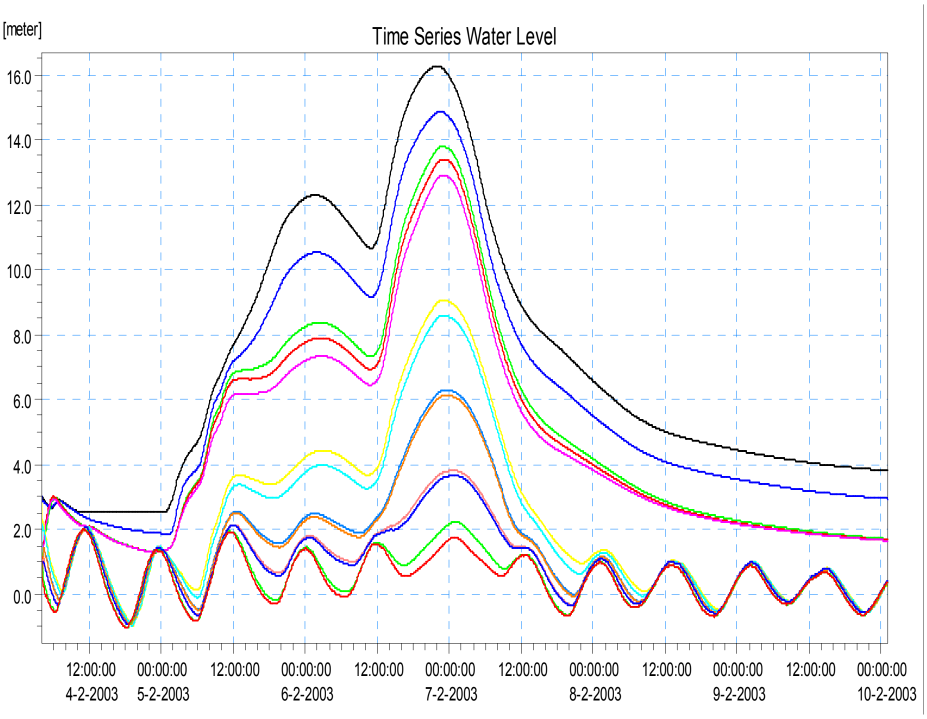
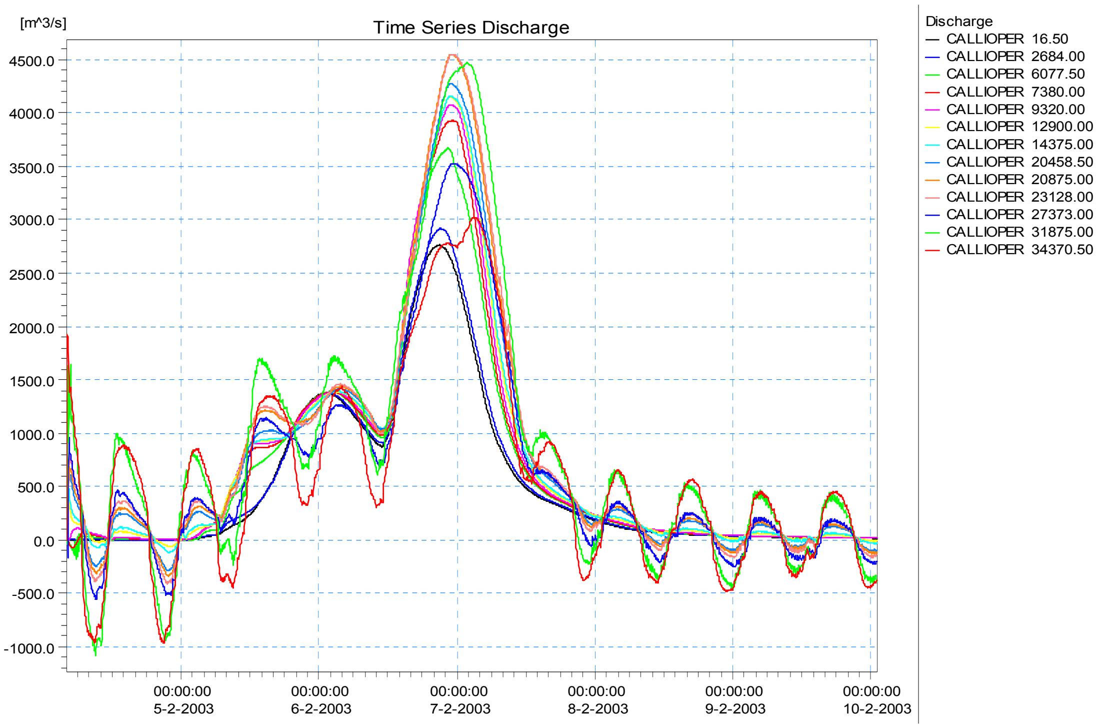


Figure 41 **Longitudinal Profile Leixlip Creek – 1973 Flood**
(Shown at peak of flood in upper reaches)

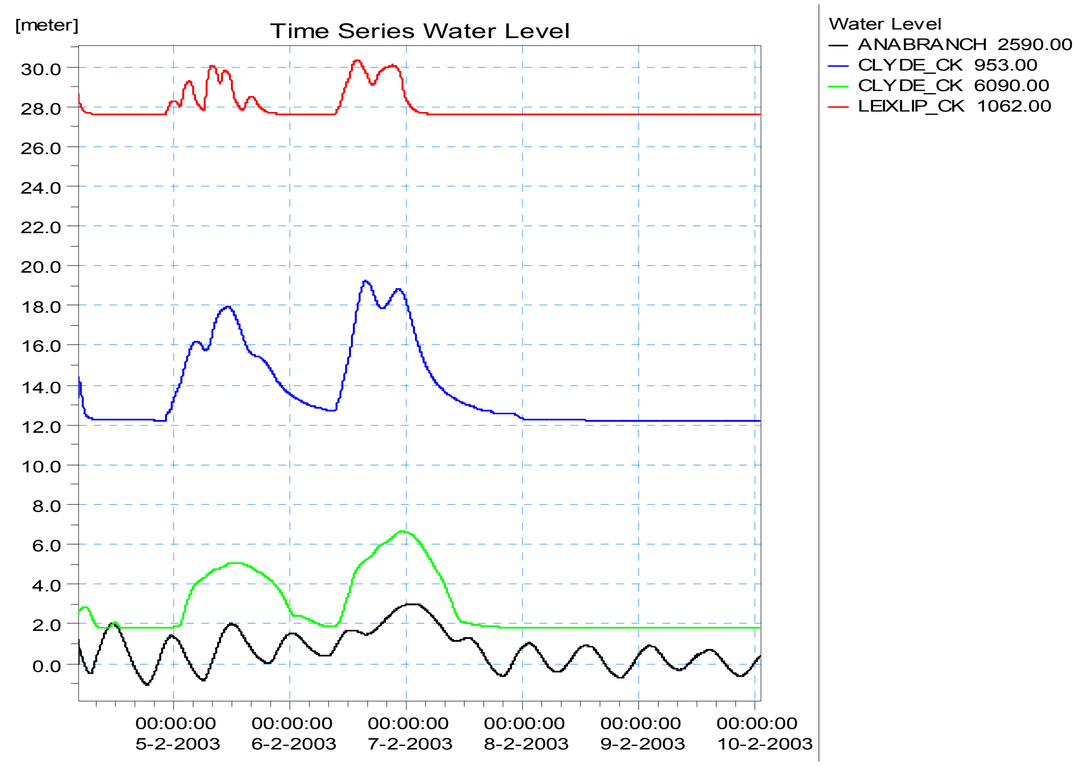


a) Water Level Hydrographs

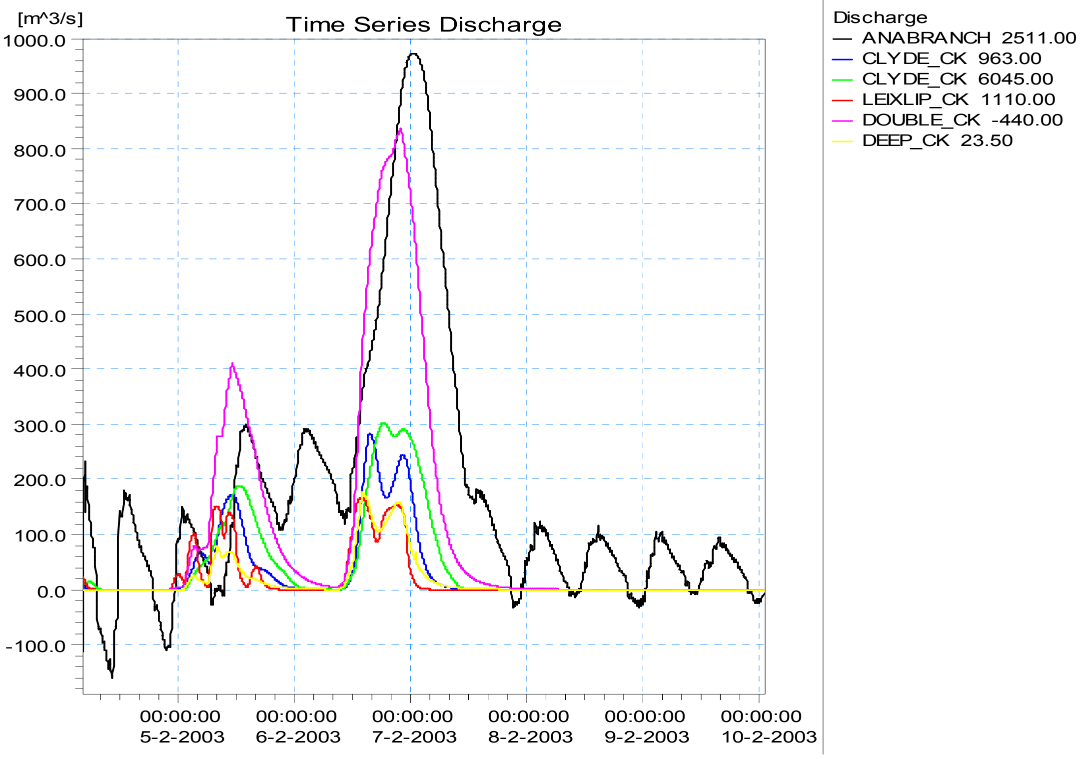


b) Discharge Hydrographs

Figure 42 Hydrographs Calliope River – February 2003 Flood



a) **Water Level Hydrographs**



b) **Discharge Hydrographs**

Figure 43 Tributary Hydrographs – February 2003 Flood

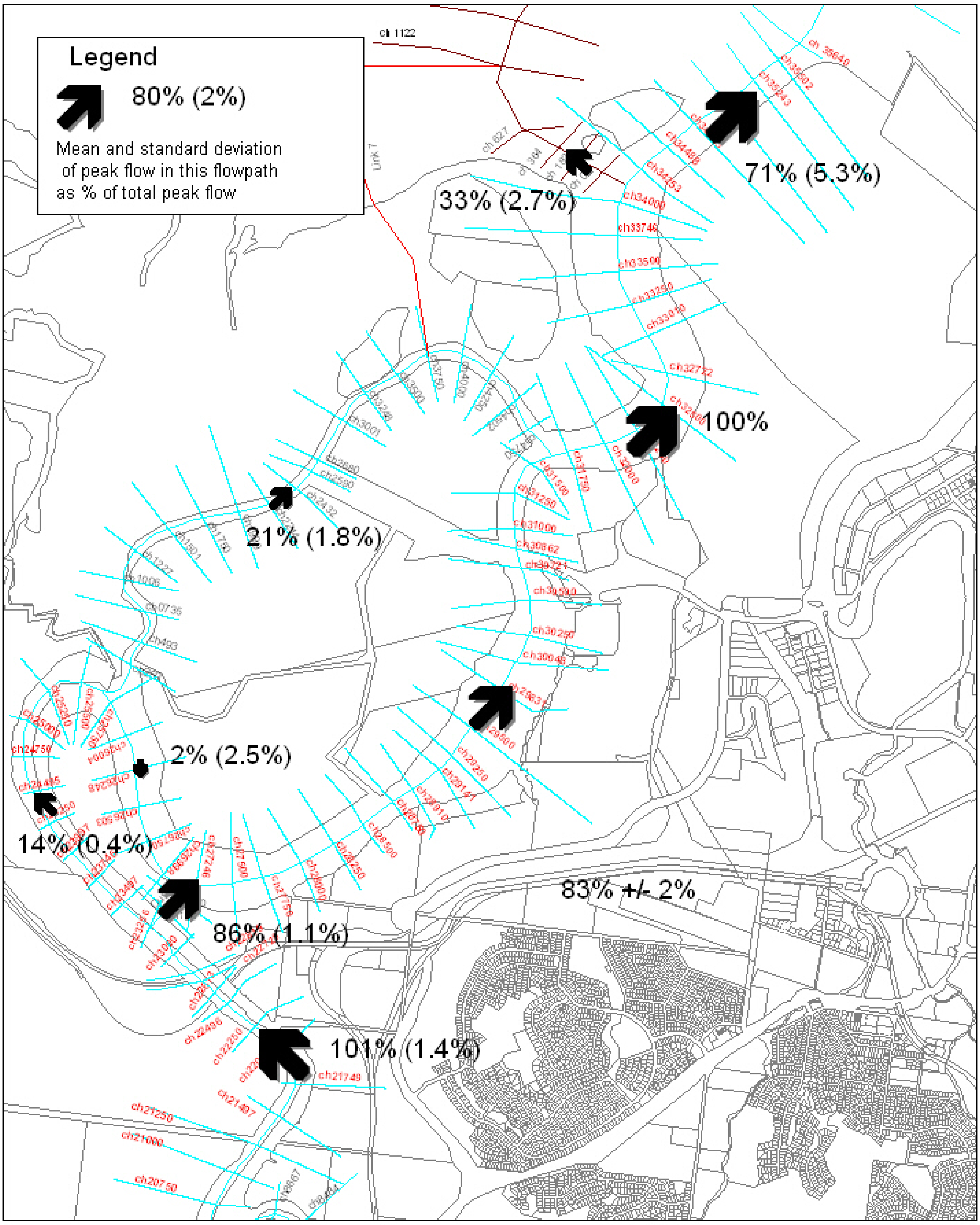


Figure 44 **Flow Distribution Lower Calliope River**

5.5. Discussion

The previous section noted discrepancies between the modelled flood level for the more recent floods (2003, 1990) and those in the 1970s, with the hydraulic model fitted to the recent floods underestimating flood levels in the 1973 flood by almost a metre.

It was considered that degree of discrepancy could indicate that a physical change has occurred since the earlier series of floods. A number of occurrences could have resulted in enlargement of the channel cross-section, for example:

- Significant erosion (channel deepening/widening) following the floods in the 1970's;
- Dredging in the lower reaches of the river since the 1970's for navigational purposes; or
- If the cut-off of the large meander upstream of the start of the Anabranch occurred in that period, this would have initiated an episode of headwards erosion.

It was decided at the SAG meeting to discuss the **Milestone 1 Report** (Sargent Consulting 2005a) that it would be prudent to undertake a brief assessment of the evidence for such a change as part of the Study. This was undertaken and subsequently reported on in **Working Paper No 1** (Sargent Consulting 2005b). The next section outlines this assessment.

On the basis of that assessment, it was determined that there has been significant channel change over the last 50 – 100 years and that the appropriate choice of hydraulic roughness was that which satisfactorily fitted the more recent flood events. This is a base Manning's **n** value of **0.057**, but this is increased by the relative roughness across each cross section according to the values given in **Table 8,** so that overall value at a given cross section is in the range of 0.034 to 0.114 (i.e. relative roughness from 0.6 to 2). These values are within the typical range with values at the low end representing the smooth sand/silt bed in the estuary reaches, and the higher values representing typical floodplain conditions.

6. Physical Changes in the Calliope River

6.1. Introduction

At the SAG meeting on 18th October 2005, it was resolved that a brief investigation and evaluation of changes to the hydraulic capacity of the Calliope River over the period since the early 1970's be undertaken, in order to reduce the uncertainty regarding the appropriate values of hydraulic roughness to be used for the design phase of the hydraulic modelling component of the study.

This uncertainty was brought about by the difference in hydraulic roughness necessary to calibrate the model for 2 floods in the 1970's and 2 more recent floods in 1990 and 2003.

The hypothesis tested was that there has been significant physical change to the channel of the Calliope River over recent years to result in the above inconsistency in modelled roughness between historic events, when it was assumed that there was no such change.

The following photographs, which were taken during the recent river survey, show that there are steep eroding banks at a number of points along the Calliope River. The steepness of the banks, lack of vegetation thereon, tunnel erosion and fretting are evidence of ongoing bank erosion resulting in river widening.

Photographs along Calliope River showing evidence of bank erosion

Another possible source of this discrepancy could be that errors in the recorded and modelled flows vary significantly between events. However, this difference was not thought to be great as the DNRM gauging station has been well rated (i.e. a large number of flow measurements have been made) and the hydrologic model performed well and predicted the 1973 peak flow at Castlehope within 8% of the recorded value when used as for model validation (**Section 4.5** refers). It was considered unlikely that errors in the flows would be sufficiently high to cause the discrepancy in modelled flood levels.

If clear evidence that physical changes to the Calliope River have occurred over the last 30 years was found, it would be appropriate to base the design runs on the model parameters obtained by calibration to the February 2003 flood (in particular) and that of December 1990. If these changes had occurred, but model parameters selected on the basis of the floods in the 1970s, there would be a significant overestimation of flood levels, of the order of a metre for an event of the magnitude of that in December 1973/January 1974 which was approximately 50 year ARI (subject to confirmation in next phase of the project).

This Section sets out the work that has been undertaken in this investigation; the conclusions reached; and recommendations in respect of the hydraulic roughness values to be used in the design flood phase of the study.

6.2. Approach

The approach to this assessment was:

- Comparison of aerial photography at various dates to identify any changes in plan form;
- Comparison of longitudinal sections (limited data);
- Comparison of cross-sections (limited data);
- A brief review of the effects of dredging: and
- Interpretation of the above.

6.3. Plan Form Changes

Aerial photographs covering the Calliope River from Castlehope to the ocean at the following dates were obtained from DNRM:

- May 1961;
- July 1970;
- December 1980;
- October 1988;and
- April 1999

Council provided 1:10,000 orthophoto maps which are based on the 1980 photography and parish maps (c 1892).

In addition photography of the large meander from which the Anabranch flows was also obtained from DNRM for May 1965, July 1973, July 1979, October 1980 and October 1989.

A copy of 1941 photography was found in a report by Duke et al (2003) but was of poor resolution.

Inspection of these aerial photographs and the parish maps showed that the only significant change in plan form of the Calliope River to be the cutoff of the neck of the large meander upstream of Gladstone from which the Anabranch flows.

The date of the parish map is uncertain but it does refer to gazettal of the limits of Port Curtis in 1892 so the survey is assumed to date from that time. The map shows only a narrow channel through the cutoff, with the 1941 aerial photography also showing a narrow channel. The later photography shows a much broader channel established through the meander neck. These are illustrated in **Figure 45**.

Approximate widths of the channel were measured from the maps/photographs, and are shown in **Figure 46.** These measurements are not of high accuracy due to the small scale of the photography and the variable tidal conditions. Nonetheless, it can be seen from **Figure 46** that there has been a significant increase in the width of the cutoff channel. This process is likely to be ongoing.

The channel width increased from about 50m in 1941 to about 150m by 1973 and to about 200m at present. This would be consistent with significant widening being triggered by the 1947 flood and being maintained by a series of smaller floods through the 1950s, followed by further widening subsequent to the 1973 and 1978 floods.

The average rate of widening has been 1.85 m/annum since c1892 but 2.7 m/annum since 1961 compared with 1.3 m/annum for the period c1892 to 1961.

The development of this meander cutoff also has implications for channel deepening as discussed in the next paragraph.

Channel widths were also estimated for a number of other locations, namely: Devil's Elbow, adjacent to Farmers Island, and at the Calliope River/Leixlip Creek confluence.

These channel widths are shown plotted against time in **Figure 47.** Whilst the width changes at these other locations are less than those at the meander cutoff, they do all show an increase over time, again consistent with erosion during and following major floods.

The average rate of widening since 1961 has been about 0.5 m/annum at each of these sites compared to about 0.1 m m/annum from c1900 to 1960.

Due to the consistency of these changes, it is reasonable to assume that these locations are typical of the whole of the study reach. These changes are also consistent with the visual information from the photographs presented in **Section 6.1**.

Hence, it was concluded from this analysis that there has been significant widening of the river, particularly since 1961.

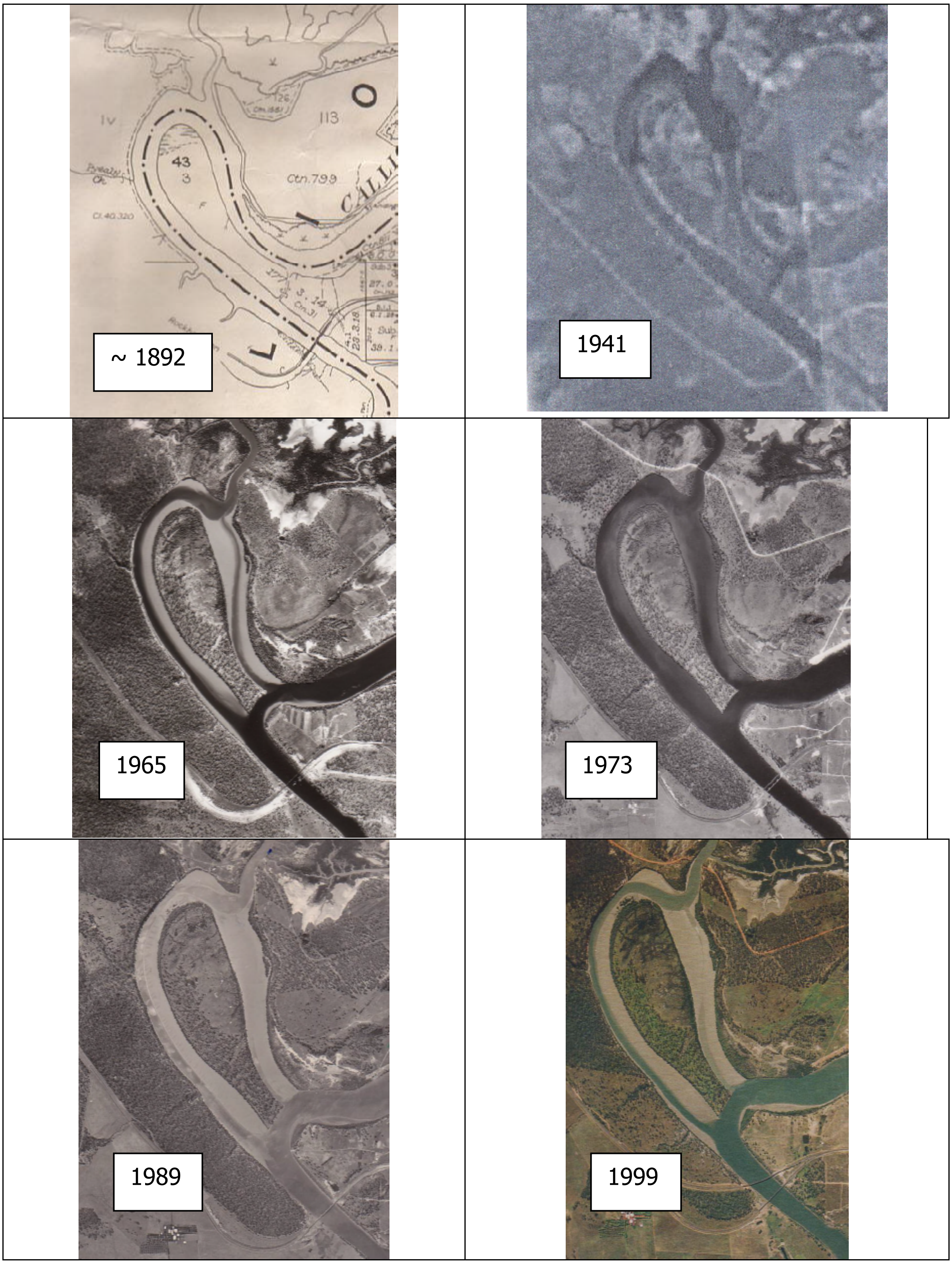


Figure 45 Development of the Meander Cutoff Channel

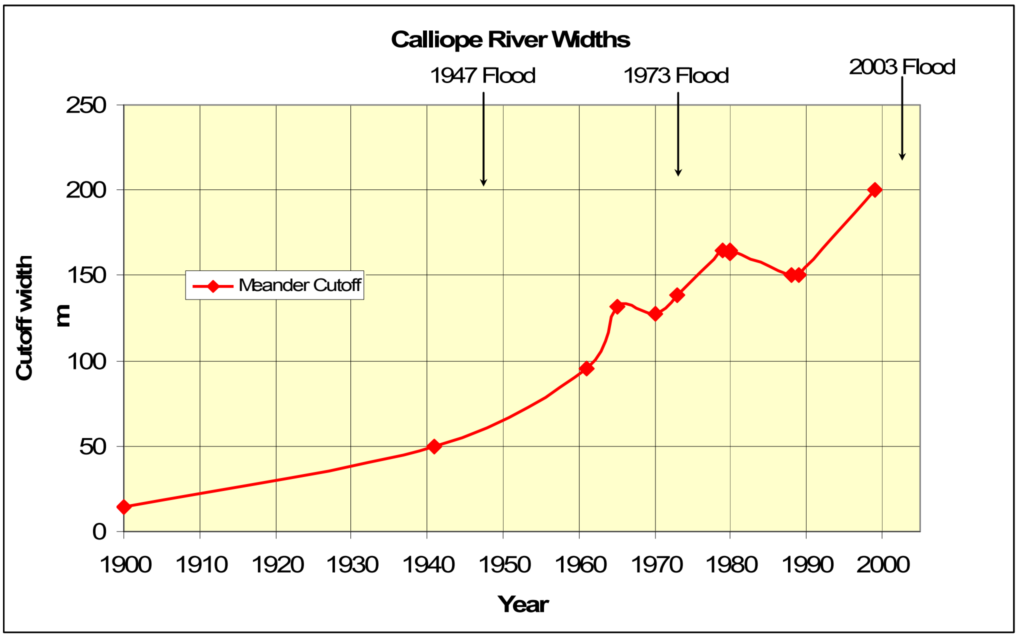


Figure 46 **Meander Cutoff Channel Widths**

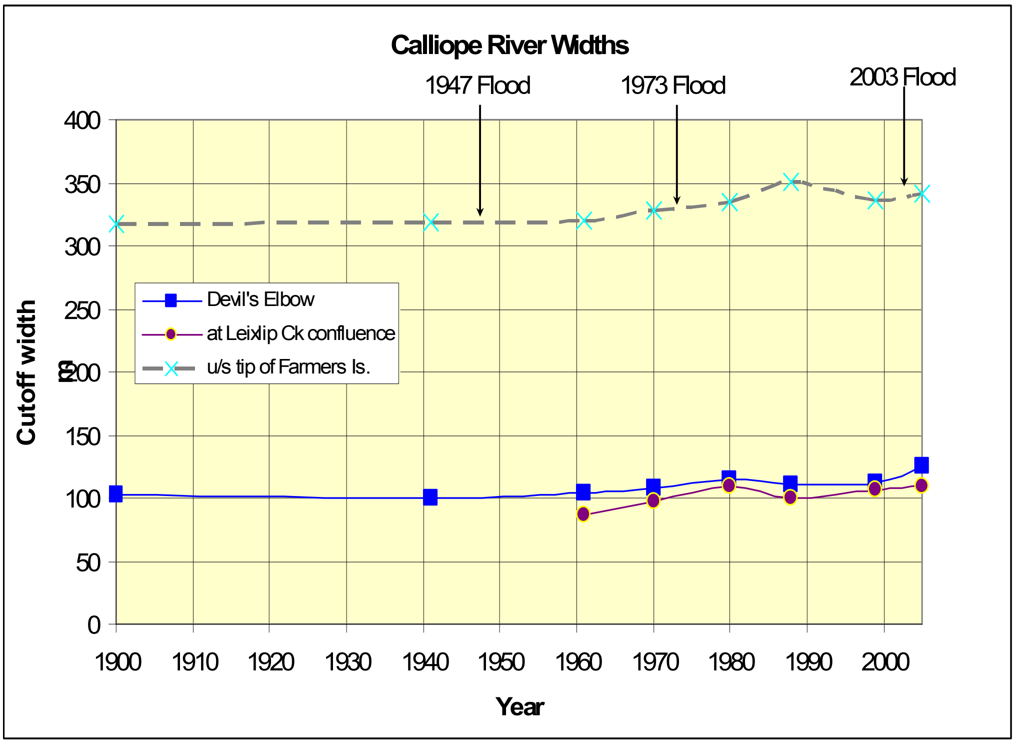


Figure 47 **Channel Widths at other locations**

6.4. Channel Gradient and Depth

A longitudinal profile was drawn along the Calliope River channel from the 2005 river survey and is shown in **Figure 48**.

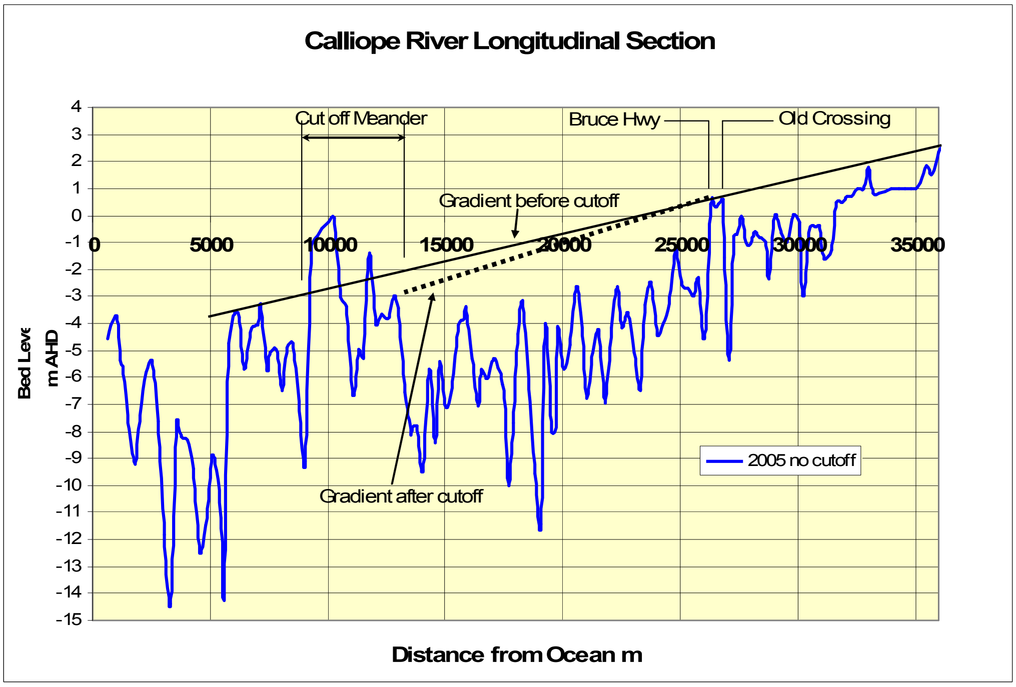


Figure 48 **Calliope River 2005 Longitudinal Profile**

Figure 48 shows the location of the meander which has now been cut off, the Bruce Highway Bridge and the Old Bruce Highway crossing. The solid sloping line (marked "gradient before cutoff") shows the controlling gradient assuming stable conditions downstream and with the rock bed at the Bruce Highway crossing also being a major hydraulic control.

The meander cutoff has shortened the river course by about 3.8 km. Ignoring other factors, the cutoff would have the effect of lowering the bed immediately upstream of the cutoff by about a metre and increasing the gradient upstream. This is represented by the dotted line in **Figure 48**. Due to this increased gradient, which results in increased flow energy and erosion potential, the channel bed level would lower overtime until it reaches the new equilibrium. As the rock control at the Bruce Highway should prevent any significant lowering there or further upstream, when fully developed there would be a bed lowering of from zero to 1m through this reach, or an average of about 0.5m. This process may still be ongoing.

As noted in the previous section regarding channel width, the rate of the recent changes appears to have increased since 1961 and this would be expected to be similar in respect of channel deepening.

It can also be seen from **Figure 48** that sediment has been deposited in the cut off meander reach particularly in the reach downstream of the Anabranch entry, where bed levels have risen about 3m.

6.5. Channel Cross Section Changes

A further comparison was carried out on typical channel cross sections. This was possible only for the period 1980 to 2005, using the 1980 orthophoto maps and the new (2005) survey. Whilst this does not cover the entire period of interest, these give some indication as to whether there has been widening and/or deepening not only of the low flow channel but also of the upper channel.

This comparison was made for 12 cross sections from near Castlehope to upstream of the confluence with Clyde Creek. All of these 12 sections showed evidence of widening and deepening of the channel on this basis. **Figure 49** shows a sample of these cross sections.

Figure 49 shows that there has been significant lowering of the ground levels in the upper part of the channel (no information is available regarding the channel below the waterline). This could only result from erosion during flood events. Whilst the 1980 mapping has only 5m contours and is therefore subject to a vertical error of ± 2.5m, such errors should be both positive and negative and not all of one sign. It can be seen from **Figure 49** that the apparent differences are up to 5m, well in excess of that expected from map error alone.

It is also significant that this widening/deepening of the upper levels of the channel was observed both upstream and downstream of the Bruce Highway/Calliope Crossing area, whereas the deepening expected as a result of the downstream meander cutoff would not be expected to propagate upstream of the Bruce Highway/Calliope Crossing.

Larger changes have probably occurred when the pre-1980 period is included but this cannot be quantified.

6.6. Dredging

The Clinton Channel which extends to just off the Calliope River mouth is maintained to a depth of 10.4m (-13.2m AHD) (Maritime Safety Queensland 2002). **Figure 50** reproduces part of this chart. Depths on this chart are based on a 1990 hydrographic survey.

Whilst this dredging could initiate headwards erosion, this does not appear to have been the case, as comparison between the DOT survey conducted in June 1990 (downstream of the Port Curtis Bridge only) and the 2005 survey shows no lowering in bed levels through the lower river, with some filling in of deep holes along the channel. These surveys do not follow the same centre line so there is some discrepancy in horizontal distances. This comparison is shown in **Figure 51**.

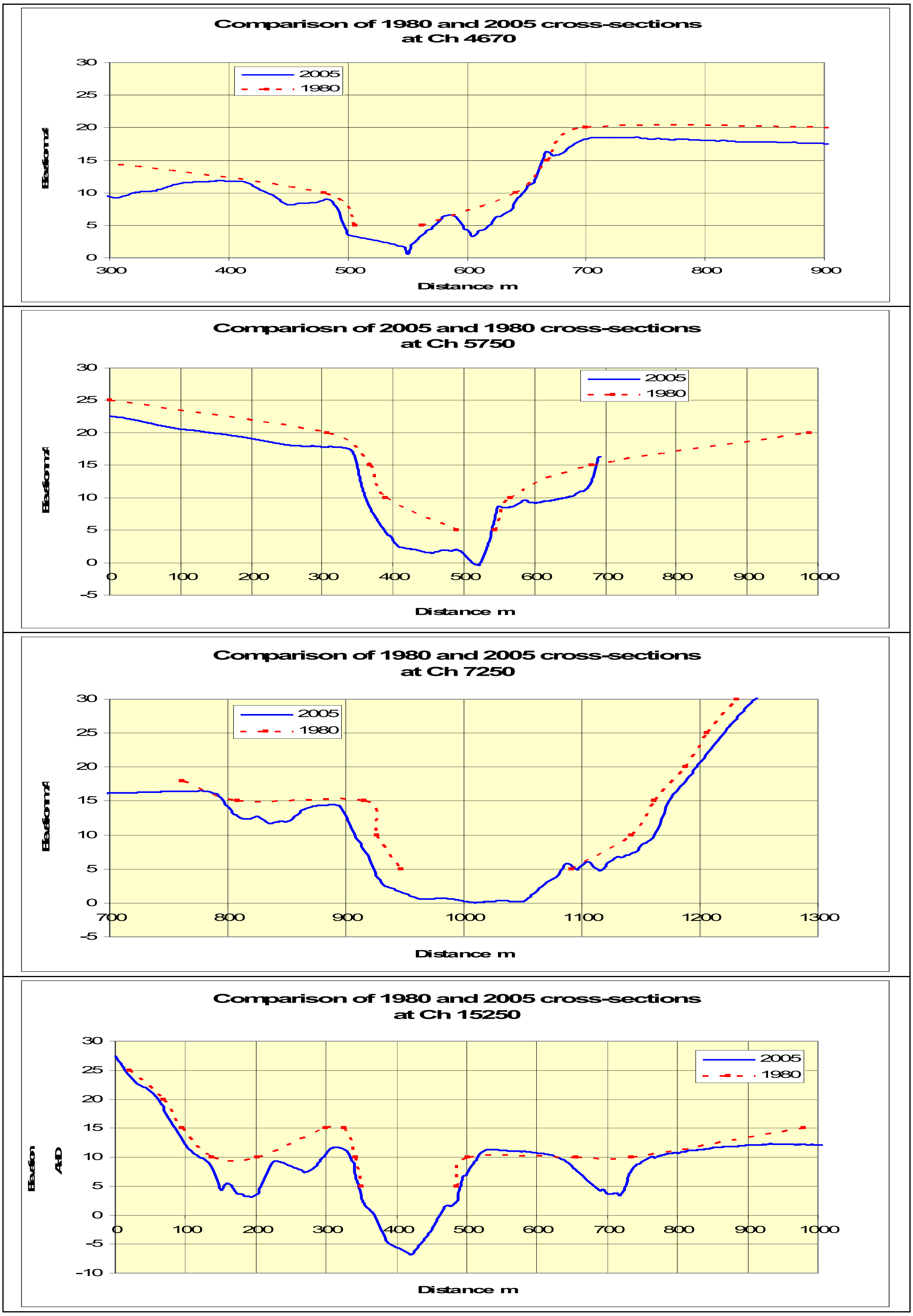


Figure 49 Comparison of 2005 and 1980 Cross Sections

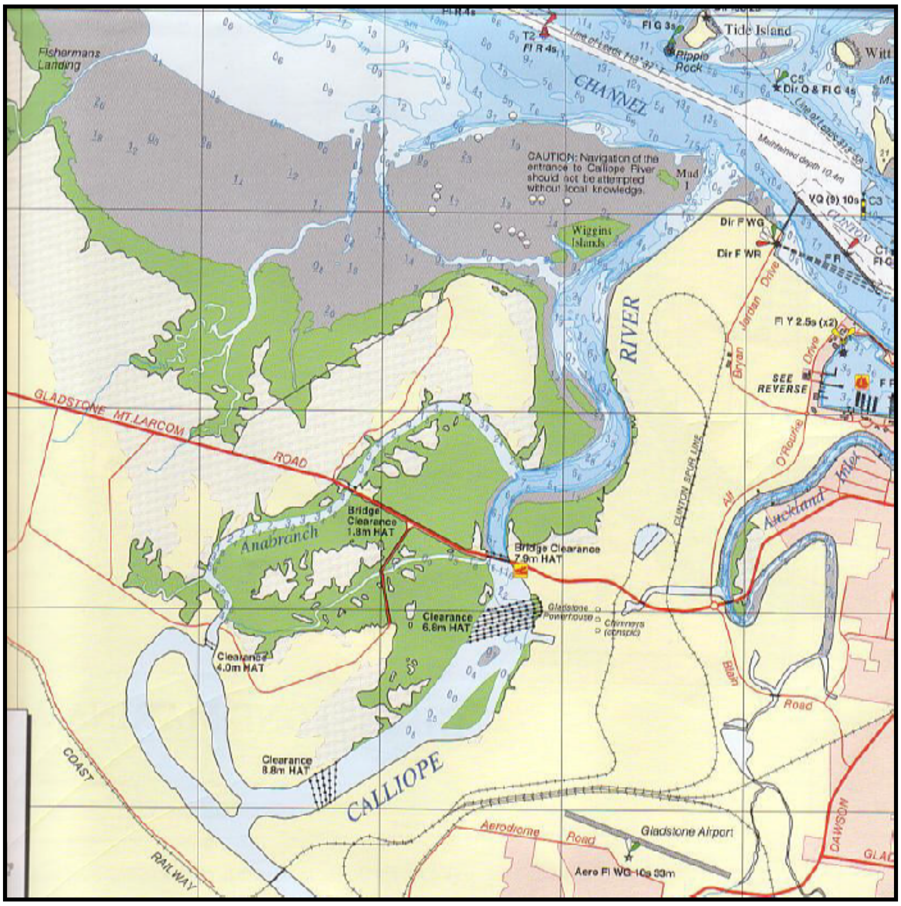


Figure 50 Part of Gladstone Harbour Chart
Reproduced from *Gladstone Boating Safety Chart* Capricorn Coast Series – Chart CC1 MARITIME SAFETY QUEENSLAND (2002)

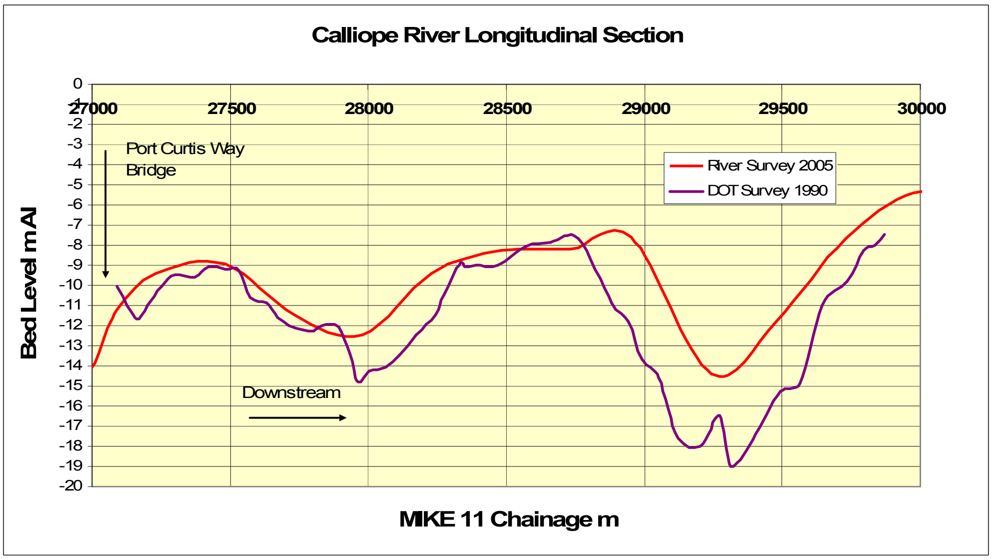


Figure 51 Comparison of River Bed Levels 1990 and 2005

6.7. Conclusions

The following have been concluded from this brief investigation of physical changes to the channel of the Calliope River over the last 100 years:

- There has been significant widening of the channel cutting across the neck of the large meander which contains the entry to the Anabranch over this period, from about 15m in 1892 to 50m in 1941 and to 200m today, with the rate of widening increasing since 1961 to 2.7 m/annum. This is consistent with the recent flood history;

- There has been a slower but still significant rate of widening at each of 3 other locations, namely: Devil's elbow, immediately upstream of Farmers Island and immediately upstream of the Calliope River/Leixlip Creek confluence. The rate of widening at these sites has also increased in the last 50 years and is currently about 0.5m per annum. Due to the consistency of these changes, it is reasonable to assume that these locations are typical of the whole of the study reach;

- The meander cutoff has shortened the river course by about 3.8 km resulting in an increased the gradient upstream. An increased gradient results in greater flow energy and erosion potential. As the rock control at the Bruce Highway should prevent any significant lowering there and upstream, when this deepening process is completed there would be a bed lowering of from zero to 1m though this reach, or an average of about 0.5m; and

- A comparison of cross sections between the 2005 mapping and the 1980 contour mapping at 12 locations (including sites upstream of the rock control at the Bruce Highway crossing) showed a lowering of levels within the higher parts of the channel which contain flow only during flood events. Whilst not of high accuracy due to the 1980 mapping having only 5m contours (i.e. possible errors of ± 2.5m), the consistency of these differences and with some being up to 5m suggests that these differences are not due to possible map error alone. This type of change is consistent with erosion during high flows. The hydraulic modelling has shown that average velocities in the major floods are of the order of 3m/s which is quite sufficient to cause significant erosion.

Hence, this investigation demonstrated that there has been quite significant change to the hydraulic capacity of the Calliope River as a result on ongoing fluvial geomorphologic change, the rate of which has increased post 1961.

Taken together, the channel changes indicated above are believed to be consistent with the difference in hydraulic roughness required to calibrate the 1973 and 2003 floods assuming that there had been no change in geometry.

Hence, it was concluded that the appropriate hydraulic roughness is that which gives the best fit to the flood which most resembles the current conditions, i.e. the February 2003 event. Using the higher roughness indicated by the 1973 flood calibration is not justified, as it is now clear that in 1973, the river cross section was smaller than at present, resulting in a higher than appropriate roughness being needed to compensate for the channel changes not being taken into account.

7. Design Flows

7.1. Direct Flood Frequency Analyses

Direct flood frequency analysis was undertaken on the flow records for the Calliope River at Castlehope.

The Queensland Department of Natural Resources, and Mines (DNRM) operates a stream gauging station on the Calliope River at Castlehope, which is at the upstream boundary of the area of interest for flood level estimation. This gauging station (No. 132001A) has been in operation since October 1938. The catchment area upstream of the gauging station is 1,310 km^2, compared to the total Calliope River catchment of 1,860 km^2. The location of the Castlehope gauging station is shown in **Figure 52**.

The following data for this station were extracted from the DNRME records:

- The Annual Maximum Series (on an October to September hydrologic year basis) for period 1940 to 2004 giving a record of 65 years; and

- The Partial Duration Series of flows for the same period which has a total of 65 flood events.

The annual maximum series comprises the highest flood flow for each hydrologic year on record, and the partial series comprises all independent flood events above a certain threshold. A disadvantage of the former is dealing with years in which no flood flows occur, when the inclusion of non-flood flows can bias the skewness of the fitted statistical distribution. Also, information regarding a succession of floods in a single year is lost in this process.

On the other hand, the partial series excludes these non-flood discharges, and does not lose the information regarding other floods in a given year. The partial series is particularly useful in respect of high frequency (low ARI) floods, but the two series generally converge as ARI increases.

A plot of each series is given in **Figure 53**, and the data used in the analysis are given in **Appendix C**.

L-moments of the annual maximum series (Hosking & Wallace 1997) were computed as a guide to the most appropriate statistical distribution. This indicated the Log Pearson Type III (LP3) distribution. This is also the statistical distribution recommended in *Australian Rainfall and Runoff* (IEAust 1987). The details of this analysis are given in **Appendix D.**

The annual maximum series was then analysed using the Log Pearson Type III (LP3) statistical distribution and other possible distributions using the maximum likelihood approach with Monte Carlo Simulation using the computer program FLIKE (Kuczera 1999). This also showed that the LP3 distribution fitted the data better than any of the other distributions tested.

On the basis of all the above factors, the LP3 distribution was preferred and has been used as the basis of the flood frequency analysis.

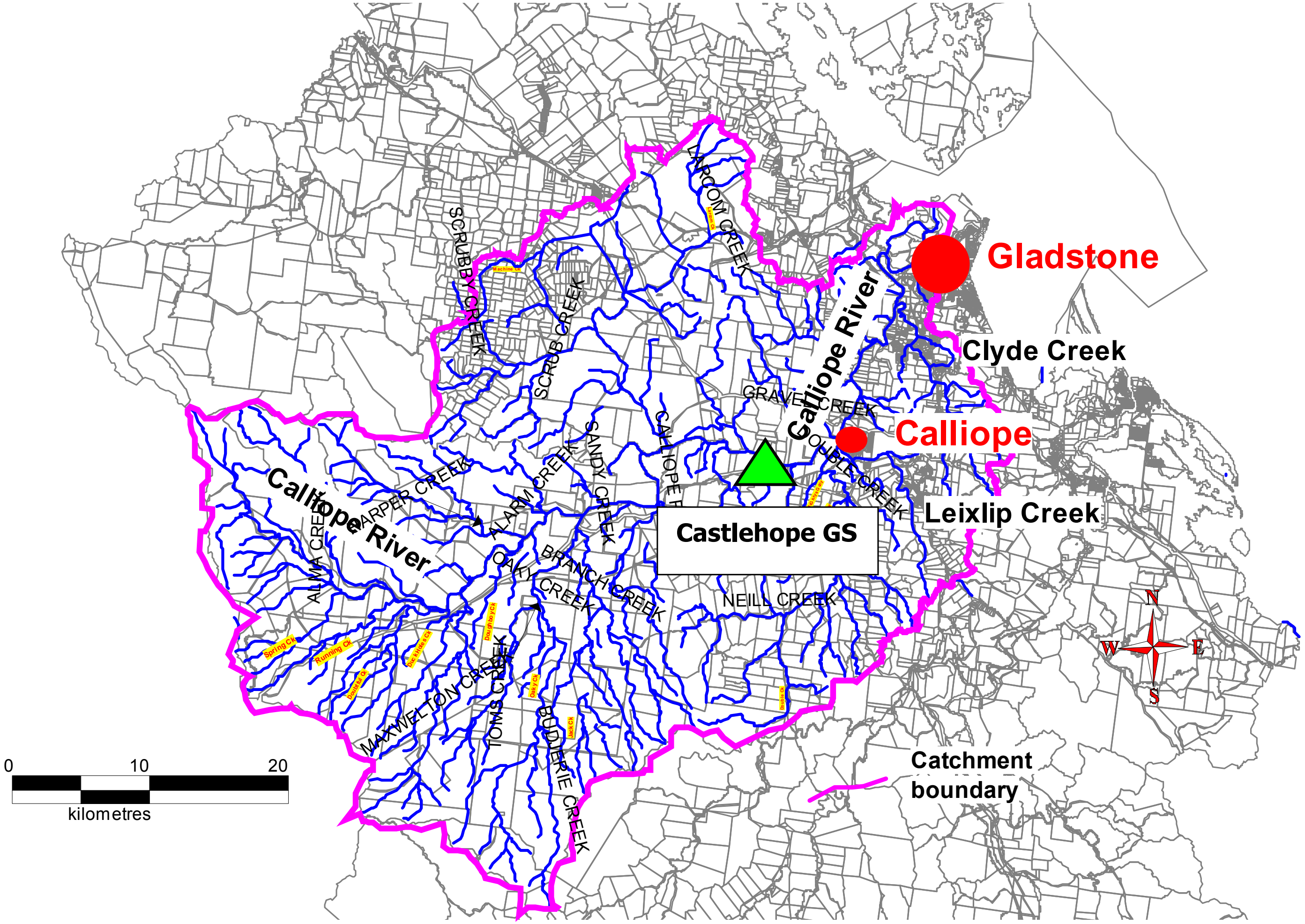
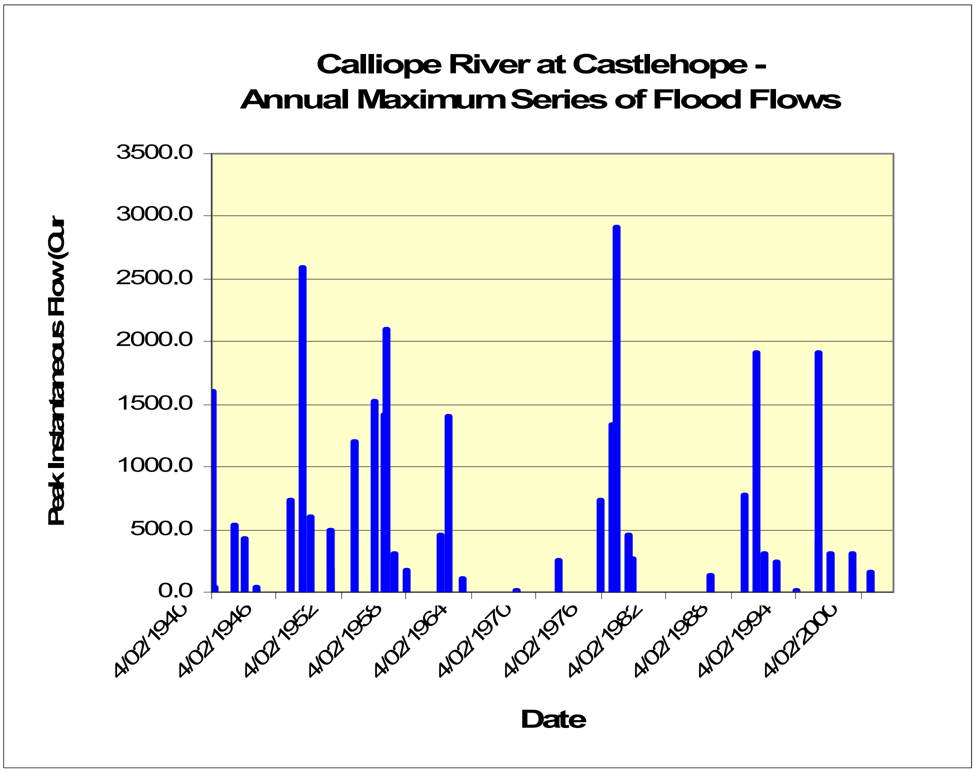


Figure 52 Calliope River Catchment



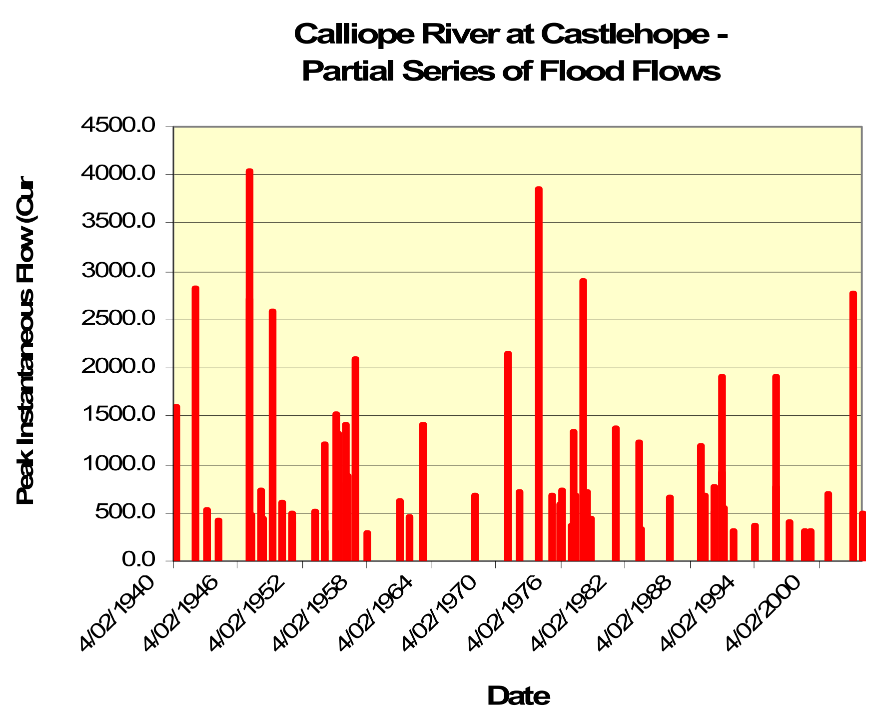


Figure 53 **Calliope River at Castlehope Annual Maximum and Partial Series of Peak Instantaneous Flow**

The fitted LP3 distribution is shown in graphical form in **Figure 54** (in both arithmetic and logarithmic scales) together with the 90% confidence band, whilst **Table 15** gives peak flood flows (and the 90% confidence band) for a range of average recurrence intervals (ARIs) estimated from the fitted distribution.

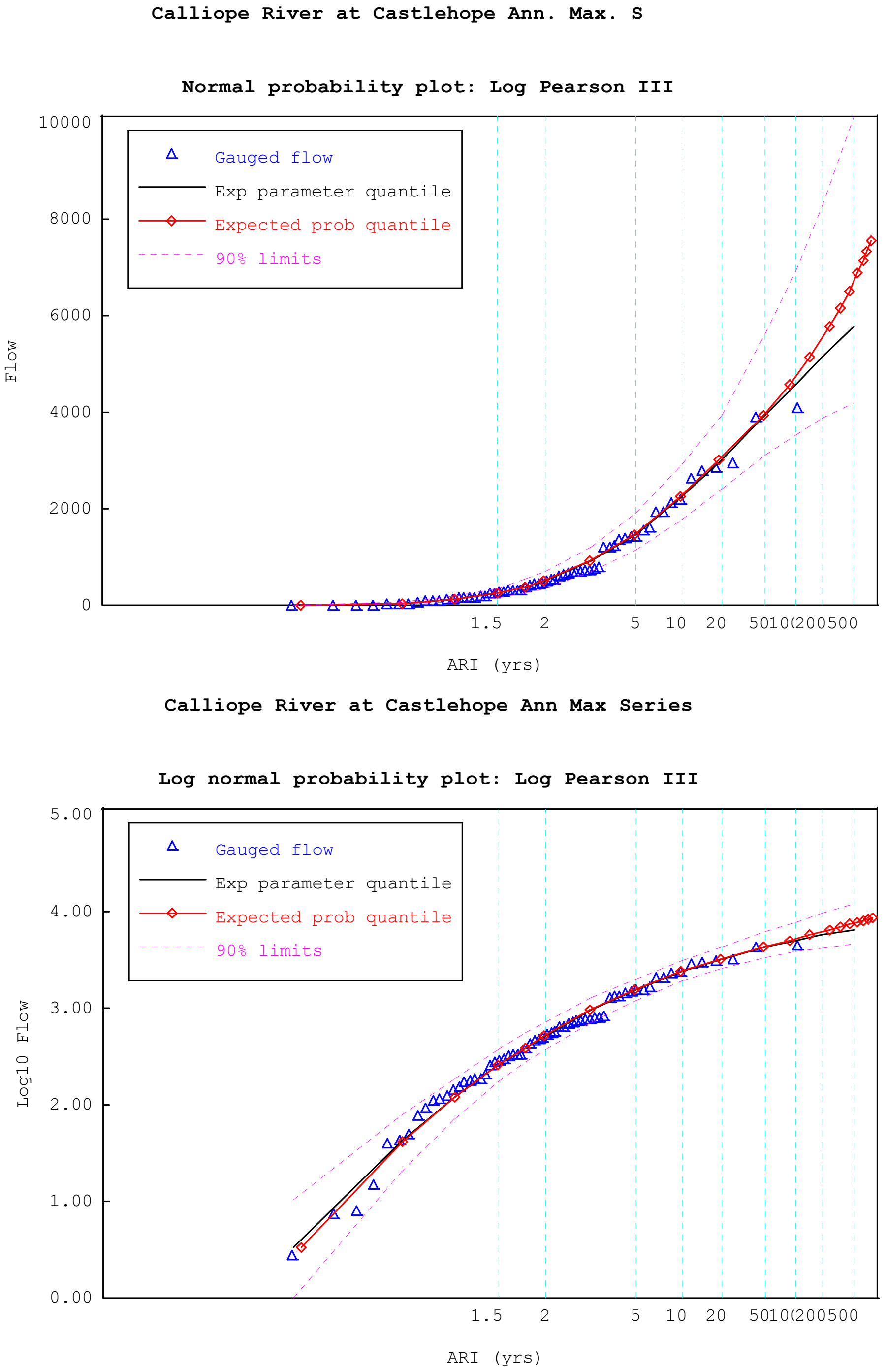


Figure 54 **Calliope River at Castlehope – Fitted Flood Frequency Curve**

Table 15 Calliope River at Castlehope Design Flow Estimates using LP3 Distribution

Average Recurrence Interval (ARI) Years	Estimated Instantaneous Peak Flow m^3/s		
	Central Estimate	90% Confidence Band	
5	1,500	1,100	1,900
10	2,200	1,750	2,900
20	3,000	2,350	3,900
50	3,900	3,050	5,550
100	4,500	3,500	6,800
200	5,000	3,800	8,200
500	5,700	4,100	10,000
1000	6,100	4,300	11,700

The partial series analysis was undertaken using the *Peaks over Threshold* (POT) method (Kottegoda 1980). For the POT model, the sensitivity of the results to the choice of threshold (i.e. flood peaks below the chosen 'threshold' are excluded from the analysis) was investigated and found to be quite sensitive. The details of these analyses are given in **Appendix D** and the results are shown for the lowest and highest threshold values used in **Figure 55.** These curves converge and cross at an ARI of 5 years (20% AEP).

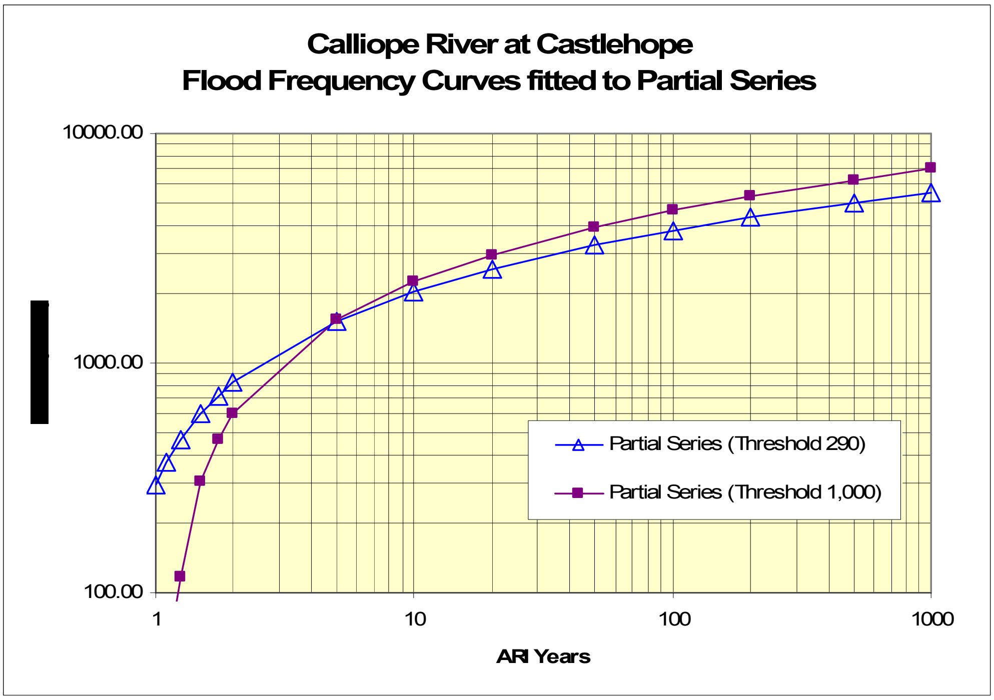


Figure 55 Flood Frequency Curves for Partial Series

In **Figure 56** the partial series results given in **Figure 55** and the annual maximum series results are superimposed.

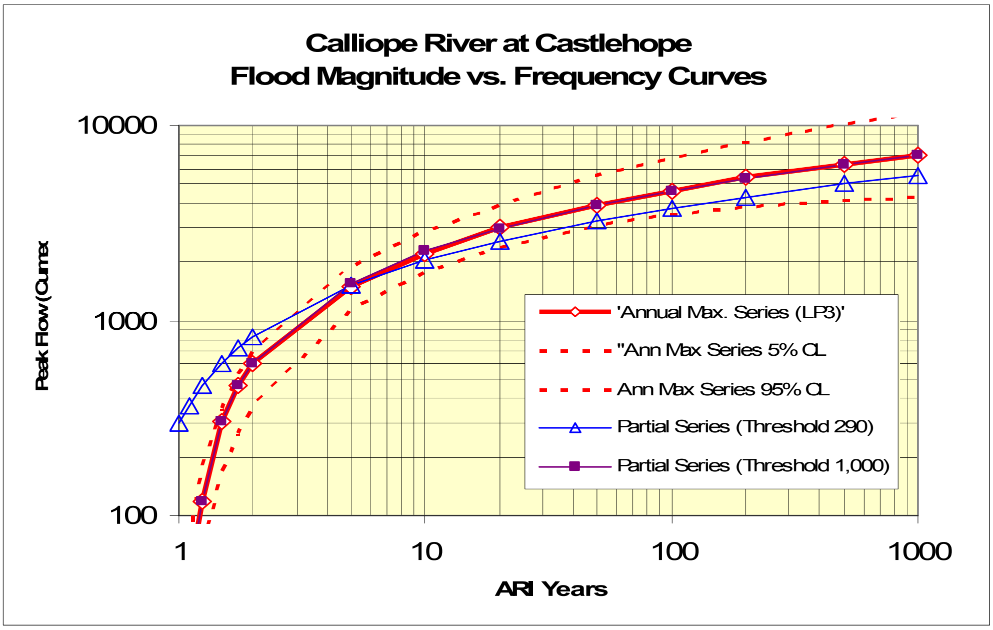


Figure 56 **Flood Frequency Curves for Annual Maximum and Partial Series**

As is normally the case, the partial series gives higher values than the annual maximum series for high frequency events, but these curves should, ideally, converge for the lower frequency (i.e. larger magnitude events). From **Figure 56**, it can be seen that the partial series curve using the high threshold level of 1,000m^3/s (i.e. floods with peaks less than 1,000m^3/s were excluded from the analysis) is very similar for ARIs from 5 years to 100 years, whereas that with the lower threshold of 290m^3/s is considerably higher for ARIs less than 5 years, the same at 5 years, and lower for all ARIs greater than 5 years. It can also be seen from **Figure 56** that all of these curves (with the exception of the low threshold partial series curve for ARIs between 1 and 2 years) lie within the 90% confidence band of the distribution fitted to the annual maximum series.

Given the closeness of these curves, and that the smallest flood for which estimates are required is 10% AEP (10 year ARI), it was decided to use the distribution fitted to the annual maximum series as the basis for the design flood estimation, thereby enabling the confidence bands to be quantified. These values are given in **Table 15**. However, in order to be conservative in respect to the more extreme floods the slightly higher values from the partial series were used for ARIs in excess of 100 years. **Table 16** shows the adopted values.

The largest historic floods were attributed probabilities on the basis of this distribution, as listed in **Table 17**, from which it can be seen that the flood of record (February 1947) has an AEP of about 1.7%, or about 60 year ARI. It should also be noted, that the 90% confidence band on these estimates is quite wide, from 25 to 500 years for the 1947 flood.

These curves are compared with results from the preliminary design runs of the hydrologic model in **Section 7.2** hereof.

Table 16 Calliope River at Castlehope Adopted Flood Frequency Curve

Average Recurrence Interval (ARI) Years	Estimated Instantaneous Peak Flow m^3/s		
	Central Estimate	90% Confidence Band	
5	1,500	1,100	1,900
10	2,200	1,750	2,900
20	3,000	2,350	3,900
50	3,900	3,050	5,550
100	4,700	3,500	6,800
200	5,600	3,800	8,200
500	6,700	4,100	10,000

Table 17 Estimated Probabilities of Historic Floods

Date of Historic Flood Peak	Peak Flow (Cumecs)	Estimated Probability			
		AEP %	ARI Years	90% Confidence Band (Years)	
12/02/1947	4040	1.7%	60	25	500
20/12/1973	3860	2.0%	50	20	300
31/01/1978	2910	5.0%	20	12	50
6/02/2003	2770	6.7%	15	8	20
29/12/1990	1910	12.5%	8	5	13

7.2. Design Flow Estimates from RORB Model

Design flow estimates were also produced using the RORB model both to provide estimates independent of the flood frequency analysis and also to provide design tributary flows for input to the design runs of the hydraulic model. This process is described in this section.

The fundamental difference of this approach to that based on the frequency analysis of flow records is that the hydrologic model approach relies on rainfall probabilities and the assumption that the runoff probability is equal to the rainfall probability. This is only the case where all other variables eg rainfall loss rates have probability neutral (i.e. median) values.

7.2.1. Design Criteria

The following are the basic design criteria to be utilised with the hydrologic model (RORB) for this study:

- The study brief requires design flow estimates for ARIs of 10, 20, 50 and 100 years and for the probable maximum flood (PMF);

- The calibration phase of the hydrologic model studies determined that the best combination of RORB model parameters for the Calliope River model is k_c = 44.5 and m = 0.88 (refer to **Section 4** hereof);

- ARR (IEAust 1987 and updates) states that the median initial loss for Queensland is in the range 15 to 35mm. The following values were used in the estimation of the preliminary design flows: 35, 30, 25 and 20mm for ARIs of 10, 20, 50 and 100 years respectively. These were subsequently modified to a constant value of 20mm for all ARIs;

- ARR (IEAust 1987 and updates) states that the median continuing loss for Queensland is 2.5 mm/hr. This value was used in the preliminary design runs and subsequently modified to 2.8mm/hr to obtain the best overall fit; and

- The RORB model estimates the rapid (or surface) runoff component of the total flow hydrograph, so baseflow has to be added to obtain the total flow hydrographs. However, in the calibration phase baseflows were found to be negligible in this catchment (refer to **Milestone Report 1**), so no baseflow allowance has been added to the design flows.

The sensitivity of the design flow rates to these parameter values were tested as described in **Section 7.2.4.**

7.2.2. Preliminary Design Runs

Preliminary runs of the RORB model were made to determine the critical storm durations for the catchment. These were made using a single design rainfall input for the catchment area to Castlehope using the data and procedures in ARR (1987) as incorporated into the RORB model software. The preliminary runs were based on current catchment conditions.

Table 18 gives the estimated peak flows from these runs for a range of storm durations and ARI for the Calliope River at Castlehope and at the river mouth and for Leixlip Creek at Clyde Creek at the upstream limit of the hydraulic model.

It can be seen from **Table 18** that the critical storm duration for flows at Castlehope is 30 hours for ARIs of 10, and 20 years, 18 or 30 hours for 50 year ARI and 18 hours for an ARI of 100 years. At the river mouth, the 18 hour duration storm was critical for the whole range of ARIs.

For Leixlip Creek, the critical duration was 2 hours for ARIs of 10 and 20 years, 3 hours or 9 hours for 50 year ARI and 9 hours for 100 year ARI.

For Clyde Creek, the critical duration was 6 hours for ARIs of 20, 50 and 100 years, but 36 hours for 10 year ARI, the last of these results appearing somewhat anomalous.

Comparison of the initial RORB estimates at Castlehope in **Table 18** with those from the direct flood frequency analysis in **Table 16**, shows that the RORB values were 5% to 16% less than those from the frequency analysis.

Whilst these differences could be reduced by modification to the RORB parameters, the RORB analysis was first repeated using an alternative rainfall dataset as outlined in **Section 7.2.3** in order to see if these gave results more consistent with those from the flood frequency analysis.

7.2.3. Runs Based on CRC-Forge Data

A new set of design rainfall data for long duration storms and for moderate to high ARI called CRC-FORGE has recently become available. This gives design rainfalls for durations of 1 to 5 days for ARIs 50 to 2,000 years for individual rainfall stations. Developed initially by the CRC for Catchment Hydrology CRCCH) for Victoria, this has now been applied to Queensland in a joint project between CRCCH, DNRM and BOM.

CRC-FORGE is a statistical (regional) analysis method that provides estimates of rare rainfall events at individual stations. However, for each station, the process includes a plot of that station's data *alone* - using a conventional (modified Cunnane) plotting position formula.

Therefore, in the ARI range 50 to 100 years, CRC-FORGE provides a fresh analysis of more up-to-date daily rainfall data for individual stations when compared with ARR.

The analysis of the daily rainfall data set (and limited pluviograph data) performed for ARR 1987 was smoothed across regions. There is some evidence to suggest that this has resulted in non-conservative design values in some geographic areas.

The Queensland CRC-FORGE project adopted the 50 and 100 year ARI estimates in preference to the values given by the procedures and data in ARR 1987 (J. Ruffini pers. com.). DNRM has provided the CRC-FORGE data for use in this study.

The availability of these estimates on a station by station basis facilitates the representation of rainfall variation across a catchment, and also enables the rainfall weighting procedure used in the design runs to replicate that used in model calibration.

Figure 57 shows the location of rainfall stations for which the CRC-Forge data are available in and close to the Calliope River Catchment. The design rainfalls for these stations were used to estimate the 50 year and 100 year catchment rainfalls for durations of 24 and 48 hours, the only relevant combinations for which a direct comparison could be made with the corresponding values from the ARR (1987) datasets. **Table 19** lists these values.

Figures 58 to **61** show the distribution of the catchment rainfalls for these events using the CRC-Forge design rainfalls.

It can be seen from **Table 19** that the CRC-FORGE data are all marginally higher than the ARR catchment estimate (7% to 8% for the 24 hour storms and 1% to 3% for 48 hour storms). Given that there were differences in the way these estimated were computed, these estimates are small.

It was decided that the use of the CRC-FORGE estimates was preferable, as their spatial distribution is both more representative of the variation over the catchment, and the procedure used with these data is the same as that used in the calibration phase.

Table 18 Preliminary RORB Estimates of Peak Flows 10 to 100 Year ARI

ARI	IL	Calliope R at Castlehope												
		1.5	2	3	4.5	6	9	12	18	24	30	36	48	72
10	35					1290	1530	1668	1785	1376	1847	1770	1325	1456
20	30					1900	2210	2413	2465	1970	2493	2424	1916	2026
50	25					2692	3133	3425	3446	2829	3447	3290	2764	2974
100	20					3408	3936	4253	4279	3581	4251	4100	3511	3558

ARI	IL	Leixlip Ck at Upstream Boundary of Hydraulic Model												
		1.5	2	3	4.5	6	9	12	18	24	30	36	48	72
10	35	83	103	101	95	98	90	97	87	84	78	86	67	62
20	30	128	140	137	126	131	138	127	110	133	99	109	96	82
50	25	182	188	191	177	180	190	164	133	180	122	133	136	102
100	20	224	227	232	228	224	234	207	165	206	149	158	169	125

ARI	IL	Clyde Ck at Upstream Boundary of Hydraulic Model												
		1.5	2	3	4.5	6	9	12	18	24	30	36	48	72
10	35	51	84	123	143	145	133	114	124	123	140	156	111	101
20	30	96	137	186	200	204	174	165	159	184	181	201	164	135
50	25	157	210	268	274	279	226	240	204	251	230	252	233	174
100	20	211	269	334	337	342	270	300	246	307	276	302	289	221

ARI	IL	Calliope R at Mouth												
		1.5	2	3	4.5	6	9	12	18	24	30	36	48	72
10	35					1240	1662	1880	2170	1954	2150	1950	1630	1690
20	30					1890	2425	2755	3116	2810	2941	2689	2370	2368
50	25					2748	3465	3964	4468	3982	4116	3700	3490	3310
100	20					3544	4380	4953	5600	4985	5095	4645	4474	4270

Note: Standard RORB runs for durations < 6 hours were not of sufficent length for peak flow to be reached in Calliope River

Table 19 Comparison of ARR and CRC-FORGE Design Rainfalls

Dataset	Duration Hours	Design Rainfall Total mm	
		50 year ARI	100 Year ARI
ARR (1987)	24	305	356
	48	424	500
CRC-FORGE	24	330	382
	48	438	504
CRC-FORGE/ ARR	24	1.08	1.07
	48	1.03	1.01
NOTE: ARR (1987) values based on a single rainfall estimated at the catchment centroid to which an areal reduction factor has been applied			
NOTE: CRC-FORGE values based on estimated catchment rainfalls based on weighted average in each sub area			

In order to estimate the critical storm durations using the CRC-FORGE data set, initially for 50 and 100 year ARI only, the RORB model was run using estimates of the CRC-FORGE point rainfalls for ARIs of 50 and 100 years for storm durations of 12, 18, 30 and 36 hours which were estimated on the basis of multiplying the 24 hour CRC-FORGE value by the ratio of ARR rainfalls for those durations and ARIs to the corresponding 24 hours value.

The rainfall temporal patterns from ARR (1987) were retained. This is equivalent to using only one pluviograph station as the same pattern is used across the catchment. Even given the latter limitation, this approach is better than using both spatial and temporal averaging as is usually adopted.

Table 20 lists the preliminary design estimates using the RORB model with the CRC-FORGE design rainfalls as outlined above, and **Table 21** compares the corresponding values from the flood frequency analysis with the 2 sets of preliminary RORB results.

It can be seen from **Table 21** that the peak flows estimated from the RORB model using CRC-FORGE rainfalls are closer to those obtained from the flood frequency analysis being 2% lower and 2% higher for the 50 and 100 year ARIs respectively, compared to -12% and -7% for the corresponding values based on ARR rainfalls.

The values from the direct frequency analysis are the primary estimates of peak flow as these are based on streamflow records for the site and not on rainfall to runoff modelling. Also this record is of reasonable length (65 years) and the statistical analysis resulted in a good fit. However, only peak flows can be estimated from these records, and it is necessary to use the rainfall – runoff model for the estimation of streamflow hydrographs for input to the hydraulic model. Hence, it is preferable for the RORB model estimates to be as consistent as possible with those from the flood frequency analysis.

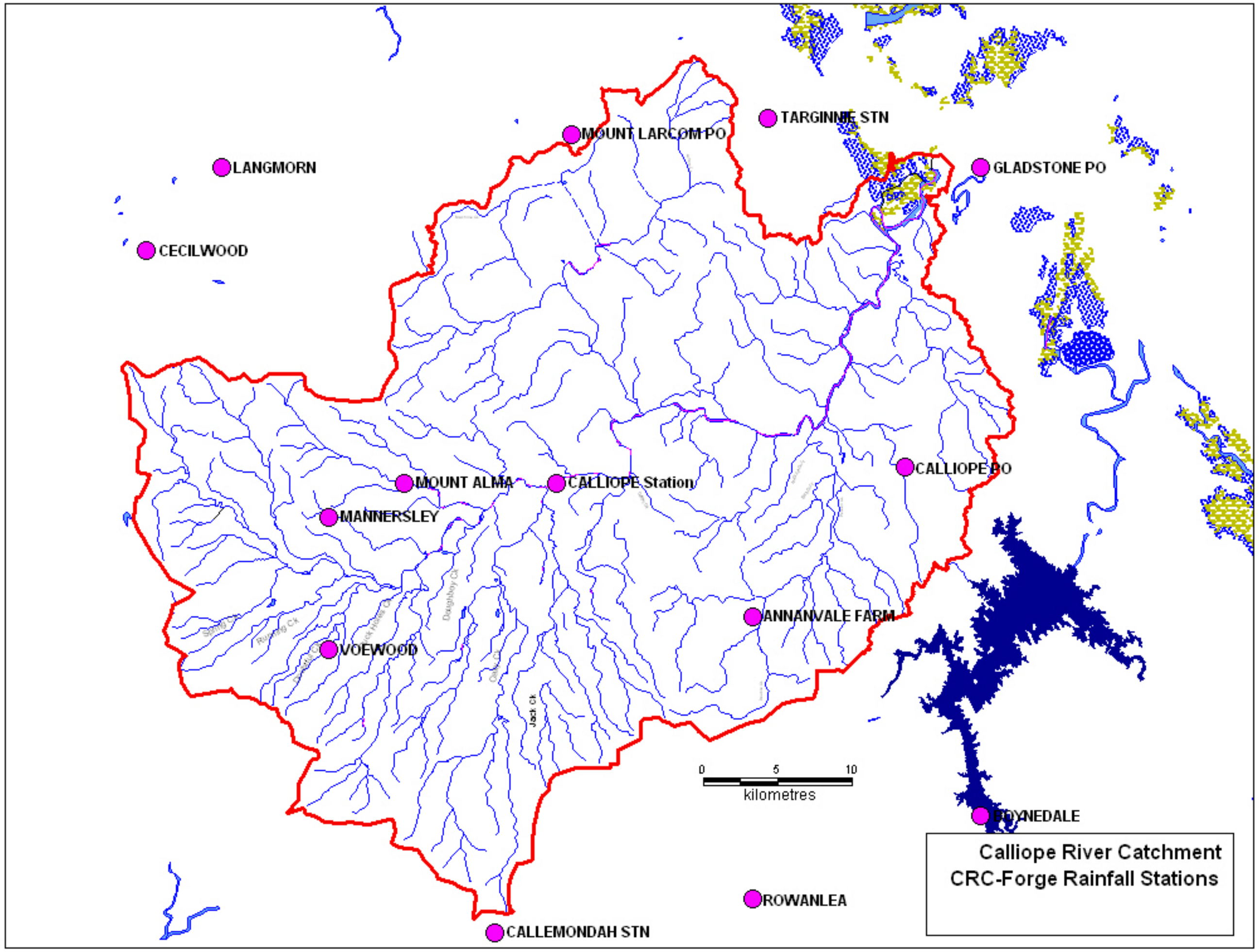


Figure 57 Location of Rainfall Stations with CRC-Forge Design Estimates

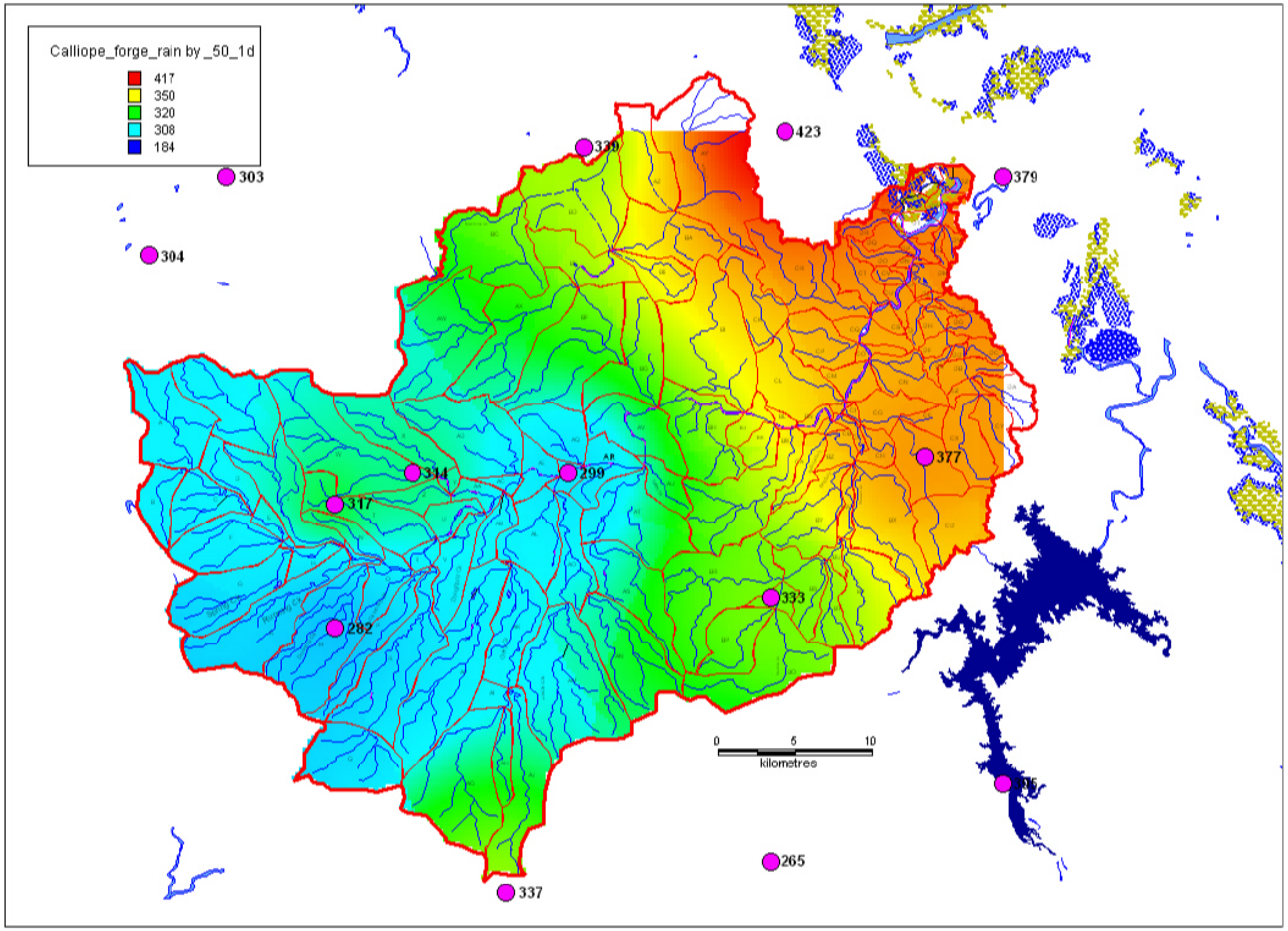


Figure 58 **Distribution of CRC-Forge Rainfall for 50 year ARI, 24 Hour Storm Duration**

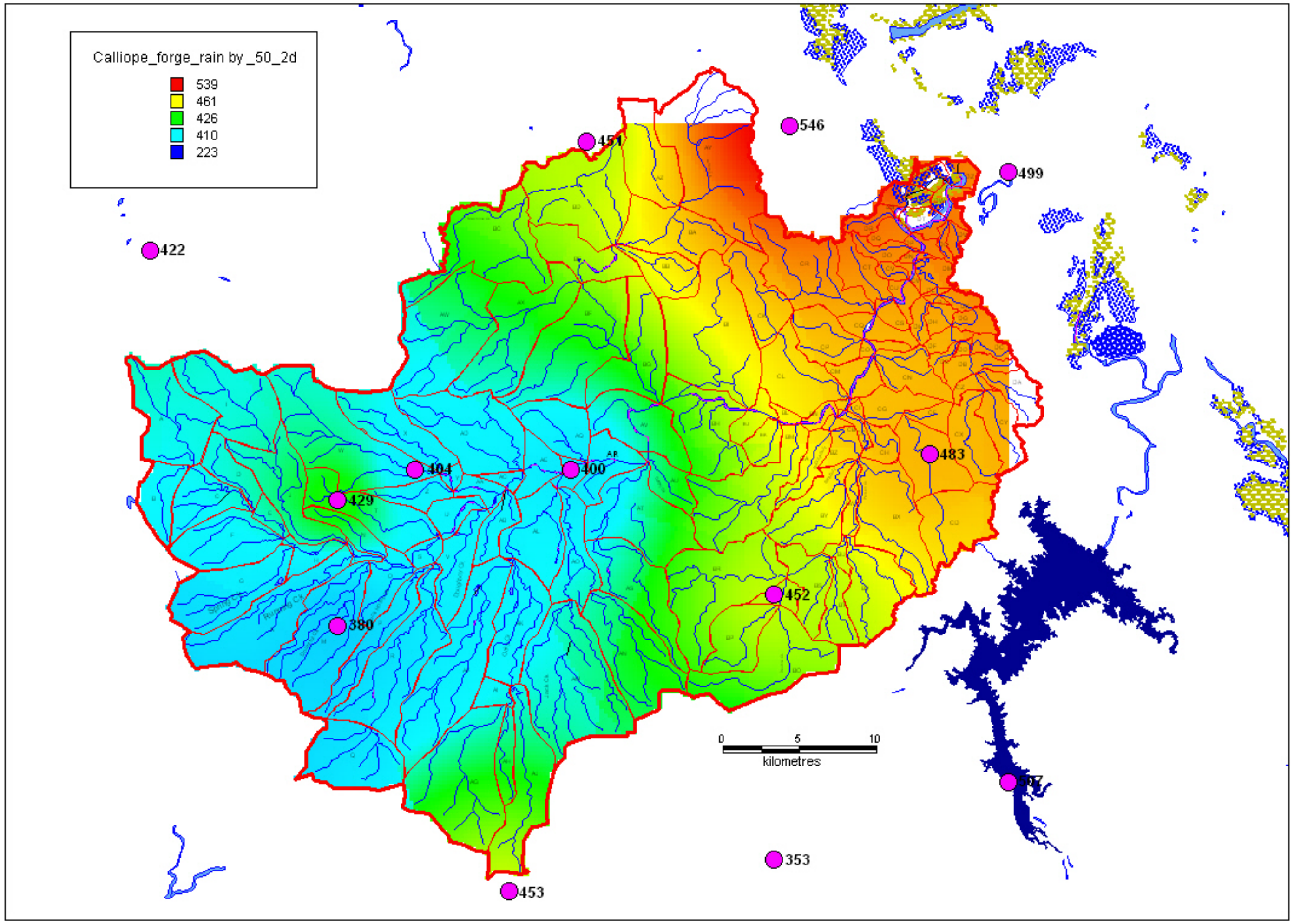


Figure 59 Distribution of CRC-Forge Rainfall for 50 year ARI, 48 Hour Storm Duration

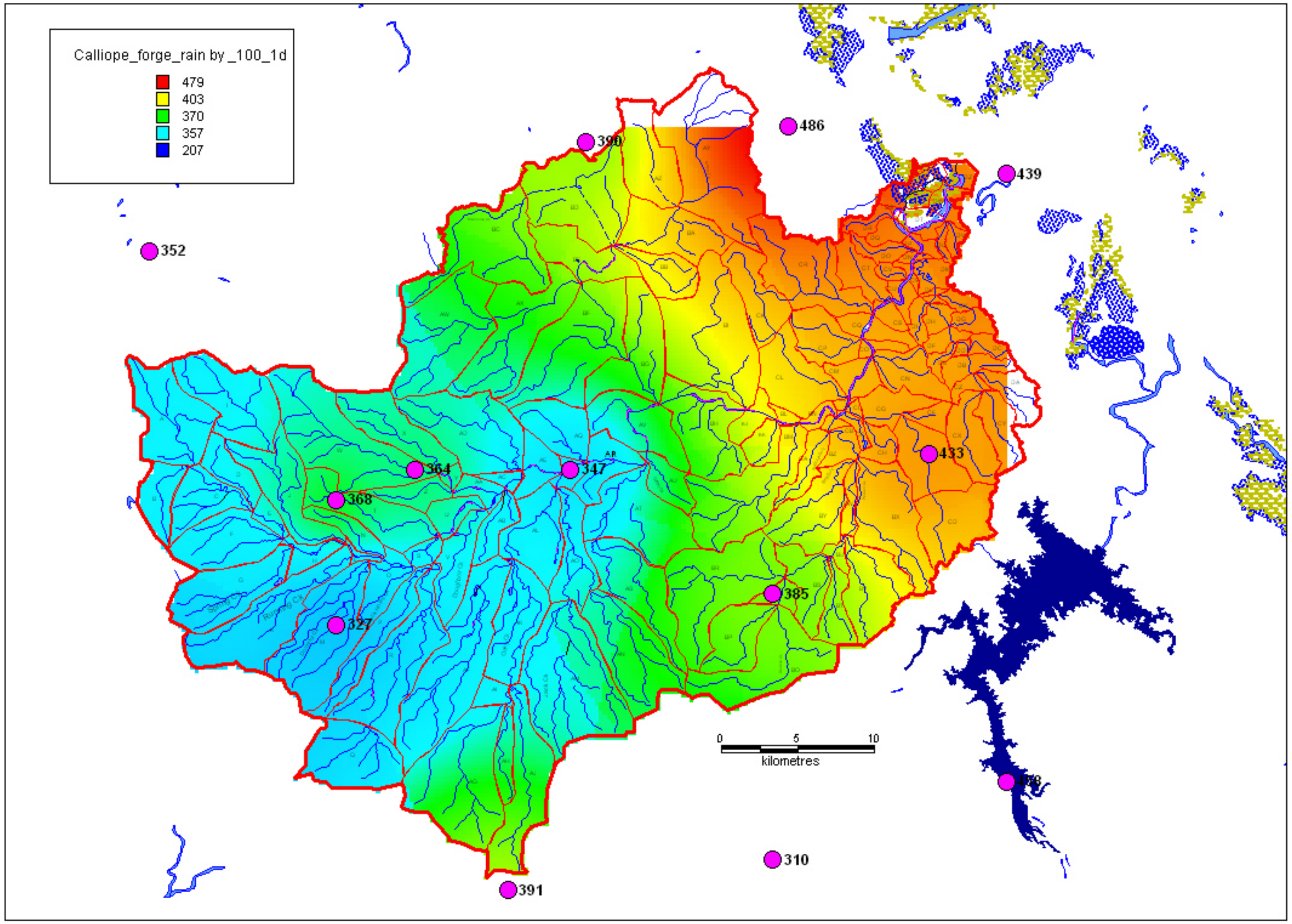


Figure 60 Distribution of CRC-Forge Rainfall for 100 year ARI, 24 Hour Storm Duration

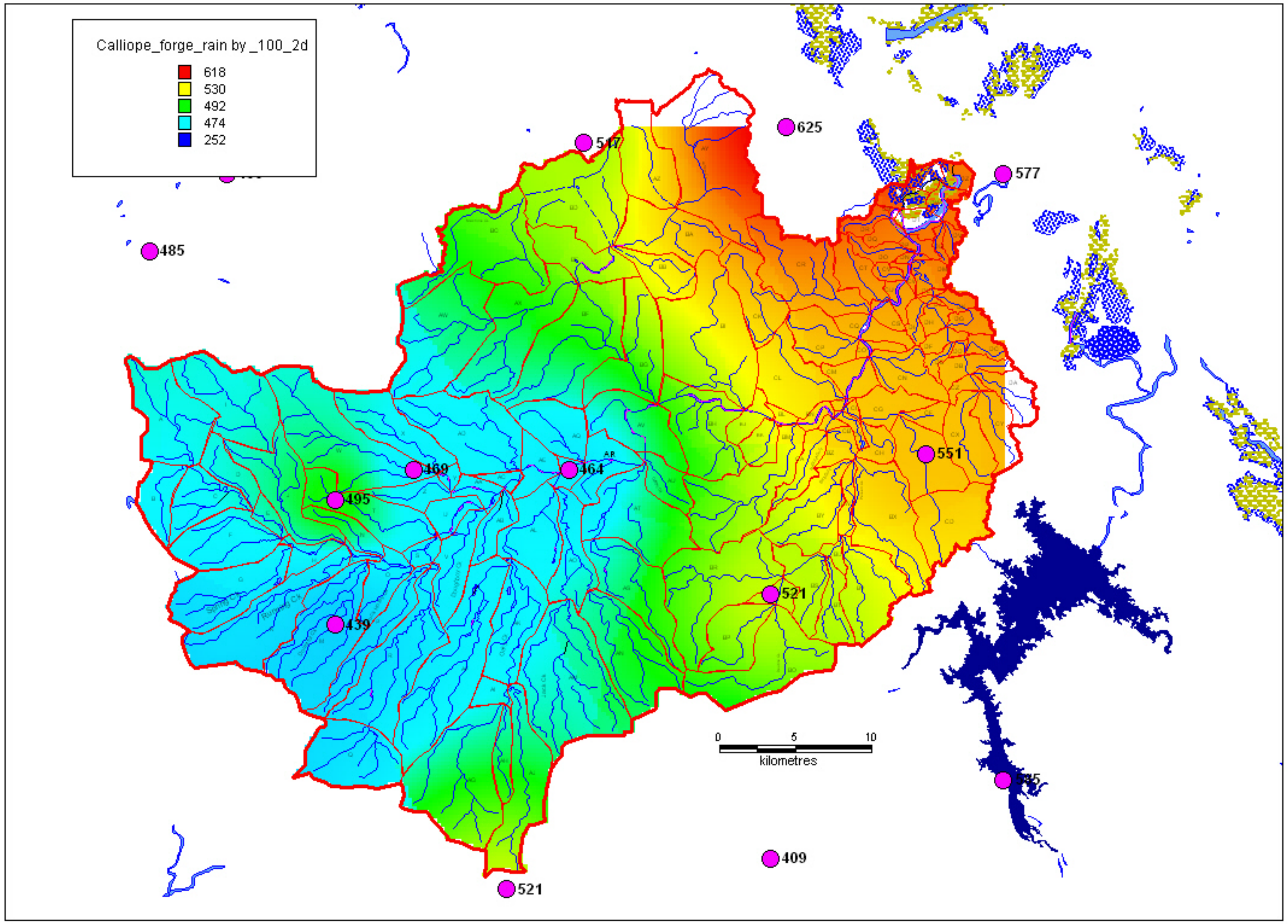


Figure 61 **Distribution of CRC-Forge Rainfall for 100 year ARI, 48 Hour Storm Duration**

Table 20 Preliminary Design Flow Estimates using CRC-FORGE Rainfalls

ARI	IL	Calliope R at Castlehope					
		12	18	24	30	36	48
50	25	3739	3826	3487	3747	3485	2890
100	20	4626	4702	4369	4532	4243	3517

ARI	IL	Leixlip Ck at Upstream Boundary of Hydraulic Model					
		12	18	24	30	36	48
50	25	257	178	279	159	169	173
100	20	313	228	325	186	197	212

ARI	IL	Clyde Ck at Upstream Boundary of Hydraulic Model					
		12	18	24	30	36	48
50	25	384	281	415	312	329	302
100	20	466	329	515	367	388	370

ARI	IL	Calliope R at Mouth					
		12	18	24	30	36	48
50	25	4370	5136	4719	4774	4137	3825
100	20	5425	6330	5835	5790	5065	4650

Table 21 Comparison of Peak Flow Estimates – Preliminary Results

AEP %	ARI Years	Peak Flows for Calliope River at Castlehope (Cumecs) based on				
		Direct Flood Frequency Analysis (FFA)	RORB Model with ARR Rainfalls		RORB Model with CRC-FORGE rainfalls (% of value from FFA)	
			Peak Flow	% of value from FFA	Peak Flow	% of value from FFA
10%	10	2,200	1,850	84.1%		
5%	20	3,000	2,490	83.0%		
2%	50	3,900	3,450	88.5%	3,830	98.2%
1%	100	4,600	4,280	93.0%	4,700	102.2%

Further runs of the RORB model were undertaken to see if this could be achieved by varying the assumed initial loss and/or continuing loss rates. This is described in **Section 7.2.4**.

7.2.4. Refined Model Runs

As noted above, further RORB model runs were undertaken to refine the model fit over the range of ARIs of interest.

It was found that the best results were obtained using an initial loss of 20mm and a continuing loss of 2.8mm/hr. These results are summarised in **Table 22**.

These results were also extended to 0.5% and 0.2% AEP (200 years and 500 years ARI) using the CRC-FORGE estimates for 24 and 48 hours and the same ratios for other durations as used for the 100 year values (this was necessary as the ARR values are to 100 year ARI only).

Table 22 Comparison of Peak Flow Estimates – Refined Results

AEP %	ARI Years	Peak Flows for Calliope River at Castlehope (Cumecs) based on				
		Direct Flood Frequency Analysis (FFA)	RORB Model with ARR Rainfalls		RORB Model with CRC-FORGE rainfalls (% of value from FFA)	
			Peak Flow	% of value from FFA	Peak Flow	% of value from FFA
10%	10	2,200	2,200	100.0%	2,140	97.3%
5%	20	3,000	2,900	96.7%	2,820	94.0%
2%	50	3,900	3,940	101.0%	3,810	97.7%
1%	100	4,600	4,800	104.3%	4,610	100.2%

It can be seen from **Table 22**, that agreement between the peak flows estimated from the RORB model using both the ARR and CRC-FORGE datasets and those from the flood frequency analysis were considerably improved by this procedure.

Consequently, these loss parameters were adopted for the model design runs. Also, even though the ARR results were good for the Calliope River at Castlehope, the use of the CRC-FORGE dataset is believed to give improved estimates of downstream and tributary inflows due to the spatial distribution detail used with this data set and its taking account of the increase in rainfalls nearer to the coast, as illustrated in **Figures 58** to **61**.

The RORB model was run with a full range of storm durations with these parameters, with the results summarised in **Table 23**. These represent the final design values for existing conditions.

The critical durations from these runs differ in some instances from those in the preliminary runs, with 12 hours being critical for 10 and 20 year ARIs at Castlehope and 18 hours for ARIs of 50 and 100 years. At the Calliope River mouth the 18 hour storm was found to be critical for all ARIs. For Leixlip Creek and Clyde Creek the critical duration was again the same for all ARIs at 3 hours and 24 hours respectively.

The relevant range of storm durations will be used in conjunction with the hydraulic model in order to ensure that the envelope of flood levels for a given ARI is determined.

7.2.5. Sensitivity Testing

Initial sensitivity of the design flows was tested by varying each parameter through its likely range of uncertainty then re-running the RORB program to quantify the changes in design flows. In order to limit the number of runs, this was limited to the 100 year ARI for the principal critical storm duration of 18 hours only, and for the rainfall data obtained using the CRC-FORGE dataset.

Table 23 Estimated Peak Flows from Final RORB Design Runs (Existing Conditions)

ARI	IL mm	CL mm/hr	Peak Flow (Cumecs) - Calliope R at Castlehope for Storm Duration (Hours)										
			2	3	4.5	6	9	12	18	24	30	36	48
10	20	2.8	882	1188	1455	1700	1905	2139	2100	1970	1986	1857	1568
20	20	2.8	1150	1546	1900	2220	2533	2817	2771	2650	2674	2512	2219
50	20	2.8	1510	2035	2546	2944	3405	3784	3814	3515	3653	3394	2775
100	20	2.8	1805	2414	3030	3505	4100	4549	4608	4288	4434	4149	3400
200	20	2.8		2926				5462	5510	5140			
500	20	2.8		3685				6810	6826	6380			

ARI	IL mm	CL mm/hr	Peak Flow (Cumecs) - Leixlip Ck at Upstream Boundary of Hydraulic Model for Storm Duration (Hours)										
			2	3	4.5	6	9	12	18	24	30	36	48
10	20	2.8	194	214	196	178	191	177	116	193	102	108	123
20	20	2.8	250	268	251	224	241	227	150	240	129	137	164
50	20	2.8	297	313	295	262	279	267	188	278	157	167	178
100	20	2.8	342	359	342	303	320	311	226	323	184	195	210
200	20	2.8		426				366	270	378			
500	20	2.8		525				448	336	446			

ARI	IL mm	CL mm/hr	Peak Flow (Cumecs) - Clyde Ck at Upstream Boundary of Hydraulic Model for Storm Duration (Hours)										
			2	3	4.5	6	9	12	18	24	30	36	48
10	20	2.8	188	235	242	254	202	255	169	269	191	204	209
20	20	2.8	240	295	305	322	260	325	214	353	246	261	279
50	20	2.8	309	377	385	398	324	395	277	427	308	325	309
100	20	2.8	362	438	446	461	379	463	324	511	363	384	366
200	20	2.8		522				547	380	606			
500	20	2.8		646				669	461	744			

ARI	IL mm	CL mm/hr	Peak Flow (Cumecs) - Calliope R at Mouth for Storm Duration (Hours)										
			2	3	4.5	6	9	12	18	24	30	36	48
10	20	2.8	955	1287	1585	1855	2140	2453	2805	2555	2515	2160	1875
20	20	2.8	1245	1670	2065	2425	2855	3253	3740	3425	3375	2920	2635
50	20	2.8	1630	2200	2765	3225	3860	4420	5130	4700	4655	4015	3670
100	20	2.8	1945	2605	3290	3835	4645	5330	6205	5705	5650	4930	4495
200	20	2.8		3155				6420	7430	6805			
500	20	2.8		3970				8045	9230	8425			

🟨 Critical Duration

The initial RORB modelling described in **Section 4** hereof found that an ***m*** value of 0.88 was optimal so there is really little uncertainty to this parameter (say 0.86 to 0.90). The corresponding optimal value for **k_c** was 44.5 and its uncertainty range, say, 38 – 52). The refinement of the RORB modelling outlined above showed that a continuing loss of 2.8 mm/hr produced the best agreement between the hydrologic model and the flood frequency analysis, so there is little scope to vary this parameter (say 2.6 to 3.0). Similarly the best value of initial loss was found to be 20mm, so variation of this parameter between 18 and 22mm has been tested. On this basis, the range of parameter variation modelled is given in **Table 24.**

Table 24 Testing of Parameter Uncertainty in RORB Model

Parameter	Central Estimate	Uncertainty Range
Initial Loss	20 mm for ARI of 10, 20, 50 and 100 years	18 – 22mm
Continuing Loss	Fixed at 2.8 mm/hr from model calibration	2.6 – 3.0 mm/hr
RORB parameter **k_c**	Fixed at 44.5 from calibration	38 -52
RORB parameter **m**	Fixed at 0.88 from calibration	0.86 – 0.90

The impact of this range individually is given in **Table 25.** This analysis showed that the estimated design flows were insensitive to the initial loss and continuing loss (<1.5% variation for 10% and 7% variation in parameter values respectively), moderately sensitive to **k_c** (about +8% to – 9% variation for 15% variation in parameter values) and very sensitive to ***m*** (about +8% to – 10% variation for 2% variation in parameter values) for the range of parameters tested.

Table 25 Basic Sensitivity Testing on RORB Model

Parameter	Central Estimate	Uncertainty Range	Peak Flow at Castlehope (Cumecs)		
			Central Estimate	Range from Central Estimate	Range %
Initial Loss	20 mm	18 - 22	4610	4575 - 4645	-0.7% to + 0.8%
Continuing Loss	2.8 mm/hr	2.6 - 3.0		4545 - 4670	-1.3% to + 1.4%
RORB parameter **kc**	44.5	38 - 52		4200 - 4980	-8.9% to +8.0%
RORB parameter **m**	0.88	0.86 - 0.90		4160 - 4950	-9.7% to +7.5%

Potential combinations of parameter variations were modelled using **@RISK** which is a *Monte Carlo* simulation add-on to *MS Excel.* The parameters listed in **Table 25** were sampled at random throughout their range assuming uniform parameter distributions (i.e. the parameter is as likely to take any value within the stated range as any other) for initial loss and continuing loss and triangular distributions for the RORB model parameters. These distributions are illustrated in **Figure 62.**

The corresponding peak flow at Castlehope for each simulation sample was modelled using RORB. **@RISK** was then used to determine the distribution of the peak flow values. As this required the RORB model to be run for each combination, this test was conducted only for the 100 year ARI case and was limited to 50 samples. The results of this analysis are shown in **Figure 63** which also shows the distribution of the samples. Although the sample was too short for the inputs distributions to be exact, this does demonstrate the likely distribution of the peak flow estimates (assuming the distributions applied to the parameters are reasonable).

The simulation results have a mean of 4,608m^3/s (compared to 4610 m^3/s for the original estimate using central values of all of the parameters), with a 90% confidence band of 4,180 m^3/s to 5.035 m^3/s which is – 9.2% to + 9.2%) compared to the mean. Comparison of this range with the values given in **Table 25** for the basic sensitivity testing shows that the combined effect of parameter uncertainty is very little greater than that indicated by testing individual parameters.

Although this has been tested only for the 100 year flow, the 90% confidence band is expected to be similar for the other ARIs as the parameter values and their likely ranges are the same.

These flow ranges provide a useful input to the sensitivity testing of the hydraulic model.

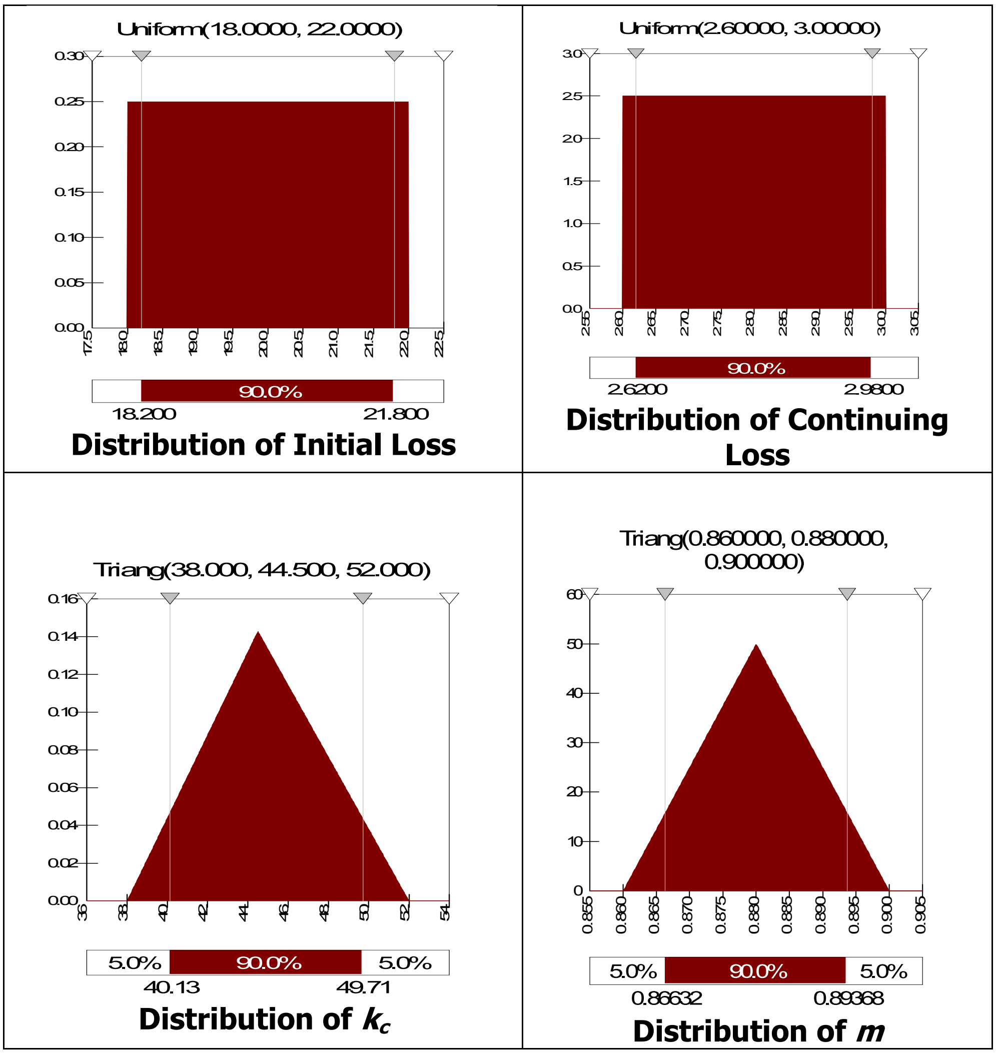
In addition to the parameters tested, there are also uncertainties in the design flows in respect of:

- Rainfall intensity – duration – frequency analysis; and
- Rainfall temporal patterns;

The first of these was minimised by inclusion of the new CRC-FORGE data. The possible errors introduced by these uncertainties were minimised by ensuring that the process used in estimating the design flows replicated that used in model calibration.

In respect of the temporal pattern, the patterns given by ARR (for Zone 3) were used throughout and these give the pattern across the whole catchment. This is equivalent to only having one pluviograph available for model calibration.

The sensitivity of the modelled flows to these uncertainties was not tested as the likely distribution of errors in each of the above is unknown.



Distribution of Initial Loss

Distribution of Continuing Loss

Distribution of k_c

Distribution of m

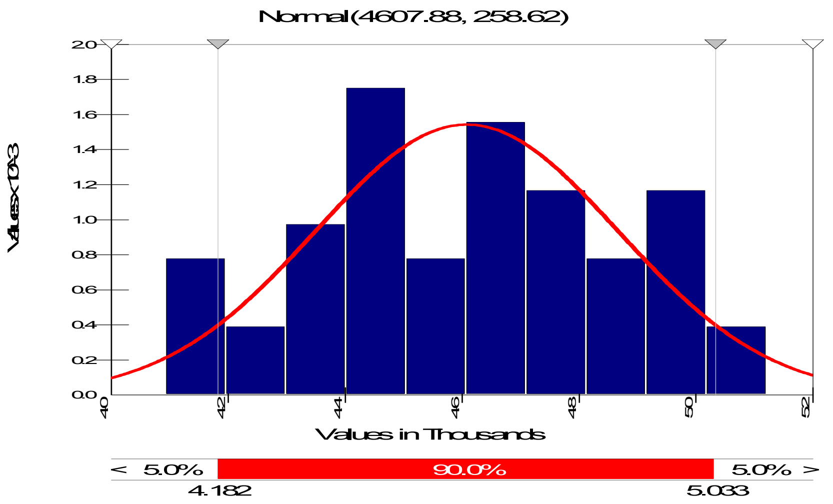
Figure 62 Assumed Distributions of RORB Model Parameters

7.2.6. Final Design Runs

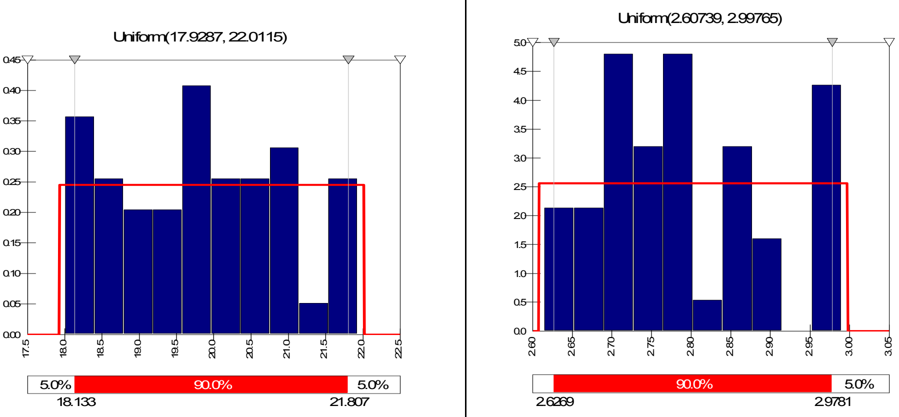
Final Design runs were undertaken to reflect ultimate catchment conditions, which were simulated by increasing the impervious area factor for those sub areas which will be subject to further development as allowed for in Council's Strategic Plan.

The peak flows from these model runs for key locations are summarised in **Table 26,** whilst **Table 27** tabulates peak flows at all the inflow locations. The hydrographs from these runs were then used to produce the inflow hydrographs for the hydraulic model. The peak flows from these runs are tabulated in **Appendix E**.

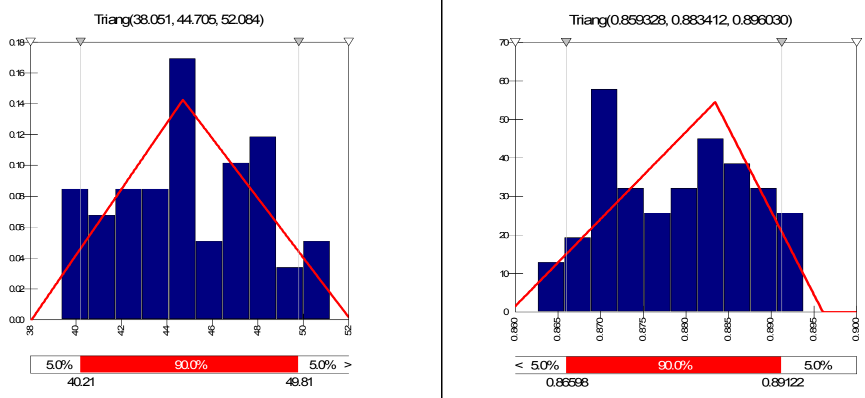
The differences in peak flows at Castlehope were 4.5%, 3.5%, 2.5% and 2% for AEPs of 10%, 5%, 2% and 1% respectively. These differences are reasonable as the areas earmarked for substantial future development are only a small proportion of the total catchment area.



Distribution of Peak Flows at Castlehope



Sample Distribution IL **Sample Distribution CL**



Sample Distribution k_c **Sample Distribution m**

Figure 63 **Sample Distributions of RORB Parameters and Estimated Peak Flow at Castlehope**

Table 26 Estimated Peak Flows from Final RORB Design Runs (Ultimate Conditions)

ARI	IL	CL	Peak Flow (Cumecs) - Calliope R at Castlehope for Storm Duration (Hours)										
	mm	mm/hr	2	3	4.5	6	9	12	18	24	30	36	48
10	20	2.8	940	1255	1530	1785	2000	2240	2193	2060	2070	1935	1675
20	20	2.8	1215	1615	1980	2310	2630	2920	2867	2740	2760	2590	2325
50	20	2.8	1575	2105	2625	3030	3505	3885	3910	3610	3735	3475	2865
100	20	2.8	1870	2485	3110	3600	4200	4650	4707	4390	4520	4230	3495
200	20	2.8		3000				5565	5608	5240			
500	20	2.8		3760				6915	6923	6480			

ARI	IL	CL	Peak Flow (Cumecs) - Leixlip Ck at Upstream Boundary of Hydraulic Model for Storm Duration (Hours)										
	mm	mm/hr	2	3	4.5	6	9	12	18	24	30	36	48
10	20	2.8	198	217	200	182	194	180	117	194	102	109	125
20	20	2.8	255	272	256	227	244	230	154	240	130	138	166
50	20	2.8	302	317	297	265	280	270	192	280	158	168	180
100	20	2.8	347	363	346	306	322	314	230	324	185	196	212
200	20	2.8		430				370	274	378			
500	20	2.8		530				450	340	447			

ARI	IL	CL	Peak Flow (Cumecs) - Clyde Ck at Upstream Boundary of Hydraulic Model for Storm Duration (Hours)										
	mm	mm/hr	2	3	4.5	6	9	12	18	24	30	36	48
10	20	2.8	190	236	243	255	203	255	170	270	192	205	210
20	20	2.8	242	296	306	323	262	326	215	354	247	262	280
50	20	2.8	311	379	387	400	325	396	278	428	309	326	310
100	20	2.8	364	440	447	462	380	464	325	512	364	385	367
200	20	2.8		523				548	381	607			
500	20	2.8		647				670	462	745			

ARI	IL	CL	Peak Flow (Cumecs) - Calliope R at Mouth for Storm Duration (Hours)										
	mm	mm/hr	2	3	4.5	6	9	12	18	24	30	36	48
10	20	2.8	1030	1370	1680	1965	2260	2580	2930	2670	2620	2245	1985
20	20	2.8	1320	1755	2165	2535	2980	3385	3865	3545	3485	3015	2755
50	20	2.8	1710	2285	2865	3335	3985	4560	5260	4820	4770	4135	3790
100	20	2.8	2025	2695	3390	3950	4775	5465	6330	5825	5765	5050	4615
200	20	2.8		3245				6565	7560	6930			
500	20	2.8		4065				8190	9355	8550			

🟨 Critical Duration

Table 27 Peak Sub Area Inflows

NOTE: Values in Table 27 are the critical values for each sub area

Sub Area	Location	Peak Inflows (Cumecs) for ARI (Years)					
		10	20	50	100	200	500
BJ	Calliope R at Castlehope	2240	2920	3910	4700	5610	6910
BK	Calliope Local Trib	49	61	70	81	110	130
BL	Calliope Local	25	31	35	60	48	60
BM	Deep Ck	155	201	240	290	370	450
BN	Calliope Local	41	49	56	63	78	100
BY	Double Ck u/s	586	755	960	1140	1605	1980
BZ	Double Ck local	81	97	109	123	155	190
CA	McGintys Ck	54	69	80	100	114	140
CB	Double Ck local	20	24	27	30	110	50
CC	Calliope Local Trib	20	25	30	34	45	50
CD	Leixlip Ck U/s	217	272	317	363	448	540
CE	Leixlip Ck local	284	341	382	431	542	660
CF	Leixlip Ck trib	34	43	50	60	76	90
CG	Leixlip Ck local	151	180	200	225	292	360
CH	Leixlip Ck trib	40	51	60	70	86	100
CI	Leixlip Ck local	16	19	22	25	30	40
CJ	Calliope Local	16	15	17	19	23	30
CL	Gravel Ck	171	218	260	310	416	510
CM	Calliope Local	103	127	146	168	197	240
CN	Vulcan Ck	97	122	140	170	208	260
CO	Calliope Local	41	49	56	64	78	100
CP	Calliope Local Trib	102	130	150	180	219	270
CQ	Calliope Local	86	106	121	139	162	200
CR	Oakey Ck	148	192	230	280	364	440
CS	Calliope Local	48	58	66	75	91	110
CT	Calliope Local Trib	67	86	100	120	144	180
CU	Calliope Local	57	68	76	87	108	130
CV	Calliope Local Trib	22	27	32	37	46	60
CW	Calliope Local	22	27	30	34	43	50
DD	Clyde Ck U/s	270	354	430	510	683	830
DE	Clyde Ck trib	23	29	34	40	49	60
DF	Clyde Ck local	47	58	65	75	90	110
DG	Clyde Ck trib	38	47	56	65	85	100
DH	Clyde Ck local	50	61	69	77	94	110
DI	Clyde Ck trib	33	41	48	55	68	80
DJ	Clyde Ck local	11	13	15	50	22	30
DK	Clyde Ck trib	27	34	40	46	60	70
DL	Clyde Ck local	11	13	15	20	23	30
DM	Clyde Ck local	70	83	94	106	135	160
DN	Calliope Local	20	25	28	31	41	50
DO	Calliope Local Trib	36	46	50	60	78	100
DP	Calliope Local	41	49	55	62	78	100
DQ	Calliope Local	61	73	82	92	117	140
DR	Calliope Local Trib	35	43	50	60	78	90
DS	Calliope Local	9	11	12	14	18	20
DT	Calliope Local	78	95	107	121	150	180
DU	Calliope Local Trib	18	22	25	30	37	40
DV	Calliope Local Trib	24	29	34	40	49	60
DW	Calliope Local	82	98	109	123	161	190
DZ	Calliope Local	57	68	77	87	110	130
DX	Anabranch Local	73	89	101	115	138	170
DY	Anabranch Local	49	64	65	74	94	120

7.3. Probable Maximum Flood

Estimation of the probable maximum flood comprised the following steps:

- Estimation of the catchment probable maximum precipitation (PMP) including its spatial and temporal distribution;
- Applying the PMP to the hydrologic model to estimate the probable maximum flood (PMF) inflow; and
- Applying the PMF inflows to the hydraulic model to compute the resulting flood levels.

The first two of these steps are described in this section, with the hydraulic model component described in **Section 8.6**.

7.3.1. Probable Maximum Precipitation

a) Catchment Rainfall

Two principal methods of estimating the PMP has been published by the Bureau of Meteorology, namely the Generalised Short Duration Method (GSDM) (BOM 2003) for durations up to 6 hours and for catchment areas up to 1,000km^2 and the Generalised Tropical Storm Model Revised (GTSMR) (BOM 2004) for durations of 1 to 5 days.

As the critical duration for the catchment had been estimated to be 18 hours, the approach adopted was to use the GTSMR methodology and data (BOM 2004) to estimate of the 24 hour PMP, and to extrapolate this to the 18 hour PMP was on the basis of the proportions of 18 hour to 24 hour rainfalls in the 100 year ARI values given in ARR.

The estimation of the catchment PMP is shown in the worksheets given in **Appendix F** hereof. This is based on:

- Extraction of initial values which are tabulated according to duration and catchment area;
- Estimation of adjustment factors applicable to the catchment which modify the initial rainfall depths for topography, decay amplitude and annual moisture factor.
- Multiplication of the initial values by the overall adjustment factor to give preliminary PMP estimates for the catchment for a range of standard durations;
- Graphing of PMP against duration and fitting a smooth curve by eye to produce an envelope curve;
- Extraction of final PMP estimates from the envelope curve for standard and if required for intermediate durations.

In addition the GSDM methodology was adopted to estimate PMP on the Leixlip Creek and Clyde Creek sub catchments which had a critical storm duration of 3 hours.

The resulting PMP values are given in **Table 28** and the envelope curve is shown in **Figure 64**.

Table 28 Estimated Probable Maximum Precipitation Calliope River Catchment

Area Applicable	Storm Duration	Estimated Catchment PMP (mm)
Calliope River Catchment	24	1220
	48	1430
	72	1630
	96	1980
	120	2250
Leixlip Creek Catchment	1	360
	2	460
	3	520
	4	580
	5	630
	6	670
Clyde Creek Catchment	1	350
	2	450
	3	510
	4	570
	5	620
	6	660

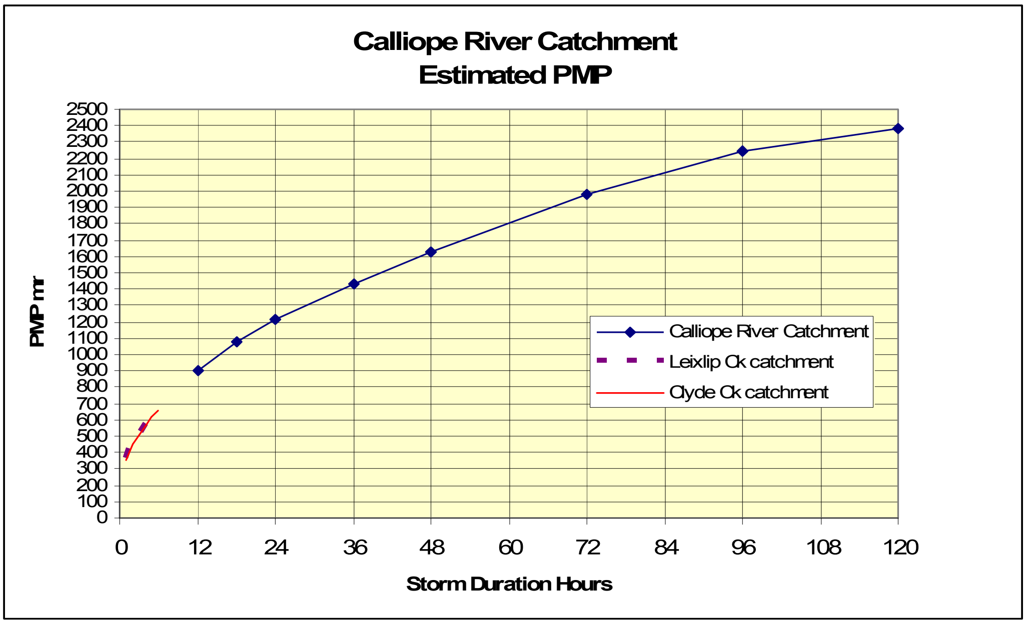


Figure 64 Estimated Catchment PMP

b) Spatial Distribution

The estimated PMP is a catchment averaged rainfall which should be distributed over the catchment to give the average amount. As was seen in the model calibration process the rainfall on the catchment is generally significantly higher in the coastal reaches than in the upstream reaches which are further inland. Both the model calibration and the 10 to 100 year ARI design runs reflect this variation. The same process for spatial distribution was also used for the PMP in order to maintain this similarity throughout.

The GTSMR methodology uses the distribution of the 50 year ARI 72 hour rainfall as the basis for spatial distribution of the PMP.

In order to replicate the procedure used for model calibration and other design runs, 50 year ARI 72 hour rainfalls for the catchment were extracted from the CRC-FORGE data base and the GIS used to determine the corresponding sub area values of this parameter. These values were then scaled to give the appropriate catchment rainfall and applied to the RORB model.

Although the GSDM provides an alternative means of estimation spatial distribution for short duration PMPs, the approach outlined above for the longer duration PMPs was used in respect Leixlip and Clyde Creeks in order to provide consistency with that used for the other design runs. It was not though that the two approaches would yield very different outcomes as both allow concentration of rainfall whilst maintaining the overall catchment average rainfall.

The spatial distributions generated using this approach are given in **Appendix F.**

c) Temporal Distribution

Temporal patterns for PMPs of various durations are given in the GTSMR data for storms of standard catchment area. The guideline requires the use of the nearest standard catchment size with no interpolation. In this case this is the 2,500 km^2 catchment. Temporal patterns for 12 and 18 hours were estimated from these on the basis of maintaining the core temporal distribution and omitting the first and/or last values as most appropriate.

Temporal distributions for Leixlip and Clyde Creeks were based on those given in the GSDM for short duration PMPs.

The temporal patterns used are given in **Appendix F** and were input to the RORB model.

7.3.2. Probable Maximum Flood Estimation

The resulting Probable Maximum Flood was estimated for durations of 1 18, 24, 36 and 48 hours for Calliope River plus 3 and 6 hours for Clyde Creek and Leixlip Creek by running the RORB model using the rainfalls, spatial distribution and temporal patterns as described above.

The resulting peak flows at key locations are summarised in **Table 29**, and those for all of the hydraulic model input locations are given in **Appendix F**.

It can be seen from **Table 29** that there is very little difference in peak flows for Calliope River at Castlehope between 12, 18 and 24 hour storms, whereas for Leixlip and Clyde Creeks the 3 hour PMP gave the maximum peak flow.

Table 29 Estimated PMF at Key Locations

Location	PMF Peak Flow (Cumecs) for Storm Duration (Hours)						
	3	6	12	18	24	36	48
Calliope River at Castlehope	N/A	N/A	20,000	20,500	20,600	18,800	11,300
Leixlip Creek at upstream model boundary	1,200	800	520	480	480	440	340
Clyde Creek at upstream model boundary	1,850	1,600	1,350	1,220	1,180	960	640

7.3.3. Accuracy of PMF Estimates

The PMF estimates are not of high accuracy given the process and assumptions used in estimating the PMP and the likely degree of realism in converting these rainfalls to flows in the hydrologic model. The latter was calibrated on flows an order of magnitude lower than the estimated PMFs, and the model parameters may no longer be valid at this degree of extrapolation.

The PMF estimates should be regarded only as an indication of the upper limit of flood flows and flood levels. It is not possible to quantify the expected accuracy of these estimates, but they would certainly not likely to be within ± 20% in terms of flows. The corresponding range of flood levels will be discussed in **Section 8.3.4.**

8. Design Flood Levels

As for the calibration runs, the design run inflows to the MIKE 11 model comprised 52 flow hydrographs at the upstream boundary of the model, tributary inflows and local catchment inflows.

Design flow hydrographs for these locations for 10, 20, 50, 100, 200 and 500 year ARI and for PMF were obtained from the corresponding RORB model run.

8.1. Initial Design Runs

Initial design runs of the hydraulic model were made with the flow estimates obtained from the RORB model using the CRC-Forge rainfall data as outlined in **Section 7.2** hereof for fully developed conditions only. The model runs were undertaken for storm durations of 3, 6, 12, 18 and 24 hours, covering the range of durations found to be critical in various parts of the model area.

8.1.1. Design Flow Inputs

Peak design flows at the 52 input locations were based on the future development as allowed for in Council's Strategic Plan as outlined in **Section 7.2.6.**

8.1.2. Downstream Boundary Conditions

The SAG, at its meeting of 15th December 2005, determined that the appropriate downstream boundary condition for all but PMF was the Highest Astronomical Tide (HAT) which at Gladstone Harbour is 2.42m AHD. This is consistent with the boundary condition used in the concurrent Auckland Creek Flood Study being undertaken by Gladstone City Council, and previous flood studies for the Boyne River.

For the PMF, the boundary condition was varied to the 1,000 year ARI storm surge level for Gladstone of 3.80m AHD as determined by the recent comprehensive investigation of storm surge levels along the east coast of Queensland (Systems Engineering Australia et al, 2003).

Sensitivity to these assumptions is discussed in **Section 8.3** hereof.

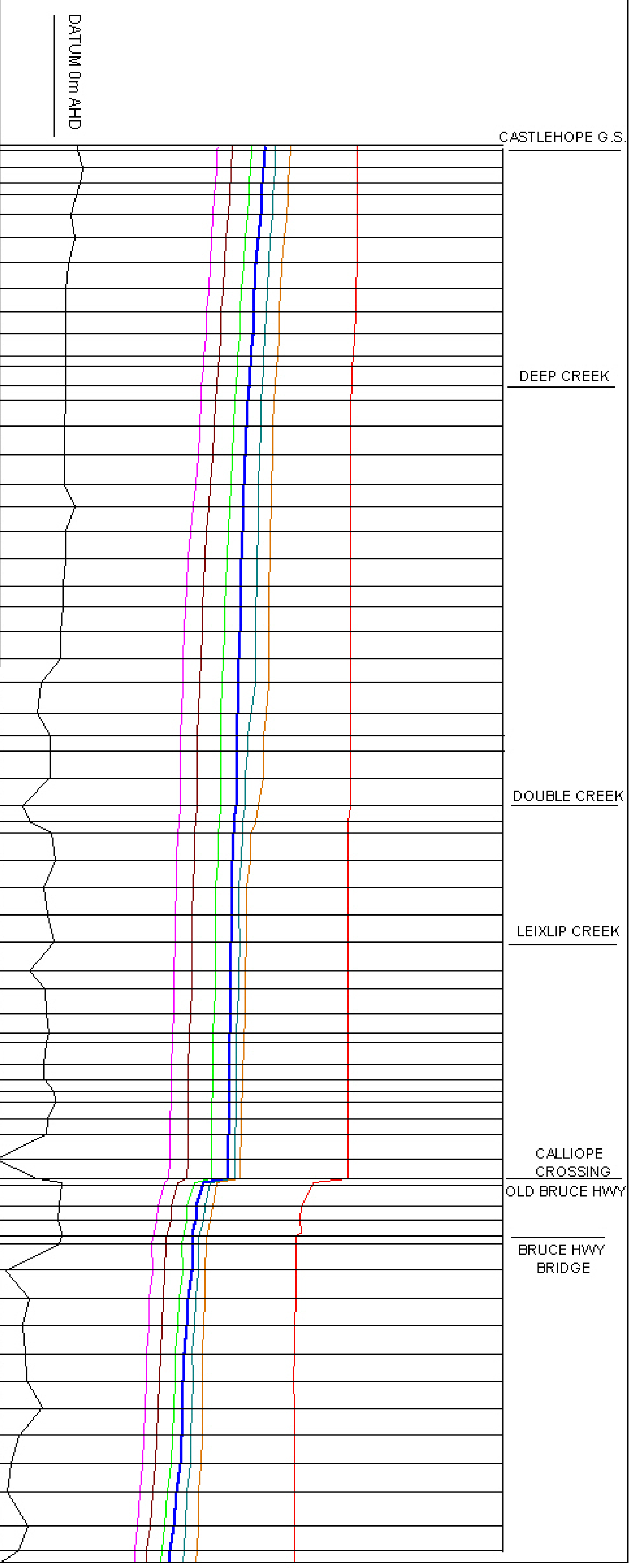
8.1.3. Design Flood Levels

Initial estimates of design flood levels were obtained by running the MIKE 11 model with the design flow input hydrographs and with the corresponding boundary conditions.

For each ARI and for PMF the model was run with storms of durations 3, 6, 12, 18 and 24 hours and the envelope of these levels (i.e. highest value at each cross section) were adopted as the peak flood levels. Design flood levels at key locations are summarised in **Table 30**, whilst the values for all cross sections are tabulated in **Appendix G** and longitudinal profiles for the major flowpaths are given in **Figures 65** to **68.**

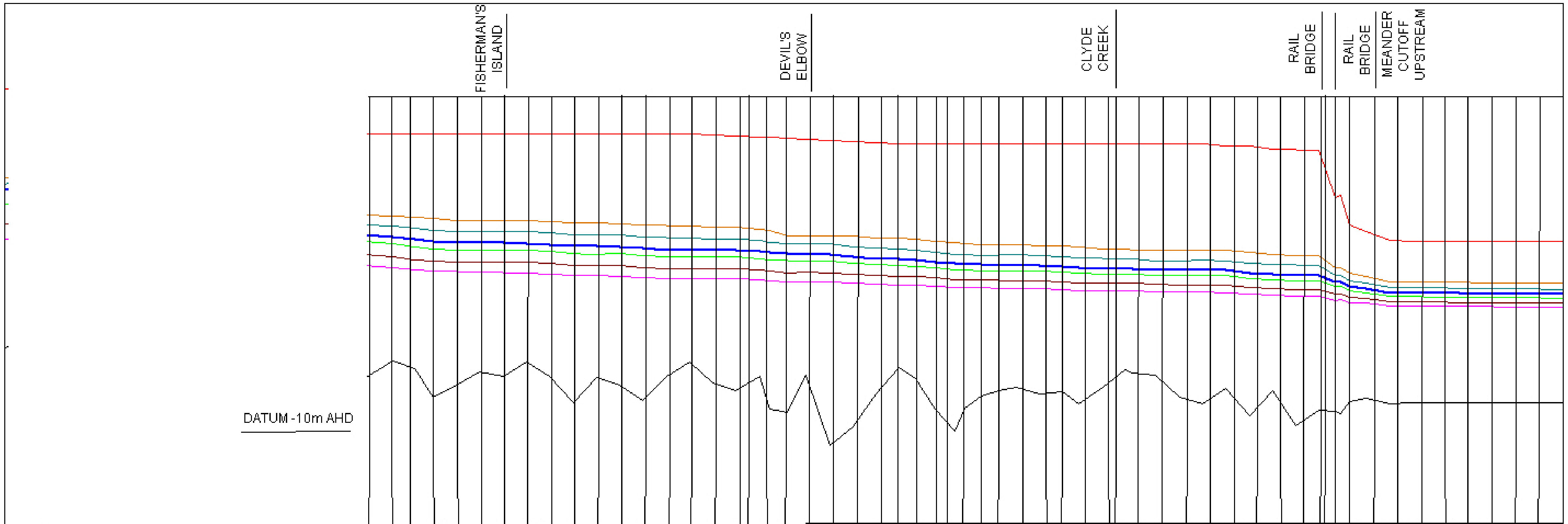
Table 30 Design Values of Peak Flood Levels at Key Locations

Flowpath	Location	MIKE 11 Chainage	Peak Flood Level (m AHD) for ARI (Years)						
			10	20	50	100	200	500	PMF
Calliope River	Castlehope GS	33	14.8	16.1	17.9	19.1	20.1	21.4	27.5
	Deep Ck	2184	13.3	14.7	16.4	17.6	18.9	20.0	27.0
	Double Ck	6000	11.4	13.0	15.1	16.5	17.3	18.5	26.9
	Leixlip Ck	7250	10.9	12.5	14.6	16.1	16.8	17.4	26.6
	Old Bruce Highway Crossing	9413	10.4	12.0	14.2	15.7	16.4	16.9	26.6
	Devil's Elbow	17250	5.9	6.9	8.2	8.9	10.0	10.9	21.1
	Clyde Creek	20750	4.9	5.7	6.7	7.2	8.2	9.4	20.7
	Meander Cutoff Upstream	23256	3.4	3.8	4.4	4.8	5.3	6.0	10.4
	Anabranch Entry	25750	3.3	3.7	4.2	4.6	5.2	5.8	10.3
	Meander Cutoff Downstream	27246	3.3	3.7	4.3	4.7	5.2	5.8	10.3
	Anabranch Re-entry	31750	2.7	2.8	3.1	3.2	3.5	3.8	6.3
	River Mouth	36500	2.4	2.4	2.4	2.4	2.4	2.4	3.8
Leixlip Creek	Model Boundary	0	32.9	33.1	33.1	33.2	33.4	33.5	34.3
	Dawson Highway	1062	30.4	30.6	30.8	30.9	31.1	31.3	32.7
	Stowe Rd	2946	25.5	25.7	25.8	25.9	26.2	26.4	27.6
	Hookes Rd	4466	21.5	22.1	22.4	22.8	23.2	23.8	27.0
	Rail Crossing	4813	21.5	22.1	22.4	22.8	23.1	23.6	27.0
	Schilling Lane	6332	15.3	15.7	16.1	16.5	17.2	17.7	25.9
	Calliope River	9261	10.9	12.5	14.6	16.1	16.8	17.4	26.6
Clyde Creek	Model Boundary	0	20.3	21.0	21.6	22.0	22.4	22.7	24.4
	Dawson Highway	953	19.0	19.8	20.8	21.1	21.4	21.6	22.8
	Rail Crossing	973	17.8	18.7	19.2	19.6	20.1	20.4	22.0
	Wyndham Rd	3820	11.6	11.9	12.2	12.5	13.0	13.5	20.6
	Jefferis Rd	6100	5.4	6.1	7.0	7.7	8.8	10.1	20.9
	Calliope River	8667	4.9	5.7	6.7	7.2	8.2	9.4	20.7



CHAINAGE m	BED LEVEL	DESIGN FLOOD LEVEL 10 YEAR ARI	DESIGN FLOOD LEVEL 20 YEAR ARI	DESIGN FLOOD LEVEL 50 YEAR ARI	DESIGN FLOOD LEVEL 100 YEAR ARI	DESIGN FLOOD LEVEL 200 YEAR ARI	DESIGN FLOOD LEVEL 500 YEAR ARI	DESIGN FLOOD LEVEL PMF
0	2.06	14.8	16.2	17.9	19.1	20.1	21.5	27.5
33	2.06	14.8	16.1	17.9	19.1	20.1	21.4	27.5
181	2.55	14.7	16.1	17.8	19.0	20.0	21.4	27.5
321	2.33	14.6	16.0	17.7	18.9	19.9	21.3	27.5
441	1.90	14.6	16.0	17.7	18.9	19.9	21.3	27.5
614	1.50	14.4	15.7	17.5	18.7	19.8	21.2	27.5
834	1.86	14.2	15.6	17.3	18.5	19.5	20.9	27.5
1066	1.20	14.1	15.5	17.2	18.3	19.4	20.7	27.5
1293	1.0	14.0	15.3	17.0	18.2	19.3	20.6	27.4
1504	1.0	13.8	15.1	16.9	18.0	19.2	20.4	27.4
1714	1.0	13.7	15.1	16.8	18.0	19.2	20.4	27.2
2000	1.0	13.6	14.9	16.7	17.8	19.0	20.2	27.1
2184	1.0	13.3	14.7	16.4	17.6	18.9	20.0	27.0
2307	1.0	13.2	14.6	16.3	17.5	18.8	19.9	27.0
2556	0.90	13.2	14.5	16.2	17.4	18.7	19.9	27.0
2812	0.85	13.0	14.3	16.1	17.3	18.6	19.8	27.0
3079	0.80	12.8	14.2	16.0	17.2	18.6	19.7	27.0
3274	1.76	12.6	14.0	15.9	17.1	18.5	19.7	26.9
3507	1.0	12.4	13.8	15.8	17.1	18.5	19.6	26.9
3757	1.0	12.1	13.6	15.6	17.0	18.4	19.6	26.9
3998	0.70	11.9	13.5	15.5	16.9	18.3	19.5	26.9
4196	0.70	11.8	13.4	15.5	16.8	18.3	19.5	26.9
4418	0.47	11.8	13.4	15.4	16.8	18.3	19.5	26.9
4670	0.50	11.7	13.2	15.3	16.7	18.3	19.5	26.9
4875	-1.30	11.6	13.1	15.2	16.6	18.3	19.4	26.9
5158	-1.59	11.5	13.0	15.1	16.6	18.3	19.2	26.9
5362	-0.40	11.4	13.0	15.1	16.5	17.5	19.0	26.9
5500	-0.43	11.4	13.0	15.1	16.5	17.5	19.0	26.9
5750	-0.42	11.4	13.0	15.1	16.5	17.3	19.0	26.9
6000	-2.90	11.4	13.0	15.1	16.5	17.3	18.5	26.9
6155	-2.23	11.3	12.8	14.9	16.3	17.1	18.2	26.6
6250	-0.28	11.2	12.8	14.8	16.2	17.0	17.8	26.6
6500	0.04	11.1	12.7	14.8	16.2	17.0	17.8	26.6
6750	-1.01	11.0	12.5	14.6	16.0	16.8	17.4	26.6
7000	-0.68	10.9	12.5	14.6	16.0	16.8	17.4	26.6
7250	-0.04	10.9	12.5	14.6	16.0	16.8	17.4	26.6
7510	-2.33	10.8	12.5	14.5	15.9	16.7	17.4	26.6
7672	-0.97	10.8	12.5	14.5	15.9	16.7	17.3	26.6
7900	-0.81	10.8	12.4	14.5	15.9	16.6	17.3	26.6
8161	-0.75	10.7	12.2	14.4	15.8	16.5	17.3	26.6
8361	-1.09	10.6	12.2	14.3	15.8	16.5	17.3	26.6
8500	-1.01	10.6	12.1	14.3	15.8	16.5	17.1	26.6
8707	-0.02	10.5	12.1	14.3	15.8	16.5	17.0	26.6
8861	-0.69	10.5	12.1	14.3	15.8	16.4	17.0	26.6
9000	-0.79	10.5	12.1	14.3	15.7	16.4	16.9	26.6
9227	-5.38	10.5	12.1	14.2	15.7	16.4	16.9	26.6
9447	0.60	10.0	11.2	12.7	13.5	14.2	14.7	23.5
9660	0.40	9.4	10.6	12.0	12.9	13.6	14.3	22.4
9907	0.63	9.3	10.6	12.0	12.9	13.5	14.2	22.3
10000	0.41	8.8	10.1	11.5	12.4	13.1	13.8	21.9
10250	-4.49	8.8	10.1	11.5	12.4	13.1	13.8	21.9
10500	-2.36	8.6	9.8	11.3	12.1	12.8	13.6	21.9
10748	-3.00	8.5	9.7	11.2	11.9	12.7	13.5	21.9
11000	-2.70	8.4	9.6	11.0	11.7	12.6	13.5	21.8
11250	-2.60	8.3	9.5	10.9	11.7	12.5	13.4	21.8
11500	-1.21	8.2	9.4	10.8	11.6	12.4	13.4	21.8
11750	-3.28	8.1	9.3	10.7	11.5	12.4	13.4	21.8
12000	-4.01	8.0	9.2	10.6	11.4	12.3	13.3	21.8
12262	-4.41	7.8	8.9	10.3	11.0	12.0	13.1	21.8
12570	-2.47	7.5	8.7	10.0	10.8	11.9	13.0	21.8

DESIGN FLOOD PROFILE
CALLIOPE RIVER CH 0 - 12570
FIGURE 65



CHAINAGE m	12570	12800	13000	13250	13500	13750	14000	14250	14500	14750	14999	15250	15500	15750
DESIGN FLOOD LEVEL PMF	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
DESIGN FLOOD LEVEL 500 YEAR ARI	13.0	12.9	12.7	12.7	12.7	12.6	12.5	12.4	12.3	12.3	12.2	12.1	11.9	11.9
DESIGN FLOOD LEVEL 200 YEAR ARI	11.9	11.7	11.5	11.5	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.8	10.7	10.7
DESIGN FLOOD LEVEL 100 YEAR ARI	10.8	10.5	10.3	10.2	10.2	10.2	10.1	10.0	9.8	9.8	9.8	9.6	9.5	9.5
DESIGN FLOOD LEVEL 50 YEAR ARI	10.0	9.7	9.5	9.5	9.5	9.4	9.4	9.2	9.1	9.1	9.0	8.8	8.7	8.7
DESIGN FLOOD LEVEL 20 YEAR ARI	8.7	8.4	8.2	8.2	8.2	8.1	8.0	7.9	7.8	7.8	7.7	7.5	7.4	7.4
DESIGN FLOOD LEVEL 10 YEAR ARI	7.5	7.2	7.1	7.1	7.1	7.0	6.9	6.8	6.7	6.7	6.6	6.4	6.4	6.4
BED LEVEL	-2.47	-3.37	-6.42	-5.09	-3.62	-4.46	-2.65	-4.16	-6.96	-4.46	-5.09	-6.76	-4.16	-2.65

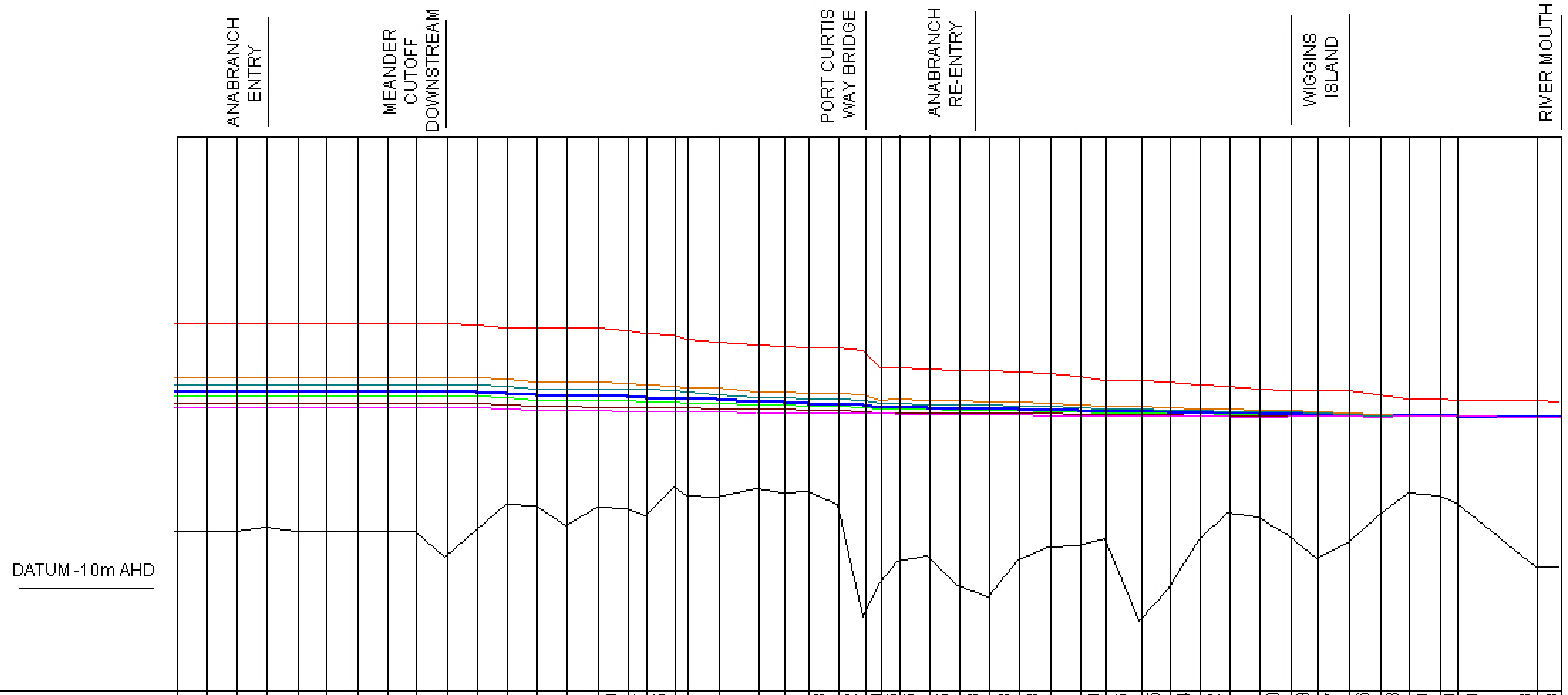
CHAINAGE m	15992	16240	16500	16604	16793	17000	17250	17500	17750	18000	18176	18386	18590	18703
DESIGN FLOOD LEVEL PMF	21.7	21.6	21.5	21.4	21.3	21.2	21.1	21.0	20.9	20.8	20.7	20.7	20.7	20.7
DESIGN FLOOD LEVEL 500 YEAR ARI	11.8	11.8	11.6	11.4	10.9	10.9	10.9	10.9	10.7	10.6	10.5	10.3	10.1	10.0
DESIGN FLOOD LEVEL 200 YEAR ARI	10.6	10.6	10.4	10.2	10.1	10.1	10.0	9.7	9.6	9.5	9.4	9.2	9.0	8.9
DESIGN FLOOD LEVEL 100 YEAR ARI	9.3	9.3	9.2	9.1	8.9	8.9	8.9	8.6	8.5	8.4	8.3	8.1	7.9	7.8
DESIGN FLOOD LEVEL 50 YEAR ARI	8.6	8.6	8.5	8.4	8.2	8.2	8.2	7.9	7.8	7.7	7.7	7.5	7.3	7.2
DESIGN FLOOD LEVEL 20 YEAR ARI	7.3	7.3	7.2	7.1	7.0	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.2	6.2
DESIGN FLOOD LEVEL 10 YEAR ARI	6.3	6.3	6.1	6.1	6.0	6.0	5.9	5.8	5.7	5.7	5.6	5.5	5.4	5.4
BED LEVEL	-4.81	-5.67	-4.16	-7.72	-8.01	-4.03	-11.54	-9.57	-6.02	-3.20	-4.40	-7.69	-10.03	-7.56

CHAINAGE m	18881	19067	19250	19500	19750	19926	20176	20500	20750	21000	21250	21497	21749	22001
DESIGN FLOOD LEVEL PMF	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.5	20.5	20.5
DESIGN FLOOD LEVEL 500 YEAR ARI	10.0	10.0	10.0	10.0	9.8	9.7	9.5	9.5	9.4	9.4	9.4	9.4	9.1	8.9
DESIGN FLOOD LEVEL 200 YEAR ARI	8.8	8.8	8.8	8.8	8.7	8.6	8.4	8.4	8.3	8.3	8.3	8.2	7.9	7.8
DESIGN FLOOD LEVEL 100 YEAR ARI	7.8	7.8	7.8	7.8	7.6	7.5	7.4	7.4	7.2	7.2	7.2	7.2	6.9	6.8
DESIGN FLOOD LEVEL 50 YEAR ARI	7.2	7.2	7.2	7.1	7.0	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.3	6.2
DESIGN FLOOD LEVEL 20 YEAR ARI	6.2	6.1	6.1	6.1	6.0	5.9	5.8	5.8	5.7	5.7	5.7	5.6	5.4	5.2
DESIGN FLOOD LEVEL 10 YEAR ARI	5.3	5.2	5.2	5.2	5.1	5.1	5.0	5.0	4.9	4.9	4.8	4.8	4.6	4.5
BED LEVEL	-6.28	-5.67	-5.31	-6.06	-5.75	-7.04	-5.30	-3.81	-4.04	-6.37	-7.11	-5.42	-8.42	-5.71

CHAINAGE m	22250	22496	22729	22819	23000	23256	23497	23746	23997	24250	24495	24750	25000
DESIGN FLOOD LEVEL PMF	20.5	20.0	15.3	12.1	11.4	10.4	10.4	10.3	10.3	10.3	10.3	10.3	10.3
DESIGN FLOOD LEVEL 500 YEAR ARI	8.8	8.8	7.5	6.8	6.5	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8
DESIGN FLOOD LEVEL 200 YEAR ARI	7.7	7.7	6.7	6.1	5.9	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2
DESIGN FLOOD LEVEL 100 YEAR ARI	6.7	6.7	5.9	5.5	5.3	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6
DESIGN FLOOD LEVEL 50 YEAR ARI	6.1	6.1	5.4	5.0	4.8	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3
DESIGN FLOOD LEVEL 20 YEAR ARI	5.2	5.2	4.6	4.3	4.2	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7
DESIGN FLOOD LEVEL 10 YEAR ARI	4.4	4.4	4.0	3.7	3.7	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3
BED LEVEL	-9.44	-7.81	-8.14	-6.83	-6.53	-7.10	-7.00	-7.00	-7.00	-7.00	-7.00	-7.00	-7.00

DESIGN FLOOD PROFILE
CALLIOPE RIVER CH 12570 - 25000

FIGURE 66



DESIGN FLOOD LEVEL PMF	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.2	10.0
DESIGN FLOOD LEVEL 500 YEAR ARI	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.6
DESIGN FLOOD LEVEL 200 YEAR ARI	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.0
DESIGN FLOOD LEVEL 100 YEAR ARI	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.5
DESIGN FLOOD LEVEL 50 YEAR ARI	4.3	4.2	4.2	4.2	4.3	4.2	4.2	4.2	4.3	4.2	4.2	4.1
DESIGN FLOOD LEVEL 20 YEAR ARI	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6
DESIGN FLOOD LEVEL 10 YEAR ARI	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2
BED LEVEL	-7.00	-7.00	-7.00	-6.62	-7.00	-7.00	-7.00	-7.00	-7.00	-9.10	-6.88	-4.71
CHAINAGE m	25000	25250	25500	25750	26004	26428	26503	26750	26998	27246	27500	27750

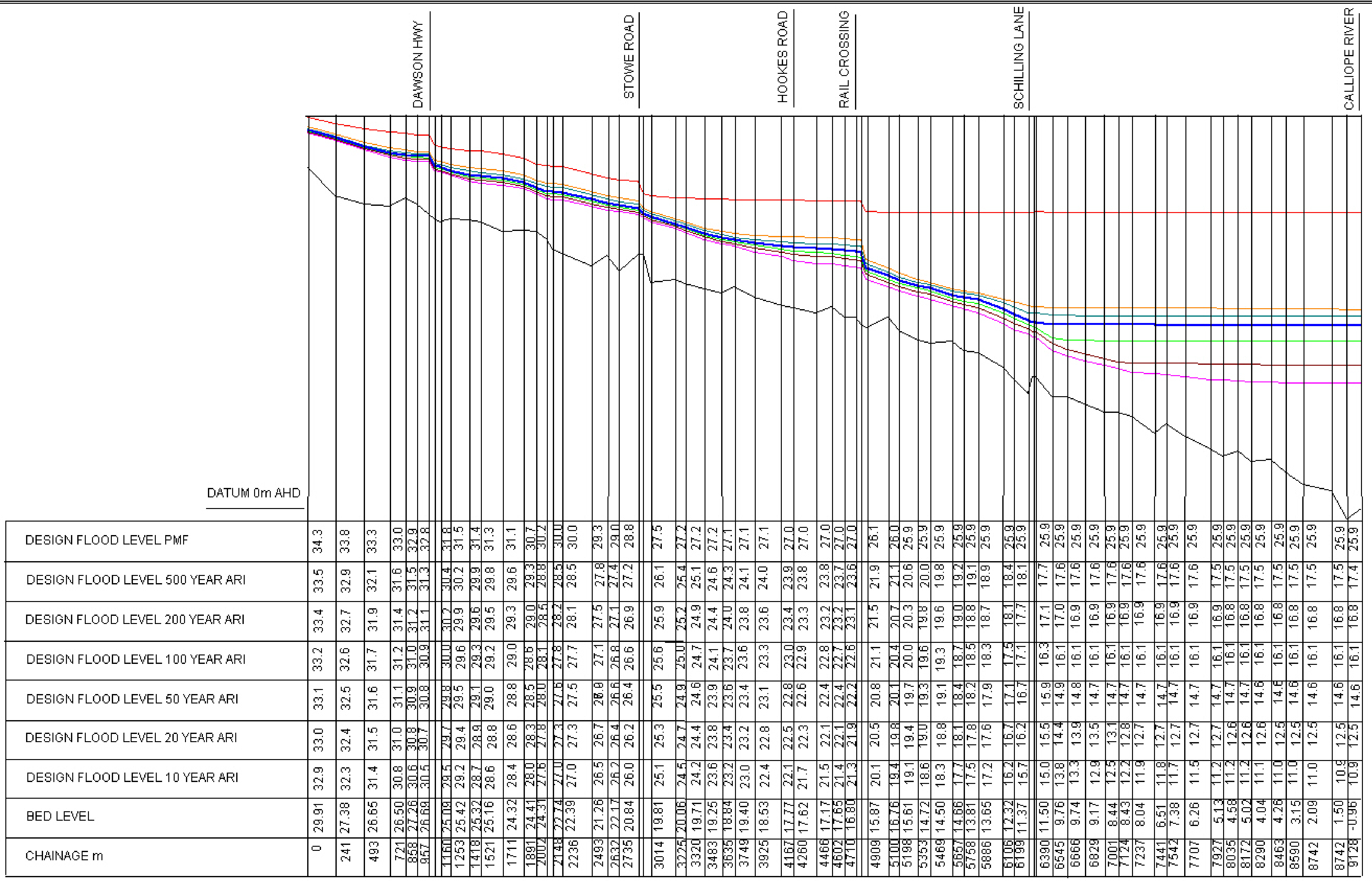
DESIGN FLOOD LEVEL PMF	10.0	9.9	9.9	9.7	9.5	9.0	8.8	8.4	8.4	8.3	8.2	8.0
DESIGN FLOOD LEVEL 500 YEAR ARI	5.5	5.4	5.4	5.3	5.2	5.0	4.9	4.7	4.6	4.5	4.4	4.3
DESIGN FLOOD LEVEL 200 YEAR ARI	4.9	4.8	4.8	4.8	4.8	4.6	4.4	4.2	4.1	4.1	4.0	3.9
DESIGN FLOOD LEVEL 100 YEAR ARI	4.3	4.3	4.3	4.2	4.1	4.0	4.0	3.8	3.7	3.7	3.6	3.5
DESIGN FLOOD LEVEL 50 YEAR ARI	3.9	3.9	3.9	3.9	3.8	3.7	3.7	3.5	3.5	3.5	3.4	3.3
DESIGN FLOOD LEVEL 20 YEAR ARI	3.4	3.4	3.4	3.3	3.3	3.3	3.2	3.1	3.1	3.1	3.0	3.0
DESIGN FLOOD LEVEL 10 YEAR ARI	3.1	3.1	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.8	2.8	2.8
BED LEVEL	-4.89	-6.47	-4.95	-5.07	-5.71	-4.07	-4.18	-3.49	-3.75	-3.62	-4.72	-14.12
CHAINAGE m	28000	28250	28500	28750	28910	29250	29500	29831	30048	30250	30500	30721

DESIGN FLOOD LEVEL PMF	6.6	6.6	6.5	6.3	6.3	6.3	6.1	5.9	5.6	5.5	5.4	5.2
DESIGN FLOOD LEVEL 500 YEAR ARI	4.0	4.0	3.9	3.9	3.8	3.8	3.7	3.6	3.4	3.4	3.3	3.2
DESIGN FLOOD LEVEL 200 YEAR ARI	3.6	3.6	3.6	3.5	3.5	3.5	3.4	3.3	3.2	3.2	3.1	3.0
DESIGN FLOOD LEVEL 100 YEAR ARI	3.3	3.3	3.3	3.2	3.2	3.2	3.1	3.1	3.0	3.0	2.9	2.9
DESIGN FLOOD LEVEL 50 YEAR ARI	3.1	3.1	3.1	3.1	3.1	3.1	3.0	2.9	2.9	2.9	2.8	2.8
DESIGN FLOOD LEVEL 20 YEAR ARI	2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.7	2.7	2.6
DESIGN FLOOD LEVEL 10 YEAR ARI	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6
BED LEVEL	-11.20	-9.45	-8.95	-11.47	-12.47	-9.38	-8.29	-8.17	-7.61	-14.40	-11.83	-7.65
CHAINAGE m	30862	31000	31250	31500	31750	32000	32250	32500	32722	33010	33250	33500

DESIGN FLOOD LEVEL PMF	5.1	5.0	4.9	4.7	4.6	4.3	4.0	4.0	3.9	3.8	3.8
DESIGN FLOOD LEVEL 500 YEAR ARI	3.1	3.1	3.0	2.9	2.9	2.7	2.6	2.6	2.6	2.5	2.4
DESIGN FLOOD LEVEL 200 YEAR ARI	2.9	2.9	2.9	2.8	2.8	2.6	2.6	2.6	2.6	2.5	2.4
DESIGN FLOOD LEVEL 100 YEAR ARI	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.5	2.4
DESIGN FLOOD LEVEL 50 YEAR ARI	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.5	2.4
DESIGN FLOOD LEVEL 20 YEAR ARI	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.5	2.4
DESIGN FLOOD LEVEL 10 YEAR ARI	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4
BED LEVEL	-5.40	-5.83	-7.40	-9.22	-7.93	-5.70	-3.78	-4.07	-4.57	-10.0	-10.0
CHAINAGE m	33746	34000	34253	34488	34743	34996	35243	35502	35640	36300	36500

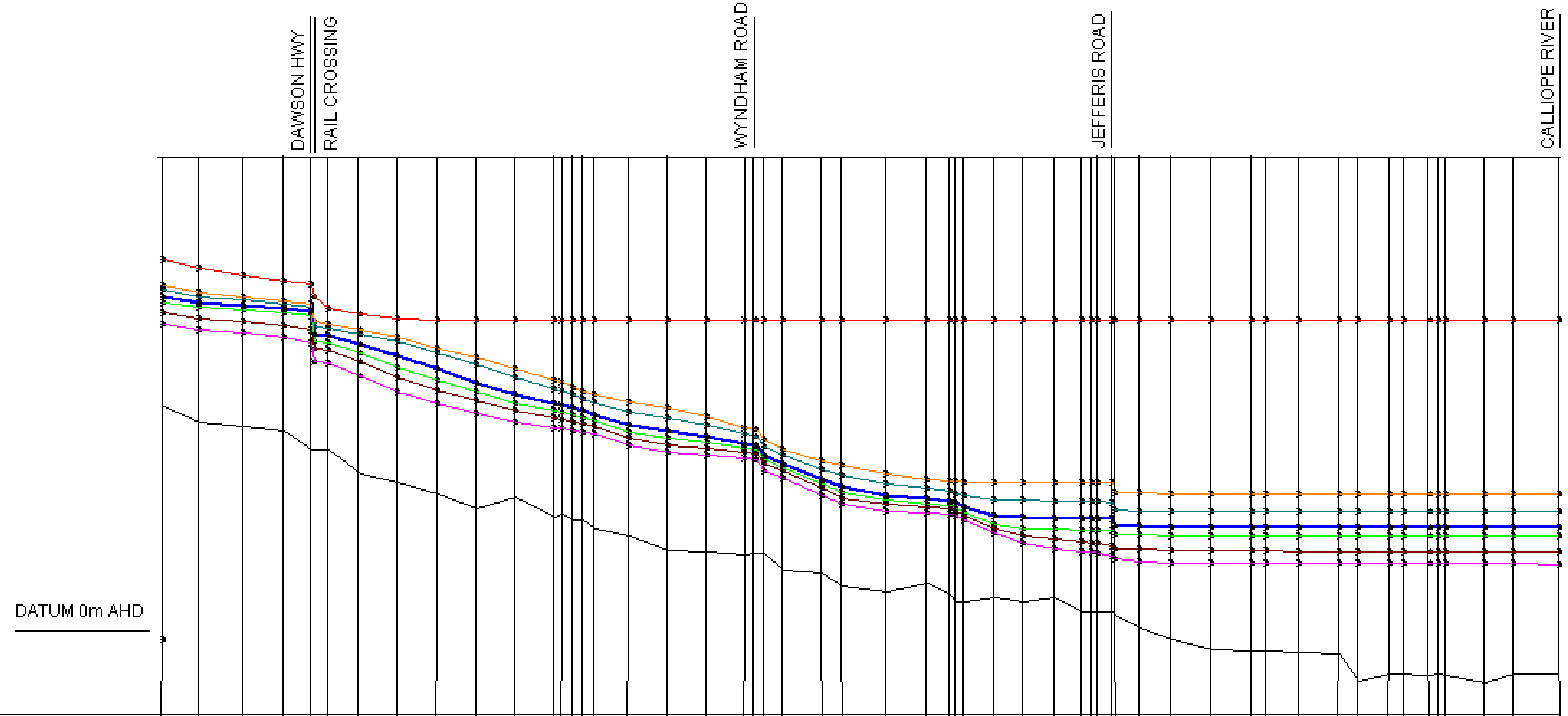
DESIGN FLOOD PROFILE
CALLIOPE RIVER CH 25000 - 36500

FIGURE 67



DESIGN FLOOD PROFILE LEIXLIP CREEK

FIGURE 68



DESIGN FLOOD LEVEL PMF	24.4	23.8	23.4	23.0	22.8	21.3	20.9	20.6	20.6	20.6	20.6
DESIGN FLOOD LEVEL 500 YEAR ARI	22.7	22.3	22.0	21.7	21.6	20.2	19.8	19.4	18.7	18.1	17.4
DESIGN FLOOD LEVEL 200 YEAR ARI	22.4	22.0	21.8	21.5	21.4	20.0	19.6	19.1	18.4	17.6	16.8
DESIGN FLOOD LEVEL 100 YEAR ARI	22.0	21.6	21.4	21.2	21.1	19.5	18.9	18.3	17.4	16.5	15.7
DESIGN FLOOD LEVEL 50 YEAR ARI	21.6	21.3	21.2	21.0	20.8	19.1	18.4	17.5	16.7	15.9	15.2
DESIGN FLOOD LEVEL 20 YEAR ARI	21.0	20.6	20.4	20.1	19.8	18.6	17.8	16.8	16.0	15.3	14.7
DESIGN FLOOD LEVEL 10 YEAR ARI	20.3	19.9	19.7	19.4	19.0	17.7	17.0	15.9	15.2	14.6	14.0
BED LEVEL	15.02	13.94	13.69	13.43	12.21	12.23	10.64	10.08	9.35	8.44	9.13
CHAINAGE m	0	233	522	780	953	1066	1262	1508	1761	2011	2261

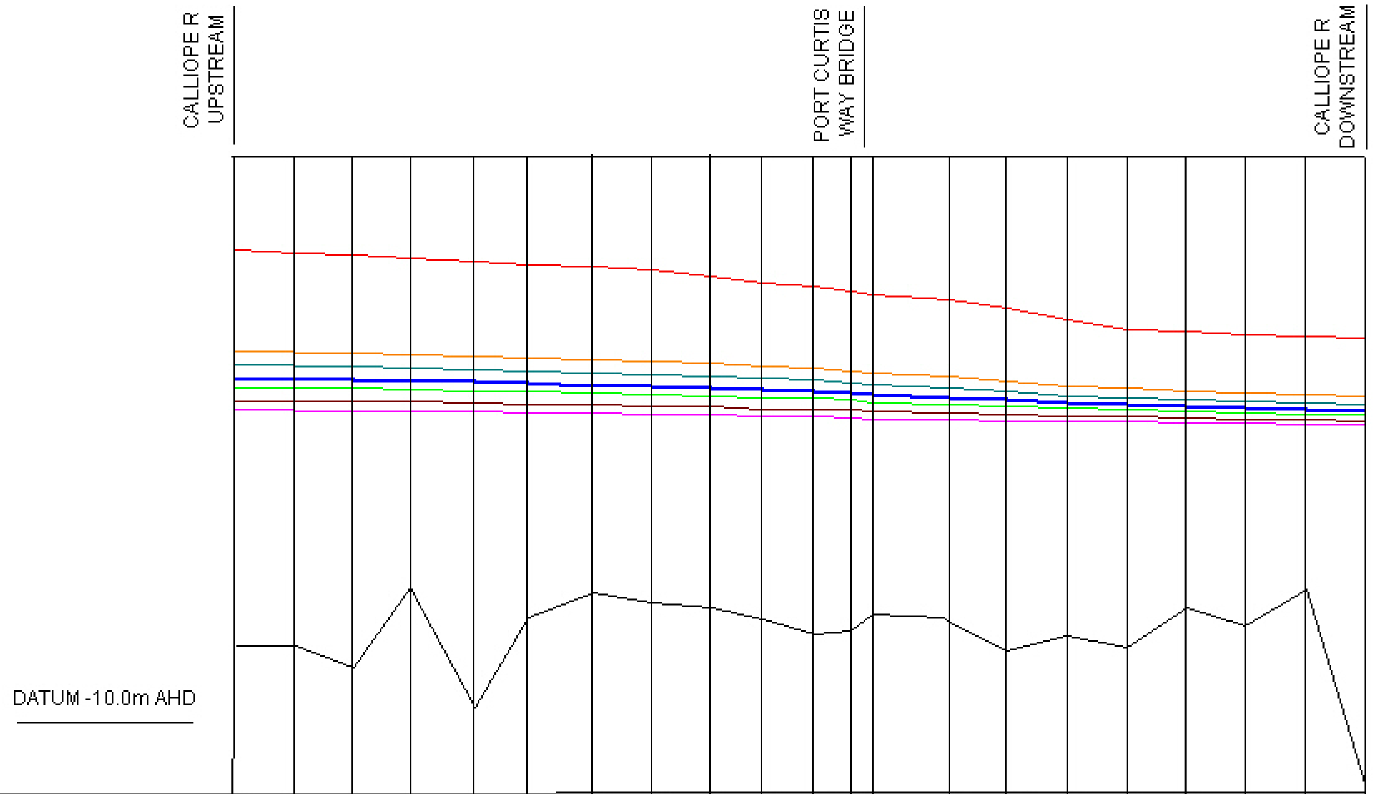
DESIGN FLOOD LEVEL PMF	20.6	20.6	20.6	20.6	20.6		20.6	20.6	20.6	20.6	20.6
DESIGN FLOOD LEVEL 500 YEAR ARI	16.7	15.7	15.2	14.9	14.4	13.6	12.8	12.2	11.5	11.2	10.7
DESIGN FLOOD LEVEL 200 YEAR ARI	16.1	15.2	14.6	14.3	13.8	13.2	12.4	11.8	10.9	10.6	10.0
DESIGN FLOOD LEVEL 100 YEAR ARI	15.2	14.5	13.8	13.4	13.0	12.6	11.9	11.3	10.3	9.8	9.3
DESIGN FLOOD LEVEL 50 YEAR ARI	14.7	14.1	13.9	12.9	12.7	12.3	11.6	11.0	10.0	9.4	8.9
DESIGN FLOOD LEVEL 20 YEAR ARI	14.2	13.7	13.5	12.5	12.3	12.0	11.3	10.8	9.7	9.1	8.7
DESIGN FLOOD LEVEL 10 YEAR ARI	13.6	13.2	12.5	12.0	11.8	11.7	10.8	10.4	9.2	8.7	8.3
BED LEVEL	7.85	7.17	6.70	5.72	5.66	5.50	5.58	4.42	4.28	3.43	3.12
CHAINAGE m	2513	2768	2989	3237	3489	3733	3855	3980	4229	4361	4646

DESIGN FLOOD LEVEL PMF	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6
DESIGN FLOOD LEVEL 500 YEAR ARI	10.3	10.1	10.1	10.1	10.1	10.1	10.1	9.4	9.4	9.4	9.4
DESIGN FLOOD LEVEL 200 YEAR ARI	9.7	9.2	9.0	9.0	8.9	8.9	8.9	8.3	8.3	8.3	8.3
DESIGN FLOOD LEVEL 100 YEAR ARI	9.1	8.5	8.0	7.9	7.8	7.8	7.8	7.3	7.3	7.3	7.3
DESIGN FLOOD LEVEL 50 YEAR ARI	8.7	8.2	7.5	7.2	7.1	7.1	7.1	6.8	6.7	6.7	6.7
DESIGN FLOOD LEVEL 20 YEAR ARI	8.5	8.0	7.2	6.7	6.5	6.3	6.2	5.9	5.8	5.7	5.7
DESIGN FLOOD LEVEL 10 YEAR ARI	8.2	7.7	6.8	6.2	5.9	5.7	5.6	5.2	5.1	5.0	4.9
BED LEVEL	3.66	2.41	2.69	2.46	2.67	1.79	1.81	1.60	0.81	0.00	-0.60
CHAINAGE m	4898	5141	5338	5519	5726	5868	6000	6110	6266	6473	6731

DESIGN FLOOD LEVEL PMF	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6
DESIGN FLOOD LEVEL 500 YEAR ARI	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
DESIGN FLOOD LEVEL 200 YEAR ARI	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
DESIGN FLOOD LEVEL 100 YEAR ARI	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
DESIGN FLOOD LEVEL 50 YEAR ARI	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
DESIGN FLOOD LEVEL 20 YEAR ARI	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
DESIGN FLOOD LEVEL 10 YEAR ARI	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
BED LEVEL	-0.70	-0.75	-0.80	-0.85	-2.68	-2.21	-1.67	-2.31	-2.74	-2.22	-2.22
CHAINAGE m	6983	7076	7288	7551	7670	7872	7965	8234	8484	8667	8964

FIGURE 69

DESIGN FLOOD PROFILE CLYDE CREEK



DESIGN FLOOD LEVEL PMF	10.0	9.9	9.8	9.7	9.5	9.4	9.3	9.2	8.9	8.6	8.5	8.3	8.1	7.9	7.6	7.0	6.7	6.6	6.4	6.4	6.3
DESIGN FLOOD LEVEL 500 YEAR ARI	5.8	5.7	5.7	5.6	5.6	5.5	5.4	5.4	5.2	5.1	5.0	4.9	4.8	4.7	4.5	4.3	4.2	4.1	4.0	3.9	3.8
DESIGN FLOOD LEVEL 200 YEAR ARI	5.2	5.1	5.1	5.1	5.0	4.9	4.9	4.8	4.7	4.6	4.5	4.5	4.3	4.2	4.1	3.9	3.8	3.8	3.6	3.6	3.5
DESIGN FLOOD LEVEL 100 YEAR ARI	4.6	4.6	4.6	4.5	4.5	4.4	4.4	4.3	4.2	4.2	4.1	4.0	3.9	3.8	3.7	3.6	3.5	3.5	3.4	3.3	3.2
DESIGN FLOOD LEVEL 50 YEAR ARI	4.2	4.2	4.2	4.2	4.1	4.1	4.0	4.0	3.9	3.8	3.8	3.7	3.6	3.5	3.4	3.3	3.3	3.3	3.2	3.1	3.1
DESIGN FLOOD LEVEL 20 YEAR ARI	3.7	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.2	3.1	3.0	3.0	3.0	2.9	2.9	2.8
DESIGN FLOOD LEVEL 10 YEAR ARI	3.3	3.3	3.3	3.2	3.2	3.2	3.1	3.1	3.1	3.0	3.0	3.0	2.9	2.9	2.8	2.8	2.8	2.8	2.7	2.7	2.7
BED LEVEL	-6.62	-6.62	-7.54	-4.12	-9.25	-5.43	-4.38	-4.82	-5.01	-5.52	-6.17	-6.04	-5.31	-5.65	-6.87	-6.21	-6.71	-5.03	-5.82	-4.24	-12.47
CHAINAGE m	0	250	493	735	1006	1227	1501	1750	1999	2214	2432	2590	2680	3001	3248	3500	3750	4000	4250	4502	4750

DESIGN FLOOD PROFILE ANABRANCH

FIGURE 70

8.3. Sensitivity and Uncertainty in Design Flood Levels

The following uncertainties required consideration in respect of result sensitivity in the hydraulic model:

- Parameter uncertainty in hydraulic model (roughness);
- Uncertainty in Design Flows; and
- Uncertainty in respect of the downstream boundary conditions.

8.3.1. Uncertainty in Model Roughness

Section 5.5 hereof discussed the calibration of the hydraulic model which concluded that, due to the paucity of historic flood levels for calibration and apparent changes in physical characteristics of the Calliope River over the period for which calibration data were available, there was considerable uncertainty in respect of the hydraulic roughness. Evaluation of the apparent physical changes in the Calliope River (**Section 6**) reduced this uncertainty and determined that the roughness based on the more recent events of 0.057 should be adopted.

In determining an appropriate freeboard allowance to account for possible errors in the model roughness and other parameters, sensitivity runs with roughness values 10% higher were undertaken. This sensitivity testing was undertaken only for the 100 year event. The results from these tests are summarised in **Figure 71**.

Reference to **Figure 71**, shows that this scenario results in an increase in peak flood level along the Calliope River from zero at the river mouth to about 0.6m downstream of the old Bruce Highway crossing.

In respect of Leixlip Creek and Clyde Creek, the maximum differences were 0.35m and 0.32m respectively, with the downstream reaches having the greatest variation due to the backwater influence from the Calliope River.

8.3.2. Uncertainty in Design Flows

In **Section 7.2.5** the uncertainty in design flows was tested (for 100 year ARI only) using *Monte Carlo* simulation. This indicated a likely range in flood flows from –9.2% to +9.2%. The impact of this degree of variation on flood level estimation was evaluated by running the 100 year ARI model with all flows factored to 109.2% respectively to simulate this variation.

The results of these runs are summarised in **Figure 72** reference to which shows that this scenario results in an increase in peak flood level along the Calliope River from zero at the river mouth to a maximum of about 0.7m in the upstream reach of the model.

In respect of Leixlip Creek and Clyde Creek, the maximum differences were both about 0.5m, again with the downstream reaches having the greatest variation due to the backwater influence from the Calliope River.

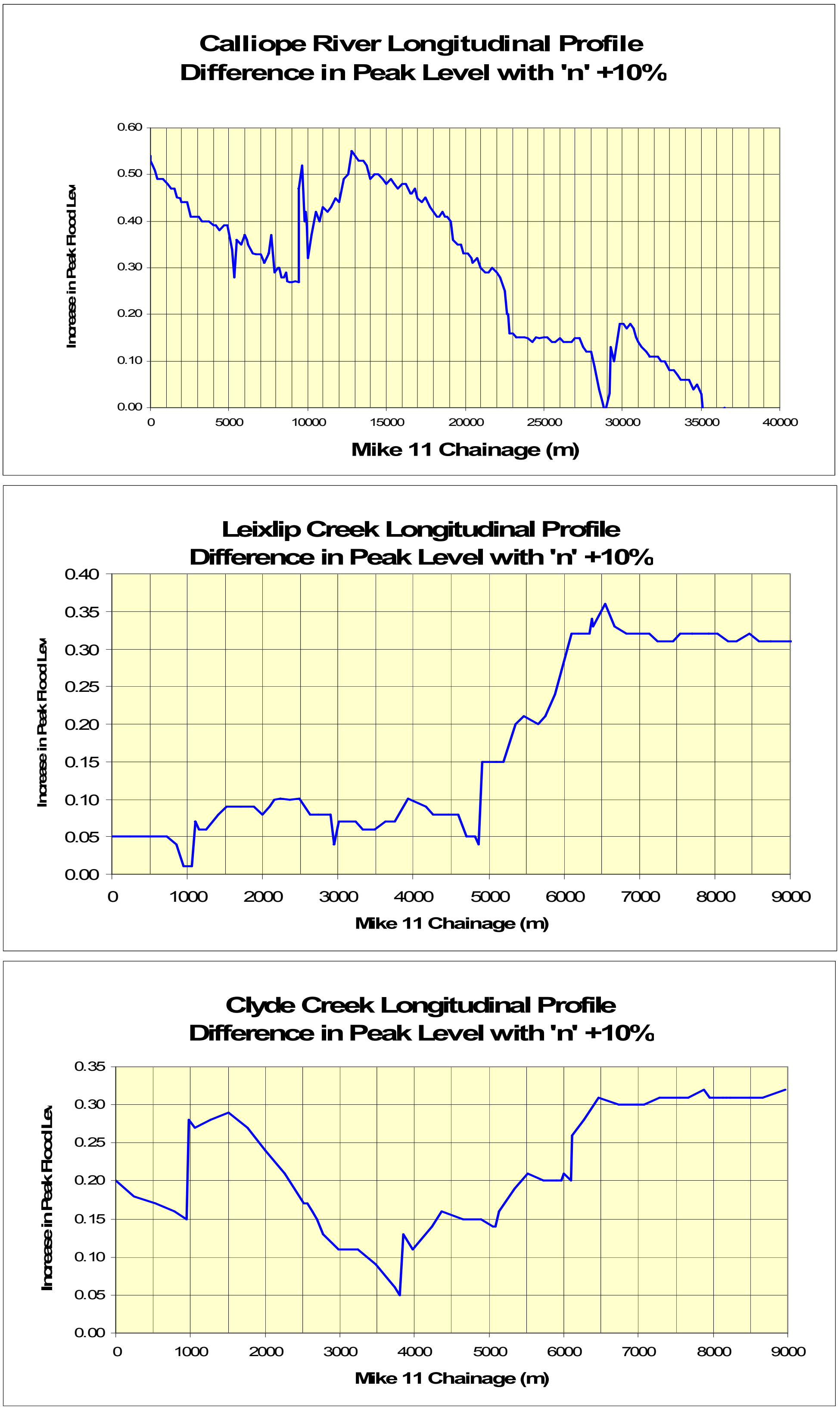


Figure 71 **Sensitivity to Roughness Variation**

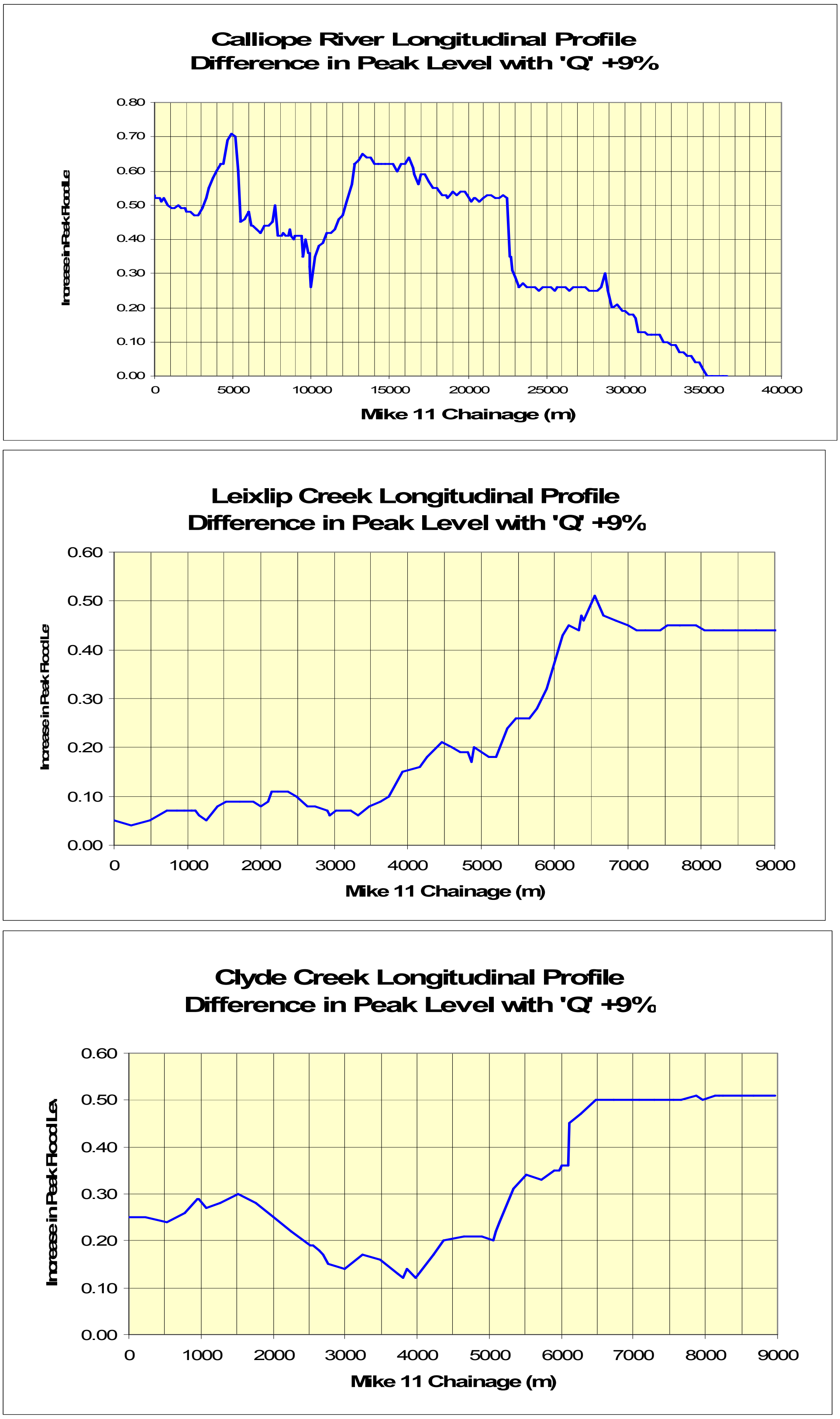


Figure 72 **Sensitivity to Flow Variation**

8.3.3. Downstream Boundary Condition

Sensitivity to the downstream boundary condition was modelled by running the 100 year ARI event with a lower and a higher boundary level. The lower level was the mean high water spring tide level of 1.63m AHD, and the higher level was the 100 year ARI storm surge level of 2.82m AHD (Systems Engineering Australia et al, 2003).

The variation resulting from these model runs are shown in **Figure 73.**

In considering the sensitivity of flood levels along the Calliope River to these changes in downstream boundary level, the following zones were identified;

- An upstream zone extending from the upper model boundary at Castlehope to the old Bruce Highway crossing (Chainage 0 to 9,430m) and including Leixlip Creek (and the other tributaries entering this reach of the river) which is not influenced by the downstream boundary condition, and in which the flood levels are determined by the flow probability alone;

- An intermediate zone in which the flood levels are influenced only marginally by the downstream boundary condition. This zone extends from downstream of the old Bruce Highway crossing to the confluence with Clyde Creek (Chainages 9,447 to 20,500m). In this zone the difference in 100 year flood level with the conditions modelled did not exceed 0.3m;

- Downstream of Clyde Creek to the upstream end of the major meander cutoff (Chainage 20,500 to 23,256m) in which the difference in 100 year flood level of up to 0.7m between these boundary conditions is significantly influenced by the downstream boundary condition; and

- A downstream zone which is dominated by tidal flows from the meander cutoff to the river mouth (Chainages 27,246 to 36,500m) and is influenced by both the downstream boundary condition and the flood flows in the river.

In a practical sense, the extent of inundation (or flood footprint) is more important than the difference in flood levels. If this difference is significant between the various boundary conditions then careful consideration needs to be given to the combination used for design. On the other hand, if the difference in flood footprint is only marginal, then there is no need to consider this in great detail as the outcome is not sensitive to the boundary condition assumption.

In this case, the latter situation occurs and, over the range of boundary conditions tested, the area flooded was found to be not significantly impacted by the starting level.

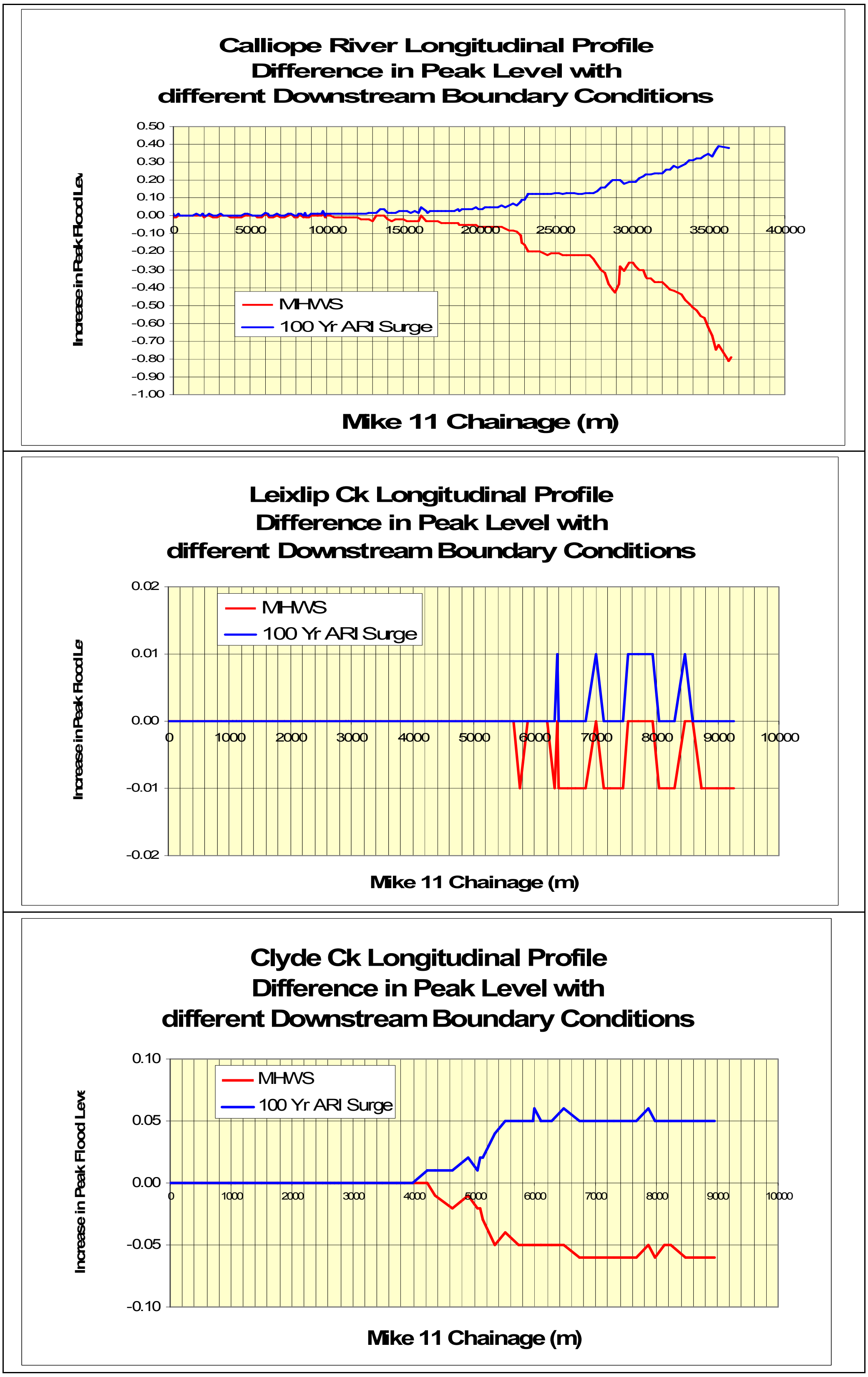


Figure 73 **Sensitivity to Downstream Boundary Condition**

8.3.4. Recommended Freeboard

In consideration of the results of these sensitivity tests, and of the lack of data on which the model calibration is based, we recommend that a freeboard of 1.0m be applied to the model results in using them for development control purposes.

This is somewhat higher than typical freeboard allowances of 500mm to 600mm but is believed to be appropriate in this case due to the relatively high uncertainty in the model results.

In respect of the PMF, a higher freeboard allowance of 2m is proposed due to the recognised the inaccuracy of the estimated PMF flows (refer to Section**7.3.3** hereof).

8.4. Design Flood Levels, Profiles and Mapping

The design flood profiles for the major waterways modelled are tabulated in **Appendix G** and are plotted in **Figures 65** to **70** for 10, 20, 50, 100, 200, 500 Year ARI and for PMF. Design flood levels at key points are given in **Table 30.**

Flood inundation plans have been prepared for the 10, 20, 50, 100, 200, 500 Year ARI and for PMF and are given in **Figures 74 to 78**. **Figure 74** shows the whole area in outline whilst **Figures 75** to **78** show greater detail.

The flood maps have been prepared using GIS software to identify and map the intersection of 2 surfaces, namely the DEM and the water surface. Whilst this is the most accurate process available, this will still result in some anomalous areas such as areas adjacent to the river which are lower than the peak flood level even if these are not hydraulically connected to the flood surface. In order to remove these anomalies, it will be necessary to examine the maps in detail and possibly undertake some ground truthing. This is outside the scope of the current commission.

8.4.1. Development Levels

Figures 79 to 83 show the proposed development levels for the model area, based on the 100 year ARI flood level plus 1m freeboard.

8.4.2. Fully Developed Waterway

The effect on 100 year ARI flood levels of full vegetation across the waterway and floodplain was estimated by increasing the relative roughness across each cross section to 2. The results of this are included in **Appendix G**.

The main impact of this was on the Calliope River upstream of the old Bruce Highway crossing, where 100 year peak flood levels rose by 1 to 2m, whereas downstream the impact reduced to zero by chainage 10,000m.

Along Leixlip Creek, the impacts increased from less than 0.2m at the upstream model boundary to 1.6m at the confluence with Calliope River. For Clyde Creek the impacts were less being in the range 0m to 0.3m.

8.4.3. Flood Immunity

Current flood immunity of highways and local roads are summarised in **Table 31** and listed in full in **Appendix H.** Where appropriate, a flow depth of 300mm has been allowed before the crossing becomes untrafficable. As the smallest design flood was 10 year ARI, crossings which are untrafficable below this level are shown as < 10 years. **Table 31** also indicates the duration of flooding in a 10 year ARI event.

Current flood immunity is below Council's standard of 10 year ARI at the following crossings:

- Leixlip Creek at Stowe Road, Hookes Road and Schilling Lane; and
- Clyde Creek at Jefferis Road and Wyndham Road (even with the proposed bridge).

Current flood immunity is below the DMR objective of 50 year ARI at the following crossings:

- Dawson Highway at Leixlip Creek and at Double Creek.

Table 31 Flood Immunity of Road and Rail Crossings

Flowpath	Road/Rail Crossing	MIKE 11 Chainage m	Crossing Level	Flood Immunity	Approx. closure duration in 10 Year ARI event	Peak Flood Level (m AHD) for ARI (Years)			
			m AHD	Years	Hours	10	20	50	100
Calliope River	Blackgate Rd/ Ferguson Rd	324	2.5	<<10	>72	14.6	16.0	17.7	18.9
	Old Bruce Highway Crossing	9413	2.0	<<10	>72	10.4	12.0	14.2	15.7
	Bruce Highway Bridge	9907	15.24	>100	N/A	9.0	10.3	11.7	12.5
	Rail Bridge 1	22576	8.35 abutments ~6	50	N/A	4.4	5.2	6.1	6.7
	Rail Bridge 2	22770	9 abutments ~8	>100	N/A	4.0	4.6	5.4	5.9
	Port Curtis Way	30721	8.32 abutment ~6	>100	N/A	2.8	3.0	3.3	3.5
Leixlip Creek	Dawson Highway	1062	29.5	<10	3	30.4	30.6	30.8	30.9
	Stowe Rd	2924	25.0	<10	12	25.8	26.0	26.2	26.3
	Hookes Rd	4466	18.5	<10	24	21.5	22.1	22.4	22.8
	Rail Crossing	4813	22	20	N/A	21.5	22.1	22.4	22.8
	Schilling Lane	6332	12.7	<10	27	15.3	15.7	16.1	16.5
Clyde Creek	Dawson Highway	953	20.82	50	N/A	19.0	19.8	20.8	21.1
	Rail Crossing	973	20.5	>100	N/A	17.8	18.7	19.2	19.6
	Wyndham Rd	3820	10.4	<10	15	11.6	11.9	12.2	12.5
	Jefferis Rd	6100	4	<10	26	5.4	6.1	7.0	7.7
Deep Ck	Dawson Highway	47	16.15	10	N/A	15.9	18.0	18.5	18.9
Double Ck	Railway Crossing	3100	15.9	50	N/A	11.6	13.1	15.2	16.6
	Dawson Highway	-440	14	<<10	24	16.6	17.1	17.6	18.0
Anabranch	Port Curtis Way	2630	5.17	>100	N/A	3.0	3.3	3.7	4.0

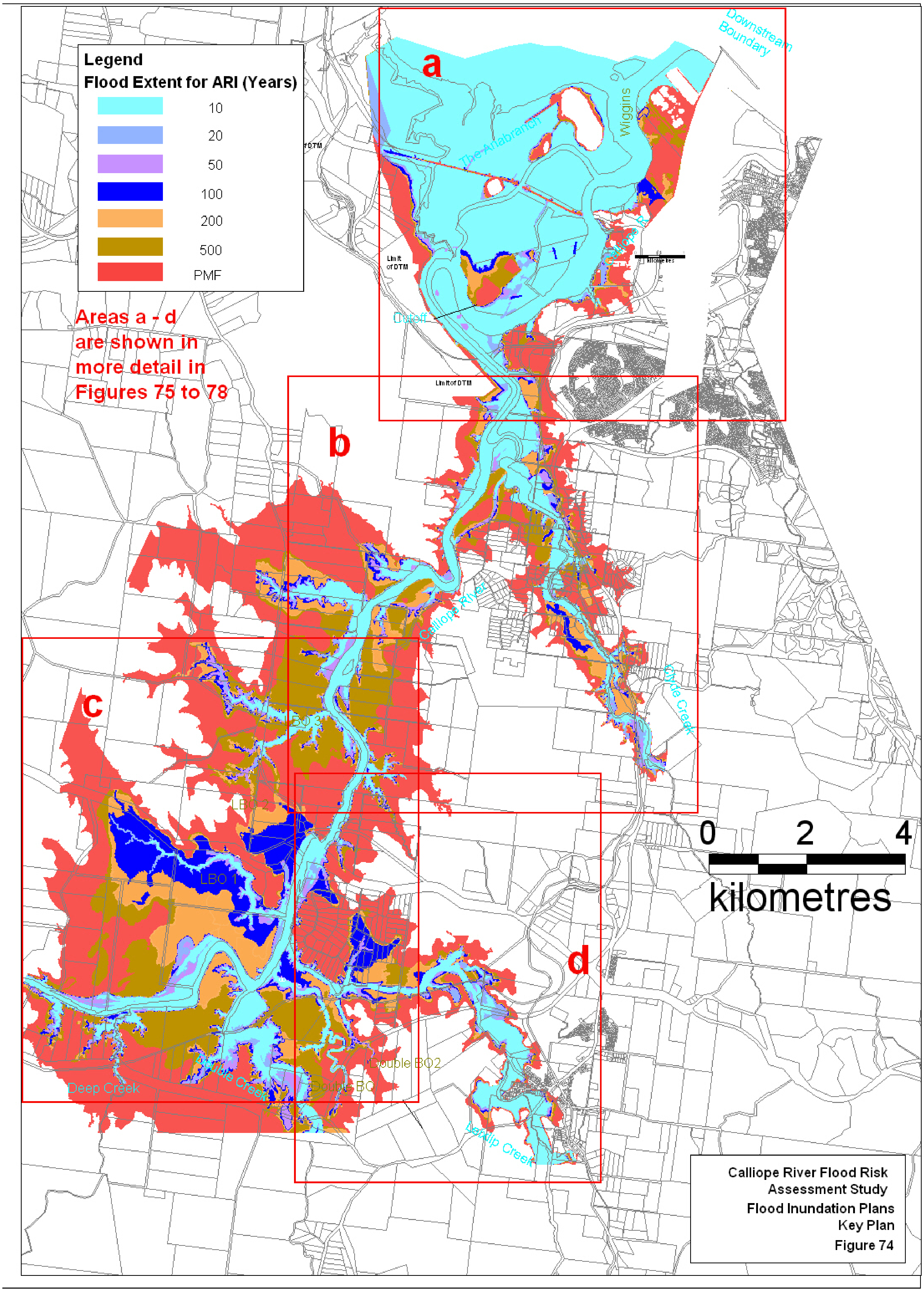


Figure 74 **Flood Inundation Key Plan**

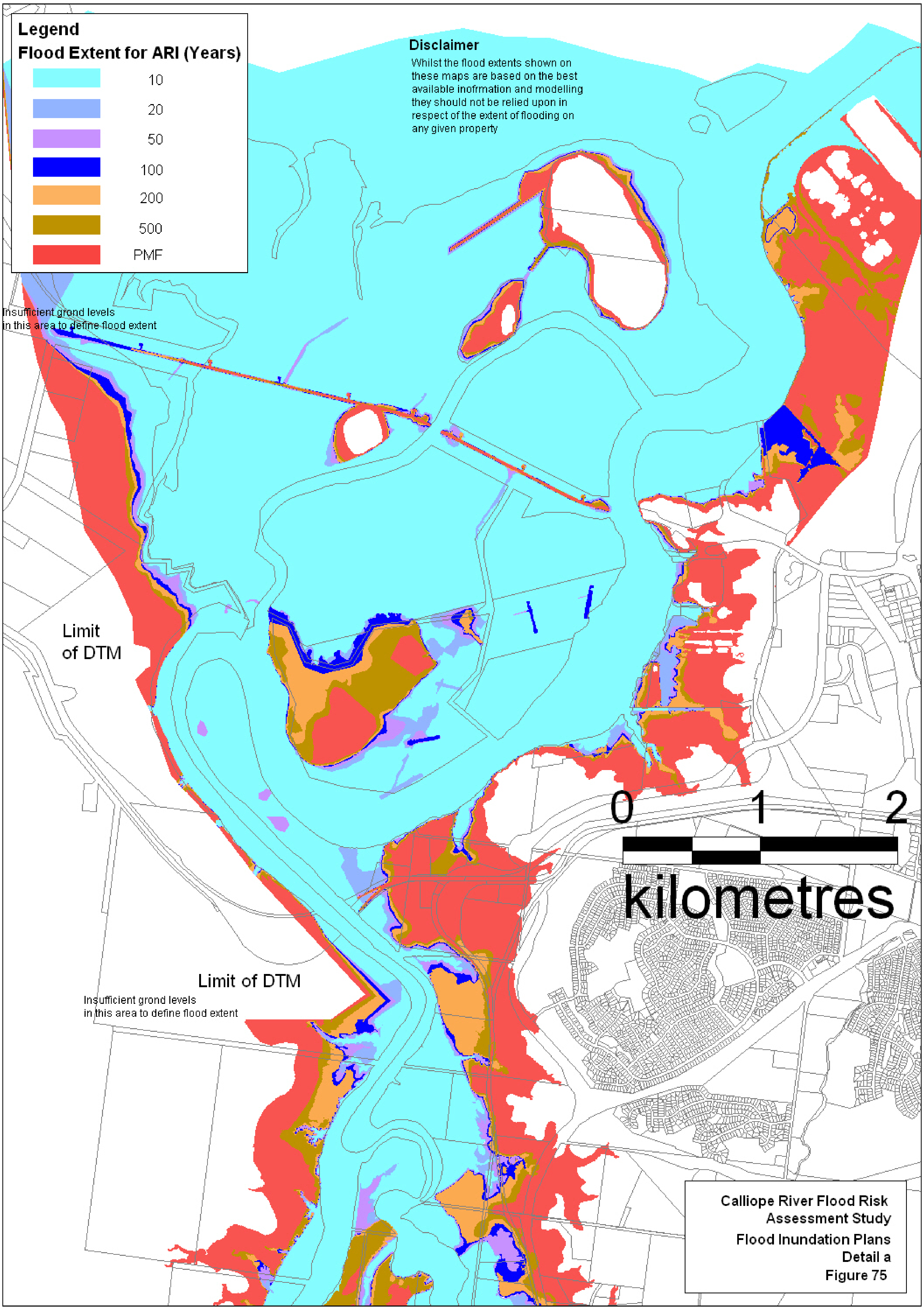


Figure 75 **Flood Inundation Plans - Detail a**

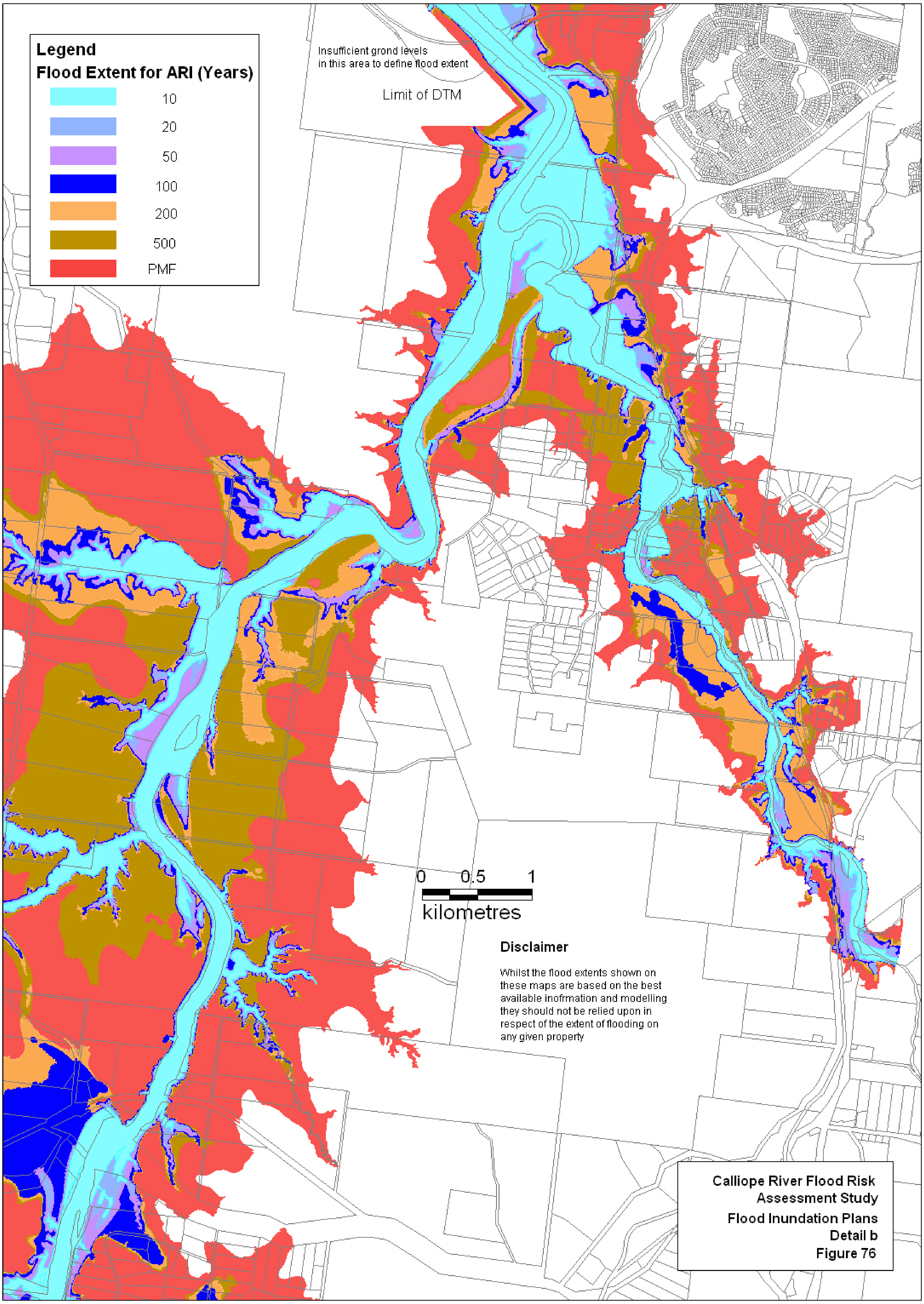


Figure 76	**Flood Inundation Plans - Detail b**

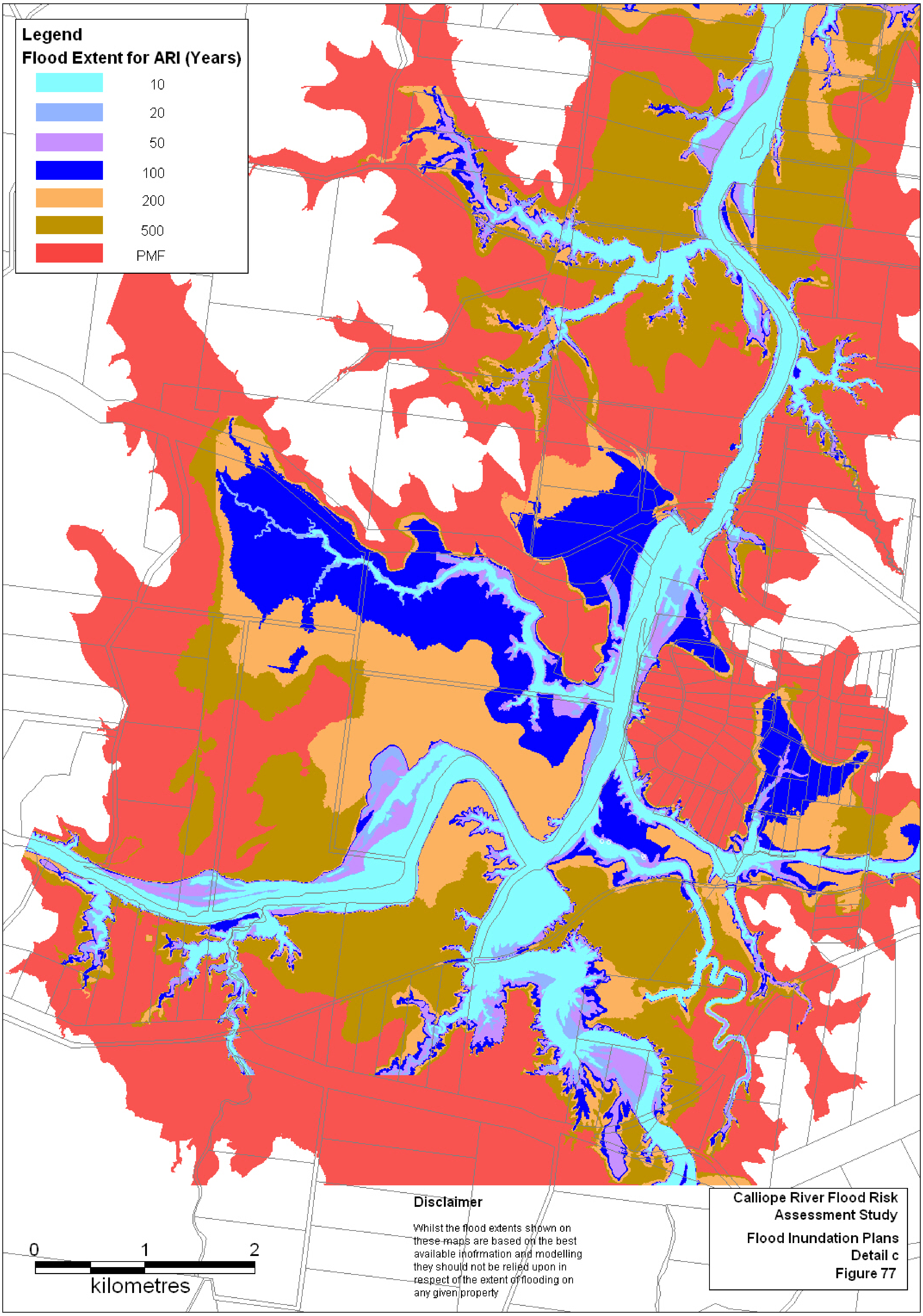
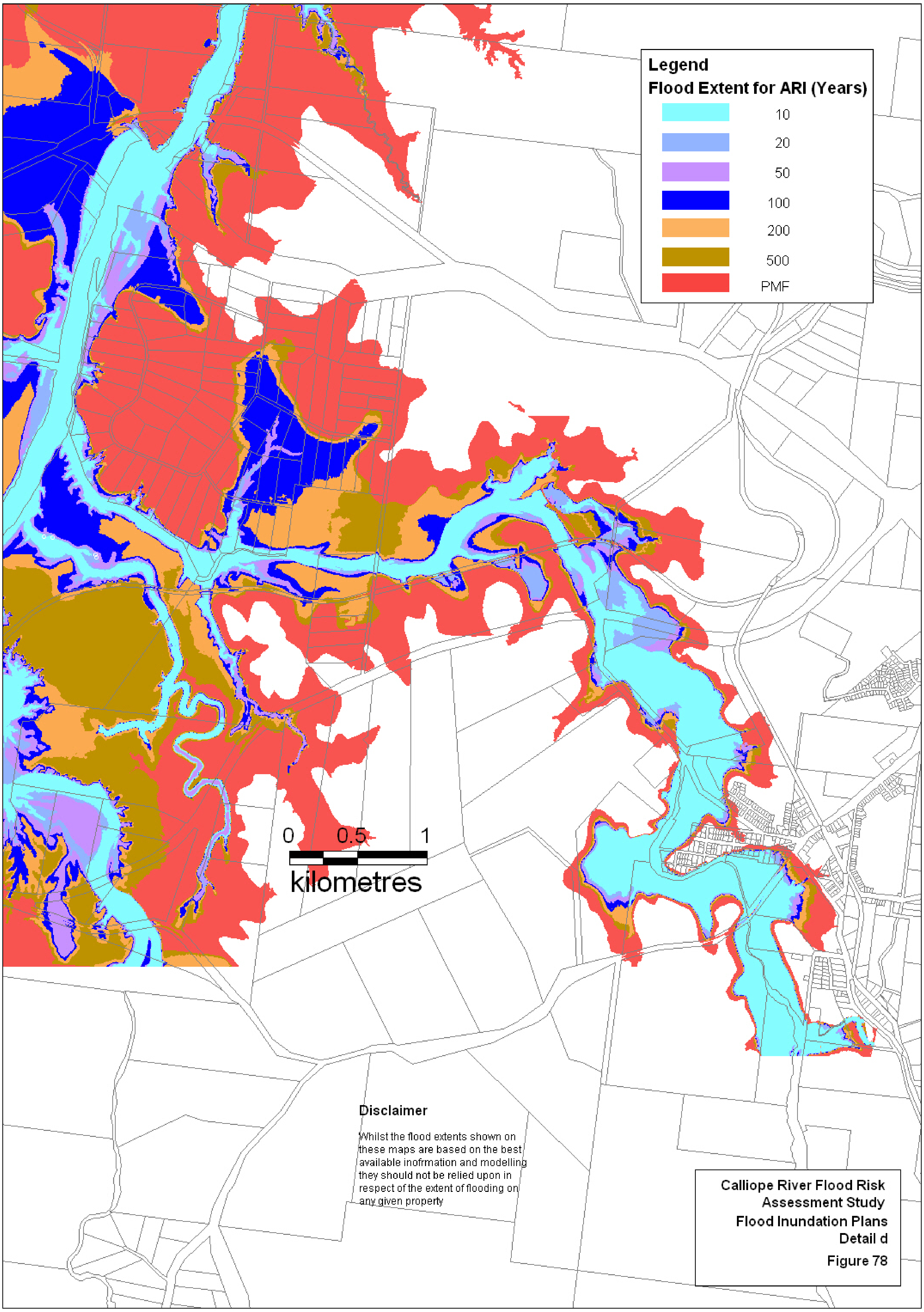


Figure 77 **Flood Inundation Plans - Detail c**



Disclaimer

Whilst the flood extents shown on these maps are based on the best available inofrmation and modelling they should not be relied upon in respect of the extent of flooding on any given property

Calliope River Flood Risk
Assessment Study
Flood Inundation Plans
Detail d
Figure 78

Figure 78 Flood Inundation Plans - Detail d

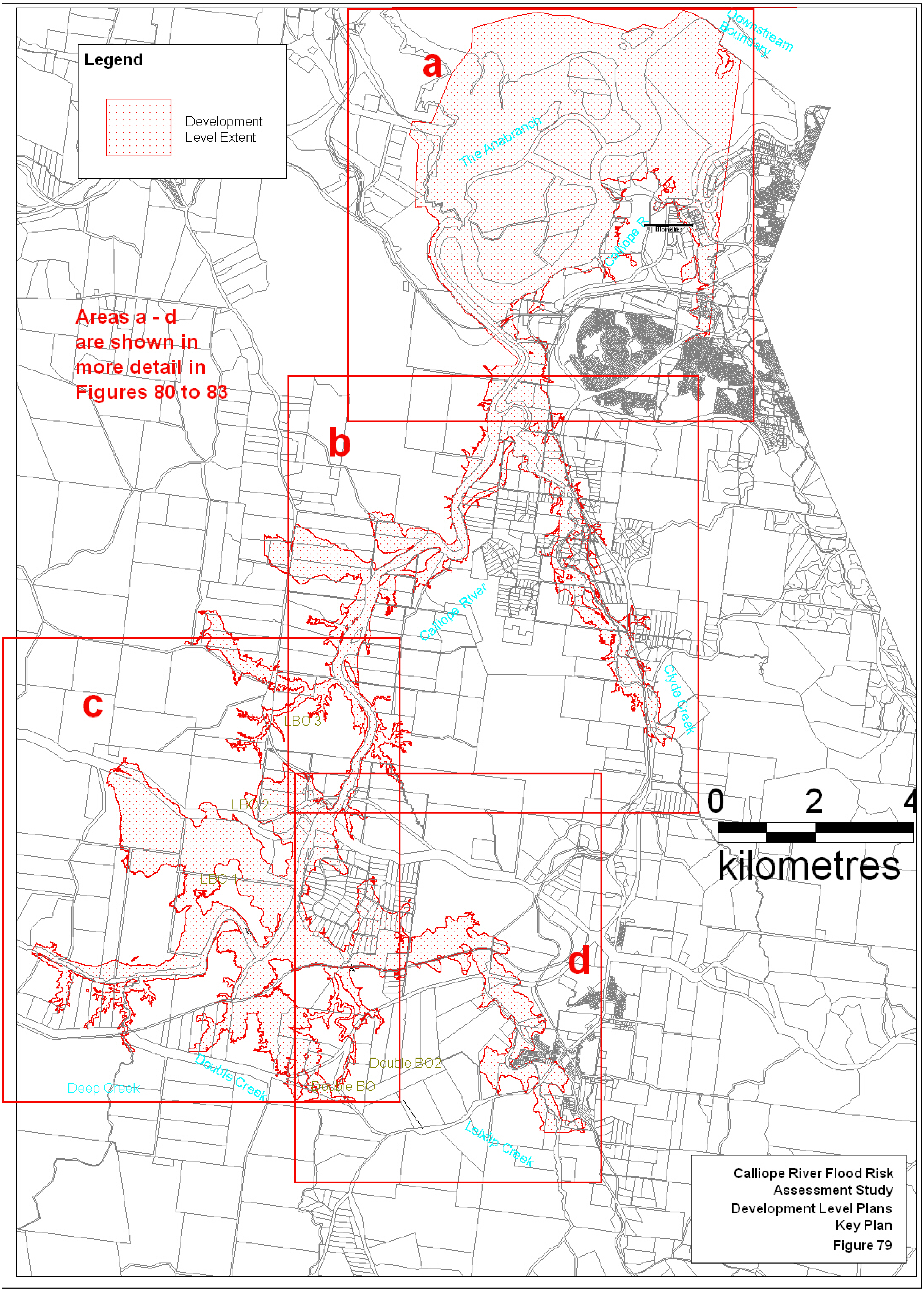


Figure 79 **Development Levels – Key Plan**

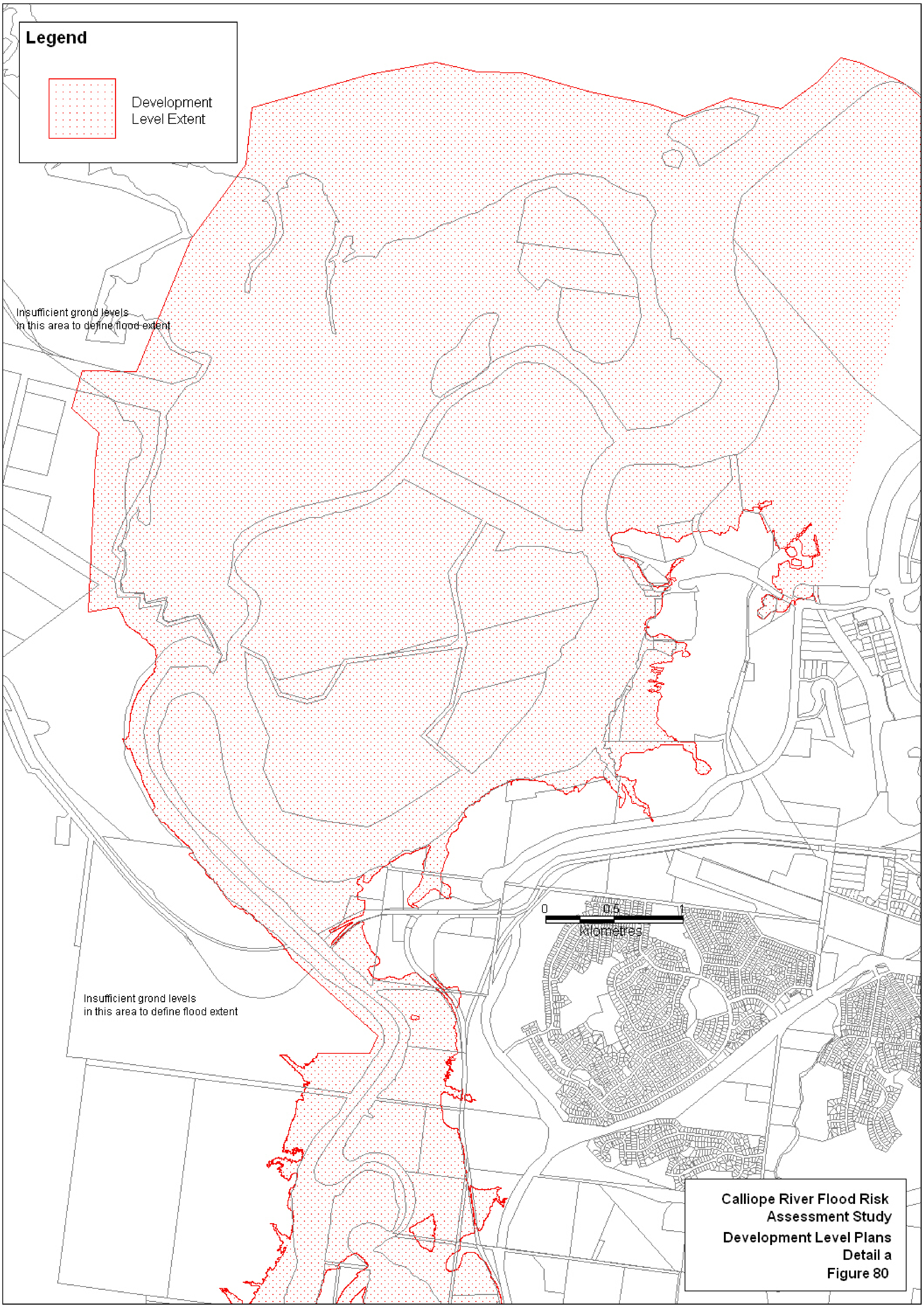


Figure 80 Development Levels - Detail a

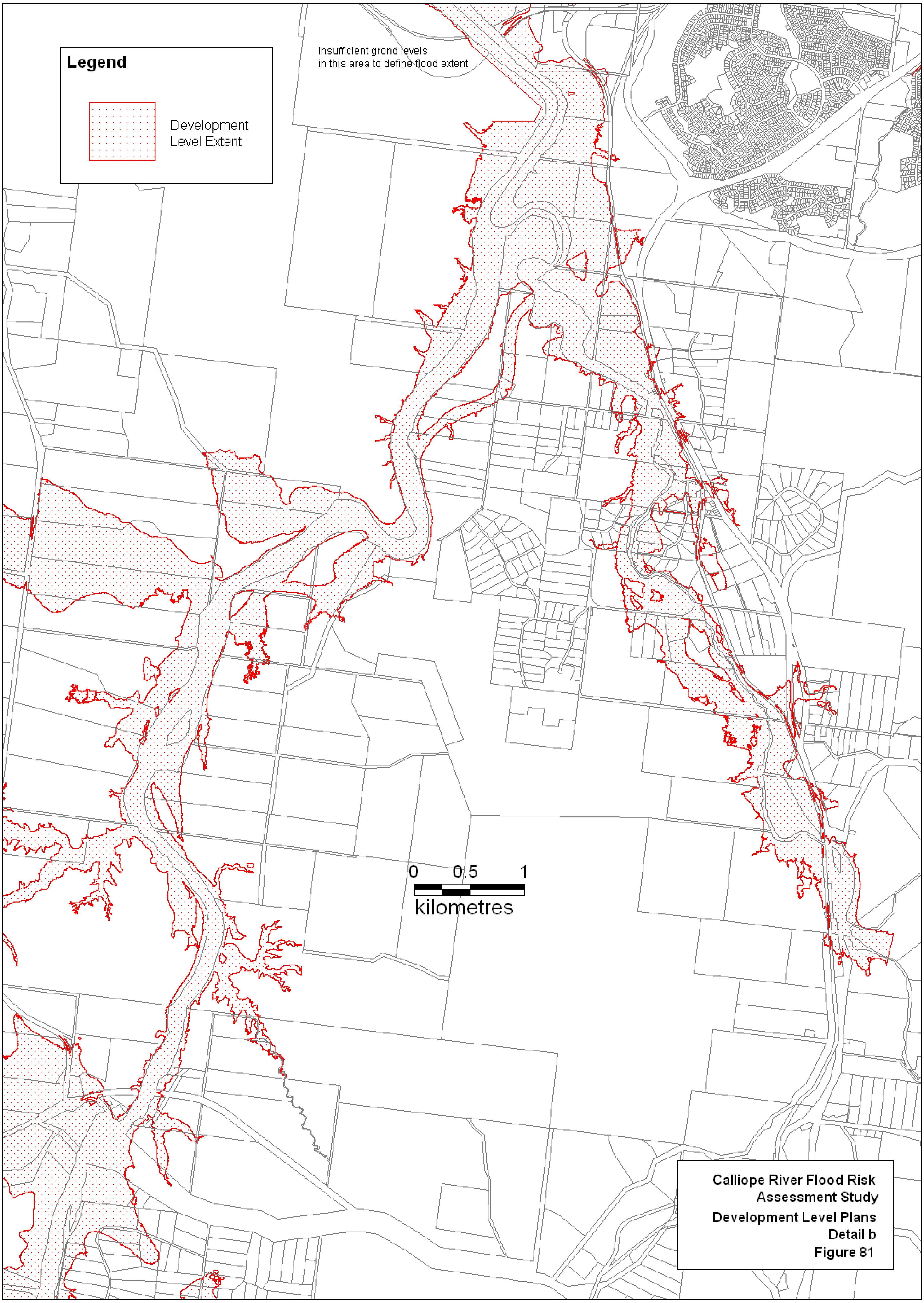


Figure 81 Development Levels - Detail b

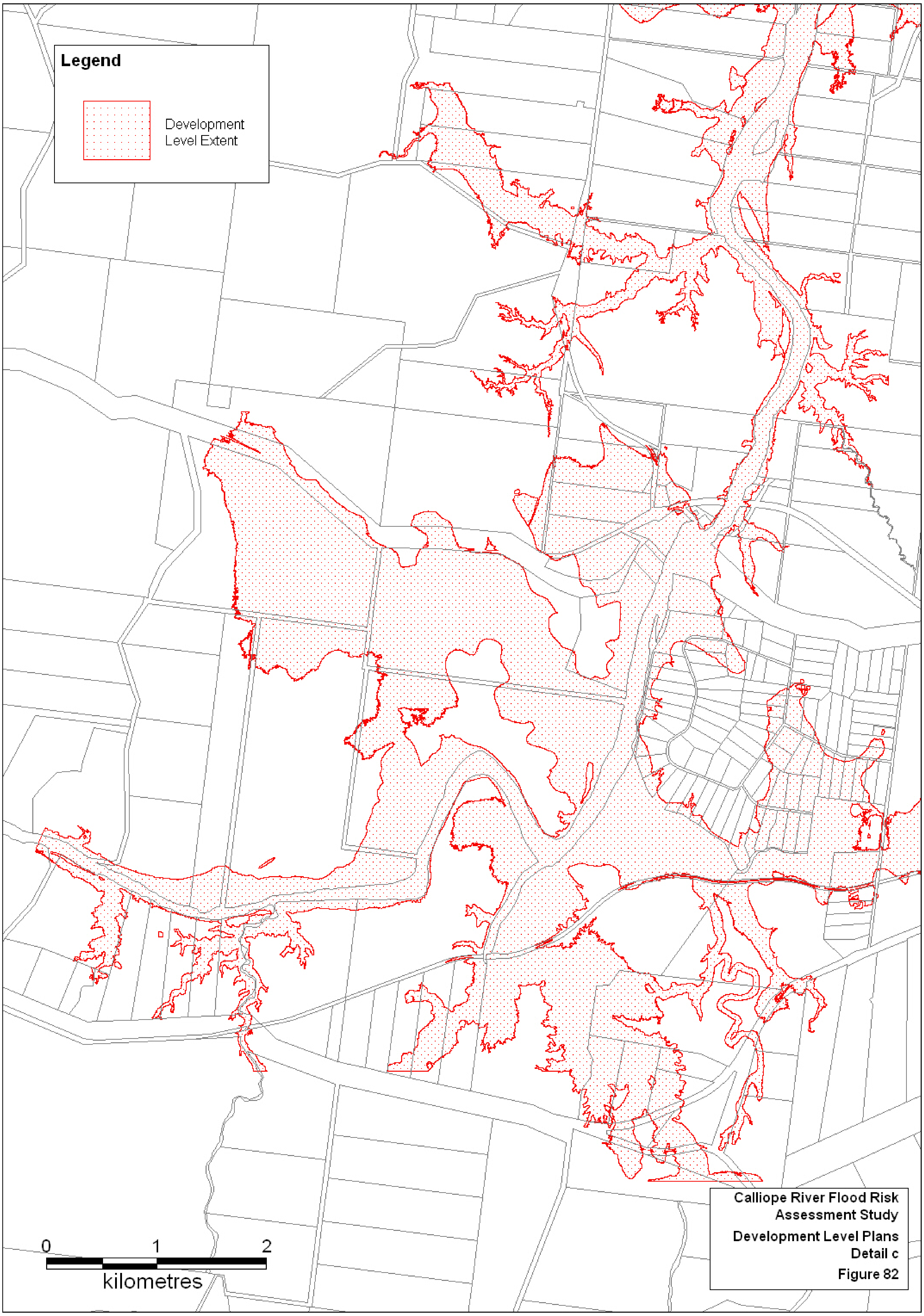


Figure 82 **Development Levels - Detail c**

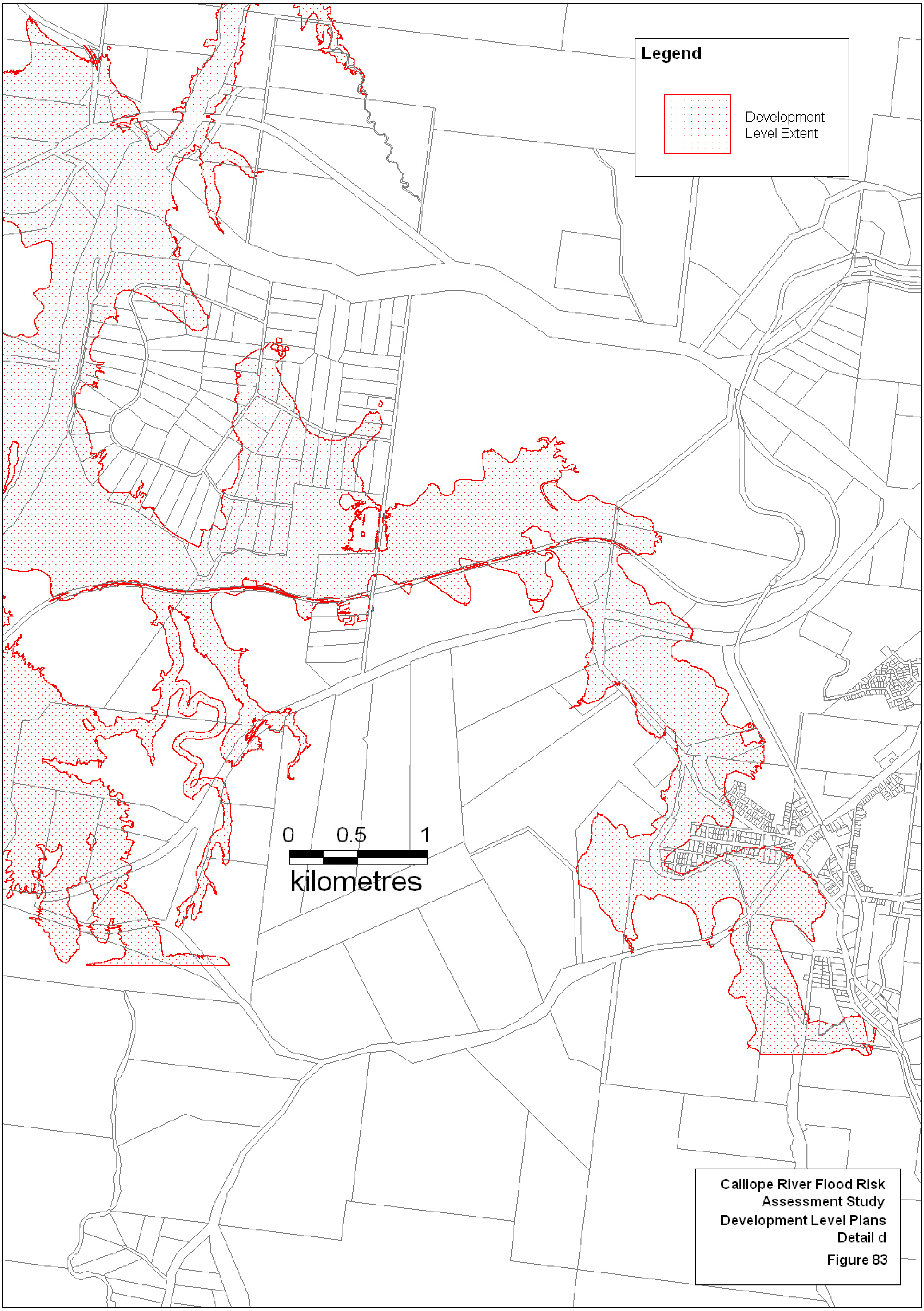


Figure 83 **Development Levels - Detail d**

9. Road Upgrade Requirements

Table 31 tabulated the current flood immunity of road and rail crossings in the Calliope River, Leixlip Creek, Clyde Creek and The Anabranch floodplains.

Table 32 lists road upgrades which would increase the flood immunity for Council roads to 10 year ARI (5 locations) and to 50 year ARI flood immunity for highways (i.e. roads under the control of the Department of Main Roads) (2 locations).

The minimum road approaches/bridge levels given in **Table 32** are based on the estimated flood level assuming 800mm from bridge/culvert soffit to road deck level where this is unknown. The waterway areas have been estimated to give the required road immunity such that the upstream level is below the deck level. These levels and waterway areas have been determined by running the MIKE 11 model with these modifications in place.

It should be noted that the upgrade requirements given herein may not be optimal and that additional work is required at the design stage should these upgrades be proceeded with in order to ensure that the most cost effective designs are developed.

Flood levels for the 10, 50 and 100 year ARI flood with the proposed works in place are given in **Appendix H.**

There are two low level crossings on the Calliope River, namely, the Old Bruce Highway Crossing and the ford between Blackgate Road and Ferguson Road at Castlehope. The Old Bruce Highway crossing is flooded at a flow much less than the 10 year ARI flow, but the actual frequency of flooding was not computed as 10 year ARI was the smallest flood computed. This crossing is shown in **Plate 1**. Although no longer a main road crossing, this causeway is still accessible to local traffic giving access for tourists and picnickers. The roadway is both narrow and in poor condition, and has no barriers apart from kerbs. Hence, this crossing is extremely dangerous even with a small depth of flow over it.

The flow depth at the ford crossing at Castlehope is 10m in a 10 year ARI flood, and is clearly impassable in all but very low flow conditions.

Both of these crossings represent a high risk during even relatively low flows, especially for visitors to the area who are unaware of local conditions. It is recommended, therefore, that at the minimum, flood depth markers and appropriate warnings signs be erected at these crossings.

Furthermore, as these crossings are not required for access i.e. both are accessible from both sides), it is further recommended that consideration be given to permanent closure of these crossings.

We understand from Council that alternative routes provide adequate access/egress to areas served by Schilling Lane and by Hookes Road and hence upgrading the flood immunity of these roads is of low priority. Council is also considering a higher immunity road into the area served by Wyndham Road. If the crossings on these roads are not to be upgraded, it is recommended that appropriate warning signs be installed.

Plate 1 **Calliope River – Old Bruce Highway Crossing**

Table 32 Road Upgrade Requirements

Flowpath	MIKE 11 Chainage m	Road Crossing	Structure	Current Crossing Level m AHD	Approx Current Immunity Level ARI (Years)	Proposed Immunity (Years)	Proposed Upgrade or Comment	Min Road/Deck Level Required m AHD (assume deck 0.8 m above soffit)
Calliope River	324	Blackgate Rd/ Ferguson Rd	Ford	2.5	<<10	<<10	No proposed change High risk crossing Upgrade impractical Recommend closure or as min. warning signs	-
	9413	Old Bruce Highway Crossing	Low level Causeway	2.0	<<10	<<10	No proposed change High risk crossing Upgrade impractical Recommend closure or as min. warning signs	-
Leixlip Creek	1062	Dawson Highway	Culverts	29.5	<10	50	Raise min road level to 31.2m Increase main culvert from 5 to 15 cells (3.0w x 2.4h)	31.20
	2924	Stowe Rd	Culvert	25.0	<10	10	Raise min road level to 26.8m Increase main culvert from 5 to 10 cells (3.6w x 3.0h)	26.80
	4466	Hookes Rd	Ford	18.5	<<10	10	Raise min road level to 22.1m New 10 cell culvert (3.6w x 2.1h) Low priority as alternative access/egress route available. Warning signs recommended.	22.10
	6332	Schilling Lane	Causeway with low flow culvert	12.7	<10	10	Raise min road level to 16.0m New 10 cell culvert (3.6w x 3.0h) Low priority as alternative access/egress route available. Warning signs recommended.	16.00
Clyde Creek	3820	Wyndham Rd	Proposed Bridge	10.4	<10	10	Increase bridge deck level and approaches to 12.2m. An alternative high immunity acess route is being considered. Warning signs recommended.	12.20
	6100	Jefferis Rd	Culvert	4	<10	10	Raise min road level to 7.1m Additional 5 cells to culvert (3.6w x 2.1h)	7.10
Deep Ck	47	Dawson Highway	Bridge	16.15	10	50	Increase bridge deck level and approaches to 18.5m	18.50
Double Ck	-440	Dawson Highway	Bridge	14	<<10	50	Increase bridge deck level and approaches to 18.1m	18.10

10. Other Physical Flood Mitigation Measures

This section deals with physical measures with the objective of mitigating property flooding, other than road upgrades. The consideration of non-structural mitigation measures is outside the scope of the project brief. Consideration of physical flood mitigation measures in this study is limited to their hydraulic efficacy and impacts, and does not extend to cost estimation, environmental or social impacts.

As all of the options considered aim to reduce property flooding, there effectiveness was estimated for 100 year ARI conditions only.

10.1. Flooding - Current Conditions

The extent of flooding in a 100 year ARI event under current conditions is shown **Figures 74 to 78.**

From the flood extent map, it can be seen that only a small number of properties are subject to inundation or isolation by floodwaters in a 100 year ARI event, as listed below:

- There are some 15 properties liable to property and/or over-floor flooding from Leixlip Creek. These properties are in Calliope Township along the right bank of Leixlip Creek, comprising 14 properties on Sutherland Street and adjacent streets, and 1 on Stowe Road. These are shown together with the 100 Year ARI flood extent in that area in **Figure 84**;
- One property fronting Clyde Creek immediately upstream of the Dawson Highway bridge which is flooded at 10 year ARI and above:
- One property fronting Clyde Creek immediately upstream of Wyndham Road: and
- Two areas adjacent to Calliope River, one near the confluence with Clyde Creek (ch 18386 – ch 19926) and another further south (ch 15750 – ch 16793) become isolated (flood islands) in floods of 100 year ARI or greater. Any future development on these areas may be subject to isolation for periods of several days, unless the access provided is to a high level. The appropriate access provision should be considered if and when development in these areas is proposed.

Considerably greater numbers of properties will be flooded or isolated in the event of an extreme flood.

10.2. Flood Mitigation Options

Physical flood mitigation measures fall into the following general categories:

- Works to increase the capacity of the waterway and/or its hydraulic structures to convey flood flows;
- Works to isolate properties from the floodwaters; and
- Works to reduce the peak discharge so that the flow is contained within the channel.

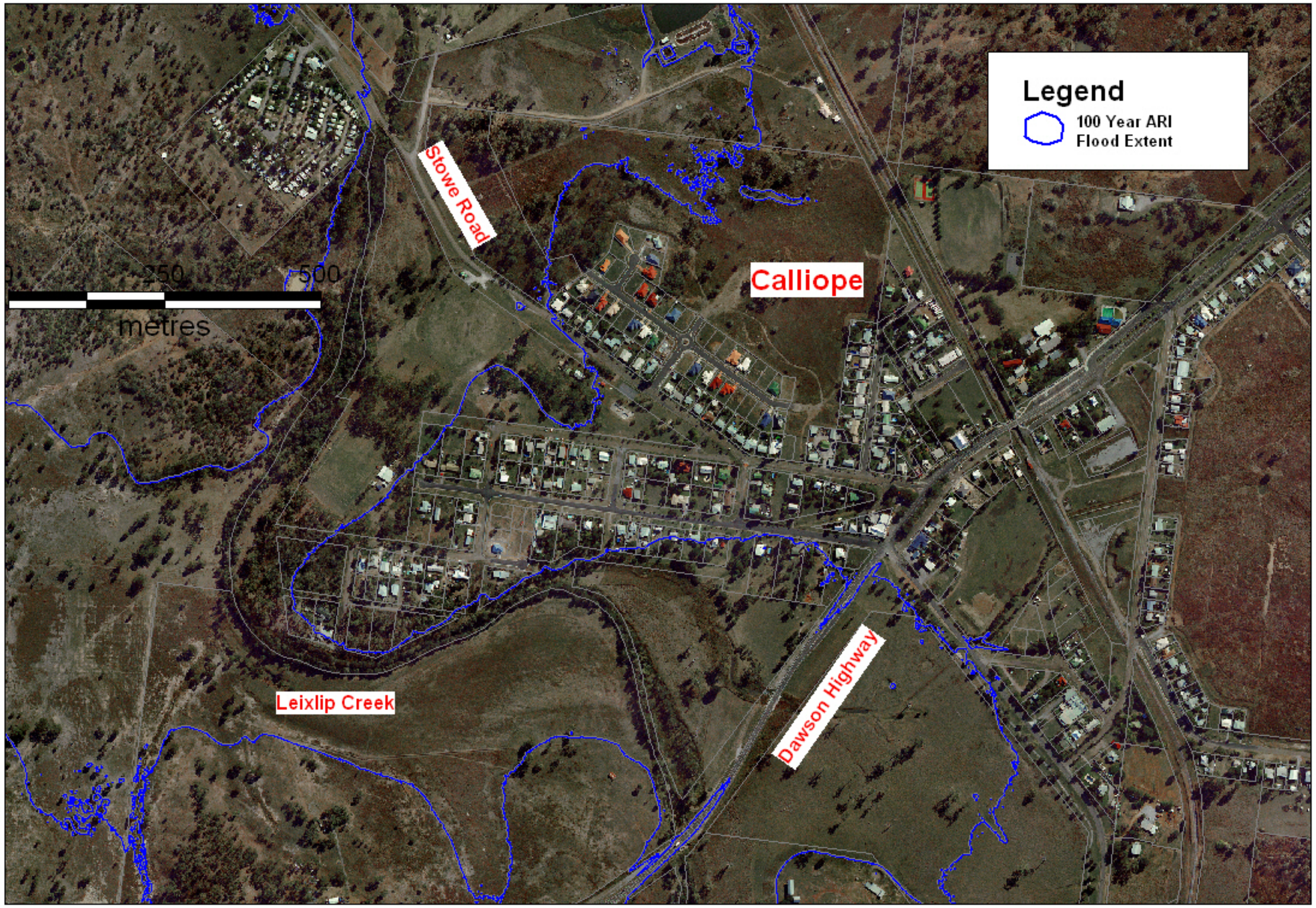


Figure 84 Flood Liable Properties along Leixlip Creek at Calliope

Options to increase channel conveyance include:

- Increasing the waterway areas of the bridges and culverts, where these are found to be a significant impediment to flows; and

- Channel enlargement works such as channel widening, diversion channels, or reducing the hydraulic roughness of the channel.

Options to prevent direct contact with the properties by the floodwaters include:

- The construction of levees - levees increase the flood level upstream so this impact needs to be taken into account; and

- Raising of non-masonry houses so that their habitable floor levels are above flood level.

The principal means of reducing peak flood flows is to introduce storage to attenuate the flood wave, resulting in the required reduction in peak flow downstream. This can be achieved by means of one or more flood mitigation dams (major detention basins) within the catchment.

This study has considered a range of potential flood mitigation measures in broad terms only. It is beyond the scope of this study to propose works in detail, and works will require further investigation in respect of their detail, economics (eg cost/benefit performance) and sustainability.

However, the study does draw some conclusions which enable some of the options to be discounted from further consideration, and makes recommendations for further investigations.

Works to increase the capacity of road crossings have been outlined in **Section 9** hereof. However, the potential for flood level reduction by vegetation reduction to reduce hydraulic roughness, or by channel enlargement were discounted without detailed analysis. Floodplain vegetation reduction requires ongoing maintenance and hence cannot be relied upon as a control measure in the medium to long term, and also has adverse environmental impacts. Similarly, channel widening has significant environmental impacts, and is very high cost, and also requires ongoing maintenance without which the channel shape may revert to its natural state in the medium/long term.

Three specific measures were identified which were considered to have sufficient potential merit to warrant their evaluation. These were:

- Construction of a levee to provide protection to the 15 properties adjacent to Leixlip Creek along Sutherland Street, Wilkin Street and Stowe Road;

- Construction of a major detention basin on Leixlip Creek to reduce peak flood flows; and

- Construction of 2 major detention basins on Clyde Creek to reduce peak flood flows.

The following paragraphs outline the options which were considered to have potential merit.

10.2.1. Levee Leixlip Creek

Figure 85 shows the alignment of a possible levee along the right bank of Leixlip Creek between the Dawson Highway and Stowe Road.

The eastern end of the levee would tie into higher ground near the junction of Sutherland Street and the Dawson Highway. From this point, the levee would pass behind the rear boundary of properties along Sutherland Street, Mary Street and Wilkin Street, then turn north through Bunting Park to join Archer Street/Stowe Road.

In order to provide protection against the 100 year flood plus 1m freeboard, this levee would vary in height from about 2m to 4m.

The MIKE 11 model was run for the 100 year ARI events (durations 3 to 24 hours) with flood levels compared to those for the 100 year flood for current conditions. The following effects were noted:

- No increase in 100 Year ARI flood level upstream of the Dawson Highway;
- A maximum increase in 100 Year ARI flood level of 0.12m within the leveed reach; and
- No increase in 100 Year ARI flood level downstream of Archer Street/Stowe Road.

Detailed results from these model runs are given in **Appendix I.**

The levee has little impact on flood levels as although it reduces the flow area, it also increases the hydraulic efficiency by substantially reducing the wetted perimeter, with a net result of only a minor reduction in the hydraulic radius.

The small increases in flood level within the leveed reach would have no significant impact on properties outside the levee as there are no buildings on the opposite (left) bank of Leixlip Creek.

It appears from this preliminary evaluation that the levee would not have significant adverse impacts on flood levels elsewhere, and is worthy of further consideration. It is outside the scope of the current study to consider aspects other than the hydraulic impacts of possible flood mitigation works.

However, as with any levee scheme the issue of drainage of the area behind the levee would be an issue which would need to be considered.

Although economic considerations are outside the scope of this report, it is considered unlikely that the levee would have a sufficiently high benefit/cost ratio to be considered favourably for subsidised funding under the *Natural Disaster Mitigation Program*.

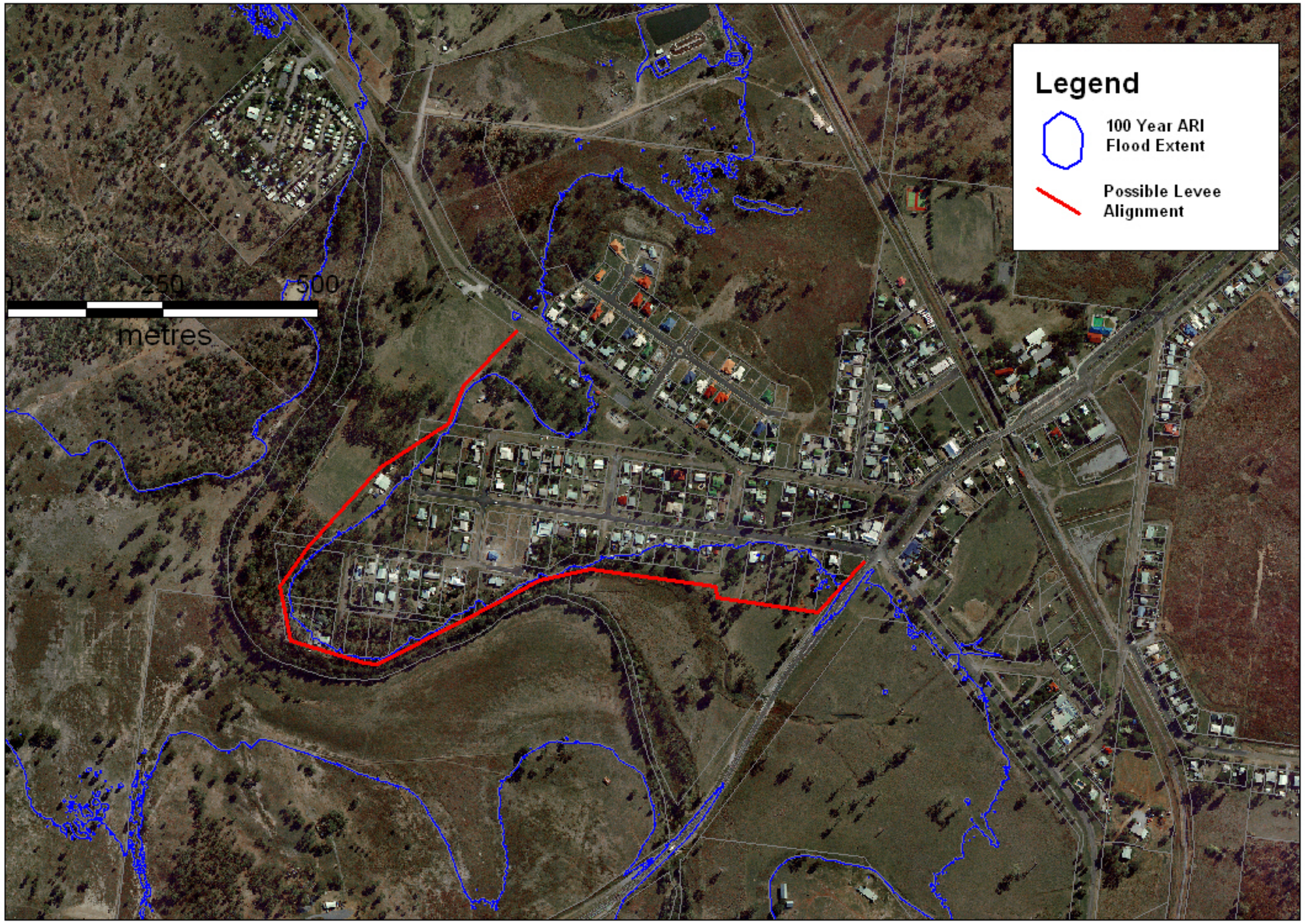


Figure 85 **Potential Levee - Leixlip Creek at Calliope**

10.2.2. Flood Mitigation Storage

The reduction of flood flow rates requires the introduction of storage. Possible storage locations on the Calliope River and its tributaries were investigated on the basis of topography, hydrology and hydraulics only.

Whilst no major site was identified on the Calliope River, a number of potential flood detention basin sites were identified on Leixlip Creek and Clyde Creek.

Potential storage sites were identified from the topographic mapping – sites were excluded where the aerial photography showed that inundation of buildings would result.

The depth/area/storage volume relationships for each of the identified sites were estimated from the contour maps using the GIS to calculate areas and a spreadsheet to compute volumes. These relationships are given in **Appendix J.**

The potential for each site to reduce flood flows was estimated using the RORB model which was modified to include the potential detention basins. The impact on flows from these runs is given in **Appendix J**.

The MIKE 11 hydraulic model was then run, for the 100 year ARI only, with input hydrographs modified to represent the outflows with the detention basins in place. The resulting peak flood levels were then compared with those under current conditions. These are given in **Appendix J.**

The following paragraphs describe the locations and assumed characteristics of the sites on Leixlip and Clyde Creeks and the outcomes from the assessment process outlined above.

a) Leixlip Creek

The possible location for a detention basin on Leixlip Creek was identified as shown in **Figure 86**. This location is approximately 5km south of Calliope Township and about 1.5km south of the racecourse. An oblique aerial view looking upstream into the storage area is given in **Figure 87.**

At this point Leixlip Creek passes from higher ground into the valley area. The creek bed level at this point is about 58m and the maximum storage potential at this site is about 18,000 ML at an elevation of 90m, which would require construction of a main dam and a saddle dam.

The RORB model was run with the following parameters, for ARIs of 10, 50 and 100 years only:

- Spillway level 89m, spillway length 20m
- Pipe outlet elevation 58m, diameter 1.0m.

By maximising storage and limiting outlet capacity, these parameters would be expected to result in maximum or near maximum peak flow attenuation for this site.

With these parameters the peak 100 year ARI inflow of 360m^3/s was reduced to only 10m^3/s with no spillway discharge.

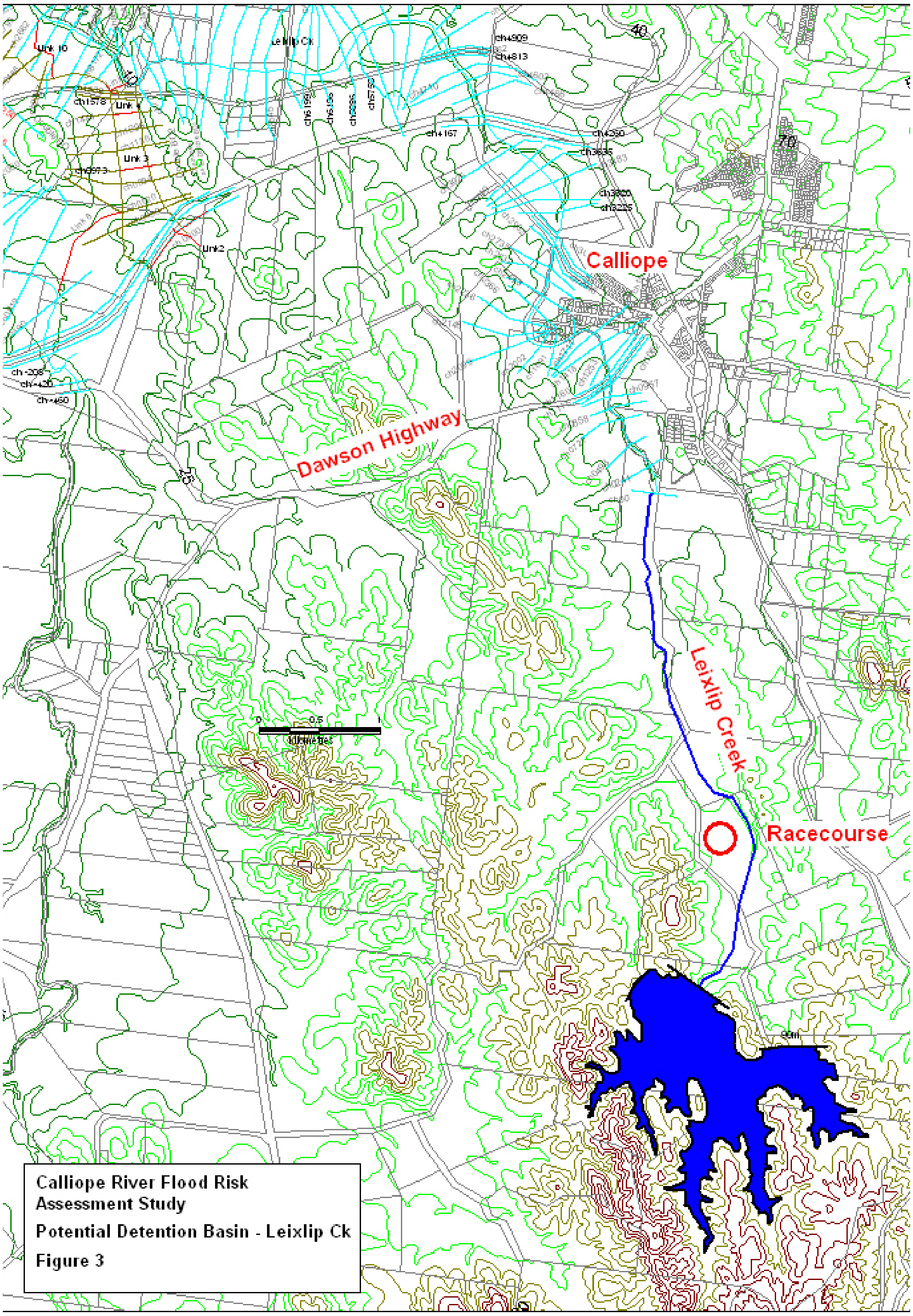


Figure 86 **Potential Detention Basin – Leixlip Creek**

Figure 87 Oblique View of Detention Basin Location – Leixlip Creek
(Source photography Google Earth)

The resulting flood level reductions at key points are summarised in **Table 33** and are given in detail in **Appendix J**.

Table 33 Flood Level Reductions due to Potential Detention Basin - Leixlip Creek

Location	MIKE 11 Chainage m	Reduction in Peak Flood Level (m) for ARI (years)			Comments
		10	50	100	
Dawson Highway	1062	-0.52	-0.42	-0.45	Insufficient to obviate need for culvert upgrade or levee
Stowe Road	2946	-0.43	-0.44	-0.43	Insufficient to obviate need for culvert upgrade
Schilling Lane	6332	-0.91	-1.15	-1.21	Insufficient to obviate need for culvert upgrade

Hence, although the detention basin has the potential to substantially reduce flows from the upstream catchment, this reduction would not be sufficient to obviate the need for culvert upgrades as the road crossings downstream, nor that of the levee to protect properties in the Sutherland Road area of Calliope Township.

It was concluded, therefore, that there was no significant flood mitigation benefit to be gained from the construction of this detention basin.

b) Clyde Creek

Two possible locations for detention basins on Clyde Creek were identified as shown in **Figure 88**. These locations are immediately south of the Bruce Highway approximately 3km east of the Bruce Highway/Dawson Highway junction. The large basin would utilise a raised Bruce Highway embankment as its dam, whilst the smaller on the tributary, Ginger Beer Creek, would be formed by a small dam upstream of the highway.

The former site is not ideal as it requires a relatively long embankment, but this is mitigated by using the highway embankment to effect the impoundment. Depending on the degree of development at the site, the embankment may require raising. An oblique aerial view of this site is given in **Figure 89.**

The creek bed levels at these locations are about 50m and 54m for Clyde Creek and Ginger Beer Creek respectively, and the maximum storage potential at these sites are about 17,000 ML at an elevation of 80m for Clyde Creek and about 2,500 ML at an elevation of 70m for Ginger Beer Creek.

The RORB model was run with the following parameters, for ARIs of 10, 50 and 100 years only:

- Clyde Creek - spillway level 79m, spillway length 20m, pipe outlet elevation 50m, diameter 1.0m
- Ginger Beer Creek - spillway level 68m, spillway length 20m, pipe outlet elevation 54m, diameter 1.0m.

By maximising storage and limiting outlet capacity, these parameters would be expected to result in maximum or near maximum peak flow attenuation for this site.

With these parameters the peak 100 year ARI inflows of 130m^3/s for the Clyde Creek basin was reduced to only 7m^3/s with no spillway discharge, and that for Ginger Beer Creek from 150m^3/s to only 8m^3/s with no spillway discharge. The combined effect of these basins at the upstream boundary of the hydraulic model was to reduce the 100 year peak flow from 440m^3/s to 250m^3/s.

The resulting flood level reductions at key points are summarised in **Table 34** and are given in detail in **Appendix J**.

Table 34 Flood Level Reductions due to Potential Detention Basin - Clyde Creek

Location	MIKE 11 Chainage m	Reduction in Peak Flood Level (m) for ARI (years)			Comments
		10	50	100	
Dawson Highway	953	-1.43	-2.23	-2.02	Would increase flood immunity of crossing from 50 to 100 years
Wyndham Road	3800	-0.51	-0.59	-0.64	Insufficient to obviate need for increase in deck level of proposed bridge
Jefferis Road	6100	-0.30	-0.50	-0.48	Insufficient to obviate need for culvert upgrade

Hence, although the detention basins have the potential to substantially reduce flows from the upstream catchment, this reduction would not be sufficient to obviate the need for bridge/culvert upgrades as the road crossings downstream.

It was concluded, therefore, that there was no significant flood mitigation benefit to be gained from the construction of this detention basin.

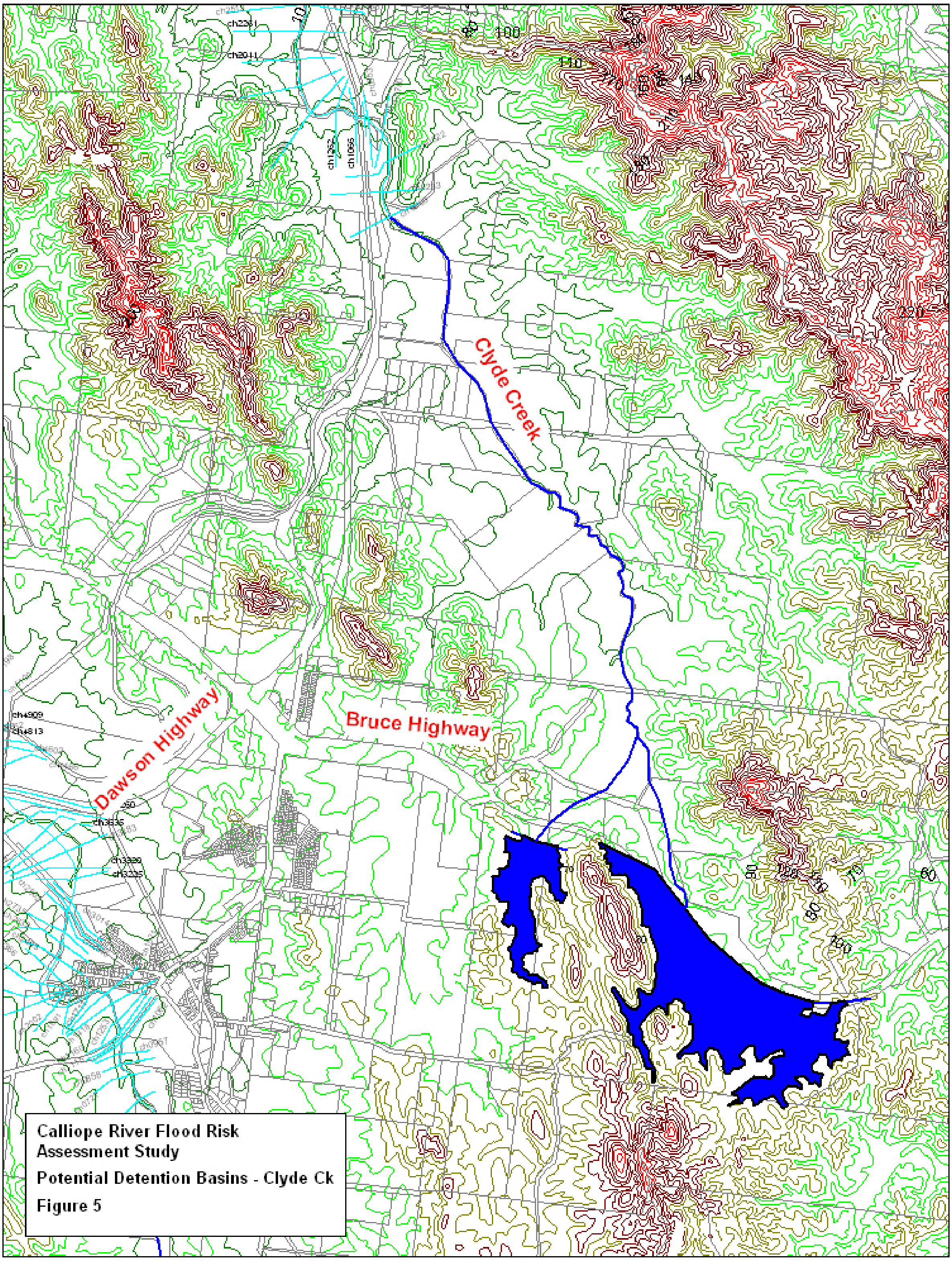


Figure 88 Potential Detention Basins – Clyde Creek

Figure 89 **Oblique View of Detention Basin Location – Clyde Creek**
(Source photography Google Earth)

11. Summary of Conclusions and Recommendations

11.1. Hydrologic and Hydraulic Model Calibration

The following conclusions were reached in respect of the setup and calibration phases of the hydrologic and hydraulic modelling components of the study which form the content of this Milestone Report:

- The calibrated RORB hydrologic model satisfactorily represented both the quantum of flood flows and their distribution from the Calliope River catchment into the reaches of the lower Calliope River represented in the hydraulic model;

- There were inconsistencies in the hydraulic model calibration between the more recent flood events (2003, 1990) and those from the 1970s (1978, 1973);

- These inconsistencies were resolved by the brief assessment of physical changes to the channel capacity of the Calliope River which concluded that there has been significant channel widening/deepening occurring over recent years, and hence the hydraulic model parameters should be estimated from the most recent flood events only; and

- Whilst the data available for calibration of the hydrologic model were reasonable, there were too few historic flood level data in respect of the hydraulic model to obtain a reach by reach calibration, and even less to calibrate the tributaries.

11.2. Design Flood Estimation

11.2.1. Conclusions

The following conclusions were reached in respect of the design flood estimation component of the study:

- The flood extent or footprint is not very sensitive to the assumed downstream boundary condition (within an appropriate range);

- That the likely accuracy of the estimated 100 year ARI flood levels is of the order of ±1m, and hence that an appropriate freeboard allowance when using these estimates for town planning purposes is 1m; and

- The likely accuracy of the PMF is of the order of ±2m.

11.2.2. Recommendations

The following recommendations are made in respect of design flood estimation:

- Flood maps should carry a suitable disclaimer regarding their being based on the best available information but that these maps should not be relied upon to define the extent of flooding on any particular property;

- Given the relatively poor accuracy associated with the estimated flood levels, we recommend that Council considers the installation of peak level indicators through the hydraulic model extent. These are of relatively low cost, and will allow the collection of improved flood level data over time, which can then be used to refine the calibration of the hydraulic model and thereby, to reduce the uncertainty inherent in the estimated flood levels; and

- Due to the findings that there is ongoing channel widening and deepening occurring in the Calliope River, that a number of monitoring sites be established to better quantify this.

11.3. Physical Flood Mitigation Measures

11.3.1. Conclusions

The following conclusions were reached in respect of physical flood mitigation measures:

Flood Immunity of Road Crossings

- The flood immunity of a number of road crossings within the study area for which Calliope Shire Council is responsible is less than 10 year ARI (as listed in **Table 31**) and the measures required to upgrade these crossings have been determined to a preliminary design level (**Table 32**);

- The flood immunity of the Dawson Highway crossings of Leixlip Creek and Double Creek are less than 10 year ARI; and

- There are two low level crossings on the Calliope River, namely, the Old Bruce Highway Crossing and the ford between Blackgate Road and Ferguson Road at Castlehope, which represent a high risk during even relatively low flows, especially for visitors to the area who are unaware of local conditions.

Flood Mitigation Measures

- There is the potential to construct a levee to prevent flooding up to 100 year ARI to about 15 properties along Leixlip Creek without unduly impacting on flood levels upstream; and

- Potential detention storage sites within the Leixlip Creek and Clyde Creek catchments were identified and found to have some potential to reduce flood levels downstream. However, this potential was found to be insufficient to obviate the need for the upgrade of road crossings.

11.3.2. Recommendations

The following recommendations are made in respect of road upgrading and physical flood mitigation measures:

Low Level Crossings

- That at the minimum, Calliope Shire Council considers the installation of flood depth markers and appropriate warnings signs at these crossings; and

- As these crossings are not required for access i.e. both are accessible from both sides), it is further recommended that consideration be given to permanent closure of these crossings.

Flood Immunity of Road Crossings

- That Calliope Shire Council considers the upgrade of the flood liable roads in the study area which are under its control (as listed in **Table 1**) to achieve a flood immunity of 10 year ARI;

- Where these crossings are low priority for raising of their flood immunity due to the availability (or planned availability) of alternative means of access/egress during flood that appropriate warning signs be installed; and

- That Calliope Shire Council lobbies the Queensland Government to upgrade the flood immunity of the Dawson Highway at Leixlip Creek and Double Creek to 50 year ARI.

Flood Mitigation Measures

a) Levees

The construction of a levee to mitigate flooding from Leixlip Creek in the Sutherland Street area of Calliope Township would be possible without adverse impacts on flooding elsewhere.

Although economic considerations are outside the scope of this report, it is considered unlikely that the levee would have a sufficiently high benefit/cost ratio to be considered favourably for subsidised funding under the *Natural Disaster Mitigation Program*. Hence, further work on this is not considered to be warranted at this time.

b) Detention Basins

As it was concluded that there was no significant flood mitigation benefit to be gained from the construction of the identified detention basins on Leixlip Creek and Clyde Creek, it is recommended that no further work on these possible schemes be undertaken.

12. References

BUREAU OF METEOROLOGY (2003) *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method*

BUREAU OF METEOROLOGY (2004) *Guide to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method*

CHOW V T (1973) *Open Channel Hydraulics* McGraw Hill

DANISH HYDRAULICS INSTITUTE *MIKE 11 Reference Manual*

DUKE ET AL (2003) *Assessing Historical Change in Coastal Environments - Port Curtis, Fitzroy River Estuary and Moreton Bay Regions*

EARTHTECH in association with SARGENT CONSULTING (2003) *Natural Disaster Risk Management Study Report* prepared for Calliope Shire Council

HOSKING JRM, WALLACE JR (1997) *Regional Frequency Analysis – An Approach based on L- Moments* Cambridge University Press

INSTITUTION OF ENGINEERS AUSTRALIA (1987 and updates) *Australian Rainfall and Runoff – A Guide to Flood Estimation*, Canberra

KOTTEGODA N T (1980) *Stochastic Water Resources Technology* Macmillan

LAURENSON E M AND MEIN R G (1997*) RORB Version 4 Runoff Routing Program User Manual* Monash University Dept. of Civil Engineering

MARITIME SAFETY QUEENSLAND (2002) *Gladstone Boating Safety Chart* Capricorn Coast Series – Chart CC1

SARGENT CONSULTING (2004a) *Calliope River Flood Study – Milestone Report 1 Model Setup and Calibration* prepared for Calliope Shire Council and Gladstone City Council

SARGENT CONSULTING (2004b) *Calliope River Flood Study – Working Paper 1 Brief Assessment of Physical Changes to Calliope River* prepared for Calliope Shire Council and Gladstone City Council

SARGENT CONSULTING (2004c) *Calliope River Flood Study – Milestone Report 2 Hydrologic and Hydraulic Analysis and 100 Year ARI Inundation Plan* prepared for Calliope Shire Council and Gladstone City Council

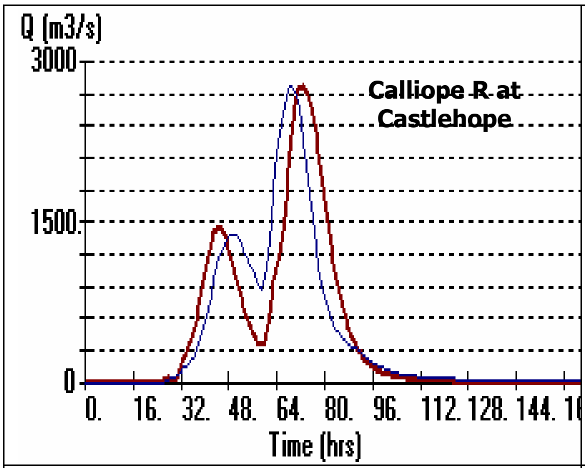
SARGENT CONSULTING (2004d) *Calliope River Flood Study – Milestone Report 3 Assessment of Flood Mitigation Measures* prepared for Calliope Shire Council and Gladstone City Council

SYSTEMS ENGINEERING AUSTRALIA, BUREAU OF METEOROLOGY, JAMES COOK UNIVERSITY (2003) *Queensland Climate Change and Community Vulnerability to Tropical Cyclones – Ocean Hazards Assessment Stage 3 – Surge Plus Tide Statistics for Selected Open Coast Locations along the Queensland East Coast* prepared for the Queensland Government

Appendix A
RORB Model Calibration Results

Note: Hydrographs shown using best overall parameters. These did not necessarily give the best fit to each individual event.

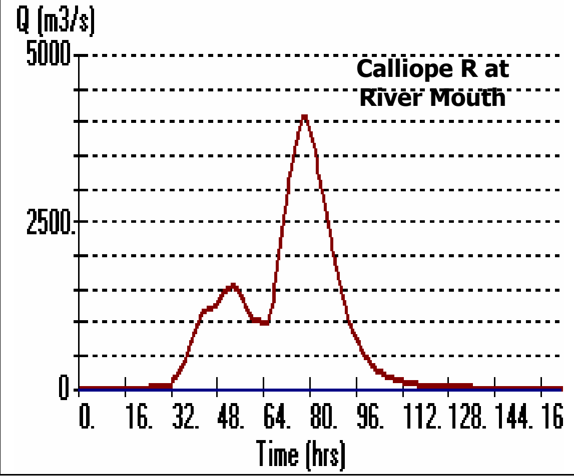
February 2003 Flood



Calliope River
Initial time:
0000 hours 4th February 2003

kc = 44.5 IL =120 . mm
m = 0.88 CL = 17.84

	Calc.	Actual
Peak discharge,m^3/s	2772.	2765.
Time to peak,h	72.0	69.0
Volume,m^3	2.62E+08	2.61E+08
Time to centroid,h	65.8	65.5
Lag (c.m. to c.m.),h	13.4	13.1
Lag to peak,h	19.6	16.6

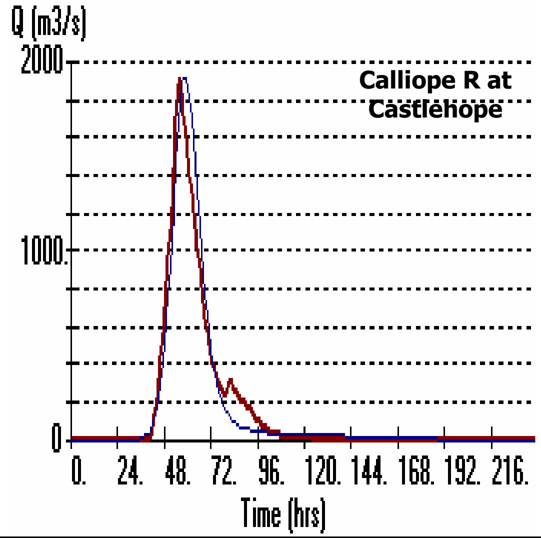


Calliope River
Initial time:
0000 hours 4th February 2003

kc = 44.5 IL = 120. mm
m = 0.88 CL = 17.84
Calculated hydrograph, Calliope River at Mouth

	Calc.
Peak discharge,m^3/s	4081.
Time to peak,h	78.0
Volume,m^3	4.21E+08
Time to centroid,h	72.3
Lag (c.m. to c.m.),h	19.4
Lag to peak,h	25.0

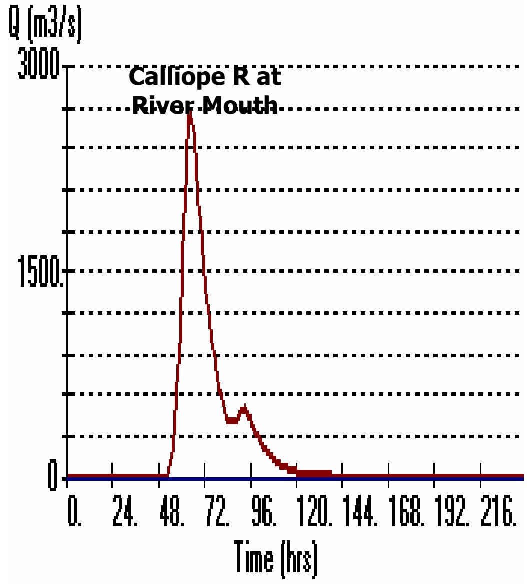
December 1990 Flood



Calliope River
Initial time:
0000 hours 27th December 1990

kc = 44.5 IL =190. mm
m = 0.88 CL = 1.84
7- Gauging station at: Calliope River at Castlehope

	Calc.	Actual
Peak discharge,m^3/s	1910.	1910.
Time to peak,h	56.0	58.0
Volume,m^3	1.35E+08	1.34E+08
Time to centroid,h	62.5	63.9
Lag (c.m. to c.m.),h	14.5	15.8
Lag to peak,h	7.95	9.95

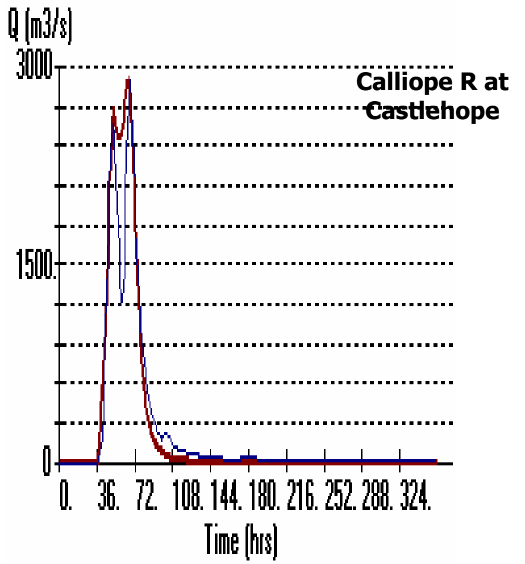


Calliope River
Initial time:
0000 hours 27th December 1990

kc = 44.5 IL = 190. mm
m = 0.88 CL = 1.84
7- Calculated hydrograph, Calliope River at Mouth

	Calc.
Peak discharge,m^3/s	2645.
Time to peak,h	65.0
Volume,m^3	1.75E+08
Time to centroid,h	73.7
Lag (c.m. to c.m.),h	23.1
Lag to peak,h	14.5

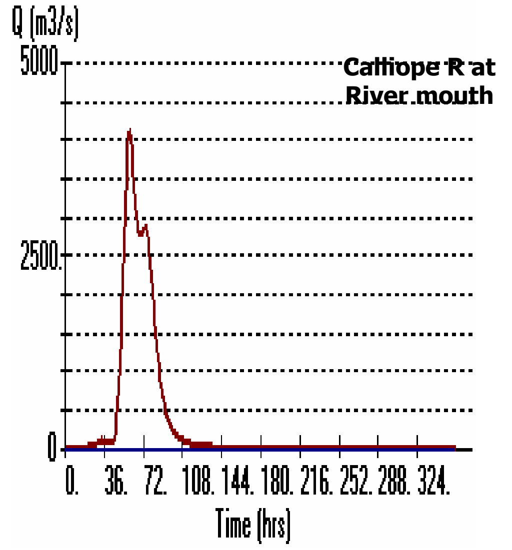
Jan/Feb 1978 Flood



Calliope River
Initial time:
0000 hours 29th January 1978

kc = 44.5 IL = . mm
m = 0.88 CL = 5.37
Gauging station at: Calliope River at Castlehope

	Calc.	Actual
Peak discharge,m^3/s	2894.	2899.
Time to peak,h	66.0	68.0
Volume,m^3	3.08E+08	3.07E+08
Time to centroid,h	61.9	71.9
Lag to peak,h	17.7	19.7

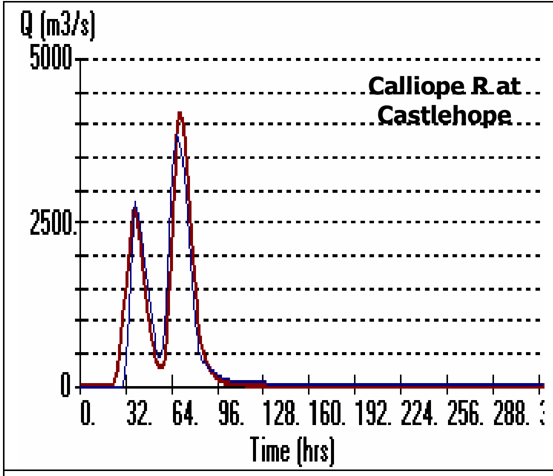


Calliope River
Initial time:
0000 hours 29th January 1978

kc = 44.5 IL = . mm
m = 0.88 CL = 5.37
10- Calculated hydrograph, Calliope River at Mouth

	Calc.
Peak discharge,m^3/s	4090.
Time to peak,h	59.0
Volume,m^3	3.97E+08
Time to centroid,h	68.7
Lag (c.m. to c.m.),h	21.3
Lag to peak,h	11.6

December 1973 Flood

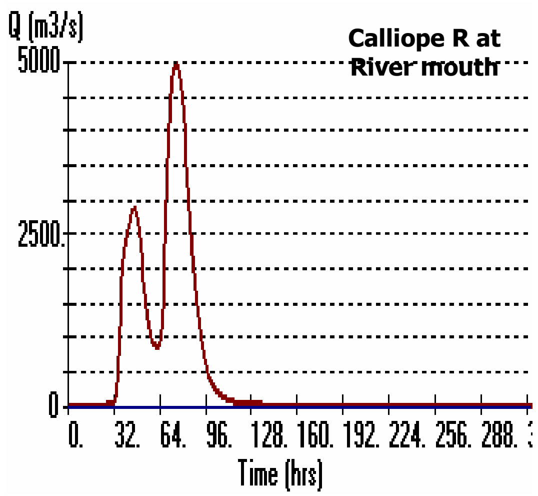


Calliope River
Initial time:
0000 hours18th December 1973

kc = 44.5 IL = . mm
m = 0.88 CL = 2.26

1- Gauging station at: Calliope River at Castlehope

	Calc.	Actual
Peak discharge,m^3/s	4170.	3864.
Time to peak,h	70.0	68.0
Volume,m^3	4.01E+08	4.01E+08
Time to centroid,h	59.8	66.2
Lag (c.m. to c.m.),h	12.7	19.0
Lag to peak,h	22.8	20.8



Calliope River
Initial time:
0000 hours18th December 1973

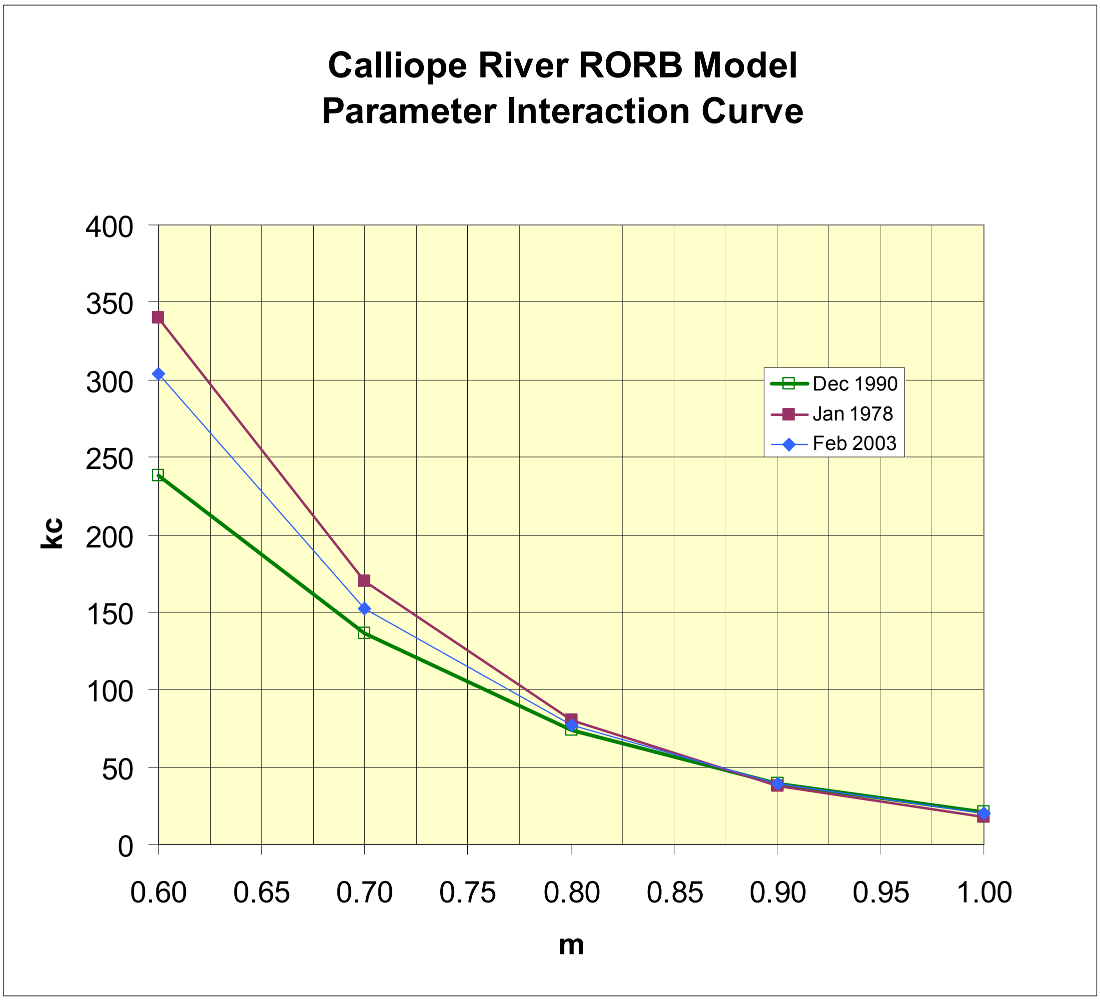
kc = 44.5 IL = . mm
m = 0.88 CL = 2.26

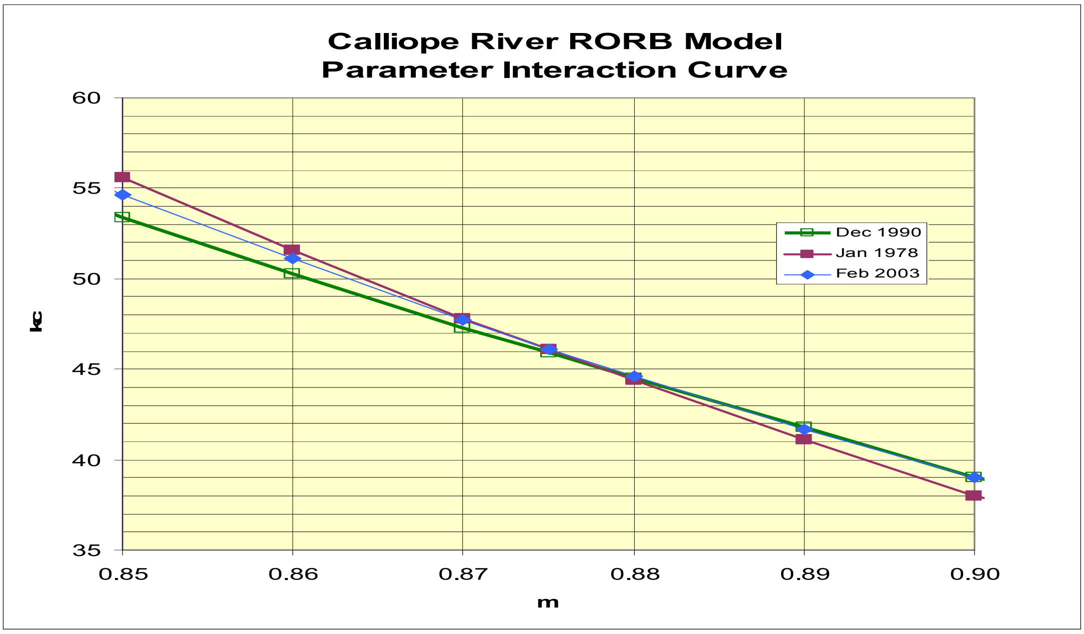
1- Calculated hydrograph, Calliope River at Mouth

	Calc.
Peak discharge,m^3/s	4976.
Time to peak,h	75.0
Volume,m^3	5.51E+08
Time to centroid,h	68.0
Lag (c.m. to c.m.),h	19.8
Lag to peak,h	26.8

RORB Model Calibration   Summary of Fitted Model Parameters and Loss Rates

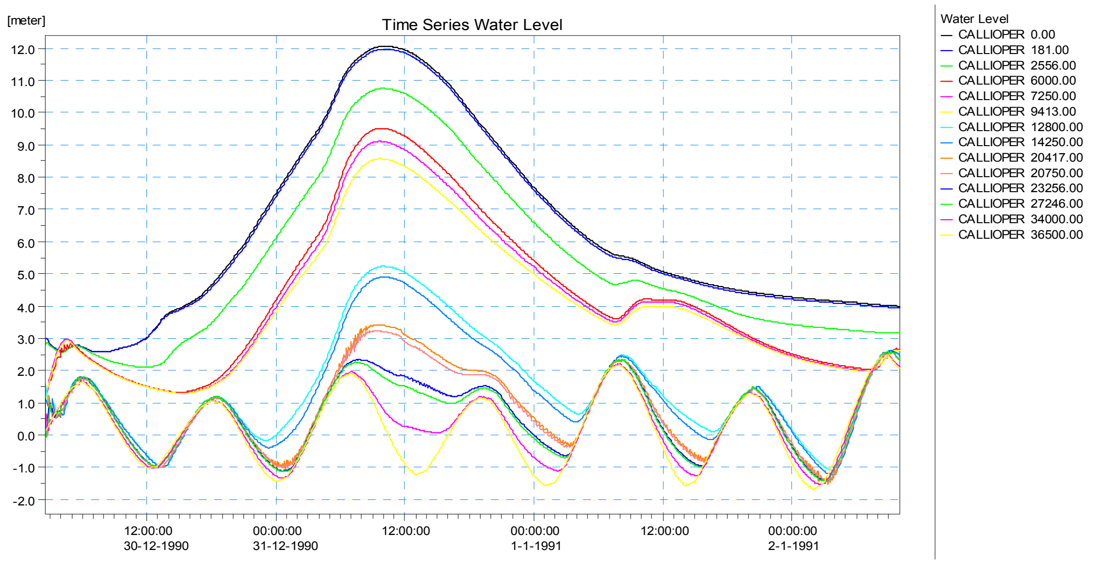
Event Date	Peak Flow		First Burst		Second Burst		Second Burst		m	kc	Time to Peak		Time to Centroid	
			Initial Loss	Cont. Loss	Initial Loss	Cont. Loss	Initial Loss	Cont. Loss						
	Observed cumecs	Estimated cumecs	mm	mm/hr	mm	mm/hr	mm	mm/hr			Observed Hrs	Estimated Hrs	Observed Hrs	Estimated Hrs
Jan 1978	2899	2929	40	7.58	30	1.88	60	1.41	**0.6**	**340**	68	64	71.9	72.9
	2899	2896	40	7.58	30	1.88	60	1.41	**0.7**	**170**	68	65	71.9	71.9
	2899	2923	40	7.58	30	1.88	60	1.41	**0.8**	**80**	68	65	71.9	63.6
	2899	2902	40	7.58	30	1.88	60	1.41	**0.9**	**38**	68	66	71.9	61.4
	2899	2865	40	7.58	30	1.88	60	1.41	**1.0**	**18**	68	66	71.9	60.1
Dec 1990	1907	1907	190	1.84	N/A	N/A	N/A	N/A	**0.6**	**238**	58	55	63.9	69.6
	1910	1906	190	1.84	N/A	N/A	N/A	N/A	**0.7**	**136**	58	55	63.9	66.8
	1910	1906	190	1.84	N/A	N/A	N/A	N/A	**0.8**	**73.5**	58	55	63.9	64
	1910	1918	190	1.84	N/A	N/A	N/A	N/A	**0.9**	**39**	58	56	63.9	62.2
	1910	1915	190	1.84	N/A	N/A	N/A	N/A	**1.0**	**20.5**	58	56	63.9	61.1
Feb 2003	2765	2756	120	17.8	0	1.83	N/A	N/A	**0.6**	**304**	69	70	65.5	66.6
	2765	2765	120	17.8	0	1.83	N/A	N/A	**0.7**	**152**	69	71	65.5	64.4
	2765	2764	120	17.8	0	1.83	N/A	N/A	**0.8**	**77**	69	71	65.5	62.5
	2765	2763	120	17.8	0	1.83	N/A	N/A	**0.9**	**39**	69	72	65.5	61.4
	2765	2766	120	17.8	0	1.83	N/A	N/A	**1.0**	**20**	69	73	65.5	60.7


Calliope River RORB Model
Parameter Interaction Curve
kc
400
350
300
250
200
150
100
50
0
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
m
Dec 1990
Jan 1978
Feb 2003

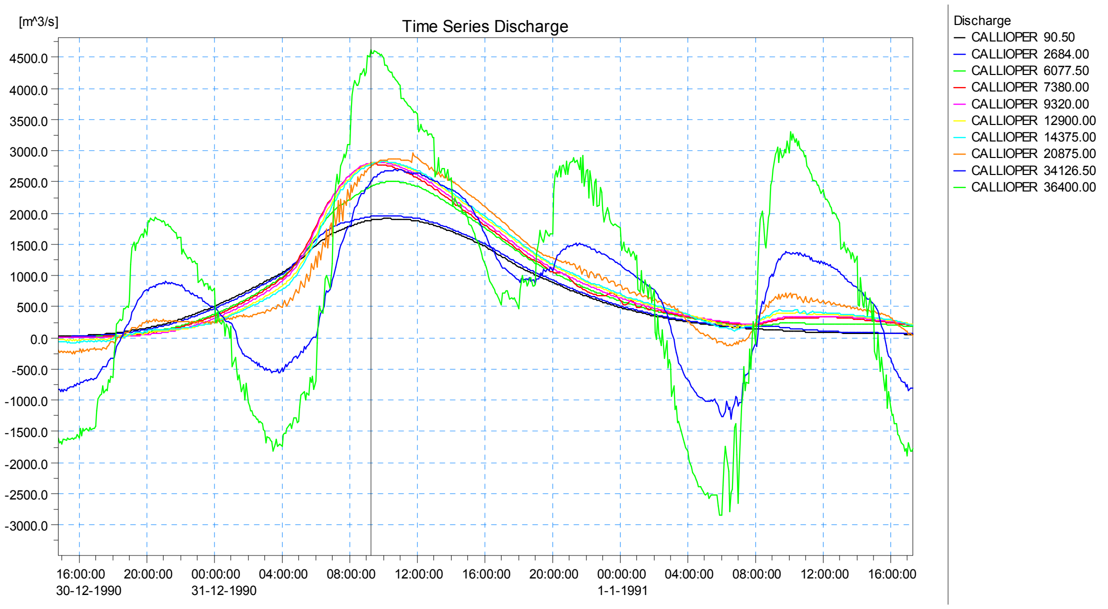

Calliope River RORB Model
Parameter Interaction Curve
kc
60
55
50
45
40
35
0.85
0.86
0.87
0.88
0.89
0.90
m
Dec 1990
Jan 1978
Feb 2003

Appendix B
MIKE 11 Model Calibration Runs

Hydrographs for 1990, 1978 and 1973 Floods

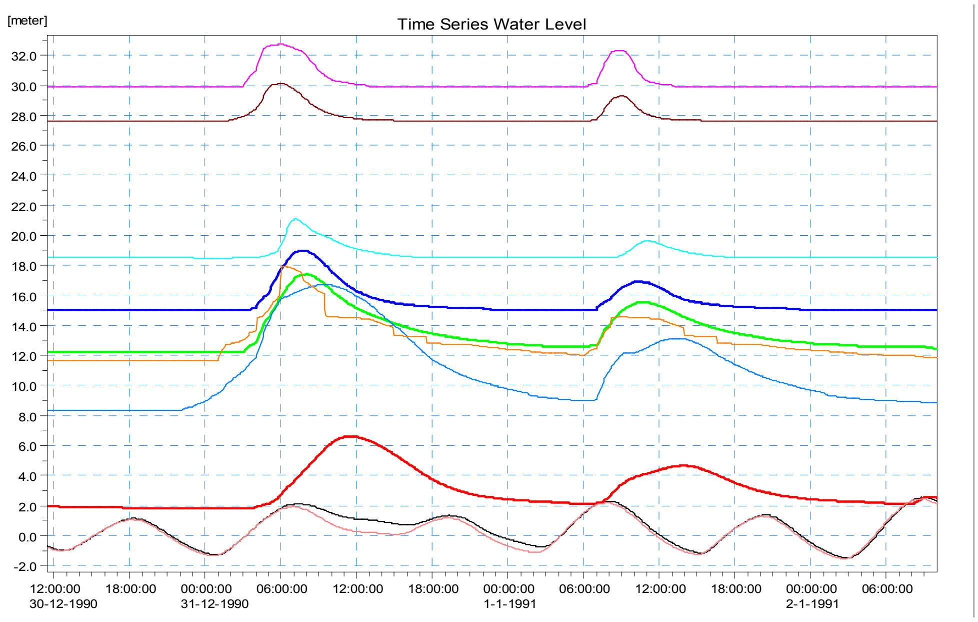


a) Water Level Hydrographs

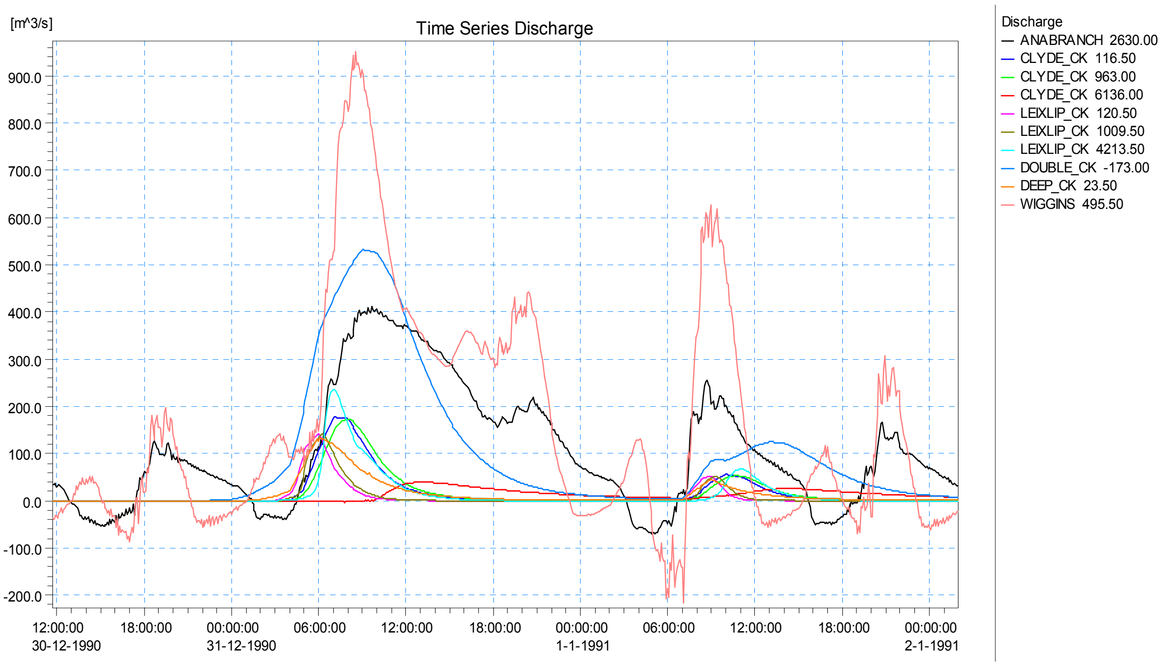


b) **Discharge Hydrographs**

Figure B1 Hydrographs Calliope River – December 1990 Flood

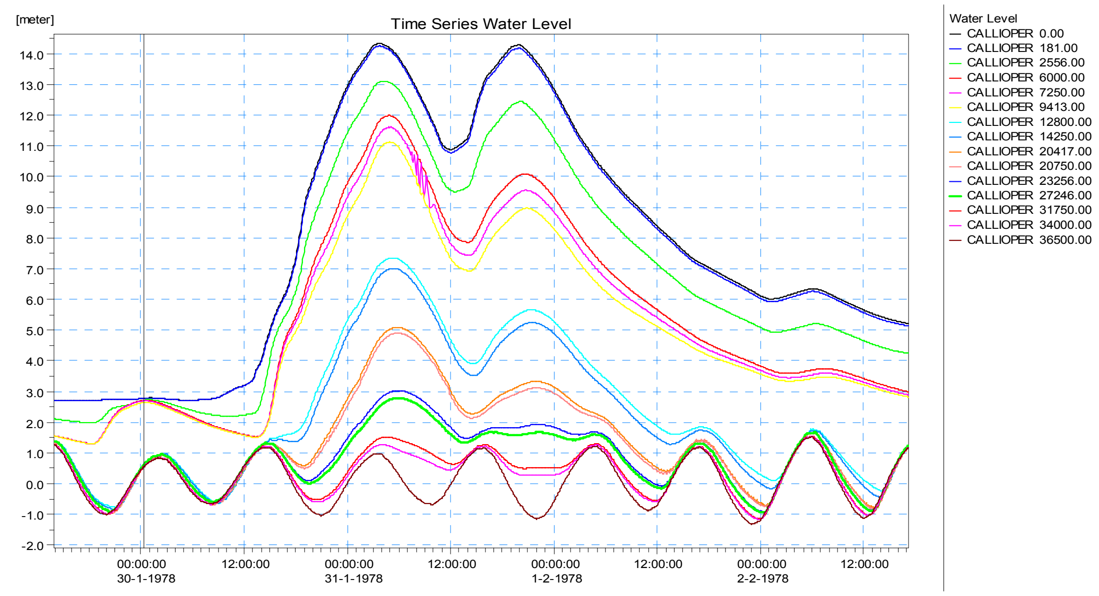


a) Water Level Hydrographs

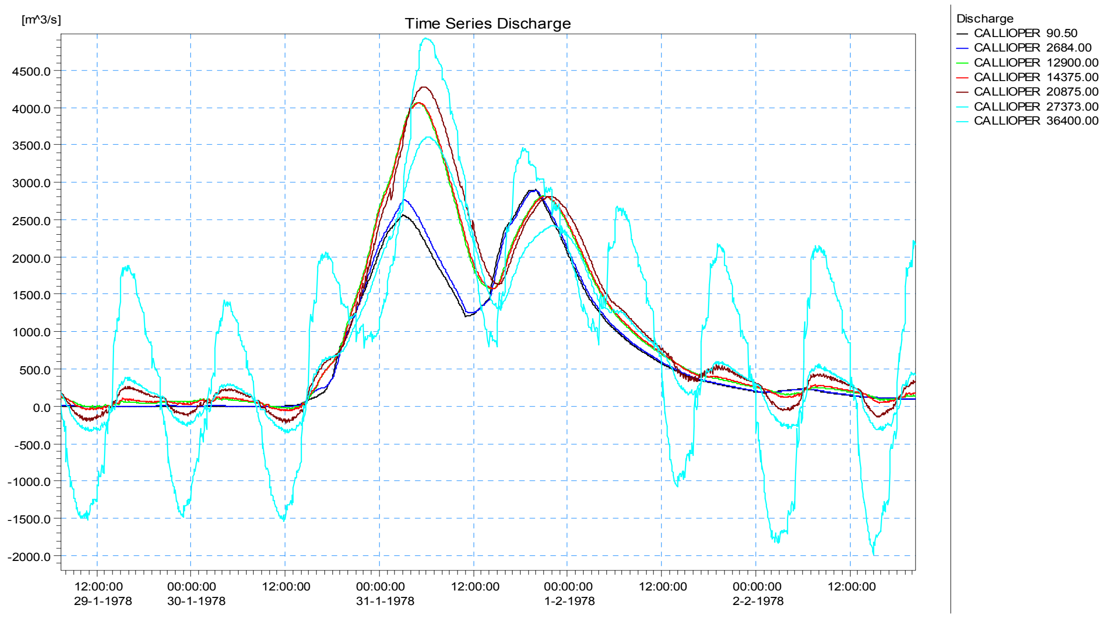


b) Discharge Hydrographs

Figure B2 Hydrographs Tributaries – December 1990 Flood

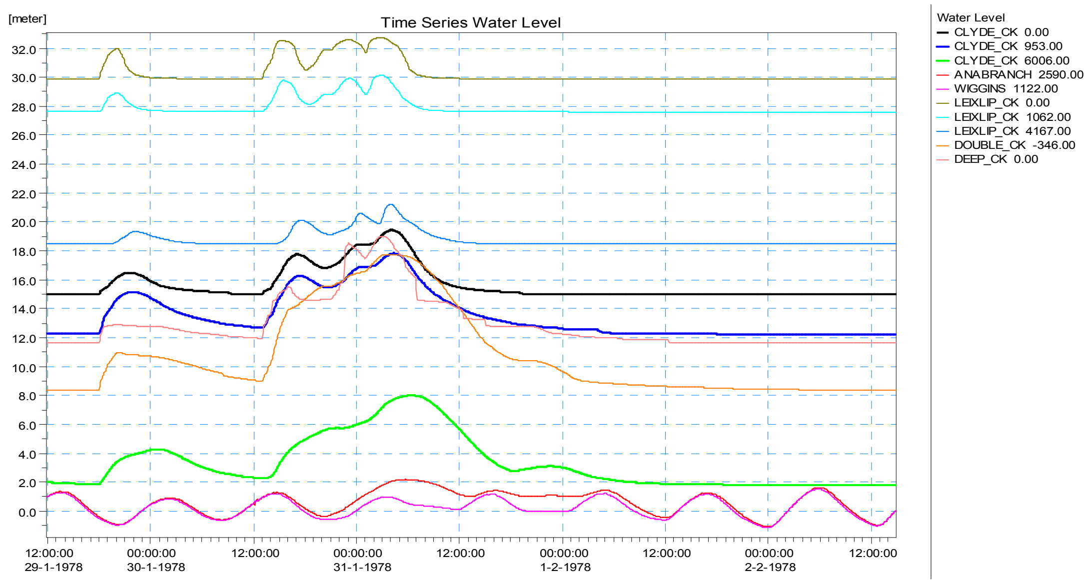


a) **Water Level Hydrographs**

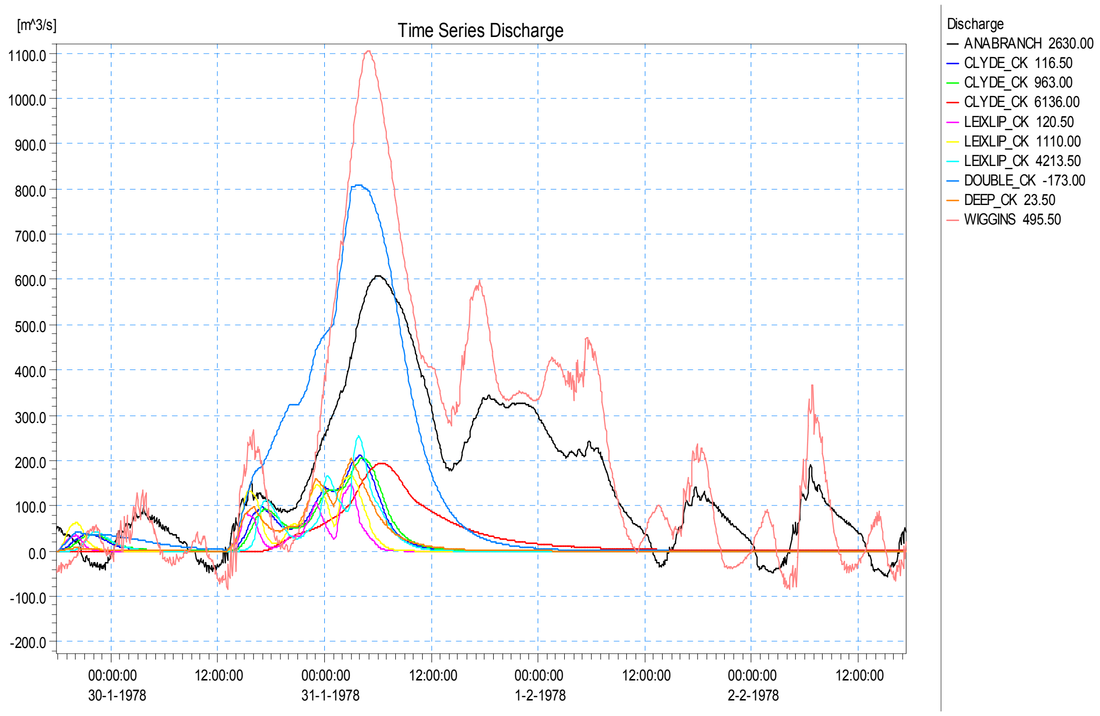


b) **Discharge Hydrographs**

Figure B3 Hydrographs Calliope River – January 1978 Flood

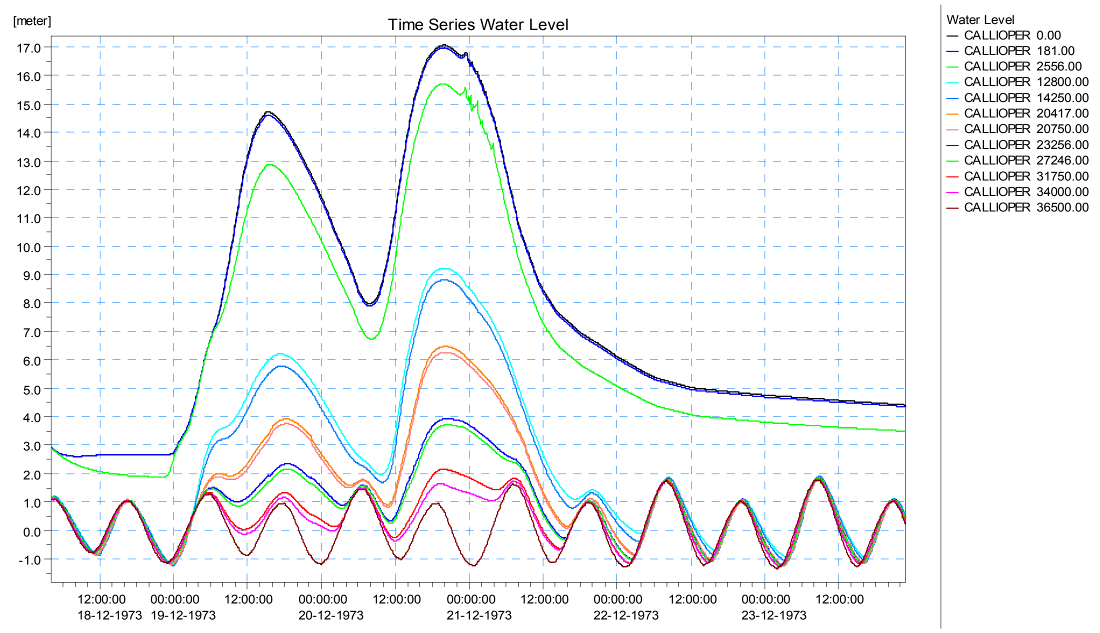


a) Water Level Hydrographs

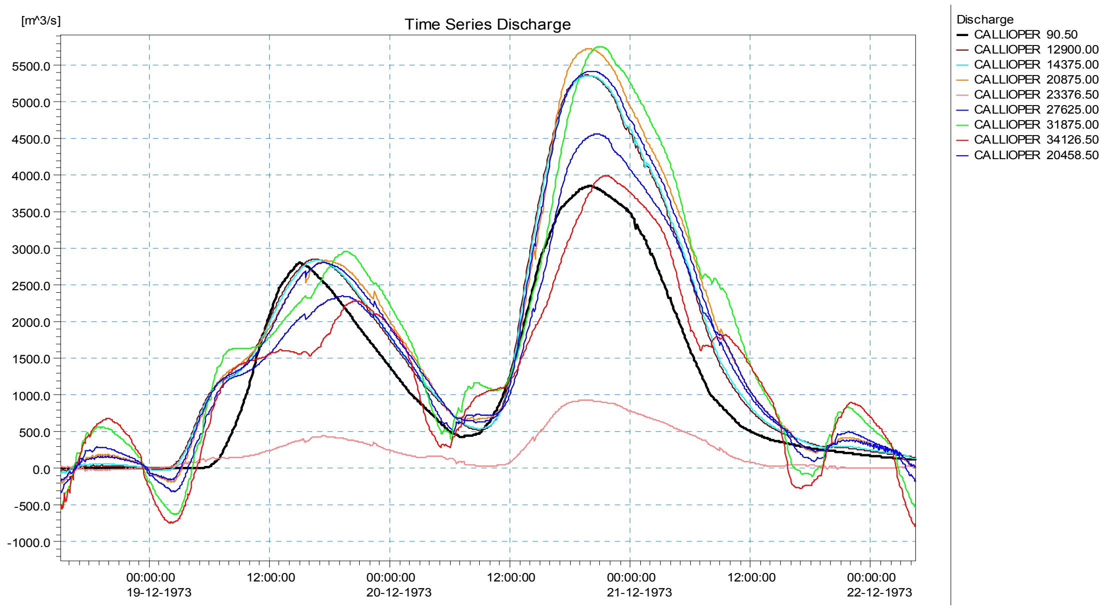


b) Discharge Hydrographs

Figure B4 Hydrographs Tributaries – January 1978 Flood

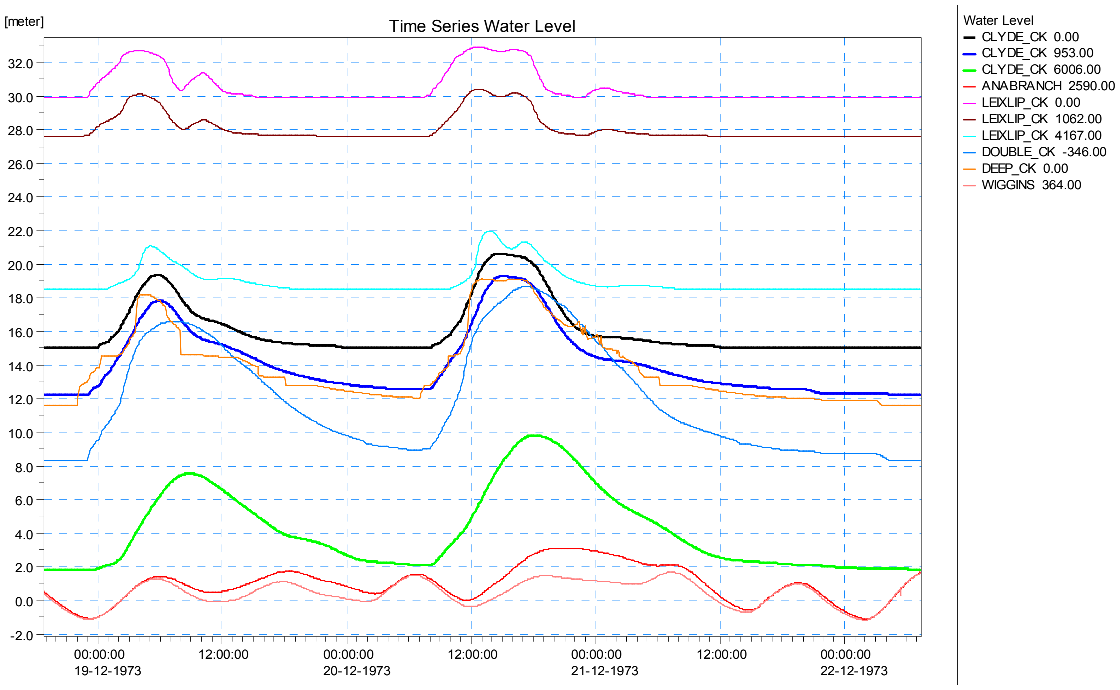


a) Water Level Hydrographs

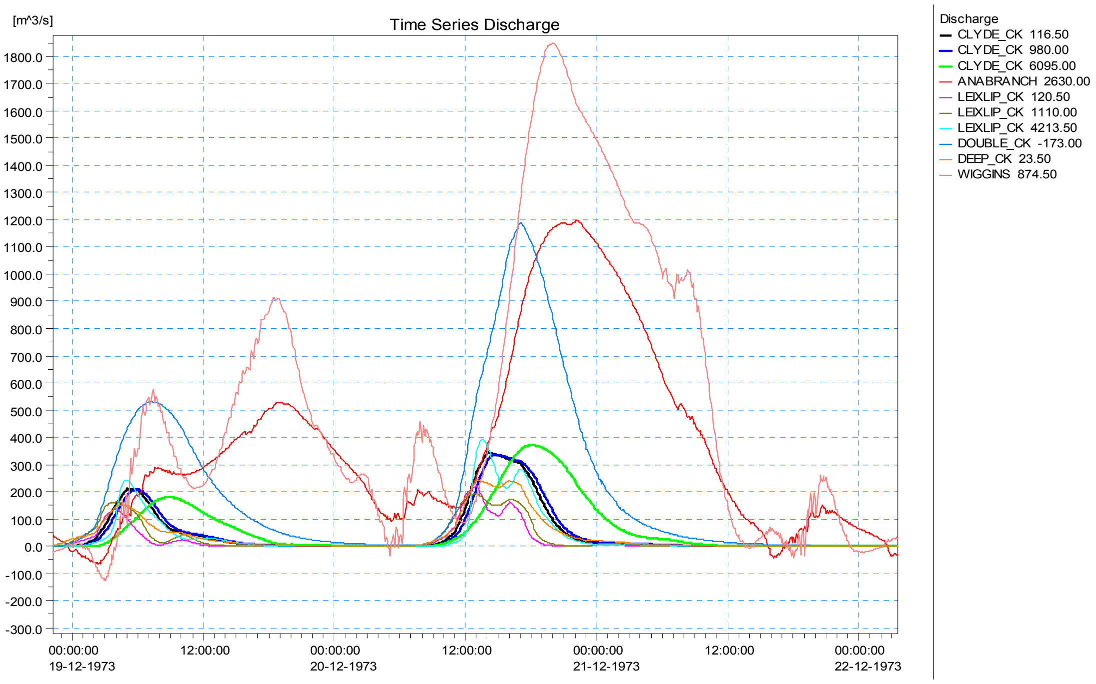


b) Discharge Hydrographs

Figure B5 Hydrographs Calliope River – December 1973 Flood



a) Water Level Hydrographs



b) Discharge Hydrographs

Figure B6 Hydrographs Tributaries – December 1973 Flood

Appendix C
River Gauging Station Records used in Analysis

Calliope River at Castlehope
Gauging Station 132001A

Note: **Annual maximum series based on October – September Hydrologic Year**
Partial Duration Series threshold 290 m3/s

Date	Instantaneous Peak Flows (Cumecs)	
	Annual Maximum Series	Partial Duration Series
4/02/1940		388.3
18/03/1940	1599.6	1599.6
14/03/1941	46.6	
10/02/1942	2827.8	2827.8
13/02/1943	539.4	539.4
18/02/1944	423.7	423.7
1/01/1945	40.8	
24/01/1946	163.4	
12/02/1947	4037.7	4037.7
1/03/1947		2712.4
31/03/1947		486.2
1/03/1948	732.1	732.1
1/05/1948		435.8
3/03/1949	2589.4	2589.4
12/03/1950	604.7	604.7
11/01/1951		411.7
21/01/1951	494.5	494.5
29/04/1952	193.7	
23/03/1953	521.0	521.0
12/02/1954	1203.6	1203.6
28/02/1954		312.0
21/02/1955		512.4
8/03/1955	1526.7	1526.7
25/05/1955		1318.9
23/01/1956		809.0
9/02/1956	1416.7	1416.7
10/03/1956		877.9
21/12/1956	2098.8	2098.8
1/02/1958	301.8	301.8
18/02/1959	171.9	
21/12/1959	116.8	
18/02/1961	631.6	631.6
18/11/1961	456.1	456.1
26/03/1963	1409.3	1409.3
3/07/1964	108.2	
12/10/1964	2.7	
1/02/1966	7.8	
22/06/1967	72.2	
14/01/1968		343.7
16/02/1968	684.9	684.9
26/12/1968	14.7	
7/12/1969	107.2	

Date	Instantaneous Peak Flows (Cumecs)	
	Annual Maximum Series	Partial Duration Series
31/01/1971	2153.8	2153.8
22/02/1971		1004.0
19/02/1972	709.9	709.9
17/02/1973	256.0	
20/12/1973	3863.8	3863.8
27/02/1975	675.1	675.1
25/12/1975		581.1
6/03/1976	738.4	738.4
24/12/1976		362.6
11/03/1977	1332.7	1332.7
16/05/1977		681.4
31/01/1978	2908.1	2908.1
10/07/1978		714.5
4/11/1978	449.8	449.8
7/01/1980	273.1	
8/02/1981	1384.5	1384.5
25/02/1982	38.5	
3/05/1983	1228.0	1228.0
24/05/1983		335.9
11/11/1983	89.3	
4/04/1985	173.8	
4/02/1986	667.5	667.5
29/01/1987	133.9	
5/07/1988	280.5	
18/12/1988	1200.0	1200.0
25/04/1989		686.7
28/03/1990	772.4	772.4
20/04/1990		509.9
29/12/1990	1911.7	1911.7
5/01/1991		915.4
9/02/1991		560.0
21/02/1992	313.2	313.2
11/07/1993	245.3	
3/02/1994	361.5	361.5
3/11/1994	7.2	
5/01/1996		776.4
9/01/1996	1904.9	1904.9
23/03/1997	396.0	396.0
11/09/1998	307.6	307.6
28/02/1999		296.3
4/03/1999	309.8	309.8
9/11/1999	143.1	
31/10/2000	704.5	704.5
5/01/2002	165.9	
6/02/2003	2768.4	2768.4
31/01/2004		494.4

Appendix D
Distribution Fitting Results

a) L- Moments

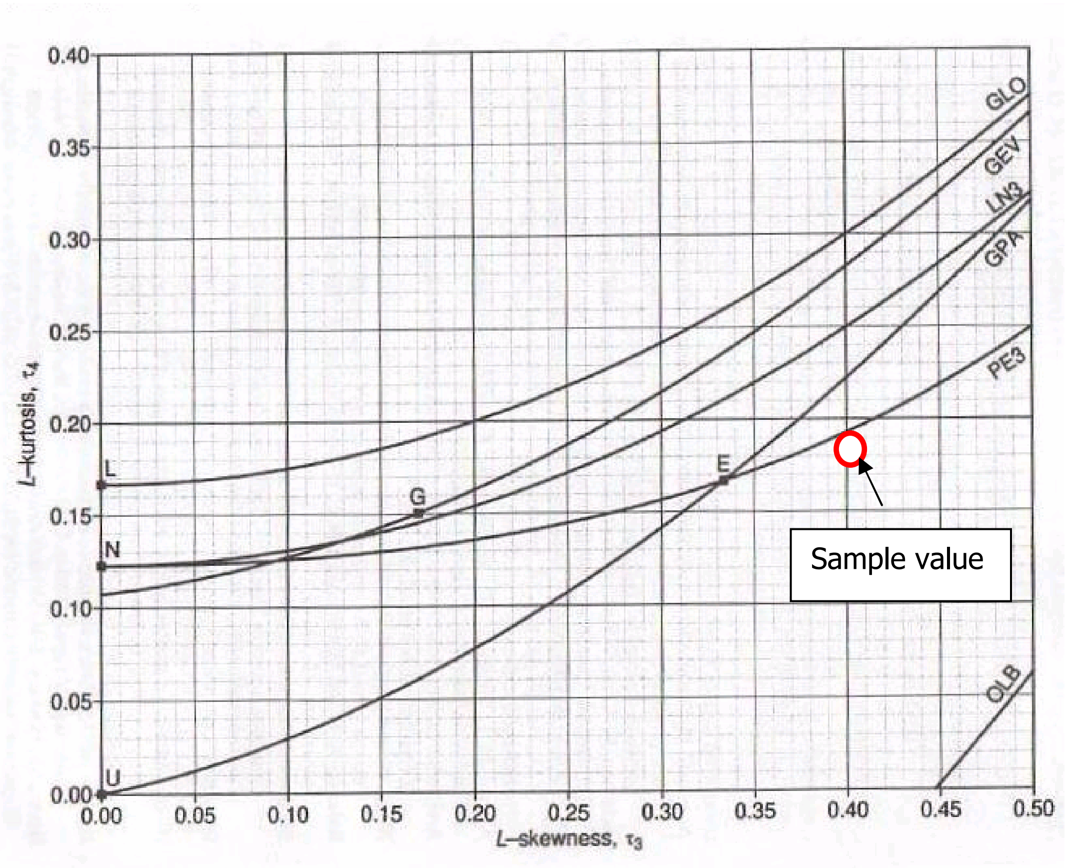
Use Annual Max data in ascending order

j	x(j,n)	(j-1)/(n-1)x	j-1)(j-2)/(n-1)(n-2)x	(j-1)(j-2)(j-3)/(n-1)(n-2)(n-3)x
1	2.7			
2	7.2	0.11		
3	7.8	0.24	0.00	
4	14.7	0.69	0.02	0.00
5	38.5	2.41	0.11	0.00
6	40.8	3.19	0.20	0.01
7	46.6	4.37	0.35	0.02
8	72.2	7.90	0.75	0.06
9	89.3	11.16	1.24	0.12
10	107.2	15.08	1.91	0.22
11	108.2	16.90	2.41	0.31
12	116.8	20.07	3.19	0.46
13	133.9	25.10	4.38	0.71
14	143.1	29.07	5.54	0.98
15	163.4	35.75	7.38	1.43
16	165.9	38.88	8.64	1.81
17	171.9	42.98	10.23	2.31
18	173.8	46.15	11.72	2.84
19	193.7	54.47	14.70	3.79
20	245.3	72.83	20.81	5.71
21	256.0	80.01	24.13	7.01
22	273.1	89.59	28.44	8.72
23	280.5	96.43	32.14	10.37
24	301.8	108.46	37.88	12.83
25	307.6	115.35	42.11	14.94
26	309.8	121.02	46.10	17.10
27	313.2	127.22	50.48	19.54
28	361.5	152.51	62.94	25.38
29	396.0	173.27	74.26	31.14
30	423.7	191.98	85.32	37.16
31	449.8	210.84	97.06	43.83
32	456.1	220.92	105.20	49.21
33	494.4	247.21	121.64	58.86
34	494.5	254.96	129.50	64.75
35	521.0	276.75	144.97	74.82
36	539.4	294.96	159.19	84.73
37	604.7	340.13	188.96	103.62
38	631.6	365.17	208.67	117.80
39	667.5	396.32	232.76	135.15
40	675.1	411.41	248.15	148.09
41	684.9	428.09	265.01	162.42
42	704.5	451.32	286.55	180.25
43	709.9	465.88	303.19	195.61
44	732.1	491.91	327.94	216.86
45	738.4	507.65	346.49	234.72
46	772.4	543.10	379.31	263.07
47	1200.0	862.52	616.09	437.22
48	1203.6	883.92	645.40	468.43
49	1228.0	920.99	687.08	509.77
50	1332.7	1020.32	777.39	589.31
51	1384.5	1081.66	841.29	651.32
52	1409.3	1123.04	891.30	704.42
53	1416.7	1151.05	931.80	751.46
54	1526.7	1264.33	1043.58	858.42
55	1599.6	1349.65	1135.42	952.28
56	1904.9	1637.06	1403.19	1199.50
57	1911.7	1672.73	1460.32	1271.89
58	2098.8	1869.28	1661.58	1473.98
59	2153.8	1951.90	1766.00	1595.10
60	2589.4	2387.07	2197.62	2020.39
61	2768.4	2595.36	2430.57	2273.76
62	2827.8	2695.23	2566.88	2442.68
63	2908.1	2817.22	2727.79	2639.79
64	3863.8	3803.46	3743.09	3682.71
65	4037.7	4037.69	4037.69	4037.69
SUM	**54508.0**	**42714.27**	**35686.06**	**30898.90**

Computed L - Moments

n =	65	sample l-moments				
b0 =	838.5846	l1 =	838.5846	τ =	0.567	
b1 =	657.1426	l2 =	475.7006			
b2 =	549.0164	l3 =	189.8274	τ_3 =	0.399	L -skewness
b3 =	475.3677	l4 =	83.98977	τ_4 =	0.177	L - kurtosis

L- Moment Ratio Diagram (Source: Hosking & Wallace 1997)

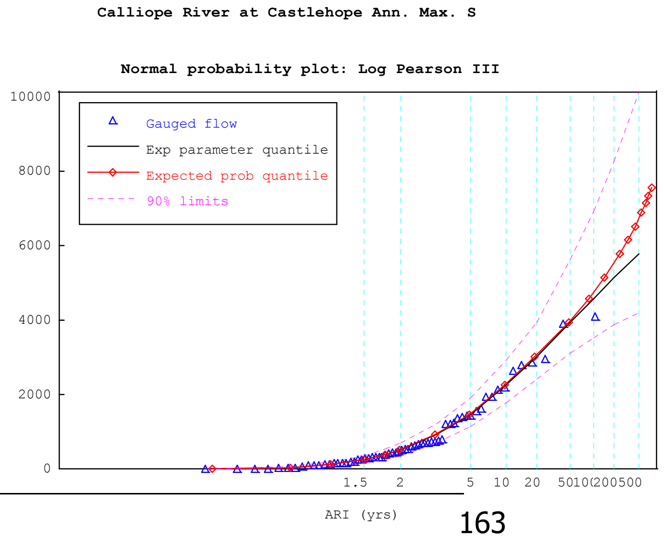


Key to Distributions:
E – exponential G – Gumbel L – Logistic N – Normal
U – Uniform GLO – Generalised logistic GEV - Generalised extreme value
GPA – Generalised pareto LN3 – Lognormal PE3 – Pearson Type III

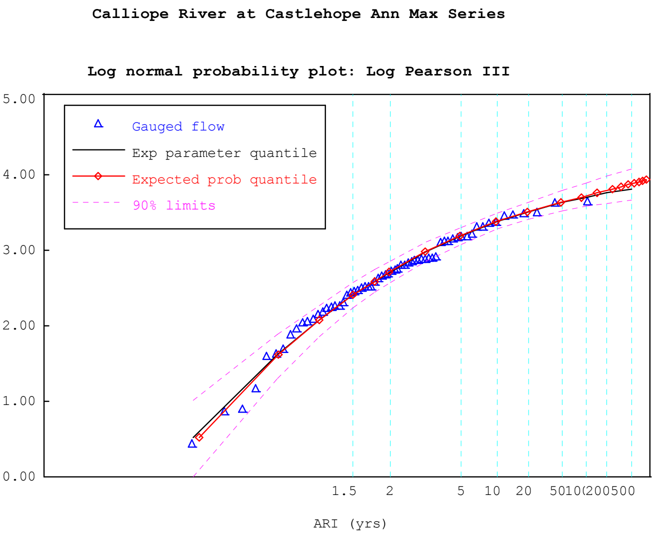
Annual Maximum Series Analysis

```
          FLIKE program version 4.50
Title: Calliope River at Castlehope Ann. Max. Series

 Input Data for Flood Frequency Analysis for Model: Log Pearson III
& Gauged Annual Maximum Discharge Data
 Obs   Discharge Year Incremental Error coefficient  Cunnane
                           error zone        of variation  ARI,yrs*
 ------------------------------------------------------------
  1    1600.00 1940        1           0.000     6.06
  2      47.00 1941      1          0.000     1.11
  3    2828.00 1942        1           0.000    17.83
  4     539.00 1943       1           0.000     2.17
  5     424.00 1944       1           0.000     1.86
  6      41.00 1945      1          0.000     1.10
  7     163.00 1946       1           0.000     1.29
  8    4038.00 1947        1           0.000   107.00
  9     732.00 1948       1           0.000     2.97
 10     2589.00 1949        1           0.000    11.46
 11      605.00 1950       1           0.000     2.24
 12      495.00 1951       1           0.000     2.03
 13      194.00 1952       1           0.000     1.41
 14      521.00 1953       1           0.000     2.10
 15     1204.00 1954        1           0.000     3.65
 16     1527.00 1955        1           0.000     5.53
 17     1417.00 1956        1           0.000     5.10
 18     2099.00 1957        1           0.000     8.45
 19      302.00 1958       1           0.000     1.58
 20      172.00 1959       1           0.000     1.35
 21      117.00 1960       1           0.000     1.22
 22      632.00 1961       1           0.000     2.33
 23      456.00 1962       1           0.000     1.97
 24     1409.00 1963        1           0.000     4.72
 25      108.00 1964       1           0.000     1.20
 26        3.00 1965      1          0.000     1.01
 27        8.00 1966      1          0.000     1.04
 28       72.00 1967       1          0.000     1.13
 29      685.00 1968       1           0.000     2.61
 30       15.00 1969       1          0.000     1.06
 31      107.00 1970       1           0.000     1.18
 32     2154.00 1971        1           0.000     9.73
 33      710.00 1972       1           0.000     2.84
 34      256.00 1973       1           0.000     1.47
 35     3864.00 1974        1           0.000    40.12
 36      675.00 1975       1           0.000     2.51
 37      738.00 1976       1           0.000     3.12
 38     1333.00 1977        1           0.000     4.12
 39     2908.00 1978        1           0.000    24.69
 40      450.00 1979       1           0.000     1.91
 41      273.00 1980       1           0.000     1.51
 42     1385.00 1981        1           0.000     4.40
 43       39.00 1982       1          0.000     1.08
 44     1228.00 1983        1           0.000     3.87
 45       89.00 1984       1          0.000     1.15
 46      174.00 1985       1           0.000     1.38
 47      668.00 1986       1           0.000     2.41
 48      134.00 1987       1           0.000     1.24
 49      281.00 1988       1           0.000     1.54
 50     1200.00 1989        1           0.000     3.45
 51      772.00 1990       1           0.000     3.28
 52     1912.00 1991        1           0.000     7.47
 53      313.00 1992       1           0.000     1.71
 54      245.00 1993       1           0.000     1.44
 55      362.00 1994       1           0.000     1.75
 56        7.00 1995      1          0.000     1.03
 57     1905.00 1996        1           0.000     6.69
 58      396.00 1997       1           0.000     1.80
 59      308.00 1998       1           0.000     1.62
 60      310.00 1999       1           0.000     1.66
 61      143.00 2000       1           0.000     1.27
 62      705.00 2001       1           0.000     2.72
 63      166.00 2002       1           0.000     1.32
 64     2768.00 2003        1           0.000    13.96
Note: Cunnane plotting position is based on gauged flows only
& Posterior Parameter Results
Data file: castlehope.fld
Calliope River at Castlehope Ann. Max. Series
```

```
        Flood model: Log Pearson III

         >>> Fitting algorithm: Global probabilistic search

         Parameter   Lower bound   Upper bound
         -------------------------------------
               1       -1.79647       13.69407
               2       -1.86494        2.74023
               3       -5.00000        5.00000
        Incremental error model: Normal
        Solution PROBABLY found in 2387 iterations
        Maximized log-posterior density =    -492.861

         No Parameter                     Initial value    Most probable value
         ---------------------------------------------------------------------
          1 Mean (loge flow)                  5.94880              5.94878
          2 loge [Std dev (loge flow)]          0.43764              0.45228
          3 Skew (loge flow)                 -0.99388             -1.14759

        --------------------------------------------------
        &Zero flow threshold:      0.0000
         Number of gauged flows below flow threshold =     0

        --------------------------------------------------
        & Parameter Moments based on Multi-normal Approximation to Posterior Distribution
         No           Mean          Std dev        Correlation
         ---------------------------------------------------
          1       5.94878       0.22365  1.000
          2       0.45228       0.17517 -0.701  1.000
          3      -1.14759       0.34576  0.321 -0.823  1.000
         ---------------------------------------------------
         Note: Parameters are roughly normally distributed.
               This approximation improves with sample size.
               Std devs may be correct to about 1 to 2 sig figs.
               Check approximation visually using View Output log-pdf Surface option.


        & Summary of Posterior Moments from Importance Sampling
         No           Mean          Std dev        Correlation
         ---------------------------------------------------
          1       5.93849       0.19864  1.000
          2       0.45405       0.11357 -0.596  1.000
          3      -1.02069       0.23845  0.001 -0.542  1.000
         ---------------------------------------------------
Note: Posterior expected parameters are the most
      accurate in the mean-squared-error sense.
      They should be used in preference to the most probable parameters


Upper bound =     8299.90

&  Recurrence    Exp parameter     Monte Carlo 90% quantile
 interval        quantile              probability limits
    yrs
         ----------------------------------------------------------
           1.010          3.15           0.67          10.07
           1.100         40.74          19.14           73.10
           1.250        115.53          69.32          177.90
           1.500        246.70         165.67          354.58
           1.750        374.00         263.05          522.09
           2.000        493.66         357.10          679.88
           3.000        895.11         674.48         1198.72
           5.000       1448.76        1126.13         1890.35
          10.000       2225.19        1767.11         2869.01
          20.000       2981.57        2374.26         3884.64
          50.000       3901.91        3059.47         5547.82
         100.000        4521.40        3491.24         6841.97
         200.000        5070.89        3818.11         8160.79
         500.000        5693.27        4134.77        10111.37
        1000.000         6091.46        4303.69        11676.46
```



```
&   Expected Probability Flood based on
        Monte Carlo samples =  5000
        Probability weight  = 1.000
        Scalng factor       = 1.500

    Flood       Expected    <----------ARI------------>
    magnitude   probability      yrs     95% limits
  ------------------------------------------------------
      3.15      0.01157     1.01     1.01     1.01
     40.74      0.09200     1.10     1.10     1.10
    115.53      0.19986     1.25     1.25     1.25
    246.70      0.33226     1.50     1.49     1.50
    374.00      0.42692     1.74     1.74     1.75
    493.66      0.49789     1.99     1.99     2.00
    895.11      0.66349     2.97     2.96     2.98
   1448.76      0.79640     4.91     4.88     4.94
   2225.19      0.89707     9.72     9.64     9.79
   2981.57      0.94804    19.25    19.03    19.47
   3901.91      0.97865    46.84    45.98    47.74
   4521.40      0.98849    86.86    84.59    89.25
   5070.89      0.99309   144.79   139.99   149.92
   5693.27      0.99590   244.15   234.23   254.94
   6091.46      0.99698   331.37   316.42   347.81
   6433.66      0.99764   424.40   403.65   447.39
   6810.78      0.99818   549.33   520.27   581.83
   7046.96      0.99844   641.13   605.64   681.03
   7247.09      0.99863   728.00   686.22   775.20
   7464.85      0.99880   832.77   783.15   889.11
```



Partial Series Flows

Date	Instantaneous Peak Flows (Cumecs)							
	All peaks series	Ann Max series	Threshold 300	Threshold 400	Threshold 500	Threshold 600	Threshold 800	Threshold 1000
4/02/1940	388		388					
18/03/1940	1600	1600	1600	1600	1600	1600	1600	1600
14/03/1941		47						
10/02/1942	2828	2828	2828	2828	2828	2828	2828	2828
13/02/1943	539	539	539	539	539			
18/02/1944	424	424	424	424				
		41						
		163						
12/02/1947	4038	4038	4038	4038	4038	4038	4038	4038
1/03/1947	2712		2712	2712	2712	2712	2712	2712
31/03/1947	486		486	486				
1/03/1948	732	732	732	732	732	732		
1/05/1948	436		436	436				
3/03/1949	2589	2589	2589	2589	2589	2589	2589	2589
12/03/1950	605	605	605	605	605	605		
11/01/1951	412		412	412				
21/01/1951	494	494	494	494				
		194						
23/03/1953	521	521	521	521	521			
12/02/1954	1204	1204	1204	1204	1204	1204	1204	1204
28/02/1954	312		312					
21/02/1955	512		512	512	512			
8/03/1955	1527	1527	1527	1527	1527	1527	1527	1527
25/05/1955	1319		1319	1319	1319	1319	1319	1319
23/01/1956	809		809	809	809	809	809	
9/02/1956	1417	1417	1417	1417	1417	1417	1417	1417
10/03/1956	878		878	878	878	878	878	
21/12/1956	2099	2099	2099	2099	2099	2099	2099	2099
1/02/1958	302	302	302					
		172						
		117						
18/02/1961	632	632	632	632	632	632		
18/11/1961	456	456	456	456				
26/03/1963	1409	1409	1409	1409	1409	1409	1409	1409
14/01/1968	344	108	344					
		3						
		8						
		72						
16/02/1968	685	685	685	685	685	685		
		15						
		107						
31/01/1971	2154	2154	2154	2154	2154	2154	2154	2154
22/02/1971	1004		1004	1004	1004	1004	1004	1004
19/02/1972	710	710	710	710	710	710		
		256						
20/12/1973	3864	3864	3864	3864	3864	3864	3864	3864
27/02/1975	675	675	675	675	675	675		
25/12/1975	581		581	581	581			
6/03/1976	738	738	738	738	738	738		
24/12/1976	363		363					
11/03/1977	1333	1333	1333	1333	1333	1333	1333	1333
16/05/1977	681		681	681	681	681		
31/01/1978	2908	2908	2908	2908	2908	2908	2908	2908
10/07/1978	715		715	715	715	715		
4/11/1978	450	450	450	450				
		273						
8/02/1981	1385	1385	1385	1385	1385	1385	1385	1385
		38						
3/05/1983	1228	1228	1228	1228	1228	1228	1228	1228
24/05/1983	336		336					
		89						
		174						
4/02/1986	667	667	667	667	667	667		
		134						
		281						
18/12/1988	1200	1200	1200	1200	1200	1200	1200	1200
25/04/1989	687		687	687	687	687		
28/03/1990	772	772	772	772	772	772		
20/04/1990	510		510	510	510			
29/12/1990	1912	1912	1912	1912	1912	1912	1912	1912
5/01/1991	915		915	915	915	915	915	
9/02/1991	560		560	560	560			
21/02/1992	313	313	313					
		245						
3/02/1994	362	362	362					
		7						
5/01/1996	776		776	776	776	776		
9/01/1996	1905	1905	1905	1905	1905	1905	1905	1905
23/03/1997	396	396	396					
11/09/1998	308	308	308					
28/02/1999	296							
4/03/1999	310	310	310					
		143						
31/10/2000	705	705	705	705	705	705		
		166						
6/02/2003	2768	2768	2768	2768	2768	2768	2768	2768
31/01/2004	494		494	494				

Partial Series Analysis

Parameter	Instantaneous Peak Flows (Cumecs)						
	All peaks series	Threshold 300	Threshold 400	Threshold 500	Threshold 600	Threshold 800	Threshold 1000
Min	296	302	412	510	605	809	1004
Max	4038	4038	4038	4038	4038	4038	4038
POT model							
no yrs	65	65	65	65	65	65	65
no exc	65	64	53	45	39	25	22
Av no exc/year	1.00	0.98	0.82	0.69	0.60	0.38	0.34
Threshold	296	302	412	510	605	809	1004
Ave exc	1041	1053	1201	1333	1456	1880	2018
Sd exc	874	876	894	908	916	898	869
lambda	0.001	0.001	0.001	0.001	0.001	0.001	0.001
l1	757	763	802	836	865	1088	1030
T years	Q(T)	Q(T)	Q(T)	Q(T)	Q(T)	Q(T)	Q(T)
1	296	290	248	202	163	1	10
1	368	363	324	282	245	10	50
1	465	460	427	389	356	12	118
2	603	599	573	541	513	211	306
2	720	717	697	670	647	378	464
2	821	819	804	782	762	524	602
5	1514	1518	1538	1548	1554	1520	1546
10	2039	2047	2094	2128	2154	2274	2260
20	2563	2575	2650	2708	2753	3028	2974
50	3256	3274	3384	3474	3545	4025	3918
100	3781	3803	3940	4054	4145	4779	4632
200	4306	4332	4496	4634	4744	5533	5346
500	4999	5031	5231	5400	5536	6530	6290
1000	5523	5560	5786	5980	6135	7284	7004

Appendix E
RORB Model Results

Design Flows 10 Year ARI

Sub Area	Location	Peak Inflows (Cumecs) for 20 Year ARI for Storm Duration (Hours)					Envelope
		3	6	12	18	24	
BJ	Calliope R at Castlehope	1250	1780	2240	2190	2060	2240
BK	Calliope Local Trib	46	41	42	30	49	49
BL	Calliope Local	25	17	18	11	17	25
BM	Deep Ck	25	141	152	113	155	155
BN	Calliope Local	41	27	28	17	27	41
BY	Double Ck u/s	381	526	586	448	558	586
BZ	Double Ck local	81	55	54	34	54	81
CA	McGintys Ck	47	45	48	34	54	54
CB	Double Ck local	20	16	15	10	15	20
CC	Calliope Local Trib	20	18	18	13	20	20
CD	Leixlip Ck U/s	217	182	180	117	194	217
CE	Leixlip Ck local	284	200	199	120	194	284
CF	Leixlip Ck trib	33	30	30	21	34	34
CG	Leixlip Ck local	151	109	102	64	102	151
CH	Leixlip Ck trib	36	32	34	25	40	40
CI	Leixlip Ck local	16	11	11	7	11	16
CJ	Calliope Local	16	8	9	5	8	16
CL	Gravel Ck	148	161	169	134	171	171
CM	Calliope Local	103	78	79	45	76	103
CN	Vulcan Ck	88	79	83	59	97	97
CO	Calliope Local	41	28	29	17	27	41
CP	Calliope Local Trib	92	84	89	64	102	102
CQ	Calliope Local	86	65	66	38	64	86
CR	Oakey Ck	127	136	144	110	148	148
CS	Calliope Local	48	33	34	20	32	48
CT	Calliope Local Trib	59	57	60	43	67	67
CU	Calliope Local	57	39	40	24	38	57
CV	Calliope Local Trib	22	18	18	12	20	22
CW	Calliope Local	22	16	15	9	15	22
DD	Clyde Ck U/s	236	255	253	170	270	270
DE	Clyde Ck trib	23	20	20	13	21	23
DF	Clyde Ck local	47	34	35	20	32	47
DG	Clyde Ck trib	38	33	32	23	37	38
DH	Clyde Ck local	50	36	37	22	35	50
DI	Clyde Ck trib	33	28	28	19	30	33
DJ	Clyde Ck local	11	8	8	5	8	11
DK	Clyde Ck trib	27	24	23	16	26	27
DL	Clyde Ck local	11	9	9	5	8	11
DM	Clyde Ck local	70	51	48	30	48	70
DN	Calliope Local	20	15	14	9	14	20
DO	Calliope Local Trib	33	30	31	22	36	36
DP	Calliope Local	41	28	28	17	27	41
DQ	Calliope Local	61	42	41	26	41	61
DR	Calliope Local Trib	34	30	29	21	35	35
DS	Calliope Local	9	7	6	4	6	9
DT	Calliope Local	78	52	55	33	52	78
DU	Calliope Local Trib	18	16	16	12	17	18
DV	Calliope Local Trib	24	21	21	16	22	24
DW	Calliope Local	82	69	65	41	60	82
DZ	Calliope Local	57	39	39	24	38	57
DX	Anabranch Local	73	52	54	31	49	73
DY	Anabranch Local	49	33	33	20	32	49

Design Flows 20 Year ARI

Sub Area	Location	Peak Inflows (Cumecs) for 20 Year ARI for Storm Duration (Hours)					Envelope
		3	6	12	18	24	
BJ	Calliope R at Castlehope	1610	2310	2920	2870	2740	2920
BK	Calliope Local Trib	59	53	53	40	61	61
BL	Calliope Local	31	22	22	10	22	31
BM	Deep Ck	167	177	192	140	201	201
BN	Calliope Local	49	36	34	20	35	49
BY	Double Ck u/s	489	679	755	570	743	755
BZ	Double Ck local	97	72	68	40	69	97
CA	McGintys Ck	60	56	60	40	69	69
CB	Double Ck local	24	20	19	10	18	24
CC	Calliope Local Trib	25	22	23	20	25	25
CD	Leixlip Ck U/s	272	227	230	150	241	272
CE	Leixlip Ck local	341	259	245	160	249	341
CF	Leixlip Ck trib	42	38	38	30	43	43
CG	Leixlip Ck local	180	141	134	90	131	180
CH	Leixlip Ck trib	44	40	43	30	51	51
CI	Leixlip Ck local	19	14	14	10	14	19
CJ	Calliope Local	15	10	10	10	10	15
CL	Gravel Ck	185	200	214	170	218	218
CM	Calliope Local	127	96	99	60	93	127
CN	Vulcan Ck	110	101	105	80	122	122
CO	Calliope Local	49	35	36	20	35	49
CP	Calliope Local Trib	114	104	111	80	130	130
CQ	Calliope Local	106	80	83	50	78	106
CR	Oakey Ck	159	171	184	140	192	192
CS	Calliope Local	58	41	42	30	42	58
CT	Calliope Local Trib	74	70	76	50	86	86
CU	Calliope Local	68	50	48	30	49	68
CV	Calliope Local Trib	27	23	23	20	25	27
CW	Calliope Local	27	20	19	10	19	27
DD	Clyde Ck U/s	296	323	326	210	354	354
DE	Clyde Ck trib	29	25	25	20	26	29
DF	Clyde Ck local	58	42	44	30	42	58
DG	Clyde Ck trib	47	42	42	30	47	47
DH	Clyde Ck local	61	45	45	30	45	61
DI	Clyde Ck trib	41	35	35	20	37	41
DJ	Clyde Ck local	13	10	10	10	10	13
DK	Clyde Ck trib	34	30	30	20	33	34
DL	Clyde Ck local	13	11	11	10	10	13
DM	Clyde Ck local	83	65	61	40	61	83
DN	Calliope Local	25	20	19	10	18	25
DO	Calliope Local Trib	41	37	39	30	46	46
DP	Calliope Local	49	36	34	20	35	49
DQ	Calliope Local	73	55	52	30	53	73
DR	Calliope Local Trib	42	38	38	30	43	43
DS	Calliope Local	11	9	8	10	8	11
DT	Calliope Local	95	69	67	40	68	95
DU	Calliope Local Trib	22	20	20	20	21	22
DV	Calliope Local Trib	29	26	26	20	28	29
DW	Calliope Local	98	86	82	50	75	98
DZ	Calliope Local	68	51	48	30	49	68
DX	Anabranch Local	89	64	67	40	64	89
DY	Anabranch Local	58	44	41	30	64	64

Design Flows 50 Year ARI

Sub Area	Location	Peak Inflows (Cumecs) for 50 Year ARI for Storm Duration (Hours)				
		3	6	12	18	24
BJ	Calliope R at Castlehope	2110	3030	3890	3910	3610
BK	Calliope Local Trib	69	60	60	50	70
BL	Calliope Local	35	30	20	20	30
BM	Deep Ck	211	220	230	180	240
BN	Calliope Local	56	40	40	30	40
BY	Double Ck u/s	644	890	960	760	940
BZ	Double Ck local	109	90	80	50	80
CA	McGintys Ck	73	70	70	50	80
CB	Double Ck local	27	20	20	10	20
CC	Calliope Local Trib	30	30	30	20	30
CD	Leixlip Ck U/s	317	270	270	190	280
CE	Leixlip Ck local	382	310	290	190	290
CF	Leixlip Ck trib	49	40	40	30	50
CG	Leixlip Ck local	200	170	160	100	150
CH	Leixlip Ck trib	54	50	50	40	60
CI	Leixlip Ck local	22	20	20	10	20
CJ	Calliope Local	17	10	10	10	10
CL	Gravel Ck	232	250	260	210	260
CM	Calliope Local	146	110	110	70	110
CN	Vulcan Ck	132	120	120	90	140
CO	Calliope Local	56	40	40	30	40
CP	Calliope Local Trib	139	130	130	100	150
CQ	Calliope Local	121	90	100	60	90
CR	Oakey Ck	203	210	220	180	230
CS	Calliope Local	66	50	50	30	50
CT	Calliope Local Trib	91	90	90	70	100
CU	Calliope Local	76	60	60	40	60
CV	Calliope Local Trib	32	30	30	20	30
CW	Calliope Local	30	20	20	10	20
DD	Clyde Ck U/s	379	400	400	280	430
DE	Clyde Ck trib	34	30	30	20	30
DF	Clyde Ck local	65	50	50	30	50
DG	Clyde Ck trib	56	50	50	40	50
DH	Clyde Ck local	69	50	50	30	50
DI	Clyde Ck trib	48	40	40	30	40
DJ	Clyde Ck local	15	10	10	10	10
DK	Clyde Ck trib	40	40	40	30	40
DL	Clyde Ck local	15	10	10	10	10
DM	Clyde Ck local	94	80	70	50	70
DN	Calliope Local	28	20	20	10	20
DO	Calliope Local Trib	50	40	50	30	50
DP	Calliope Local	55	40	40	30	40
DQ	Calliope Local	82	70	60	40	60
DR	Calliope Local Trib	50	40	40	30	50
DS	Calliope Local	12	10	10	10	10
DT	Calliope Local	107	80	80	10	80
DU	Calliope Local Trib	25	20	20	20	20
DV	Calliope Local Trib	34	30	30	20	30
DW	Calliope Local	109	100	100	60	90
DZ	Calliope Local	77	60	60	40	60
DX	Anabranch Local	101	70	80	50	70
DY	Anabranch Local	65	50	50	30	50

Design Flows 100 Year ARI

Sub Area	Location	Peak Inflows (Cumecs) for 100 Year ARI for Storm Duration (Hours)				
		3	6	12	18	24
BJ	Calliope R at Castlehope	2490	3600	4650	4700	4390
BK	Calliope Local Trib	81	70	70	60	80
BL	Calliope Local	39	30	30	60	30
BM	Deep Ck	243	250	270	210	290
BN	Calliope Local	63	50	50	30	50
BY	Double Ck u/s	758	1050	1140	890	1140
BZ	Double Ck local	123	100	100	60	100
CA	McGintys Ck	84	80	80	60	100
CB	Double Ck local	30	30	30	20	20
CC	Calliope Local Trib	34	30	30	20	30
CD	Leixlip Ck U/s	363	310	310	230	320
CE	Leixlip Ck local	431	360	350	230	340
CF	Leixlip Ck trib	57	50	50	40	60
CG	Leixlip Ck local	225	190	190	120	180
CH	Leixlip Ck trib	62	60	60	50	70
CI	Leixlip Ck local	25	20	20	10	20
CJ	Calliope Local	19	10	10	10	10
CL	Gravel Ck	268	280	300	250	310
CM	Calliope Local	168	130	130	90	130
CN	Vulcan Ck	152	140	140	110	170
CO	Calliope Local	64	50	50	30	50
CP	Calliope Local Trib	160	150	150	120	180
CQ	Calliope Local	139	110	110	80	110
CR	Oakey Ck	237	250	260	210	280
CS	Calliope Local	75	60	60	40	60
CT	Calliope Local Trib	105	100	100	80	120
CU	Calliope Local	87	70	70	40	70
CV	Calliope Local Trib	37	30	30	20	30
CW	Calliope Local	34	30	30	20	30
DD	Clyde Ck U/s	440	460	460	330	510
DE	Clyde Ck trib	39	30	30	30	40
DF	Clyde Ck local	75	60	60	40	60
DG	Clyde Ck trib	65	60	60	40	60
DH	Clyde Ck local	77	60	60	40	60
DI	Clyde Ck trib	55	50	50	40	50
DJ	Clyde Ck local	17	10	10	10	50
DK	Clyde Ck trib	46	40	40	30	40
DL	Clyde Ck local	17	20	20	10	10
DM	Clyde Ck local	106	90	90	60	80
DN	Calliope Local	31	30	30	20	20
DO	Calliope Local Trib	57	50	50	40	60
DP	Calliope Local	62	50	50	30	50
DQ	Calliope Local	92	80	70	50	70
DR	Calliope Local Trib	58	50	50	40	60
DS	Calliope Local	14	10	10	10	10
DT	Calliope Local	121	100	90	60	90
DU	Calliope Local Trib	29	30	30	20	30
DV	Calliope Local Trib	38	30	30	30	40
DW	Calliope Local	123	110	110	70	100
DZ	Calliope Local	87	70	70	50	70
DX	Anabranch Local	115	90	90	60	90
DY	Anabranch Local	74	60	60	40	60

Design Flows 200 Year ARI

Sub Area	Location	Peak Inflows (Cumecs) for 200 Year ARI for Storm Duration (Hours)					Envelope
		3	6	12	18	24	
BJ	Calliope R at Castlehope	3000	5530	5570	5610	5240	5610
BK	Calliope Local Trib	98	110	88	68	100	110
BL	Calliope Local	46	48	37	24	40	48
BM	Deep Ck	286	370	315	246	340	370
BN	Calliope Local	73	78	60	39	60	78
BY	Double Ck u/s	914	1605	1350	1045	1360	1605
BZ	Double Ck local	141	155	118	77	110	155
CA	McGintys Ck	99	114	96	75	110	114
CB	Double Ck local	35	39	30	20	110	110
CC	Calliope Local Trib	40	45	36	29	40	45
CD	Leixlip Ck U/s	430	448	369	274	370	448
CE	Leixlip Ck local	501	542	414	271	400	542
CF	Leixlip Ck trib	67	76	61	49	70	76
CG	Leixlip Ck local	259	292	226	148	210	292
CH	Leixlip Ck trib	74	86	70	55	80	86
CI	Leixlip Ck local	29	30	23	15	20	30
CJ	Calliope Local	22	23	17	11	20	23
CL	Gravel Ck	316	416	351	286	360	416
CM	Calliope Local	197	196	154	107	150	197
CN	Vulcan Ck	179	208	167	136	200	208
CO	Calliope Local	74	78	58	38	60	78
CP	Calliope Local Trib	190	219	180	142	210	219
CQ	Calliope Local	162	161	129	90	130	162
CR	Oakey Ck	281	364	309	245	330	364
CS	Calliope Local	87	91	69	45	70	91
CT	Calliope Local Trib	124	144	122	94	140	144
CU	Calliope Local	100	108	82	54	80	108
CV	Calliope Local Trib	44	46	38	28	40	46
CW	Calliope Local	39	43	33	21	30	43
DD	Clyde Ck U/s	523	683	548	381	610	683
DE	Clyde Ck trib	46	49	40	30	40	49
DF	Clyde Ck local	87	90	67	46	70	90
DG	Clyde Ck trib	77	85	69	53	70	85
DH	Clyde Ck local	90	94	71	47	70	94
DI	Clyde Ck trib	64	68	56	43	60	68
DJ	Clyde Ck local	20	22	17	11	20	22
DK	Clyde Ck trib	55	60	49	38	50	60
DL	Clyde Ck local	20	23	18	12	20	23
DM	Clyde Ck local	123	135	104	68	100	135
DN	Calliope Local	36	41	32	21	30	41
DO	Calliope Local Trib	67	78	64	51	70	78
DP	Calliope Local	72	78	60	39	60	78
DQ	Calliope Local	107	117	90	59	80	117
DR	Calliope Local Trib	70	78	63	49	70	78
DS	Calliope Local	16	18	14	9	10	18
DT	Calliope Local	140	150	114	75	110	150
DU	Calliope Local Trib	34	37	30	24	30	37
DV	Calliope Local Trib	45	49	40	32	40	49
DW	Calliope Local	142	161	128	85	120	161
DZ	Calliope Local	101	110	84	55	80	110
DX	Anabranch Local	135	138	103	69	110	138
DY	Anabranch Local	86	94	72	47	70	94

Design Flows 500 Year ARI

Sub Area	Location	Peak Inflows (Cumecs) for 500 Year ARI for Storm Duration (Hours)					Envelope
		3	6	12	18	24	
BJ	Calliope R at Castlehope	3760	6860	6910	6900	6480	6910
BK	Calliope Local Trib	120	130	110	90	120	130
BL	Calliope Local	50	60	50	30	40	60
BM	Deep Ck	350	450	380	300	410	450
BN	Calliope Local	90	100	70	50	70	100
BY	Double Ck u/s	1150	1980	1660	1270	1700	1980
BZ	Double Ck local	170	190	150	100	140	190
CA	McGintys Ck	120	140	120	90	140	140
CB	Double Ck local	40	50	40	20	30	50
CC	Calliope Local Trib	50	50	40	40	50	50
CD	Leixlip Ck U/s	530	540	450	340	450	540
CE	Leixlip Ck local	600	660	510	330	480	660
CF	Leixlip Ck trib	80	90	80	60	80	90
CG	Leixlip Ck local	310	360	280	180	250	360
CH	Leixlip Ck trib	90	100	80	70	100	100
CI	Leixlip Ck local	30	40	30	20	30	40
CJ	Calliope Local	30	30	20	10	20	30
CL	Gravel Ck	390	510	430	350	440	510
CM	Calliope Local	240	240	190	130	190	240
CN	Vulcan Ck	220	260	200	170	240	260
CO	Calliope Local	90	100	70	50	70	100
CP	Calliope Local Trib	230	270	220	180	260	270
CQ	Calliope Local	200	200	160	110	160	200
CR	Oakey Ck	340	440	380	300	400	440
CS	Calliope Local	100	110	90	60	80	110
CT	Calliope Local Trib	150	180	150	120	170	180
CU	Calliope Local	120	130	100	70	100	130
CV	Calliope Local Trib	50	60	50	40	50	60
CW	Calliope Local	50	50	40	30	40	50
DD	Clyde Ck U/s	650	830	670	460	750	830
DE	Clyde Ck trib	60	60	50	40	50	60
DF	Clyde Ck local	110	110	80	60	80	110
DG	Clyde Ck trib	100	100	80	70	90	100
DH	Clyde Ck local	110	110	90	60	90	110
DI	Clyde Ck trib	80	80	70	50	70	80
DJ	Clyde Ck local	20	30	20	10	20	30
DK	Clyde Ck trib	70	70	60	50	60	70
DL	Clyde Ck local	20	30	20	10	20	30
DM	Clyde Ck local	150	160	130	80	120	160
DN	Calliope Local	40	50	40	30	30	50
DO	Calliope Local Trib	80	100	80	60	90	100
DP	Calliope Local	90	100	70	50	70	100
DQ	Calliope Local	130	140	110	70	100	140
DR	Calliope Local Trib	90	90	80	60	80	90
DS	Calliope Local	20	20	20	10	20	20
DT	Calliope Local	170	180	140	90	130	180
DU	Calliope Local Trib	40	40	40	30	40	40
DV	Calliope Local Trib	50	60	50	40	50	60
DW	Calliope Local	170	190	150	100	140	190
DZ	Calliope Local	120	130	100	70	100	130
DX	Anabranch Local	160	170	130	90	130	170
DY	Anabranch Local	100	120	90	60	80	120

Appendix F
PMP and PMF Estimation

LOCATION INFORMATION

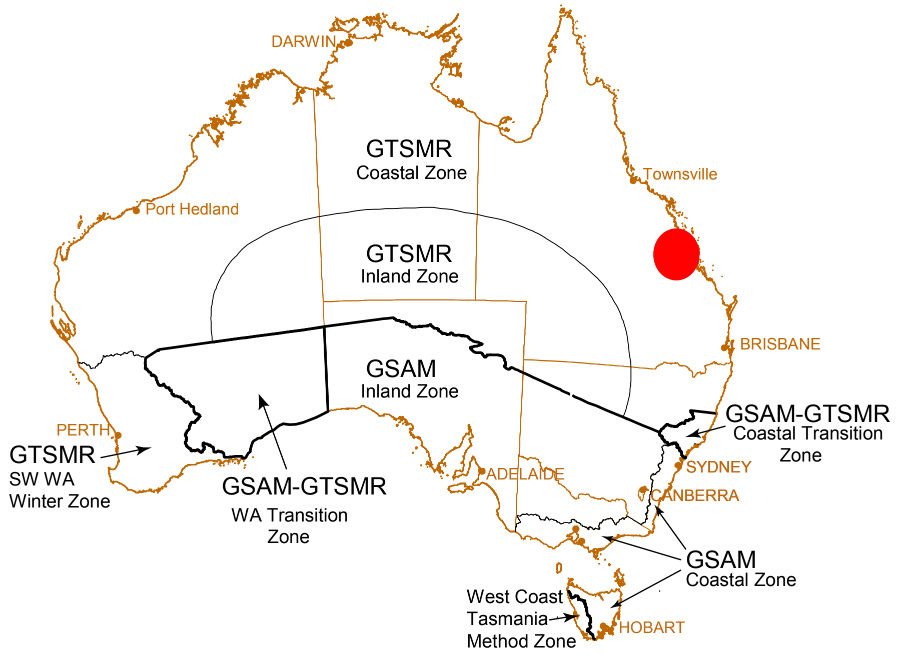
Catchment Name …Calliope River………………. State ……Qld….

GTSMR zone(s) ………GTSMR……………………………………………………..………………………

WORKSHEET 1: PMP Method Selection

Catchment Name……Calliope River Catchment Area …1,860 km^2……………

LONG DURATION PMP



NB This diagram can is also available as a shapefile: [CD-ROM drive]:pmp_zones\zones_all.shp
or it can be printed on A3 paper from [CD-ROM drive]:documents\method_zones.pdf

CIRCLE THE ZONE IN WHICH THE CATCHMENT IS LOCATED:

[✓ GTSMR (Coastal)]	GTSMR (Inland)
GTSMR (Coastal & SWWA)	Coastal Transition - GTSMR Coastal - GSAM Coastal
GSAM (Coastal)	WA Transition - GTSMR Coastal - GSAM Inland
GSAM (Inland)	WCTas

SHORT DURATION PMP (GSDM)

Is the catchment less than 1000km²? — NO → Short duration PMP estimates can **not** be calculated for the catchment

YES ↓

Is the catchment less than 500km² and south of 30°S? — NO → PMP estimates for up to 6 hours can be calculated using the **GSDM** for this catchment

NO → PMP estimates for up to 6 hours can be calculated using the **GSDM** for this catchment and can include **winter** estimates

PMP METHOD SUMMARY

Fill in the table below with the PMP method/s applicable to the catchment, referring to Table 1.1 for any additional information needed. NB: for the Transition zones, write separate entries for GTSMR and GSAM.

METHOD	ZONE	SEASON	DURATIONS
GTSMR	*Coastal*	*Annual*	*24-120 hours*

CATCHMENT FACTORS

Topographical Adjustment Factor **TAF** = …….1.33……….. (1.0 – 2.0)

Decay Amplitude Factor **DAF** = ….….1.0………. (0.7 – 1.0)

Annual Moisture Adjustment Factor $MAF_a = EPW_{catchment}/120.00$

Extreme Precipitable Water ($EPW_{catchment}$) = ………92.8 $\mathbf{MAF_a}$ = ………0.773……. (0.4 – 1.1)

Winter Moisture Adjustment Factor (where applicable) N/A $MAF_w = EPW_{catchment\_winter}/82.30$

Winter EPW ($EPW_{catchment\_winter}$) = ………… $\mathbf{MAF_w}$ = …N/A……………. (0.4 – 1.1)

PMP VALUES (mm) - Annual

Duration (hours)	Initial Depth (**D_a**)	PMP Estimate **=D_axTAFxDAFxMAF$_a$**	Final PMP Estimate (from envelope) Leixlip CK	Final PMP Estimate (from envelope) Clyde Ck
1	Where applicable, calculate GSDM (Bureau of Meteorology, 2003) depths GSDM depths used for Leixlip Ck and Clyde Creek only – catchment areas 58 and 72 km^2 respectively		360	350
2			460	450
3			520	510
4			580	570
5			630	620
6			670	660
12	(no preliminary estimates available)			
24	1188	1222	1220	1220
36	1394	1434	1430	1430
48	1585	1630	1630	1630
72	1922	1977	1980	1980
96	2188	2250	2250	2250
120	2310	2376	2380	2380

PMP VALUES (mm) – Winter (not applicable)

WORKSHEET 2: Generalised Tropical Storm Method Revised (GTSMR)

Figures D1 to **D3** show the PMP factors with the Calliope River catchment boundary superimposed. **Figure D4** shows the computed PMP for 24 to 120 hours using the GTSMR methodology, plus extrapolated 12 and 18 hour values. **Figure D4** also shows PMPs for 1 to 6 hours for the Leixlip Creek and Clyde Creek catchment calculated using the GSDM approach.

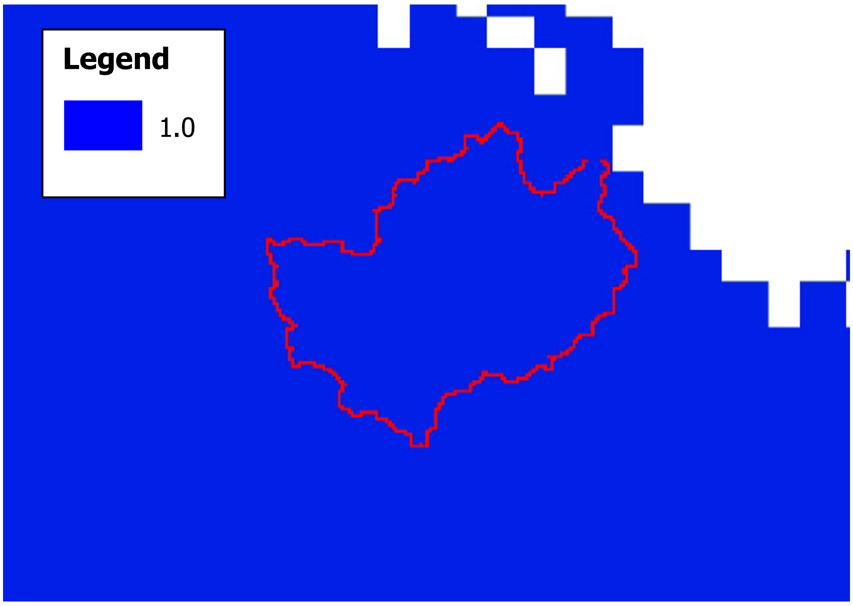


Figure D1 Distribution of DAF

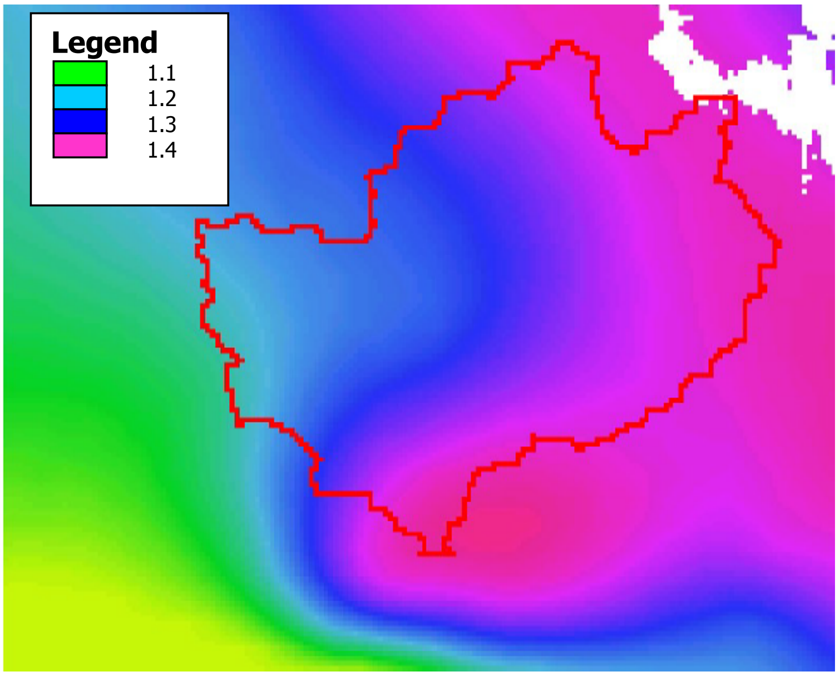


Figure D2 Distribution of TAF

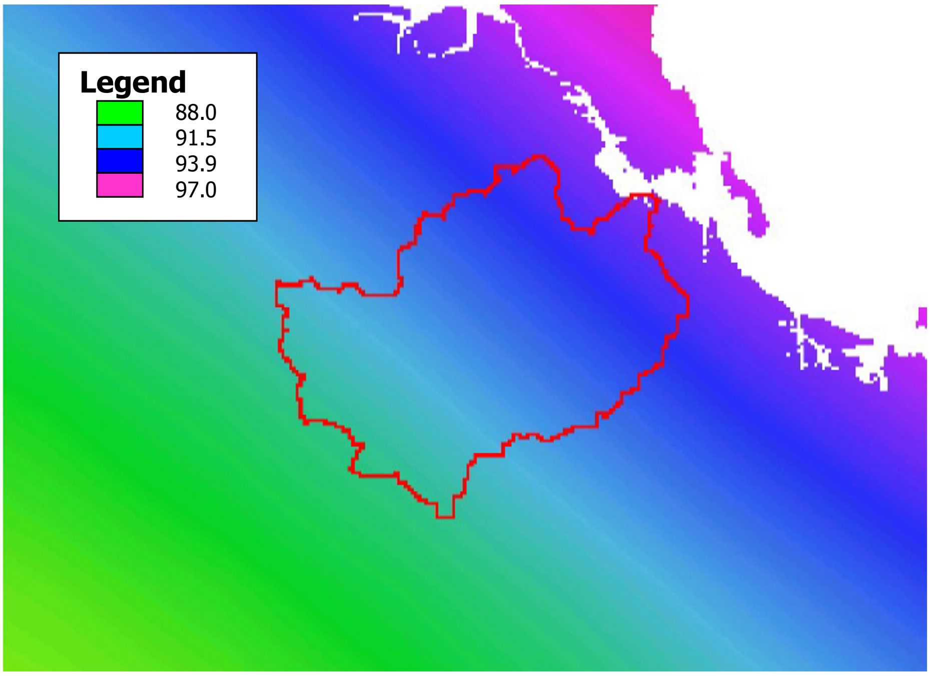


Figure D3 Distribution of EPW

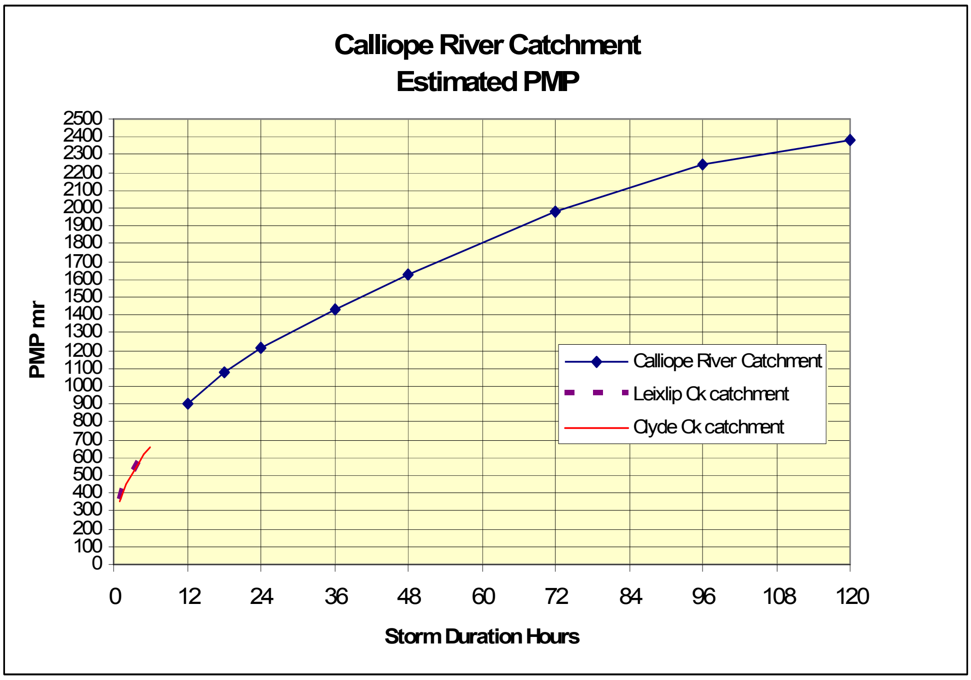


Figure D4 Estimated Catchment PMP

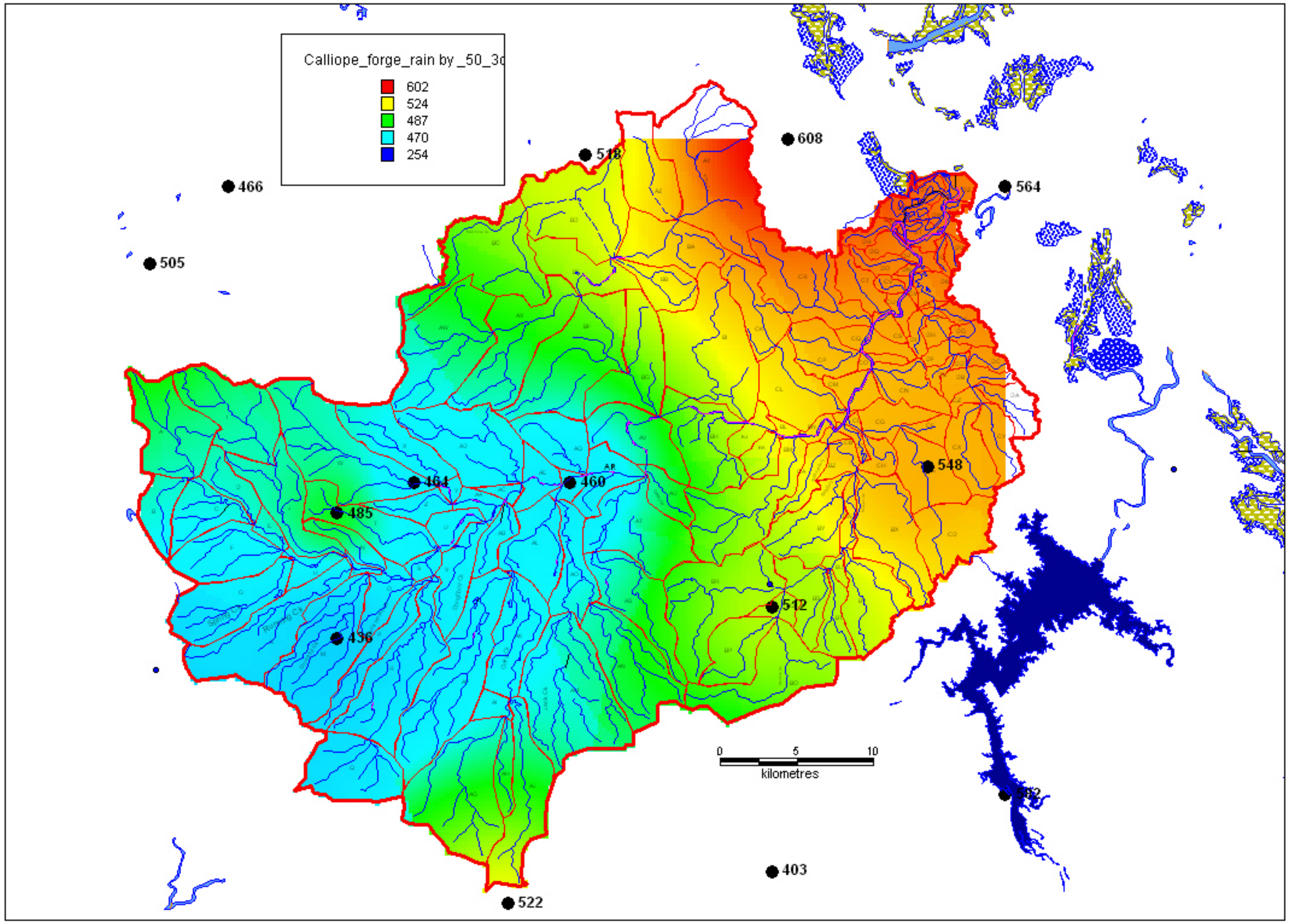


Figure D5 **Spatial Distribution of 50 year 72 Hour Rainfall**

Spatial Distribution of PMP Estimates

RORB subarea	Area km2	50 yr, 72 hr Catchment Mean mm	PMP Estimates (mm) for Durations (Hours) of				
			12	18	24	36	48
		499	900	1080	1220	1430	1630
A	28.06	478	862	1034	1168	1369	1561
B	11.23	471	849	1019	1151	1349	1538
C	14.50	471	849	1019	1151	1349	1538
D	8.77	473	853	1023	1156	1355	1545
E	3.52	473	853	1023	1156	1355	1545
F	21.31	467	842	1010	1141	1338	1525
G	25.92	454	819	982	1110	1301	1483
H	5.70	467	842	1010	1141	1338	1525
I	28.76	477	860	1032	1166	1367	1558
J	22.66	476	858	1030	1163	1364	1554
K	33.35	450	811	974	1100	1289	1470
L	1.55	467	842	1010	1141	1338	1525
M	37.27	440	793	952	1075	1261	1437
N	6.96	480	865	1039	1173	1375	1567
O	10.56	460	829	995	1124	1318	1502
P	15.65	444	801	961	1085	1272	1450
Q	24.94	451	813	976	1102	1292	1473
R	34.67	452	815	978	1105	1295	1476
S	3.60	466	840	1008	1139	1335	1522
T	21.63	477	860	1032	1166	1367	1558
U	6.55	467	842	1010	1141	1338	1525
V	14.18	466	840	1008	1139	1335	1522
W	43.32	473	853	1023	1156	1355	1545
X	19.77	467	842	1010	1141	1338	1525
Y	1.85	466	840	1008	1139	1335	1522
Z	7.48	465	838	1006	1137	1332	1518
AA	4.89	467	842	1010	1141	1338	1525
AB	7.72	467	842	1010	1141	1338	1525
AC	2.52	465	838	1006	1137	1332	1518
AD	32.61	467	842	1010	1141	1338	1525
AE	7.97	462	833	1000	1129	1324	1509
AF	46.04	465	838	1006	1137	1332	1518
AG	44.55	490	884	1060	1198	1404	1600
AH	7.08	482	869	1043	1178	1381	1574
AI	4.15	470	847	1017	1149	1346	1535
AJ	27.09	492	887	1065	1203	1410	1607
AK	21.86	467	842	1010	1141	1338	1525
AL	19.74	466	840	1008	1139	1335	1522
AM	50.58	473	853	1023	1156	1355	1545
AN	30.71	485	874	1049	1185	1389	1584
AO	15.51	468	844	1013	1144	1341	1528
AP	3.48	460	829	995	1124	1318	1502
AQ	14.96	465	838	1006	1137	1332	1518
AR	11.59	465	838	1006	1137	1332	1518
AS	24.38	487	878	1054	1190	1395	1590
AT	30.07	476	858	1030	1163	1364	1554
AU	8.17	484	873	1047	1183	1387	1581
AV	21.26	479	864	1036	1171	1372	1564
AW	39.94	481	867	1041	1176	1378	1571
AX	35.13	487	878	1054	1190	1395	1590
AY	55.31	577	1040	1248	1410	1653	1884
AZ	21.13	532	959	1151	1300	1524	1737

Spatial Distribution of PMP Estimates (Contd)

RORB subarea	Area km2	50 yr, 72 hr Catchment Mean mm	PMP Estimates (mm) for Durations (Hours) of				
			12	18	24	36	48
		499	900	1080	1220	1430	1630
BA	21.20	538	970	1164	1315	1541	1757
BB	11.52	526	948	1138	1286	1507	1718
BC	37.35	502	905	1086	1227	1438	1639
BD	37.46	518	934	1121	1266	1484	1692
BE	16.46	513	925	1110	1254	1470	1675
BF	41.17	492	887	1065	1203	1410	1607
BG	25.29	492	887	1065	1203	1410	1607
BH	26.30	503	907	1088	1229	1441	1643
BI	45.55	522	941	1129	1276	1495	1705
BJ	5.64	519	936	1123	1269	1487	1695
BK	6.09	520	938	1125	1271	1490	1698
BL	1.71	527	950	1140	1288	1510	1721
BM	32.69	514	927	1112	1256	1473	1678
BN	2.65	536	966	1160	1310	1536	1750
BO	30.66	504	909	1090	1232	1444	1646
BP	15.75	506	912	1095	1237	1450	1652
BQ	4.09	512	923	1108	1251	1467	1672
BR	39.70	505	911	1093	1234	1447	1649
BS	13.18	512	923	1108	1251	1467	1672
BT	8.98	513	925	1110	1254	1470	1675
BU	2.29	516	930	1116	1261	1478	1685
BV	21.39	518	934	1121	1266	1484	1692
BW	4.24	534	963	1155	1305	1530	1744
BX	29.41	537	968	1162	1313	1538	1754
BY	21.51	522	941	1129	1276	1495	1705
BZ	5.04	541	975	1171	1322	1550	1767
CA	7.67	528	952	1142	1291	1513	1724
CB	1.25	540	974	1168	1320	1547	1763
CC	2.24	543	979	1175	1327	1556	1773
CD	21.11	541	975	1171	1322	1550	1767
CE	17.82	548	988	1186	1339	1570	1790
CF	3.85	548	988	1186	1339	1570	1790
CG	9.00	546	984	1181	1335	1564	1783
CH	5.11	546	984	1181	1335	1564	1783
CI	1.04	543	979	1175	1327	1556	1773
CJ	0.80	542	977	1173	1325	1553	1770
CK	16.57	544	981	1177	1330	1558	1776
CL	20.69	533	961	1153	1303	1527	1741
CM	8.06	544	981	1177	1330	1558	1776
CN	11.96	547	986	1184	1337	1567	1786
CO	2.70	547	986	1184	1337	1567	1786
CP	13.44	545	983	1179	1332	1561	1780
CQ	6.67	549	990	1188	1342	1573	1793
CR	29.51	558	1006	1207	1364	1599	1822
CS	3.13	552	995	1194	1349	1581	1803
CT	9.20	560	1010	1212	1369	1604	1829
CU	3.56	555	1001	1201	1357	1590	1812
CV	2.16	559	1008	1209	1366	1601	1825
CW	1.37	558	1006	1207	1364	1599	1822
CX	14.66	548	988	1186	1339	1570	1790
CY	10.45	551	993	1192	1347	1579	1799
CZ	2.55	549	990	1188	1342	1573	1793

Spatial Distribution of PMP Estimates (Contd)

RORB subarea	Area km2	50 yr, 72 hr Catchment Mean mm	PMP Estimates (mm) for Durations (Hours) of				
			12	18	24	36	48
		499	900	1080	1220	1430	1630
DA	8.88	553	997	1197	1352	1584	1806
DB	6.40	549	990	1188	1342	1573	1793
DC	3.56	555	1001	1201	1357	1590	1812
DD	1.03	551	993	1192	1347	1579	1799
DE	2.25	549	990	1188	1342	1573	1793
DF	3.36	550	992	1190	1344	1576	1796
DG	4.14	558	1006	1207	1364	1599	1822
DH	3.34	553	997	1197	1352	1584	1806
DI	3.20	552	995	1194	1349	1581	1803
DJ	0.70	554	999	1199	1354	1587	1809
DK	2.87	559	1008	1209	1366	1601	1825
DL	0.65	556	1003	1203	1359	1593	1816
DM	4.25	563	1015	1218	1376	1613	1839
DN	1.18	561	1012	1214	1371	1607	1832
DO	4.47	563	1015	1218	1376	1613	1839
DP	2.46	566	1021	1225	1383	1622	1848
DQ	3.63	565	1019	1222	1381	1619	1845
DR	3.78	570	1028	1233	1393	1633	1861
DS	0.52	572	1031	1238	1398	1639	1868
DT	4.87	567	1022	1227	1386	1624	1852
DU	1.71	565	1019	1222	1381	1619	1845
DV	2.31	564	1017	1220	1379	1616	1842
DW	4.71	567	1022	1227	1386	1624	1852
DX	4.88	573	1033	1240	1401	1642	1871
DY	2.92	569	1026	1231	1391	1630	1858
DZ	3.44	565	1019	1222	1381	1619	1845

Stream Name	RORB subarea	Area km2	PMP Estimates (mm) for Durations (Hours) for Leixlip Ck and Clyde Ck	
			3 Hrs	6 Hrs
Leixlip CK	CD	21.11	516	665
Leixlip CK	CE	17.82	523	674
Cogoa Ck	CF	3.85	523	674
Leixlip CK	CG	9.00	521	671
Ogre Ck	CH	5.11	521	671
Leixlip CK	CI	1.04	518	668
Ginger Beer C	CX	14.66	506	655
Clyde Ck	CY	10.45	509	659
Clyde Ck	CZ	2.55	507	656
Clarke Ck	DA	8.88	511	661
Clyde Ck	DB	6.40	507	656
Unnamed	DC	3.56	513	663
Clyde Ck	DD	1.03	509	659
Unnamed	DE	2.25	507	656
Clyde Ck	DF	3.36	508	657
Unnamed	DG	4.14	515	667
Clyde Ck	DH	3.34	511	661
Unnamed	DI	3.20	510	660
Clyde Ck	DJ	0.70	512	662
Unnamed	DK	2.87	516	668
Clyde Ck	DL	0.65	514	665
Clyde Ck	DM	4.25	520	673

PMP Temporal Patterns for 12 to 48 hour durations
Source BOM – GTSMR (24 to 48 Hours)

24HOURS

Time_hrs	Time_%	Incremental_%	Cumulative_%
3	12.5	9.00	9.00
6	25	11.64	20.65
9	37.5	13.52	34.16
12	50	23.18	57.35
15	62.5	17.00	74.35
18	75	7.64	81.99
21	87.5	12.58	94.57
24	100	5.43	100.00

Estimated 18 HOURS

Time_hrs	Time_%	Incremental_%	Cumulative_%
3	16.7%	13.6%	13.6%
6	33.3%	15.8%	29.4%
9	50.0%	27.1%	56.5%
12	66.7%	19.9%	76.4%
15	83.3%	8.9%	85.3%
18	100.0%	14.7%	100.0%

36HOURS

Time_hrs	Time_%	Incremental_%	Cumulative_%
3	8.33	2.95	2.95
6	16.67	4.69	7.64
9	25	7.13	14.77
12	33.33	6.33	21.10
15	41.67	10.96	32.07
18	50	9.93	42.00
21	58.33	12.52	54.51
24	66.67	17.44	71.96
27	75	9.23	81.19
30	83.33	5.56	86.75
33	91.67	8.02	94.77
36	100	5.23	100.00

Estimated 12 HOURS

Time_hrs	Time_%	Incremental_%	Cumulative_%
3	16.7%	17.8%	17.8%
6	33.3%	20.7%	38.5%
9	50.0%	35.5%	73.9%
12	66.7%	26.0%	100.0%

48HOURS

Time_hrs	Time_%	Incremental_%	Cumulative_%
3	6.25	5.56	5.56
6	12.5	3.57	9.13
9	18.75	4.35	13.49
12	25	9.72	23.21
15	31.25	10.92	34.13
18	37.5	2.49	36.62
21	43.75	9.05	45.66
24	50	6.07	51.73
27	56.25	8.17	59.90
30	62.5	4.68	64.58
33	68.75	1.49	66.07
36	75	15.17	81.24
39	81.25	3.48	84.73
42	87.5	7.22	91.95
45	93.75	5.54	97.49
48	100	2.51	100.00

PMP Temporal Patterns for 3 and 6 hour durations
Source BOM – GSDM

% time	% PMP cumulative	% PMP increment
0	0	
5	4	4
10	10	6
15	18	8
20	25	7
25	32	7
30	39	7
35	46	7
40	52	6
45	59	7
50	64	5
55	70	6
60	75	5
65	80	5
70	85	5
75	89	4
80	92	3
85	95	3
90	97	2
95	99	2
100	100	1

3hr	20 increments of	9	mins
6hr	20 increments of	18	mins

Adopted Peak PMF Inputs

Sub Area	Location	Peak Inflows (Cumecs) for PMF for Storm Duration (Hours)					Envelope
		3	6	12	18	24	
BJ	Calliope R at Castlehope			19800	20500	20600	20600
BK	Calliope Local Trib			160	140	140	160
BL	Calliope Local			50	40	40	50
BM	Deep Ck			830	750	730	830
BN	Calliope Local			80	70	70	80
BY	Double Ck u/s			4430	4030	3900	4430
BZ	Double Ck local			150	130	130	150
CA	McGintys Ck			200	190	180	200
CB	Double Ck local			40	30	30	40
CC	Calliope Local Trib			60	60	50	60
CD	Leixlip Ck U/s	1200	860	580	530	520	1200
CE	Leixlip Ck local	1170	790	520	480	480	1170
CF	Leixlip Ck trib	204	150	110	100	90	204
CG	Leixlip Ck local	600	410	270	240	240	600
CH	Leixlip Ck trib	247	190	140	130	120	247
CI	Leixlip Ck local	68	50	30	30	30	68
CJ	Calliope Local			20	20	20	20
CL	Gravel Ck			970	890	860	970
CM	Calliope Local			230	210	210	230
CN	Vulcan Ck			330	300	290	330
CO	Calliope Local			80	70	70	80
CP	Calliope Local Trib			370	340	320	370
CQ	Calliope Local			190	170	170	190
CR	Oakey Ck			800	730	710	800
CS	Calliope Local			90	80	80	90
CT	Calliope Local Trib			260	240	230	260
CU	Calliope Local			110	100	100	110
CV	Calliope Local Trib			60	60	50	60
CW	Calliope Local			40	40	40	40
DD	Clyde Ck U/s	1840	1590	1330	1210	1170	1840
DE	Clyde Ck trib	124.4	90	60	60	60	124.4
DF	Clyde Ck local	205.6	140	100	90	90	205.6
DG	Clyde Ck trib	222.3	160	120	110	100	222.3
DH	Clyde Ck local	208.9	140	100	90	90	208.9
DI	Clyde Ck trib	175.9	130	90	80	80	175.9
DJ	Clyde Ck local	45.13	30	20	20	20	45.13
DK	Clyde Ck trib	155.8	110	80	70	70	155.8
DL	Clyde Ck local	42.9	30	20	20	20	42.9
DM	Clyde Ck local	279.3	190	130	120	120	279.3
DN	Calliope Local			40	30	30	40
DO	Calliope Local Trib			130	120	110	130
DP	Calliope Local			70	70	70	70
DQ	Calliope Local			110	100	100	110
DR	Calliope Local Trib			110	100	100	110
DS	Calliope Local			20	10	10	20
DT	Calliope Local			150	130	130	150
DU	Calliope Local Trib			50	50	40	50
DV	Calliope Local Trib			70	60	60	70
DW	Calliope Local			140	130	130	140
DZ	Calliope Local			100	100	100	100
DX	Anabranch Local			150	130	130	150
DY	Anabranch Local			90	80	80	90

Appendix G
Hydraulic Model Results

Design Flood Levels

		PEAK FLOOD WATER LEVEL FOR ARI (years)								DEVELOPMENT LEVEL (1OO Year ARI + 1m FREEBOARD) m AHD
FLOW PATH NAME	MIKE 11 CHAINAGE m	DOWNSTREAM BOUNDARY CONDITION HAT (2.42m AHD)						1000 Yr storm surge 3.80 m AHD	Fully Vegetated Waterway	
		10 Year	20 Year	50 Year	100 Year	200 Year	500 Year	PMF	100 Year	
CALLIOPER	0	14.77	16.16	17.93	19.07	20.08	21.46	27.52	20.97	20.07
CALLIOPER	33	14.75	16.14	17.90	19.05	20.06	21.43	27.49	20.95	20.05
CALLIOPER	181	14.67	16.05	17.82	18.98	20.00	21.40	27.49	20.89	19.98
CALLIOPER	324	14.57	15.95	17.72	18.87	19.90	21.26	27.49	20.71	19.87
CALLIOPER	441	14.46	15.85	17.62	18.77	19.81	21.17	27.49	20.52	19.77
CALLIOPER	614	14.35	15.73	17.53	18.70	19.77	21.15	27.49	20.37	19.70
CALLIOPER	834	14.23	15.59	17.33	18.46	19.53	20.85	27.49	20.16	19.46
CALLIOPER	1066	14.12	15.46	17.19	18.32	19.40	20.68	27.49	20.05	19.32
CALLIOPER	1293	13.95	15.28	17.02	18.17	19.29	20.55	27.36	19.93	19.17
CALLIOPER	1504	13.80	15.12	16.85	18.01	19.18	20.42	27.44	19.79	19.01
CALLIOPER	1714	13.71	15.06	16.82	17.99	19.15	20.37	27.24	19.72	18.99
CALLIOPER	1908	13.57	14.90	16.66	17.84	19.03	20.22	27.09	19.56	18.84
CALLIOPER	2000	13.48	14.82	16.58	17.76	18.96	20.13	27.03	19.45	18.76
CALLIOPER	2184	13.34	14.66	16.43	17.62	18.85	20.01	27.04	19.20	18.62
CALLIOPER	2307	13.25	14.57	16.33	17.52	18.77	19.92	26.97	19.00	18.52
CALLIOPER	2556	13.15	14.46	16.23	17.43	18.70	19.85	27.09	18.76	18.43
CALLIOPER	2812	13.02	14.33	16.12	17.33	18.62	19.77	26.92	18.67	18.33
CALLIOPER	3079	12.84	14.17	16.00	17.22	18.55	19.69	27.01	18.55	18.22
CALLIOPER	3274	12.59	13.96	15.85	17.13	18.50	19.65	26.86	18.30	18.13
CALLIOPER	3507	12.36	13.81	15.76	17.07	18.47	19.61	26.89	18.14	18.07
CALLIOPER	3757	12.07	13.59	15.62	16.96	18.40	19.55	26.87	17.99	17.96
CALLIOPER	3998	11.94	13.47	15.51	16.88	18.34	19.50	26.87	17.88	17.88
CALLIOPER	4196	11.82	13.38	15.45	16.83	18.32	19.47	26.87	17.83	17.83
CALLIOPER	4418	11.79	13.35	15.43	16.82	18.31	20.33	26.87	17.79	17.82
CALLIOPER	4670	11.65	13.23	15.33	16.71	18.29	19.72	26.87	17.67	17.71
CALLIOPER	4875	11.58	13.14	15.21	16.59	18.29	19.44	26.87	17.52	17.59
CALLIOPER	5158	11.48	13.02	15.09	16.65	19.52	19.20	26.87	17.35	17.65
CALLIOPER	5362	11.41	12.94	15.00	16.45	17.53	19.00	26.87	17.33	17.45
CALLIOPER	5500	11.41	12.99	15.06	16.45	17.53	18.96	26.87	17.33	17.45
CALLIOPER	5750	11.41	12.97	15.06	16.45	17.30	18.96	26.87	17.30	17.45
CALLIOPER	6000	11.41	12.98	15.07	16.45	17.30	18.49	26.87	17.29	17.45
CALLIOPER	6155	11.29	12.82	14.89	16.27	17.06	18.22	26.62	17.11	17.27
CALLIOPER	6250	11.20	12.75	14.84	16.24	17.03	17.75	26.62	17.08	17.24
CALLIOPER	6500	11.08	12.66	14.77	16.18	16.95	17.75	26.62	16.98	17.18
CALLIOPER	6750	10.99	12.53	14.63	16.01	16.78	17.44	26.62	16.82	17.01
CALLIOPER	7000	10.92	12.51	14.57	16.00	16.78	17.44	26.62	16.84	17.00
CALLIOPER	7250	10.94	12.51	14.62	16.05	16.82	17.44	26.62	16.86	17.05
CALLIOPER	7510	10.78	12.45	14.46	15.94	16.73	17.35	26.62	16.79	16.94
CALLIOPER	7672	10.81	12.45	14.57	15.92	16.74	17.33	26.62	16.79	16.92
CALLIOPER	7900	10.81	12.37	14.49	15.92	16.63	17.26	26.62	16.71	16.92
CALLIOPER	8084	10.71	12.27	14.40	15.84	16.54	17.46	26.62	16.64	16.84
CALLIOPER	8161	10.66	12.21	14.36	15.81	16.52	17.25	26.62	16.61	16.81
CALLIOPER	8361	10.59	12.15	14.31	15.77	16.46	17.35	26.62	16.44	16.77
CALLIOPER	8500	10.57	12.13	14.30	15.77	16.47	17.10	26.62	16.43	16.77
CALLIOPER	8612	10.55	12.13	14.30	15.76	16.51	17.05	26.62	16.44	16.76
CALLIOPER	8707	10.52	12.10	14.28	15.76	16.46	17.00	26.62	16.42	16.76
CALLIOPER	8861	10.49	12.08	14.27	15.75	16.44	16.98	26.62	16.40	16.75
CALLIOPER	9000	10.47	12.06	14.25	15.72	16.41	16.91	26.62	16.37	16.72
CALLIOPER	9227	10.47	12.05	14.23	15.70	16.39	16.89	26.62	16.35	16.70
CALLIOPER	9413	10.38	11.98	14.18	15.65	16.35	16.85	26.62	16.32	16.65
CALLIOPER	9447	9.98	11.21	12.65	13.52	14.17	14.69	23.50	14.86	14.52
CALLIOPER	9660	9.43	10.62	12.01	12.85	13.63	14.31	22.43	14.12	13.85
CALLIOPER	9784	9.26	10.55	12.04	12.85	13.52	14.17	22.32	13.30	13.85
CALLIOPER	9907	9.00	10.26	11.70	12.50	13.20	13.91	22.40	12.85	13.50
CALLIOPER	9928	8.88	10.13	11.59	12.41	13.07	13.80	21.89	12.53	13.41
CALLIOPER	10000	8.81	10.05	11.51	12.41	13.02	13.77	21.89	12.44	13.41
CALLIOPER	10250	8.85	10.12	11.61	12.41	13.11	13.70	21.89	12.36	13.41
CALLIOPER	10500	8.59	9.83	11.28	12.06	12.82	13.62	21.89	11.97	13.06
CALLIOPER	10748	8.51	9.74	11.17	11.94	12.71	13.54	21.86	11.88	12.94
CALLIOPER	11000	8.36	9.57	10.97	11.74	12.58	13.46	21.83	11.74	12.74
CALLIOPER	11250	8.30	9.51	10.92	11.68	12.52	13.41	21.73	11.69	12.68
CALLIOPER	11500	8.19	9.39	10.79	11.55	12.43	13.36	21.79	11.61	12.55
CALLIOPER	11750	8.07	9.26	10.68	11.47	12.40	13.35	21.78	11.56	12.47
CALLIOPER	12000	7.98	9.20	10.62	11.40	12.34	13.30	21.66	11.50	12.40
CALLIOPER	12262	7.75	8.90	10.26	11.01	12.04	13.11	21.72	11.24	12.01
CALLIOPER	12570	7.50	8.66	10.03	10.79	11.90	13.02	21.77	11.10	11.79
CALLIOPER	12800	7.23	8.36	9.71	10.49	11.72	12.90	21.78	10.91	11.49

		PEAK FLOOD WATER LEVEL FOR ARI (years)								DEVELOPMENT LEVEL (1OO Year ARI + 1m FREEBOARD) m AHD
FLOW PATH NAME	MIKE 11 CHAINAGE m	DOWNSTREAM BOUNDARY CONDITION HAT (2.42m AHD)						1000 Yr storm surge 3.80 m AHD	Fully Vegetated Waterway	
		10 Year	20 Year	50 Year	100 Year	200 Year	500 Year	PMF	100 Year	
CALLIOPER	13000	7.09	8.18	9.49	10.27	11.51	12.72	21.83	10.69	11.27
CALLIOPER	13250	6.92	8.03	9.38	10.15	11.38	12.59	21.80	10.55	11.15
CALLIOPER	13500	7.06	8.19	9.53	10.15	11.51	12.67	21.80	10.55	11.15
CALLIOPER	13750	6.96	8.08	9.41	10.15	11.38	12.57	21.80	10.55	11.15
CALLIOPER	14000	6.91	8.02	9.35	10.11	11.32	12.52	21.80	10.47	11.11
CALLIOPER	14250	6.80	7.90	9.23	9.99	11.22	12.43	21.69	10.34	10.99
CALLIOPER	14500	6.65	7.74	9.07	9.82	11.05	12.30	21.78	10.17	10.82
CALLIOPER	14750	6.67	7.76	9.08	9.82	11.05	12.29	21.98	10.16	10.82
CALLIOPER	14999	6.60	7.70	9.02	9.77	10.99	12.22	21.77	10.10	10.77
CALLIOPER	15250	6.44	7.52	8.83	9.58	10.81	12.07	21.78	9.90	10.58
CALLIOPER	15500	6.34	7.39	8.66	9.39	10.57	11.77	21.76	9.69	10.39
CALLIOPER	15750	6.35	7.42	8.72	9.47	10.70	11.93	21.76	9.76	10.47
CALLIOPER	15992	6.26	7.31	8.60	9.34	10.57	11.83	21.70	9.63	10.34
CALLIOPER	16240	6.27	7.33	8.62	9.34	10.57	11.80	21.60	9.64	10.34
CALLIOPER	16500	6.14	7.19	8.48	9.21	10.40	11.62	21.50	9.48	10.21
CALLIOPER	16604	6.08	7.11	8.35	9.07	10.23	11.42	21.40	9.33	10.07
CALLIOPER	16793	5.92	6.89	8.06	8.72	10.08	10.94	21.30	8.97	9.72
CALLIOPER	17000	5.95	6.96	8.20	8.91	10.08	10.90	21.20	9.16	9.91
CALLIOPER	17250	5.92	6.93	8.15	8.86	10.02	10.90	21.10	9.10	9.86
CALLIOPER	17500	5.81	6.77	7.94	8.62	9.74	10.90	21.00	8.86	9.62
CALLIOPER	17750	5.72	6.66	7.81	8.47	9.55	10.65	20.90	8.70	9.47
CALLIOPER	18000	5.65	6.59	7.74	8.40	9.48	10.60	20.80	8.63	9.40
CALLIOPER	18176	5.59	6.52	7.65	8.30	9.37	10.49	20.73	8.53	9.30
CALLIOPER	18386	5.48	6.39	7.48	8.11	9.18	10.32	20.72	8.36	9.11
CALLIOPER	18590	5.38	6.24	7.30	7.91	8.95	10.13	20.72	8.15	8.91
CALLIOPER	18703	5.35	6.21	7.24	7.84	8.87	10.03	20.72	8.08	8.84
CALLIOPER	18881	5.31	6.16	7.18	7.78	8.83	10.00	20.72	8.03	8.78
CALLIOPER	19067	5.20	6.04	7.08	7.70	8.77	9.91	20.72	7.96	8.70
CALLIOPER	19250	5.24	6.11	7.17	7.79	8.85	9.98	20.72	8.03	8.79
CALLIOPER	19500	5.20	6.07	7.13	7.75	8.81	9.96	20.72	7.98	8.75
CALLIOPER	19750	5.09	5.95	7.00	7.61	8.67	9.81	20.94	7.81	8.61
CALLIOPER	19926	5.05	5.89	6.92	7.52	8.56	9.68	20.72	7.71	8.52
CALLIOPER	20176	5.00	5.82	6.83	7.41	8.42	9.51	21.25	7.59	8.41
CALLIOPER	20417	4.99	5.82	6.83	7.42	8.45	9.56	22.65	7.60	8.42
CALLIOPER	20500	4.99	5.81	6.82	7.41	8.44	9.55	20.95	7.59	8.41
CALLIOPER	20750	4.87	5.67	6.65	7.22	8.24	9.37	20.72	7.40	8.22
CALLIOPER	21000	4.85	5.65	6.63	7.21	8.24	9.37	20.72	7.38	8.21
CALLIOPER	21250	4.84	5.66	6.67	7.26	8.30	9.43	20.72	7.41	8.26
CALLIOPER	21497	4.80	5.61	6.61	7.19	8.23	9.36	20.50	7.33	8.19
CALLIOPER	21749	4.64	5.40	6.33	6.89	7.92	9.07	20.50	7.02	7.89
CALLIOPER	22001	4.49	5.24	6.19	6.76	7.78	8.89	20.19	6.89	7.76
CALLIOPER	22250	4.42	5.15	6.07	6.62	7.64	8.74	20.60	6.74	7.62
CALLIOPER	22496	4.43	5.17	6.10	6.66	7.68	8.79	20.03	6.76	7.66
CALLIOPER	22673	4.01	4.64	5.44	5.95	6.69	7.50	15.04	6.01	6.95
CALLIOPER	22729	4.02	4.64	5.44	5.94	6.67	7.48	15.26	6.00	6.94
CALLIOPER	22819	3.74	4.28	4.98	5.45	6.11	6.84	12.09	5.48	6.45
CALLIOPER	23000	3.67	4.17	4.82	5.25	5.85	6.52	11.38	5.28	6.25
CALLIOPER	23256	3.39	3.81	4.39	4.79	5.34	5.97	10.41	4.81	5.79
CALLIOPER	23497	3.38	3.80	4.38	4.77	5.33	5.95	10.35	4.80	5.77
CALLIOPER	23746	3.37	3.79	4.36	4.76	5.31	5.93	10.25	4.79	5.76
CALLIOPER	23997	3.35	3.77	4.34	4.73	5.28	5.90	10.25	4.76	5.73
CALLIOPER	24250	3.34	3.76	4.32	4.72	5.26	5.88	10.25	4.74	5.72
CALLIOPER	24495	3.31	3.72	4.27	4.67	5.21	5.82	10.25	4.69	5.67
CALLIOPER	24750	3.30	3.71	4.27	4.66	5.20	5.81	10.25	4.68	5.66
CALLIOPER	25000	3.29	3.70	4.25	4.64	5.18	5.80	10.25	4.67	5.64
CALLIOPER	25250	3.29	3.69	4.24	4.63	5.17	5.78	10.25	4.65	5.63
CALLIOPER	25500	3.28	3.68	4.23	4.63	5.17	5.78	10.25	4.65	5.63
CALLIOPER	25750	3.28	3.68	4.23	4.62	5.16	5.77	10.25	4.64	5.62
CALLIOPER	26004	3.28	3.68	4.23	4.62	5.16	5.78	10.25	4.64	5.62
CALLIOPER	26248	3.28	3.68	4.23	4.63	5.17	5.79	10.25	4.65	5.63
CALLIOPER	26503	3.29	3.69	4.24	4.64	5.18	5.80	10.25	4.65	5.64
CALLIOPER	26750	3.29	3.70	4.25	4.65	5.19	5.81	10.25	4.67	5.65
CALLIOPER	26998	3.29	3.70	4.25	4.65	5.20	5.82	10.25	4.67	5.65
CALLIOPER	27246	3.30	3.70	4.26	4.66	5.21	5.84	10.25	4.68	5.66

		PEAK FLOOD WATER LEVEL FOR ARI (years)								DEVELOPMENT LEVEL (1OO Year ARI + 1m FREEBOARD) m AHD
FLOW PATH NAME	MIKE 11 CHAINAGE m	DOWNSTREAM BOUNDARY CONDITION HAT (2.42m AHD)						1000 Yr storm surge 3.80 m AHD	Fully Vegetated Waterway	
		10 Year	20 Year	50 Year	100 Year	200 Year	500 Year	PMF	100 Year	
CALLIOPER	27500	3.25	3.65	4.19	4.60	5.15	5.78	10.15	4.61	5.60
CALLIOPER	27750	3.19	3.56	4.09	4.49	5.02	5.64	9.97	4.49	5.49
CALLIOPER	28000	3.10	3.44	3.94	4.33	4.86	5.47	9.98	4.34	5.33
CALLIOPER	28250	3.08	3.41	3.91	4.30	4.83	5.42	9.90	4.30	5.30
CALLIOPER	28500	3.04	3.35	3.86	4.25	4.80	5.39	9.90	4.24	5.25
CALLIOPER	28750	3.00	3.31	3.85	4.20	4.80	5.30	9.70	4.36	5.20
CALLIOPER	28910	2.98	3.28	3.80	4.10	4.80	5.20	9.50	4.69	5.10
CALLIOPER	29141	2.97	3.28	3.75	4.05	4.70	5.10	9.30	5.01	5.05
CALLIOPER	29250	2.97	3.28	3.70	4.00	4.60	5.00	9.00	4.57	5.00
CALLIOPER	29500	2.94	3.23	3.66	3.97	4.41	4.92	8.75	3.96	4.97
CALLIOPER	29831	2.88	3.14	3.53	3.77	4.18	4.65	8.42	3.81	4.77
CALLIOPER	30048	2.87	3.13	3.50	3.74	4.14	4.61	8.38	3.77	4.74
CALLIOPER	30250	2.84	3.09	3.45	3.68	4.06	4.53	8.28	3.71	4.68
CALLIOPER	30500	2.80	3.03	3.37	3.59	3.98	4.44	8.24	3.62	4.59
CALLIOPER	30721	2.78	3.00	3.32	3.52	3.88	4.31	7.96	3.55	4.52
CALLIOPER	30862	2.69	2.85	3.10	3.26	3.54	3.87	6.31	3.28	4.26
CALLIOPER	31000	2.92	2.93	3.14	3.32	3.62	3.98	6.60	3.34	4.32
CALLIOPER	31250	2.69	2.86	3.12	3.29	3.57	3.92	6.47	3.30	4.29
CALLIOPER	31500	2.68	2.83	3.08	3.24	3.51	3.85	6.33	3.25	4.24
CALLIOPER	31750	2.67	2.83	3.07	3.23	3.50	3.83	6.34	3.24	4.23
CALLIOPER	32000	2.67	2.82	3.05	3.21	3.47	3.80	6.27	3.22	4.21
CALLIOPER	32250	2.64	2.77	2.98	3.12	3.37	3.67	6.08	3.13	4.12
CALLIOPER	32500	2.61	2.82	2.92	3.05	3.27	3.55	5.88	3.06	4.05
CALLIOPER	32722	2.62	2.80	2.86	2.97	3.17	3.41	5.58	2.98	3.97
CALLIOPER	33010	2.59	2.69	2.85	2.96	3.15	3.39	5.49	2.96	3.96
CALLIOPER	33250	2.57	2.67	2.82	2.92	3.10	3.33	5.40	2.93	3.92
CALLIOPER	33500	2.55	2.63	2.77	2.86	3.02	3.22	5.22	2.86	3.86
CALLIOPER	33746	2.64	2.59	2.72	2.80	2.94	3.13	5.07	2.81	3.80
CALLIOPER	34000	2.52	2.59	2.70	2.77	2.91	3.08	5.00	2.78	3.77
CALLIOPER	34253	2.51	2.57	2.67	2.73	2.86	3.02	4.87	2.74	3.73
CALLIOPER	34488	2.59	2.58	2.63	2.69	2.79	2.93	4.74	2.69	3.69
CALLIOPER	34743	2.54	2.56	2.60	2.65	2.75	2.87	4.60	2.65	3.65
CALLIOPER	34996	2.53	2.56	2.54	2.58	2.64	2.73	4.33	2.58	3.58
CALLIOPER	35243	2.57	2.61	2.57	2.57	2.57	2.57	4.00	2.56	3.57
CALLIOPER	35502	2.55	2.61	2.55	2.55	2.55	2.55	3.99	2.56	3.55
CALLIOPER	35640	2.55	2.55	2.55	2.55	2.55	2.55	3.92	2.56	3.55
CALLIOPER	36300	2.46	2.51	2.46	2.46	2.46	2.46	3.84	2.46	3.46
CALLIOPER	36500	2.42	2.42	2.42	2.42	2.42	2.42	3.80	2.42	3.42
ANABRANCH	0	3.28	3.68	4.23	4.62	5.16	5.77	9.98	4.64	5.62
ANABRANCH	250	3.26	3.66	4.20	4.59	5.13	5.74	9.88	4.61	5.59
ANABRANCH	493	3.26	3.65	4.19	4.57	5.11	5.71	9.83	4.58	5.57
ANABRANCH	735	3.23	3.62	4.15	4.52	5.05	5.63	9.66	4.53	5.52
ANABRANCH	1006	3.20	3.58	4.10	4.47	4.99	5.57	9.54	4.47	5.47
ANABRANCH	1227	3.17	3.54	4.05	4.42	4.93	5.50	9.41	4.41	5.42
ANABRANCH	1501	3.14	3.50	4.00	4.36	4.86	5.42	9.30	4.35	5.36
ANABRANCH	1750	3.11	3.46	3.95	4.30	4.80	5.35	9.16	4.29	5.30
ANABRANCH	1999	3.07	3.41	3.89	4.23	4.70	5.24	8.90	4.22	5.23
ANABRANCH	2214	3.03	3.36	3.82	4.15	4.61	5.13	8.64	4.15	5.15
ANABRANCH	2432	3.00	3.32	3.77	4.08	4.53	5.04	8.47	4.09	5.08
ANABRANCH	2590	2.97	3.27	3.71	4.01	4.45	4.94	8.28	4.01	5.01
ANABRANCH	2680	2.91	3.20	3.61	3.91	4.34	4.83	8.12	3.91	4.91
ANABRANCH	3001	2.88	3.15	3.53	3.80	4.20	4.67	7.89	3.79	4.80
ANABRANCH	3248	2.84	3.09	3.44	3.69	4.07	4.50	7.56	3.68	4.69
ANABRANCH	3500	2.79	3.02	3.34	3.56	3.89	4.28	7.04	3.55	4.56
ANABRANCH	3750	2.79	3.01	3.31	3.52	3.82	4.18	6.65	3.51	4.52
ANABRANCH	3750	2.79	3.01	3.31	3.52	3.82	4.18	6.65	3.51	4.52
ANABRANCH	4000	2.76	2.97	3.26	3.45	3.75	4.10	6.56	3.45	4.45
ANABRANCH	4250	2.73	2.91	3.18	3.36	3.64	3.98	6.44	3.36	4.36
ANABRANCH	4502	2.69	2.86	3.12	3.29	3.57	3.91	6.39	3.30	4.29
ANABRANCH	4750	2.67	2.83	3.07	3.23	3.50	3.83	6.34	3.24	4.23

		PEAK FLOOD WATER LEVEL FOR ARI (years)								DEVELOPMENT LEVEL (1OO Year ARI + 1m FREEBOARD) m AHD
FLOW PATH NAME	MIKE 11 CHAINAGE m	DOWNSTREAM BOUNDARY CONDITION HAT (2.42m AHD)						1000 Yr storm surge 3.80 m AHD	Fully Vegetated Waterway	
		10 Year	20 Year	50 Year	100 Year	200 Year	500 Year	PMF	100 Year	
CLYDE_CK	0	20.28	20.98	21.64	21.96	22.43	22.73	24.36	22.10	22.96
CLYDE_CK	233	19.85	20.57	21.31	21.61	22.02	22.30	23.82	21.74	22.61
CLYDE_CK	522	19.72	20.41	21.15	21.43	21.77	22.00	23.35	21.50	22.43
CLYDE_CK	780	19.37	20.12	20.96	21.24	21.54	21.73	23.01	21.27	22.24
CLYDE_CK	953	19.01	19.84	20.83	21.11	21.38	21.55	22.79	21.13	22.11
CLYDE_CK	973	17.81	18.69	19.16	19.55	20.07	20.40	21.99	19.68	20.55
CLYDE_CK	1066	17.73	18.59	19.06	19.46	19.98	20.21	21.27	19.60	20.46
CLYDE_CK	1262	16.95	17.84	18.37	18.91	19.61	19.84	20.92	19.16	19.91
CLYDE_CK	1508	15.94	16.82	17.49	18.25	19.13	19.37	20.58	18.59	19.25
CLYDE_CK	1761	15.20	16.03	16.65	17.36	18.37	18.70	20.56	17.70	18.36
CLYDE_CK	2011	14.56	15.31	15.87	16.50	17.63	18.09	20.56	16.79	17.50
CLYDE_CK	2261	13.99	14.68	15.17	15.73	16.80	17.42	20.55	15.91	16.73
CLYDE_CK	2513	13.61	14.23	14.67	15.18	16.11	16.68	20.55	15.35	16.18
CLYDE_CK	2560	13.55	14.16	14.59	15.08	15.97	16.53	20.55	15.25	16.08
CLYDE_CK	2634	13.41	13.99	14.40	14.87	15.70	16.22	20.55	15.04	15.87
CLYDE_CK	2696	13.31	13.87	14.25	14.70	15.47	15.92	20.55	14.85	15.70
CLYDE_CK	2768	13.19	13.71	14.06	14.47	15.21	15.68	20.55	14.62	15.47
CLYDE_CK	2989	12.53	12.99	13.34	13.75	14.61	15.22	20.55	13.96	14.75
CLYDE_CK	3237	12.01	12.53	12.94	13.37	14.25	14.90	20.55	13.59	14.37
CLYDE_CK	3489	11.84	12.30	12.67	13.04	13.80	14.35	20.55	13.25	14.04
CLYDE_CK	3733	11.65	12.03	12.32	12.62	13.18	13.59	20.55	12.73	13.62
CLYDE_CK	3800	11.57	11.93	12.20	12.48	13.04	13.47	20.55	12.57	13.48
CLYDE_CK	3855	10.82	11.26	11.56	11.88	12.44	12.83	20.55	12.05	12.88
CLYDE_CK	3980	10.40	10.80	11.04	11.29	11.80	12.23	20.55	11.44	12.29
CLYDE_CK	4229	9.22	9.68	9.96	10.28	10.94	11.49	20.55	10.49	11.28
CLYDE_CK	4361	8.66	9.09	9.42	9.81	10.57	11.20	20.55	10.07	10.81
CLYDE_CK	4646	8.28	8.66	8.94	9.30	10.01	10.65	20.55	9.52	10.30
CLYDE_CK	4898	8.16	8.49	8.73	9.05	9.68	10.29	20.55	9.23	10.05
CLYDE_CK	5048	8.08	8.39	8.60	8.90	9.51	10.17	20.55	9.05	9.90
CLYDE_CK	5089	7.95	8.25	8.45	8.75	9.39	10.15	20.55	8.89	9.75
CLYDE_CK	5141	7.72	8.01	8.19	8.51	9.22	10.12	20.55	8.66	9.51
CLYDE_CK	5338	6.82	7.16	7.45	8.00	9.02	10.10	20.55	8.23	9.00
CLYDE_CK	5519	6.21	6.69	7.18	7.88	8.98	10.09	20.55	8.11	8.88
CLYDE_CK	5726	5.87	6.45	7.13	7.81	8.93	10.08	20.55	8.00	8.81
CLYDE_CK	5898	5.68	6.27	7.08	7.77	8.87	10.08	20.55	7.88	8.77
CLYDE_CK	5967	5.62	6.22	7.07	7.76	8.85	10.07	20.55	7.84	8.76
CLYDE_CK	6000	5.56	6.18	7.06	7.75	8.85	10.07	20.55	7.82	8.75
CLYDE_CK	6090	5.40	6.07	7.04	7.74	8.82	10.07	20.55	7.76	8.74
CLYDE_CK	6110	5.20	5.87	6.79	7.34	8.29	9.41	20.55	7.45	8.34
CLYDE_CK	6266	5.05	5.80	6.74	7.30	8.28	9.40	20.55	7.43	8.30
CLYDE_CK	6473	4.95	5.73	6.69	7.25	8.25	9.38	20.55	7.41	8.25
CLYDE_CK	6731	4.93	5.71	6.68	7.25	8.25	9.38	20.55	7.41	8.25
CLYDE_CK	6983	4.92	5.71	6.68	7.25	8.25	9.38	20.55	7.41	8.25
CLYDE_CK	7076	4.92	5.71	6.68	7.25	8.25	9.38	20.55	7.41	8.25
CLYDE_CK	7288	4.91	5.70	6.67	7.24	8.25	9.38	20.55	7.41	8.24
CLYDE_CK	7551	4.91	5.70	6.67	7.24	8.25	9.38	20.55	7.41	8.24
CLYDE_CK	7670	4.91	5.70	6.67	7.24	8.25	9.38	20.55	7.41	8.24
CLYDE_CK	7872	4.90	5.69	6.67	7.23	8.25	9.37	20.55	7.41	8.23
CLYDE_CK	7965	4.90	5.69	6.67	7.24	8.25	9.37	20.55	7.41	8.24
CLYDE_CK	8131	4.90	5.69	6.66	7.23	8.24	9.37	20.55	7.41	8.23
CLYDE_CK	8189	4.90	5.69	6.66	7.23	8.24	9.37	20.55	7.40	8.23
CLYDE_CK	8234	4.90	5.69	6.66	7.23	8.24	9.37	20.55	7.41	8.23
CLYDE_CK	8484	4.89	5.69	6.66	7.23	8.24	9.37	20.55	7.40	8.23
CLYDE_CK	8667	4.88	5.68	6.66	7.23	8.24	9.37	20.55	7.40	8.23
CLYDE_CK	8964	4.87	5.67	6.65	7.22	8.24	9.37	20.55	7.40	8.22

		PEAK FLOOD WATER LEVEL FOR ARI (years)								DEVELOPMENT LEVEL (1OO Year ARI + 1m FREEBOARD) m AHD
FLOW PATH NAME	MIKE 11 CHAINAGE m	DOWNSTREAM BOUNDARY CONDITION HAT (2.42m AHD)						1000 Yr storm surge 3.80 m AHD	Fully Vegetated Waterway	
		10 Year	20 Year	50 Year	100 Year	200 Year	500 Year	PMF	100 Year	
LEIXLIP_CK	0	32.94	33.05	33.13	33.21	33.35	33.49	34.33	33.34	34.21
LEIXLIP_CK	241	32.29	32.40	32.48	32.56	32.70	32.85	33.79	32.68	33.56
LEIXLIP_CK	493	31.42	31.53	31.63	31.72	31.88	32.06	33.27	31.85	32.72
LEIXLIP_CK	721	30.80	30.98	31.11	31.23	31.42	31.63	33.02	31.33	32.23
LEIXLIP_CK	858	30.58	30.77	30.92	31.04	31.24	31.46	32.89	31.10	32.04
LEIXLIP_CK	957	30.46	30.65	30.79	30.91	31.12	31.32	32.78	30.93	31.91
LEIXLIP_CK	1062	30.42	30.61	30.75	30.87	31.07	31.27	32.73	30.87	31.87
LEIXLIP_CK	1115	29.60	29.79	29.93	30.06	30.29	30.53	31.89	30.20	31.06
LEIXLIP_CK	1160	29.51	29.68	29.82	29.95	30.19	30.43	31.77	30.10	30.95
LEIXLIP_CK	1253	29.24	29.39	29.52	29.64	29.90	30.16	31.54	29.82	30.64
LEIXLIP_CK	1418	28.69	28.91	29.09	29.25	29.59	29.90	31.40	29.48	30.25
LEIXLIP_CK	1521	28.55	28.79	28.98	29.15	29.51	29.82	31.33	29.38	30.15
LEIXLIP_CK	1711	28.35	28.59	28.79	28.96	29.32	29.64	31.12	29.18	29.96
LEIXLIP_CK	1891	28.03	28.26	28.46	28.62	28.98	29.28	30.69	28.82	29.62
LEIXLIP_CK	2002	27.62	27.82	27.99	28.14	28.48	28.78	30.16	28.34	29.14
LEIXLIP_CK	2099	27.15	27.40	27.62	27.80	28.20	28.53	30.04	27.98	28.80
LEIXLIP_CK	2148	27.06	27.33	27.57	27.76	28.17	28.50	30.02	27.93	28.76
LEIXLIP_CK	2236	27.01	27.28	27.52	27.71	28.13	28.46	29.98	27.88	28.71
LEIXLIP_CK	2493	26.48	26.73	26.95	27.12	27.52	27.81	29.32	27.31	28.12
LEIXLIP_CK	2632	26.18	26.40	26.59	26.76	27.13	27.42	28.96	26.99	27.76
LEIXLIP_CK	2735	26.03	26.22	26.41	26.56	26.91	27.19	28.80	26.81	27.56
LEIXLIP_CK	2902	25.79	25.97	26.15	26.31	26.69	26.97	28.72	26.57	27.31
LEIXLIP_CK	2946	25.52	25.65	25.78	25.89	26.15	26.36	27.56	26.08	26.89
LEIXLIP_CK	3014	25.11	25.28	25.45	25.58	25.88	26.09	27.46	25.75	26.58
LEIXLIP_CK	3225	24.53	24.71	24.87	25.00	25.24	25.43	27.24	25.15	26.00
LEIXLIP_CK	3320	24.23	24.40	24.55	24.66	24.91	25.09	27.22	24.82	25.66
LEIXLIP_CK	3483	23.60	23.80	23.93	24.08	24.37	24.60	27.17	24.25	25.08
LEIXLIP_CK	3635	23.17	23.41	23.57	23.74	24.01	24.28	27.12	23.89	24.74
LEIXLIP_CK	3749	22.97	23.22	23.39	23.56	23.81	24.12	27.08	23.72	24.56
LEIXLIP_CK	3925	22.44	22.82	23.06	23.28	23.56	23.97	27.06	23.44	24.28
LEIXLIP_CK	4167	22.06	22.50	22.77	23.04	23.39	23.85	27.04	23.17	24.04
LEIXLIP_CK	4260	21.68	22.26	22.55	22.89	23.30	23.80	27.03	23.02	23.89
LEIXLIP_CK	4466	21.46	22.11	22.42	22.79	23.23	23.75	27.00	22.91	23.79
LEIXLIP_CK	4602	21.40	22.05	22.35	22.72	23.17	23.70	26.99	22.85	23.72
LEIXLIP_CK	4710	21.27	21.93	22.22	22.63	23.11	23.64	26.98	22.78	23.63
LEIXLIP_CK	4813	21.46	22.11	22.42	22.79	23.05	23.60	26.97	22.71	23.79
LEIXLIP_CK	4862	21.05	21.73	22.01	22.49	23.01	23.58	26.96	22.64	23.49
LEIXLIP_CK	4909	20.13	20.52	20.82	21.12	21.48	21.86	26.05	21.38	22.12
LEIXLIP_CK	5100	19.40	19.80	20.10	20.39	20.74	21.09	25.98	20.61	21.39
LEIXLIP_CK	5198	19.06	19.43	19.72	19.98	20.29	20.59	25.92	20.19	20.98
LEIXLIP_CK	5353	18.58	19.00	19.31	19.56	19.82	20.04	25.97	19.77	20.56
LEIXLIP_CK	5469	18.31	18.75	19.07	19.34	19.59	19.81	25.93	19.54	20.34
LEIXLIP_CK	5657	17.74	18.10	18.40	18.71	19.03	19.24	25.96	18.91	19.71
LEIXLIP_CK	5758	17.45	17.83	18.15	18.49	18.84	19.06	25.95	18.65	19.49
LEIXLIP_CK	5886	17.16	17.57	17.92	18.28	18.66	18.89	25.95	18.41	19.28
LEIXLIP_CK	6106	16.18	16.68	17.09	17.48	18.07	18.36	25.94	17.70	18.48
LEIXLIP_CK	6199	15.68	16.22	16.66	17.07	17.70	18.10	25.94	17.33	18.07
LEIXLIP_CK	6332	15.26	15.72	16.11	16.47	17.16	17.73	25.94	17.14	17.47
LEIXLIP_CK	6370	15.05	15.50	15.89	16.29	17.12	17.69	25.94	17.11	17.29
LEIXLIP_CK	6390	15.03	15.48	15.87	16.29	17.11	17.68	26.04	17.10	17.29
LEIXLIP_CK	6545	13.83	14.43	14.94	16.10	16.96	17.62	25.94	16.99	17.10
LEIXLIP_CK	6666	13.32	13.91	14.78	16.09	16.91	17.60	25.94	16.94	17.09
LEIXLIP_CK	6829	12.90	13.51	14.73	16.08	16.89	17.59	25.94	16.91	17.08
LEIXLIP_CK	7001	12.53	13.12	14.69	16.07	16.88	17.58	25.94	16.90	17.07
LEIXLIP_CK	7124	12.21	12.82	14.67	16.07	16.87	17.58	25.94	16.89	17.07
LEIXLIP_CK	7237	11.87	12.74	14.67	16.07	16.86	17.58	25.94	16.89	17.07
LEIXLIP_CK	7441	11.78	12.73	14.66	16.07	16.86	17.57	25.94	16.88	17.07
LEIXLIP_CK	7542	11.74	12.72	14.66	16.06	16.86	17.57	25.94	16.88	17.06
LEIXLIP_CK	7707	11.51	12.69	14.66	16.06	16.86	17.56	25.94	16.88	17.06
LEIXLIP_CK	7927	11.22	12.65	14.65	16.06	16.85	17.54	25.94	16.88	17.06
LEIXLIP_CK	8035	11.20	12.63	14.65	16.06	16.84	17.53	25.94	16.87	17.06
LEIXLIP_CK	8172	11.15	12.61	14.65	16.06	16.84	17.51	25.94	16.87	17.06
LEIXLIP_CK	8290	11.10	12.58	14.64	16.06	16.84	17.50	25.94	16.87	17.06
LEIXLIP_CK	8463	11.02	12.54	14.63	16.05	16.82	17.47	25.94	16.86	17.05
LEIXLIP_CK	8590	10.97	12.52	14.63	16.05	16.82	17.46	25.94	16.86	17.05
LEIXLIP_CK	8742	10.96	12.51	14.62	16.05	16.82	17.45	25.94	16.86	17.05
LEIXLIP_CK	8992	10.94	12.51	14.62	16.05	16.82	17.45	25.94	16.86	17.05
LEIXLIP_CK	9128	10.94	12.51	14.62	16.05	16.82	17.44	25.94	16.86	17.05
LEIXLIP_CK	9261	10.94	12.51	14.62	16.05	16.82	17.44	25.94	16.86	17.05

		PEAK FLOOD WATER LEVEL FOR ARI (years)								DEVELOPMENT LEVEL (1OO Year ARI + 1m FREEBOARD) m AHD
FLOW PATH NAME	MIKE 11 CHAINAGE m	DOWNSTREAM BOUNDARY CONDITION HAT (2.42m AHD)						1000 Yr storm surge 3.80 m AHD	Fully Vegetated Waterway	
		10 Year	20 Year	50 Year	100 Year	200 Year	500 Year	PMF	100 Year	
DOUBLE_CK	-460	16.58	17.07	17.59	18.00	18.94	19.78	29.48	18.31	19.00
DOUBLE_CK	-420	16.11	16.66	17.21	17.63	18.56	19.22	27.85	18.17	18.63
DOUBLE_CK	-208	15.57	16.22	16.80	17.30	18.20	18.89	28.83	17.99	18.30
DOUBLE_CK	0	14.98	15.67	16.30	17.13	17.91	18.66	26.96	17.84	18.13
DOUBLE_CK	59	14.68	15.43	16.10	17.07	17.86	18.60	26.82	17.79	18.07
DOUBLE_CK	138	14.36	15.18	15.89	16.99	17.80	18.55	26.46	17.74	17.99
DOUBLE_CK	490	13.19	14.07	15.54	16.79	17.65	18.39	26.48	17.60	17.79
DOUBLE_CK	819	12.68	13.61	15.41	16.72	17.57	18.34	26.53	17.52	17.72
DOUBLE_CK	1076	12.27	13.44	15.34	16.68	17.54	18.31	26.49	17.49	17.68
DOUBLE_CK	1258	12.06	13.36	15.31	16.67	17.53	18.30	26.69	17.48	17.67
DOUBLE_CK	1493	12.03	13.33	15.29	16.66	17.52	18.29	26.58	17.46	17.66
DOUBLE_CK	1695	12.01	13.31	15.28	16.65	17.51	18.28	26.43	17.46	17.65
DOUBLE_CK	2000	11.95	13.27	15.27	16.64	17.50	18.27	26.82	17.45	17.64
DOUBLE_CK	2263	11.82	13.21	15.25	16.63	17.49	18.26	26.60	17.44	17.63
DOUBLE_CK	2471	11.69	13.15	15.23	16.61	17.47	18.24	26.83	17.42	17.61
DOUBLE_CK	2562	11.64	13.13	15.22	16.61	17.47	18.24	26.93	17.42	17.61
DOUBLE_CK	2610	11.63	13.12	15.21	16.61	17.46	18.23	26.99	17.41	17.61
DOUBLE_CK	3061	11.58	13.10	15.20	16.60	17.45	18.22	26.81	17.40	17.60
DOUBLE_CK	3184	11.49	13.02	15.10	16.48	17.32	18.50	30.37	17.31	17.48
DOUBLE_CK	3352	11.48	13.01	15.09	16.48	17.32	18.27	31.72	17.31	17.48
DOUBLE_CK	3593	11.45	13.00	15.09	16.48	17.31	18.18	31.15	17.30	17.48
DOUBLE_CK	3788	11.44	12.99	15.08	16.47	17.31	18.19	29.09	17.30	17.47
DOUBLE_CK	4048	11.41	12.98	15.07	16.47	17.30	18.49	30.69	17.29	17.47
LBO1	-380	13.57	14.90	16.66	17.84	19.03	20.22	26.99	19.56	18.84
LBO1	-370	not flooded	not flooded	not flooded	not flooded	not flooded	not flooded	26.31	not flooded	
LBO1	174	not flooded	not flooded	not flooded	not flooded	not flooded	not flooded	26.50	not flooded	
LBO1	412	not flooded	not flooded	not flooded	not flooded	not flooded	not flooded	26.50	not flooded	
LBO1	612	not flooded	not flooded	not flooded	not flooded	not flooded	not flooded	26.50	not flooded	
LBO1	799	not flooded	not flooded	not flooded	not flooded	not flooded	not flooded	26.50	not flooded	
LBO1	1046	not flooded	not flooded	not flooded	not flooded	not flooded	17.35	26.50	not flooded	16.72
LBO1	1293	not flooded	not flooded	not flooded	not flooded	16.73	17.35	26.50	16.37	16.72
LBO1	1537	not flooded	not flooded	not flooded	not flooded	16.73	17.35	26.50	16.37	16.72
LBO1	1804	not flooded	not flooded	not flooded	not flooded	16.73	17.35	26.50	16.37	16.72
LBO1	2107	not flooded	not flooded	not flooded	not flooded	16.73	17.35	26.50	16.37	16.72
LBO1	2324	not flooded	not flooded	14.25	15.72	16.73	17.35	26.26	16.37	16.72
LBO1	2584	not flooded	not flooded	14.25	15.72	16.73	17.35	26.39	16.37	16.72
LBO1	2826	not flooded	12.33	14.25	15.72	16.73	17.35	26.55	16.37	16.72
LBO1	3122	10.78	12.33	14.25	15.72	16.73	17.35	26.59	16.37	16.72
LBO1	3411	10.78	12.33	14.25	15.72	16.73	17.35	26.60	16.37	16.72
LBO1	3597	10.78	12.33	14.25	15.72	16.73	17.35	26.60	16.37	16.72
LBO1	3848	10.78	12.33	14.25	15.72	16.73	17.35	27.84	16.37	16.72
LBO1	3953	10.78	12.33	14.25	15.72	16.73	17.35	27.45	16.37	16.72
LBO1	4117	10.78	12.33	14.25	15.72	16.73	17.35	26.90	16.37	16.72
LBO1	4276	10.78	12.33	14.25	15.72	16.73	17.35	26.95	16.37	16.72
LBO1	4460	10.78	12.33	14.25	15.72	16.73	17.35	27.52	16.37	16.72
LBO1	4682	10.78	12.33	14.25	15.72	16.73	17.35	27.52	16.37	16.72
LBO2	-130	10.47	12.06	14.25	15.72	16.73	16.91	26.65	16.37	16.72
LBO2	0	not flooded	not flooded	not flooded	not flooded	not flooded	12.90	23.70	15.95	
LBO2	252	not flooded	not flooded	not flooded	not flooded	not flooded	12.90	22.91	15.67	
LBO2	490	not flooded	not flooded	not flooded	not flooded	not flooded	12.90	22.88	15.43	
LBO2	737	not flooded	not flooded	not flooded	not flooded	not flooded	12.90	22.96	15.17	
LBO2	950	not flooded	not flooded	not flooded	not flooded	not flooded	12.90	22.55	14.84	
LBO2	1126	not flooded	not flooded	not flooded	10.49	11.72	12.90	22.46	14.40	11.49
LBO2	1342	not flooded	8.36	9.71	10.49	11.72	12.90	22.45	13.95	11.49
LBO2	1506	not flooded	8.36	9.71	10.49	11.72	12.90	22.60	13.52	11.49
LBO2	1765	7.23	8.36	9.71	10.49	11.72	12.90	22.50	12.08	11.49
LBO2	1962	7.23	8.36	9.71	10.49	11.72	12.90	22.51	11.74	11.49
LBO2	2162	7.23	8.36	9.71	10.49	11.72	12.90	22.58	11.47	11.49
LBO2	2415	7.23	8.36	9.71	10.49	11.72	12.90	22.62	11.31	11.49
LBO2	2656	7.23	8.36	9.71	10.49	11.72	12.90	22.02	11.18	11.49
LBO2	2656	7.23	8.36	9.71	10.49	11.72	12.90	22.02	11.18	11.49
LBO2	2862	7.23	8.36	9.71	10.49	11.72	12.90	22.30	11.03	11.49
LBO2	3006	7.23	8.36	9.71	10.49	11.72	12.90	22.00	10.98	11.49
LBO2	3196	7.23	8.36	9.71	10.49	11.72	12.90	21.78	10.91	11.49

		PEAK FLOOD WATER LEVEL FOR ARI (years)								DEVELOPMENT LEVEL (1OO Year ARI + 1m FREEBOARD) m AHD
		DOWNSTREAM BOUNDARY CONDITION HAT (2.42m AHD)						1000 Yr storm surge 3.80 m AHD	Fully Vegetated Waterway	
FLOW PATH NAME	MIKE 11 CHAINAGE m	10 Year	20 Year	50 Year	100 Year	200 Year	500 Year	PMF	100 Year	
DOUBLE_BO	0	17.09	17.17	17.24	17.31	17.48	17.72	26.52	17.39	18.31
DOUBLE_BO	59	16.45	16.56	16.65	16.76	16.95	17.72	26.42	16.97	17.76
DOUBLE_BO	138	16.36	16.36	16.42	16.55	16.82	17.72	26.57	16.86	17.55
DOUBLE_BO	499	16.00	16.00	16.00	16.00	16.82	17.71	26.41	16.86	17.00
DOUBLE_BO	620	15.74	15.74	15.74	15.89	16.82	17.69	26.67	16.86	16.89
DOUBLE_BO	864	15.23	15.23	15.53	15.89	16.82	17.65	26.81	16.86	16.89
DOUBLE_BO	973	15.00	15.23	15.52	15.89	16.82	17.64	26.36	16.86	16.89
DOUBLE_BO	1136	14.85	15.22	15.52	15.89	16.82	17.62	27.07	16.86	16.89
DOUBLE_BO	1296	14.85	15.21	15.51	15.89	16.82	17.60	26.83	16.86	16.89
DOUBLE_BO	1444	14.84	15.21	15.51	15.89	16.82	17.58	26.81	16.86	16.89
DOUBLE_BO	1578	14.84	15.21	15.50	15.89	16.82	17.58	28.19	16.86	16.89
DOUBLE_BO	1638	12.83	12.94	14.63	16.01	16.75	17.39	27.55	16.82	17.01
DOUBLE_BO	1735	12.60	12.70	14.63	16.01	16.75	17.38	27.13	16.82	17.01
DOUBLE_BO	1882	11.82	12.54	14.63	16.01	16.75	17.37	27.40	16.82	17.01
DOUBLE_BO	2267	10.99	12.54	14.63	16.01	16.75	17.37	26.76	16.82	17.01
DOUBLE_BO	2466	10.99	12.54	14.63	16.01	16.75	17.36	28.66	16.82	17.01
DOUBLE_BO	2662	10.99	12.54	14.63	16.01	16.75	17.49	28.07	16.82	17.01
DOUBLE_BO	2795	10.99	12.54	14.63	16.01	16.75	17.36	29.08	16.82	17.01
DOUBLE_BO	2917	10.99	12.54	14.63	16.01	16.75	17.84	29.33	16.82	17.01
DOUBLE_BO	3085	10.99	12.53	14.63	16.01	16.75	17.35	28.32	16.82	17.01
DEEP_CK	0	16.02	18.02	18.49	18.97	19.66	20.15	26.78	19.53	19.97
DEEP_CK	47	15.88	17.99	18.46	18.93	19.61	20.09	26.78	19.49	19.93
DEEP_CK	108	14.43	15.08	16.51	17.66	18.85	20.02	27.00	19.23	18.66
DEEP_CK	147	14.31	15.04	16.50	17.66	18.85	20.02	27.00	19.23	18.66
DEEP_CK	339	13.85	14.85	16.47	17.64	18.85	20.01	26.93	19.22	18.64
DEEP_CK	500	13.44	14.71	16.45	17.63	18.85	20.01	26.94	19.21	18.63
DEEP_CK	750	13.39	14.69	16.44	17.63	18.85	20.01	26.99	19.21	18.63
DEEP_CK	1000	13.38	14.69	16.44	17.63	18.85	20.01	26.88	19.21	18.63
DEEP_CK	1144	13.37	14.68	16.44	17.62	18.85	20.01	27.06	19.21	18.62
DEEP_CK	1623	13.34	14.66	16.43	17.62	18.85	20.01	27.02	19.20	18.62
CUTOFF	100	3.39	3.81	4.39	4.79	5.34	5.97	10.41	4.81	5.79
CUTOFF	154	3.37	3.80	4.37	4.77	5.32	5.94	10.26	4.79	5.77
CUTOFF	220	3.31	3.73	4.29	4.69	5.25	5.87	10.25	4.71	5.69
CUTOFF	256	3.30	3.70	4.26	4.66	5.21	5.84	10.25	4.68	5.66
DOUBLE_BO2	0	17.06	17.30	17.48	17.67	17.92	18.09	26.51	17.85	18.67
DOUBLE_BO2	59	16.88	17.04	17.23	17.41	17.66	17.86	26.54	17.56	18.41
DOUBLE_BO2	138	16.72	16.97	17.14	17.31	17.54	17.75	26.55	17.44	18.31
DOUBLE_BO2	499	16.33	16.54	16.65	16.77	16.99	17.66	26.36	16.93	17.77
DOUBLE_BO2	620	15.21	15.43	15.64	16.15	16.98	17.66	26.49	16.93	17.15
DOUBLE_BO2	973	13.19	13.60	14.86	16.12	16.97	17.65	26.72	16.93	17.12
DOUBLE_BO2	1136	12.98	13.43	14.85	16.12	16.97	17.65	26.35	16.93	17.12
DOUBLE_BO2	1296	12.76	13.26	14.84	16.12	16.97	17.65	26.36	16.93	17.12
DOUBLE_BO2	1444	12.39	13.09	14.84	16.12	16.97	17.65	26.60	16.93	17.12
DOUBLE_BO2	1578	12.16	13.01	14.83	16.12	16.97	17.65	26.65	16.93	17.12
DOUBLE_BO2	1618	11.51	12.69	14.66	16.06	16.86	17.56	26.82	16.88	17.06
DOUBLE_BO2	1638	11.51	12.69	14.66	16.06	16.86	17.56	26.80	16.88	17.06

Sensitivity Test Results – 100 Year ARI 18 Hour Storm Duration only

FLOW PATH NAME	CHAINAGE	18 HOUR	18 Hr HIGH n		18 Hr HIGH Q		Downstream Boundary Condition			
		BASE RUN HAT 2.42 m AHD	HAT 2.42 m AHD	Difference m	HAT 2.42 m AHD	Difference m	MHWS 1.63 m AHD	Difference m	Storm 2.82 m AHD	Difference m
CALLIOPER	0	19.07	19.61	0.54	19.60	0.53	19.07	0.00	19.08	0.01
CALLIOPER	33	19.05	19.58	0.53	19.57	0.52	19.04	-0.01	19.05	0.00
CALLIOPER	181	18.98	19.50	0.52	19.50	0.52	18.97	-0.01	18.98	0.00
CALLIOPER	324	18.87	19.38	0.51	19.39	0.52	18.87	0.00	18.88	0.01
CALLIOPER	441	18.77	19.26	0.49	19.28	0.51	18.77	0.00	18.77	0.00
CALLIOPER	614	18.70	19.19	0.49	19.22	0.52	18.70	0.00	18.70	0.00
CALLIOPER	834	18.46	18.95	0.49	18.96	0.50	18.46	0.00	18.46	0.00
CALLIOPER	1066	18.32	18.80	0.48	18.81	0.49	18.32	0.00	18.32	0.00
CALLIOPER	1293	18.17	18.64	0.47	18.66	0.49	18.17	0.00	18.17	0.00
CALLIOPER	1504	18.01	18.48	0.47	18.51	0.50	18.01	0.00	18.02	0.01
CALLIOPER	1714	17.99	18.44	0.45	18.48	0.49	17.99	0.00	17.99	0.00
CALLIOPER	1908	17.84	18.29	0.45	18.33	0.49	17.84	0.00	17.85	0.01
CALLIOPER	1908	17.84	18.29	0.45	18.33	0.49	17.84	0.00	17.85	0.01
CALLIOPER	2000	17.76	18.20	0.44	18.24	0.48	17.75	-0.01	17.76	0.00
CALLIOPER	2184	17.62	18.06	0.44	18.10	0.48	17.62	0.00	17.62	0.00
CALLIOPER	2184	17.62	18.06	0.44	18.10	0.48	17.62	0.00	17.62	0.00
CALLIOPER	2307	17.52	17.96	0.44	18.00	0.48	17.52	0.00	17.53	0.01
CALLIOPER	2556	17.43	17.84	0.41	17.90	0.47	17.42	-0.01	17.43	0.00
CALLIOPER	2812	17.33	17.74	0.41	17.80	0.47	17.32	-0.01	17.33	0.00
CALLIOPER	3079	17.22	17.63	0.41	17.71	0.49	17.22	0.00	17.23	0.01
CALLIOPER	3274	17.13	17.53	0.40	17.65	0.52	17.13	0.00	17.13	0.00
CALLIOPER	3507	17.07	17.47	0.40	17.62	0.55	17.07	0.00	17.07	0.00
CALLIOPER	3757	16.96	17.36	0.40	17.54	0.58	16.95	-0.01	16.96	0.00
CALLIOPER	3998	16.88	17.27	0.39	17.48	0.60	16.87	-0.01	16.88	0.00
CALLIOPER	4196	16.83	17.22	0.39	17.45	0.62	16.82	-0.01	16.83	0.00
CALLIOPER	4196	16.83	17.22	0.39	17.45	0.62	16.82	-0.01	16.83	0.00
CALLIOPER	4418	16.82	17.20	0.38	17.44	0.62	16.81	-0.01	16.82	0.00
CALLIOPER	4670	16.71	17.10	0.39	17.40	0.69	16.71	0.00	16.72	0.01
CALLIOPER	4875	16.59	16.98	0.39	17.30	0.71	16.59	0.00	16.60	0.01
CALLIOPER	5158	16.50	16.84	0.34	17.20	0.70	16.50	0.00	16.50	0.00
CALLIOPER	5362	16.45	16.73	0.28	17.05	0.60	16.45	0.00	16.45	0.00
CALLIOPER	5500	16.45	16.81	0.36	16.90	0.45	16.44	-0.01	16.45	0.00
CALLIOPER	5500	16.45	16.81	0.36	16.90	0.45	16.44	-0.01	16.45	0.00
CALLIOPER	5750	16.45	16.80	0.35	16.91	0.46	16.44	-0.01	16.45	0.00
CALLIOPER	6000	16.45	16.82	0.37	16.93	0.48	16.46	0.01	16.47	0.02
CALLIOPER	6000	16.45	16.82	0.37	16.93	0.48	16.46	0.01	16.47	0.02
CALLIOPER	6155	16.27	16.63	0.36	16.71	0.44	16.27	0.00	16.28	0.01
CALLIOPER	6250	16.24	16.59	0.35	16.68	0.44	16.23	-0.01	16.24	0.00
CALLIOPER	6500	16.18	16.51	0.33	16.61	0.43	16.17	-0.01	16.18	0.00
CALLIOPER	6750	16.01	16.34	0.33	16.43	0.42	16.01	0.00	16.02	0.01
CALLIOPER	6750	16.01	16.34	0.33	16.43	0.42	16.01	0.00	16.02	0.01
CALLIOPER	7000	16.00	16.33	0.33	16.44	0.44	15.99	-0.01	16.00	0.00
CALLIOPER	7250	16.05	16.36	0.31	16.49	0.44	16.04	-0.01	16.05	0.00
CALLIOPER	7250	16.05	16.36	0.31	16.49	0.44	16.04	-0.01	16.05	0.00
CALLIOPER	7510	15.94	16.27	0.33	16.39	0.45	15.94	0.00	15.95	0.01
CALLIOPER	7510	15.94	16.27	0.33	16.39	0.45	15.94	0.00	15.95	0.01
CALLIOPER	7672	15.92	16.29	0.37	16.42	0.50	15.93	0.01	15.93	0.01
CALLIOPER	7900	15.92	16.21	0.29	16.33	0.41	15.91	-0.01	15.92	0.00
CALLIOPER	8084	15.84	16.14	0.30	16.25	0.41	15.83	-0.01	15.84	0.00
CALLIOPER	8161	15.81	16.11	0.30	16.23	0.42	15.81	0.00	15.82	0.01
CALLIOPER	8361	15.77	16.05	0.28	16.18	0.41	15.77	0.00	15.78	0.01
CALLIOPER	8500	15.77	16.05	0.28	16.18	0.41	15.76	-0.01	15.77	0.00
CALLIOPER	8612	15.76	16.05	0.29	16.19	0.43	15.77	0.01	15.78	0.02
CALLIOPER	8707	15.76	16.03	0.27	16.17	0.41	15.75	-0.01	15.76	0.00
CALLIOPER	8861	15.75	16.02	0.27	16.15	0.40	15.74	-0.01	15.75	0.00
CALLIOPER	9000	15.72	15.99	0.27	16.13	0.41	15.72	0.00	15.73	0.01
CALLIOPER	9000	15.72	15.99	0.27	16.13	0.41	15.72	0.00	15.73	0.01
CALLIOPER	9227	15.70	15.97	0.27	16.11	0.41	15.70	0.00	15.71	0.01
CALLIOPER	9413	15.65	15.92	0.27	16.06	0.41	15.65	0.00	15.66	0.01
CALLIOPER	9413	15.65	15.92	0.27	16.06	0.41	15.65	0.00	15.66	0.01
CALLIOPER	9447	13.52	13.99	0.47	13.87	0.35	13.52	0.00	13.53	0.01
CALLIOPER	9447	13.52	13.99	0.47	13.87	0.35	13.52	0.00	13.53	0.01
CALLIOPER	9660	12.85	13.37	0.52	13.25	0.40	12.85	0.00	12.86	0.01
CALLIOPER	9784	12.85	13.25	0.40	13.21	0.36	12.87	0.02	12.88	0.03
CALLIOPER	9907	12.50	12.92	0.42	12.86	0.36	12.49	-0.01	12.50	0.00
CALLIOPER	9928	12.41	12.80	0.39	12.73	0.32	12.41	0.00	12.42	0.01
CALLIOPER	10000	12.41	12.73	0.32	12.67	0.26	12.41	0.00	12.42	0.01
CALLIOPER	10250	12.41	12.78	0.37	12.76	0.35	12.41	0.00	12.42	0.01
CALLIOPER	10500	12.06	12.48	0.42	12.44	0.38	12.05	-0.01	12.07	0.01
CALLIOPER	10748	11.94	12.34	0.40	12.33	0.39	11.93	-0.01	11.95	0.01
CALLIOPER	11000	11.74	12.17	0.43	12.16	0.42	11.73	-0.01	11.75	0.01
CALLIOPER	11250	11.68	12.10	0.42	12.10	0.42	11.67	-0.01	11.69	0.01
CALLIOPER	11500	11.55	11.98	0.43	11.98	0.43	11.54	-0.01	11.56	0.01
CALLIOPER	11750	11.47	11.92	0.45	11.93	0.46	11.46	-0.01	11.48	0.01
CALLIOPER	12000	11.40	11.84	0.44	11.87	0.47	11.39	-0.01	11.41	0.01
CALLIOPER	12262	11.01	11.50	0.49	11.52	0.51	10.99	-0.02	11.02	0.01
CALLIOPER	12570	10.79	11.29	0.50	11.35	0.56	10.77	-0.02	10.80	0.01
CALLIOPER	12800	10.49	11.04	0.55	11.11	0.62	10.47	-0.02	10.51	0.02

		18 HOUR	18 Hr HIGH n		18 Hr HIGH Q		Downstream Boundary Condition			
FLOW PATH NAME	CHAINAGE	BASE RUN HAT 2.42 m AHD	HAT 2.42 m AHD	Difference m	HAT 2.42 m AHD	Difference m	MHWS 1.63 m AHD	Difference m	100 Yr Storm Surge 2.82 m AHD	Difference m
CALLIOPER	13000	10.27	10.81	0.54	10.90	0.63	10.24	-0.03	10.29	0.02
CALLIOPER	13250	10.15	10.68	0.53	10.80	0.65	10.15	0.00	10.17	0.02
CALLIOPER	13500	10.15	10.68	0.53	10.79	0.64	10.15	0.00	10.19	0.04
CALLIOPER	13750	10.15	10.67	0.52	10.79	0.64	10.15	0.00	10.19	0.04
CALLIOPER	14000	10.11	10.60	0.49	10.73	0.62	10.09	-0.02	10.13	0.02
CALLIOPER	14250	9.99	10.49	0.50	10.61	0.62	9.96	-0.03	10.01	0.02
CALLIOPER	14250	9.99	10.49	0.50	10.61	0.62	9.96	-0.03	10.01	0.02
CALLIOPER	14500	9.82	10.32	0.50	10.44	0.62	9.80	-0.02	9.84	0.02
CALLIOPER	14750	9.82	10.31	0.49	10.44	0.62	9.80	-0.02	9.85	0.03
CALLIOPER	14999	9.77	10.25	0.48	10.39	0.62	9.75	-0.02	9.80	0.03
CALLIOPER	15250	9.58	10.07	0.49	10.20	0.62	9.55	-0.03	9.61	0.03
CALLIOPER	15500	9.39	9.87	0.48	9.99	0.60	9.36	-0.03	9.41	0.02
CALLIOPER	15750	9.47	9.94	0.47	10.09	0.62	9.44	-0.03	9.50	0.03
CALLIOPER	15992	9.34	9.82	0.48	9.96	0.62	9.31	-0.03	9.36	0.02
CALLIOPER	16240	9.34	9.82	0.48	9.98	0.64	9.34	0.00	9.39	0.05
CALLIOPER	16500	9.21	9.67	0.46	9.82	0.61	9.18	-0.03	9.24	0.03
CALLIOPER	16604	9.07	9.53	0.46	9.66	0.59	9.04	-0.03	9.09	0.02
CALLIOPER	16793	8.72	9.19	0.47	9.28	0.56	8.69	-0.03	8.75	0.03
CALLIOPER	17000	8.91	9.36	0.45	9.50	0.59	8.88	-0.03	8.94	0.03
CALLIOPER	17250	8.86	9.30	0.44	9.45	0.59	8.83	-0.03	8.89	0.03
CALLIOPER	17500	8.62	9.07	0.45	9.19	0.57	8.58	-0.04	8.65	0.03
CALLIOPER	17750	8.47	8.90	0.43	9.02	0.55	8.43	-0.04	8.50	0.03
CALLIOPER	18000	8.40	8.82	0.42	8.95	0.55	8.36	-0.04	8.43	0.03
CALLIOPER	18176	8.30	8.71	0.41	8.84	0.54	8.26	-0.04	8.33	0.03
CALLIOPER	18386	8.11	8.52	0.41	8.64	0.53	8.07	-0.04	8.14	0.03
CALLIOPER	18590	7.91	8.33	0.42	8.44	0.53	7.87	-0.04	7.95	0.04
CALLIOPER	18703	7.84	8.25	0.41	8.36	0.52	7.79	-0.05	7.87	0.03
CALLIOPER	18881	7.78	8.19	0.41	8.31	0.53	7.73	-0.05	7.82	0.04
CALLIOPER	19067	7.70	8.10	0.40	8.24	0.54	7.65	-0.05	7.74	0.04
CALLIOPER	19250	7.79	8.15	0.36	8.32	0.53	7.74	-0.05	7.83	0.04
CALLIOPER	19500	7.75	8.10	0.35	8.29	0.54	7.70	-0.05	7.79	0.04
CALLIOPER	19750	7.61	7.96	0.35	8.15	0.54	7.56	-0.05	7.66	0.05
CALLIOPER	19926	7.52	7.85	0.33	8.05	0.53	7.46	-0.06	7.56	0.04
CALLIOPER	20176	7.41	7.74	0.33	7.92	0.51	7.35	-0.06	7.45	0.04
CALLIOPER	20417	7.42	7.74	0.32	7.94	0.52	7.36	-0.06	7.47	0.05
CALLIOPER	20500	7.41	7.72	0.31	7.93	0.52	7.35	-0.06	7.46	0.05
CALLIOPER	20750	7.22	7.54	0.32	7.73	0.51	7.16	-0.06	7.27	0.05
CALLIOPER	20750	7.22	7.54	0.32	7.73	0.51	7.16	-0.06	7.27	0.05
CALLIOPER	21000	7.21	7.51	0.30	7.73	0.52	7.15	-0.06	7.26	0.05
CALLIOPER	21250	7.26	7.55	0.29	7.79	0.53	7.20	-0.06	7.31	0.05
CALLIOPER	21497	7.19	7.48	0.29	7.72	0.53	7.13	-0.06	7.25	0.06
CALLIOPER	21749	6.89	7.19	0.30	7.41	0.52	6.82	-0.07	6.94	0.05
CALLIOPER	22001	6.76	7.05	0.29	7.28	0.52	6.68	-0.08	6.82	0.06
CALLIOPER	22250	6.62	6.90	0.28	7.15	0.53	6.54	-0.08	6.69	0.07
CALLIOPER	22496	6.66	6.91	0.25	7.18	0.52	6.57	-0.09	6.72	0.06
CALLIOPER	22673	5.95	6.15	0.20	6.30	0.35	5.84	-0.11	6.03	0.08
CALLIOPER	22729	5.94	6.14	0.20	6.29	0.35	5.83	-0.11	6.02	0.08
CALLIOPER	22819	5.45	5.61	0.16	5.76	0.31	5.30	-0.15	5.54	0.09
CALLIOPER	23000	5.25	5.41	0.16	5.54	0.29	5.09	-0.16	5.34	0.09
CALLIOPER	23256	4.79	4.94	0.15	5.05	0.26	4.59	-0.20	4.91	0.12
CALLIOPER	23256	4.79	4.94	0.15	5.05	0.26	4.59	-0.20	4.91	0.12
CALLIOPER	23497	4.77	4.92	0.15	5.04	0.27	4.57	-0.20	4.89	0.12
CALLIOPER	23746	4.76	4.91	0.15	5.02	0.26	4.56	-0.20	4.88	0.12
CALLIOPER	23997	4.73	4.88	0.15	4.99	0.26	4.53	-0.20	4.85	0.12
CALLIOPER	24250	4.72	4.86	0.14	4.98	0.26	4.51	-0.21	4.84	0.12
CALLIOPER	24495	4.67	4.82	0.15	4.92	0.25	4.45	-0.22	4.79	0.12
CALLIOPER	24750	4.66	4.81	0.15	4.92	0.26	4.45	-0.21	4.78	0.12
CALLIOPER	25000	4.64	4.79	0.15	4.90	0.26	4.43	-0.21	4.77	0.13
CALLIOPER	25250	4.63	4.78	0.15	4.89	0.26	4.42	-0.21	4.76	0.13
CALLIOPER	25500	4.63	4.77	0.14	4.88	0.25	4.41	-0.22	4.75	0.12
CALLIOPER	25750	4.62	4.76	0.14	4.88	0.26	4.40	-0.22	4.75	0.13
CALLIOPER	25750	4.62	4.76	0.14	4.88	0.26	4.40	-0.22	4.75	0.13
CALLIOPER	26004	4.62	4.77	0.15	4.88	0.26	4.40	-0.22	4.75	0.13
CALLIOPER	26248	4.63	4.77	0.14	4.89	0.26	4.41	-0.22	4.76	0.13
CALLIOPER	26503	4.64	4.78	0.14	4.89	0.25	4.42	-0.22	4.76	0.12
CALLIOPER	26750	4.65	4.79	0.14	4.91	0.26	4.43	-0.22	4.77	0.12
CALLIOPER	26998	4.65	4.80	0.15	4.91	0.26	4.43	-0.22	4.78	0.13
CALLIOPER	27246	4.66	4.81	0.15	4.92	0.26	4.44	-0.22	4.79	0.13

FLOW PATH NAME	CHAINAGE	18 HOUR	18 Hr HIGH n		18 Hr HIGH Q		Downstream Boundary Condition			
		BASE RUN HAT 2.42 m AHD	HAT 2.42 m AHD	Difference m	HAT 2.42 m AHD	Difference m	MHWS 1.63 m AHD	Difference m	100 Yr Storm Surge 2.82 m AHD	Difference m
CALLIOPER	27500	4.60	4.73	0.13	4.86	0.26	4.36	-0.24	4.73	0.13
CALLIOPER	27750	4.49	4.61	0.12	4.74	0.25	4.22	-0.27	4.63	0.14
CALLIOPER	28000	4.33	4.45	0.12	4.58	0.25	4.03	-0.30	4.49	0.16
CALLIOPER	28250	4.30	4.39	0.09	4.55	0.25	3.98	-0.32	4.46	0.16
CALLIOPER	28500	4.25	4.29	0.04	4.51	0.26	3.87	-0.38	4.43	0.18
CALLIOPER	28750	4.20	4.21	0.01	4.50	0.30	3.79	-0.41	4.40	0.20
CALLIOPER	28910	4.15	4.14	-0.01	4.40	0.25	3.72	-0.43	4.35	0.20
CALLIOPER	29141	4.10	4.13	0.03	4.30	0.20	3.72	-0.38	4.30	0.20
CALLIOPER	29250	4.00	4.13	0.13	4.20	0.20	3.72	-0.28	4.20	0.20
CALLIOPER	29500	3.97	4.07	0.10	4.18	0.21	3.66	-0.31	4.15	0.18
CALLIOPER	29831	3.77	3.95	0.18	3.96	0.19	3.51	-0.26	3.96	0.19
CALLIOPER	30048	3.74	3.92	0.18	3.93	0.19	3.48	-0.26	3.93	0.19
CALLIOPER	30250	3.68	3.85	0.17	3.86	0.18	3.40	-0.28	3.87	0.19
CALLIOPER	30500	3.59	3.77	0.18	3.77	0.18	3.29	-0.30	3.80	0.21
CALLIOPER	30721	3.52	3.69	0.17	3.69	0.17	3.22	-0.30	3.74	0.22
CALLIOPER	30862	3.26	3.41	0.15	3.39	0.13	2.92	-0.34	3.49	0.23
CALLIOPER	31000	3.32	3.46	0.14	3.45	0.13	2.97	-0.35	3.55	0.23
CALLIOPER	31250	3.29	3.42	0.13	3.42	0.13	2.94	-0.35	3.52	0.23
CALLIOPER	31500	3.24	3.36	0.12	3.36	0.12	2.87	-0.37	3.48	0.24
CALLIOPER	31750	3.23	3.34	0.11	3.35	0.12	2.86	-0.37	3.47	0.24
CALLIOPER	31750	3.23	3.34	0.11	3.35	0.12	2.86	-0.37	3.47	0.24
CALLIOPER	32000	3.21	3.32	0.11	3.33	0.12	2.84	-0.37	3.45	0.24
CALLIOPER	32250	3.12	3.23	0.11	3.24	0.12	2.73	-0.39	3.38	0.26
CALLIOPER	32500	3.05	3.15	0.10	3.15	0.10	2.64	-0.41	3.31	0.26
CALLIOPER	32722	2.97	3.07	0.10	3.07	0.10	2.55	-0.42	3.25	0.28
CALLIOPER	33010	2.96	3.04	0.08	3.05	0.09	2.53	-0.43	3.23	0.27
CALLIOPER	33250	2.92	3.00	0.08	3.01	0.09	2.48	-0.44	3.20	0.28
CALLIOPER	33500	2.86	2.93	0.07	2.93	0.07	2.39	-0.47	3.15	0.29
CALLIOPER	33746	2.80	2.86	0.06	2.87	0.07	2.31	-0.49	3.11	0.31
CALLIOPER	34000	2.77	2.83	0.06	2.83	0.06	2.26	-0.51	3.08	0.31
CALLIOPER	34000	2.77	2.83	0.06	2.83	0.06	2.26	-0.51	3.08	0.31
CALLIOPER	34253	2.73	2.79	0.06	2.79	0.06	2.20	-0.53	3.05	0.32
CALLIOPER	34488	2.69	2.73	0.04	2.73	0.04	2.13	-0.56	3.01	0.32
CALLIOPER	34743	2.65	2.70	0.05	2.69	0.04	2.08	-0.57	2.99	0.34
CALLIOPER	34996	2.58	2.61	0.03	2.60	0.02	1.96	-0.62	2.93	0.35
CALLIOPER	35243	2.57	2.51	-0.06	2.57	0.00	1.90	-0.67	2.90	0.33
CALLIOPER	35502	2.55	2.50	-0.05	2.55	0.00	1.80	-0.75	2.92	0.37
CALLIOPER	35640	2.50	2.49	-0.01	2.50	0.00	1.78	-0.72	2.89	0.39
CALLIOPER	36300	2.46	2.45	-0.01	2.46	0.00	1.65	-0.81	2.84	0.38
CALLIOPER	36300	2.46	2.45	-0.01	2.46	0.00	1.65	-0.81	2.84	0.38
CALLIOPER	36500	2.42	2.42	0.00	2.42	0.00	1.63	-0.79	2.82	0.40
ANABRANCH	0	4.62	4.76	0.14	4.88	0.26	4.40	-0.22	4.75	0.13
ANABRANCH	250	4.59	4.73	0.14	4.85	0.26	4.37	-0.22	4.72	0.13
ANABRANCH	493	4.57	4.71	0.14	4.82	0.25	4.36	-0.21	4.70	0.13
ANABRANCH	735	4.52	4.66	0.14	4.77	0.25	4.30	-0.22	4.65	0.13
ANABRANCH	1006	4.47	4.61	0.14	4.72	0.25	4.25	-0.22	4.60	0.13
ANABRANCH	1227	4.42	4.55	0.13	4.66	0.24	4.20	-0.22	4.55	0.13
ANABRANCH	1501	4.36	4.49	0.13	4.59	0.23	4.13	-0.23	4.49	0.13
ANABRANCH	1750	4.30	4.43	0.13	4.53	0.23	4.08	-0.22	4.44	0.14
ANABRANCH	1999	4.23	4.35	0.12	4.45	0.22	4.00	-0.23	4.36	0.13
ANABRANCH	2214	4.15	4.27	0.12	4.36	0.21	3.92	-0.23	4.29	0.14
ANABRANCH	2432	4.08	4.20	0.12	4.29	0.21	3.85	-0.23	4.22	0.14
ANABRANCH	2590	4.01	4.13	0.12	4.21	0.20	3.77	-0.24	4.16	0.15
ANABRANCH	2680	3.91	4.04	0.13	4.11	0.20	3.66	-0.25	4.06	0.15
ANABRANCH	3001	3.80	3.92	0.12	3.99	0.19	3.54	-0.26	3.96	0.16
ANABRANCH	3248	3.69	3.81	0.12	3.87	0.18	3.43	-0.26	3.86	0.17
ANABRANCH	3500	3.56	3.68	0.12	3.71	0.15	3.29	-0.27	3.74	0.18
ANABRANCH	3750	3.52	3.62	0.10	3.66	0.14	3.25	-0.27	3.69	0.17
ANABRANCH	3750	3.52	3.62	0.10	3.66	0.14	3.25	-0.27	3.69	0.17
ANABRANCH	4000	3.45	3.55	0.10	3.59	0.14	3.16	-0.29	3.64	0.19
ANABRANCH	4250	3.36	3.47	0.11	3.49	0.13	3.04	-0.32	3.56	0.20
ANABRANCH	4502	3.29	3.40	0.11	3.42	0.13	2.94	-0.35	3.51	0.22
ANABRANCH	4750	3.23	3.34	0.11	3.35	0.12	2.86	-0.37	3.47	0.24

FLOW PATH NAME	CHAINAGE	18 HOUR	18 Hr HIGH n		18 Hr HIGH Q		Downstream Boundary Condition			
		BASE RUN HAT 2.42 m AHD	HAT 2.42 m AHD	Difference m	HAT 2.42 m AHD	Difference m	MHWS 1.63 m AHD	Difference m	100 Yr Storm Surge 2.82 m AHD	Difference m
CLYDE_CK	0	20.74	20.94	0.20	20.99	0.25	20.74	0.00	20.74	0.00
CLYDE_CK	233	20.32	20.50	0.18	20.57	0.25	20.32	0.00	20.32	0.00
CLYDE_CK	522	20.17	20.34	0.17	20.41	0.24	20.17	0.00	20.17	0.00
CLYDE_CK	780	19.87	20.03	0.16	20.13	0.26	19.87	0.00	19.87	0.00
CLYDE_CK	953	19.56	19.71	0.15	19.85	0.29	19.56	0.00	19.56	0.00
CLYDE_CK	973	18.41	18.69	0.28	18.70	0.29	18.41	0.00	18.41	0.00
CLYDE_CK	1066	18.33	18.60	0.27	18.60	0.27	18.33	0.00	18.33	0.00
CLYDE_CK	1262	17.57	17.85	0.28	17.85	0.28	17.57	0.00	17.57	0.00
CLYDE_CK	1508	16.53	16.82	0.29	16.83	0.30	16.53	0.00	16.53	0.00
CLYDE_CK	1761	15.75	16.02	0.27	16.03	0.28	15.75	0.00	15.75	0.00
CLYDE_CK	2011	15.07	15.31	0.24	15.32	0.25	15.07	0.00	15.07	0.00
CLYDE_CK	2261	14.46	14.67	0.21	14.68	0.22	14.46	0.00	14.46	0.00
CLYDE_CK	2513	14.05	14.22	0.17	14.24	0.19	14.05	0.00	14.05	0.00
CLYDE_CK	2560	13.98	14.15	0.17	14.17	0.19	13.98	0.00	13.98	0.00
CLYDE_CK	2634	13.82	13.98	0.16	14.00	0.18	13.82	0.00	13.82	0.00
CLYDE_CK	2696	13.70	13.85	0.15	13.87	0.17	13.70	0.00	13.70	0.00
CLYDE_CK	2768	13.56	13.69	0.13	13.71	0.15	13.56	0.00	13.56	0.00
CLYDE_CK	2989	12.85	12.96	0.11	12.99	0.14	12.85	0.00	12.85	0.00
CLYDE_CK	3237	12.36	12.47	0.11	12.53	0.17	12.36	0.00	12.36	0.00
CLYDE_CK	3489	12.15	12.24	0.09	12.31	0.16	12.15	0.00	12.15	0.00
CLYDE_CK	3733	11.90	11.96	0.06	12.03	0.13	11.90	0.00	11.90	0.00
CLYDE_CK	3800	11.81	11.86	0.05	11.93	0.12	11.81	0.00	11.81	0.00
CLYDE_CK	3855	11.13	11.26	0.13	11.27	0.14	11.13	0.00	11.13	0.00
CLYDE_CK	3980	10.69	10.80	0.11	10.81	0.12	10.69	0.00	10.69	0.00
CLYDE_CK	4229	9.57	9.71	0.14	9.74	0.17	9.57	0.00	9.58	0.01
CLYDE_CK	4361	9.03	9.19	0.16	9.23	0.20	9.02	-0.01	9.04	0.01
CLYDE_CK	4646	8.65	8.80	0.15	8.86	0.21	8.63	-0.02	8.66	0.01
CLYDE_CK	4898	8.51	8.66	0.15	8.72	0.21	8.50	-0.01	8.53	0.02
CLYDE_CK	5048	8.43	8.57	0.14	8.63	0.20	8.41	-0.02	8.44	0.01
CLYDE_CK	5089	8.33	8.47	0.14	8.55	0.22	8.31	-0.02	8.35	0.02
CLYDE_CK	5141	8.17	8.33	0.16	8.41	0.24	8.14	-0.03	8.19	0.02
CLYDE_CK	5338	7.90	8.09	0.19	8.21	0.31	7.85	-0.05	7.94	0.04
CLYDE_CK	5519	7.84	8.05	0.21	8.18	0.34	7.80	-0.04	7.89	0.05
CLYDE_CK	5726	7.81	8.01	0.20	8.14	0.33	7.76	-0.05	7.86	0.05
CLYDE_CK	5898	7.77	7.97	0.20	8.12	0.35	7.72	-0.05	7.82	0.05
CLYDE_CK	5967	7.76	7.96	0.20	8.11	0.35	7.71	-0.05	7.81	0.05
CLYDE_CK	6000	7.75	7.96	0.21	8.11	0.36	7.70	-0.05	7.81	0.06
CLYDE_CK	6090	7.74	7.94	0.20	8.10	0.36	7.69	-0.05	7.79	0.05
CLYDE_CK	6110	7.34	7.60	0.26	7.79	0.45	7.29	-0.05	7.39	0.05
CLYDE_CK	6266	7.30	7.58	0.28	7.77	0.47	7.25	-0.05	7.35	0.05
CLYDE_CK	6473	7.25	7.56	0.31	7.75	0.50	7.20	-0.05	7.31	0.06
CLYDE_CK	6731	7.25	7.55	0.30	7.75	0.50	7.19	-0.06	7.30	0.05
CLYDE_CK	6983	7.25	7.55	0.30	7.75	0.50	7.19	-0.06	7.30	0.05
CLYDE_CK	7076	7.25	7.55	0.30	7.75	0.50	7.19	-0.06	7.30	0.05
CLYDE_CK	7288	7.24	7.55	0.31	7.74	0.50	7.18	-0.06	7.29	0.05
CLYDE_CK	7551	7.24	7.55	0.31	7.74	0.50	7.18	-0.06	7.29	0.05
CLYDE_CK	7670	7.24	7.55	0.31	7.74	0.50	7.18	-0.06	7.29	0.05
CLYDE_CK	7872	7.23	7.55	0.32	7.74	0.51	7.18	-0.05	7.29	0.06
CLYDE_CK	7965	7.24	7.55	0.31	7.74	0.50	7.18	-0.06	7.29	0.05
CLYDE_CK	8131	7.23	7.54	0.31	7.74	0.51	7.18	-0.05	7.28	0.05
CLYDE_CK	8189	7.23	7.54	0.31	7.74	0.51	7.18	-0.05	7.28	0.05
CLYDE_CK	8234	7.23	7.54	0.31	7.74	0.51	7.18	-0.05	7.28	0.05
CLYDE_CK	8484	7.23	7.54	0.31	7.74	0.51	7.17	-0.06	7.28	0.05
CLYDE_CK	8667	7.23	7.54	0.31	7.74	0.51	7.17	-0.06	7.28	0.05
CLYDE_CK	8964	7.22	7.54	0.32	7.73	0.51	7.16	-0.06	7.27	0.05

FLOW PATH NAME	CHAINAGE	18 HOUR	18 Hr HIGH n		18 Hr HIGH Q		Downstream Boundary Condition			
		BASE RUN HAT 2.42 m AHD	HAT 2.42 m AHD	Difference m	HAT 2.42 m AHD	Difference m	MHWS 1.63 m AHD	Difference m	100 Yr Storm Surge 2.82 m AHD	Difference m
LEIXLIP_CK	0	32.97	33.02	0.05	33.02	0.05	32.97	0.00	32.97	0.00
LEIXLIP_CK	241	32.31	32.36	0.05	32.35	0.04	32.31	0.00	32.31	0.00
LEIXLIP_CK	493	31.45	31.50	0.05	31.50	0.05	31.45	0.00	31.45	0.00
LEIXLIP_CK	721	30.85	30.90	0.05	30.92	0.07	30.85	0.00	30.85	0.00
LEIXLIP_CK	858	30.62	30.66	0.04	30.69	0.07	30.62	0.00	30.62	0.00
LEIXLIP_CK	957	30.49	30.50	0.01	30.56	0.07	30.49	0.00	30.49	0.00
LEIXLIP_CK	1062	30.45	30.46	0.01	30.52	0.07	30.45	0.00	30.45	0.00
LEIXLIP_CK	1062	30.45	30.46	0.01	30.52	0.07	30.45	0.00	30.45	0.00
LEIXLIP_CK	1115	29.64	29.71	0.07	29.71	0.07	29.64	0.00	29.64	0.00
LEIXLIP_CK	1115	29.64	29.71	0.07	29.71	0.07	29.64	0.00	29.64	0.00
LEIXLIP_CK	1160	29.55	29.61	0.06	29.61	0.06	29.55	0.00	29.55	0.00
LEIXLIP_CK	1253	29.28	29.34	0.06	29.33	0.05	29.28	0.00	29.28	0.00
LEIXLIP_CK	1418	28.78	28.86	0.08	28.86	0.08	28.78	0.00	28.78	0.00
LEIXLIP_CK	1521	28.65	28.74	0.09	28.74	0.09	28.65	0.00	28.65	0.00
LEIXLIP_CK	1711	28.46	28.55	0.09	28.55	0.09	28.46	0.00	28.46	0.00
LEIXLIP_CK	1891	28.14	28.23	0.09	28.23	0.09	28.14	0.00	28.14	0.00
LEIXLIP_CK	2002	27.72	27.80	0.08	27.80	0.08	27.72	0.00	27.72	0.00
LEIXLIP_CK	2099	27.31	27.40	0.09	27.40	0.09	27.31	0.00	27.31	0.00
LEIXLIP_CK	2148	27.23	27.33	0.10	27.34	0.11	27.23	0.00	27.23	0.00
LEIXLIP_CK	2236	27.18	27.28	0.10	27.29	0.11	27.18	0.00	27.18	0.00
LEIXLIP_CK	2366	27.03	27.13	0.10	27.14	0.11	27.03	0.00	27.03	0.00
LEIXLIP_CK	2493	26.65	26.75	0.10	26.75	0.10	26.65	0.00	26.65	0.00
LEIXLIP_CK	2632	26.34	26.42	0.08	26.42	0.08	26.34	0.00	26.34	0.00
LEIXLIP_CK	2735	26.17	26.25	0.08	26.25	0.08	26.17	0.00	26.17	0.00
LEIXLIP_CK	2902	25.92	26.00	0.08	25.99	0.07	25.92	0.00	25.92	0.00
LEIXLIP_CK	2902	25.92	26.00	0.08	25.99	0.07	25.92	0.00	25.92	0.00
LEIXLIP_CK	2946	25.62	25.66	0.04	25.68	0.06	25.62	0.00	25.62	0.00
LEIXLIP_CK	2946	25.62	25.66	0.04	25.68	0.06	25.62	0.00	25.62	0.00
LEIXLIP_CK	3014	25.23	25.30	0.07	25.30	0.07	25.23	0.00	25.23	0.00
LEIXLIP_CK	3225	24.66	24.73	0.07	24.73	0.07	24.66	0.00	24.66	0.00
LEIXLIP_CK	3320	24.36	24.42	0.06	24.42	0.06	24.36	0.00	24.36	0.00
LEIXLIP_CK	3483	23.74	23.80	0.06	23.82	0.08	23.74	0.00	23.74	0.00
LEIXLIP_CK	3635	23.33	23.40	0.07	23.42	0.09	23.33	0.00	23.33	0.00
LEIXLIP_CK	3749	23.13	23.20	0.07	23.23	0.10	23.13	0.00	23.13	0.00
LEIXLIP_CK	3925	22.66	22.76	0.10	22.81	0.15	22.66	0.00	22.66	0.00
LEIXLIP_CK	4167	22.32	22.41	0.09	22.48	0.16	22.32	0.00	22.32	0.00
LEIXLIP_CK	4260	22.04	22.12	0.08	22.22	0.18	22.04	0.00	22.04	0.00
LEIXLIP_CK	4466	21.87	21.95	0.08	22.08	0.21	21.87	0.00	21.87	0.00
LEIXLIP_CK	4602	21.81	21.89	0.08	22.01	0.20	21.81	0.00	21.81	0.00
LEIXLIP_CK	4710	21.71	21.76	0.05	21.90	0.19	21.71	0.00	21.71	0.00
LEIXLIP_CK	4813	21.64	21.69	0.05	21.83	0.19	21.64	0.00	21.64	0.00
LEIXLIP_CK	4862	21.53	21.57	0.04	21.70	0.17	21.53	0.00	21.53	0.00
LEIXLIP_CK	4909	20.28	20.43	0.15	20.48	0.20	20.28	0.00	20.28	0.00
LEIXLIP_CK	5100	19.55	19.70	0.15	19.73	0.18	19.55	0.00	19.55	0.00
LEIXLIP_CK	5198	19.19	19.34	0.15	19.37	0.18	19.19	0.00	19.19	0.00
LEIXLIP_CK	5353	18.72	18.92	0.20	18.96	0.24	18.72	0.00	18.72	0.00
LEIXLIP_CK	5469	18.47	18.68	0.21	18.73	0.26	18.47	0.00	18.47	0.00
LEIXLIP_CK	5657	17.91	18.11	0.20	18.17	0.26	17.91	0.00	17.91	0.00
LEIXLIP_CK	5758	17.68	17.89	0.21	17.96	0.28	17.67	-0.01	17.68	0.00
LEIXLIP_CK	5886	17.46	17.70	0.24	17.78	0.32	17.46	0.00	17.46	0.00
LEIXLIP_CK	6106	16.79	17.11	0.32	17.22	0.43	16.79	0.00	16.79	0.00
LEIXLIP_CK	6199	16.58	16.90	0.32	17.03	0.45	16.58	0.00	16.58	0.00
LEIXLIP_CK	6332	16.36	16.68	0.32	16.80	0.44	16.35	-0.01	16.36	0.00
LEIXLIP_CK	6370	16.29	16.63	0.34	16.76	0.47	16.29	0.00	16.30	0.01
LEIXLIP_CK	6390	16.29	16.62	0.33	16.75	0.46	16.28	-0.01	16.29	0.00
LEIXLIP_CK	6545	16.10	16.46	0.36	16.61	0.51	16.09	-0.01	16.10	0.00
LEIXLIP_CK	6666	16.09	16.42	0.33	16.56	0.47	16.08	-0.01	16.09	0.00
LEIXLIP_CK	6829	16.08	16.40	0.32	16.54	0.46	16.07	-0.01	16.08	0.00
LEIXLIP_CK	7001	16.07	16.39	0.32	16.52	0.45	16.07	0.00	16.08	0.01
LEIXLIP_CK	7124	16.07	16.39	0.32	16.51	0.44	16.06	-0.01	16.07	0.00
LEIXLIP_CK	7237	16.07	16.38	0.31	16.51	0.44	16.06	-0.01	16.07	0.00
LEIXLIP_CK	7441	16.07	16.38	0.31	16.51	0.44	16.06	-0.01	16.07	0.00
LEIXLIP_CK	7542	16.06	16.38	0.32	16.51	0.45	16.06	0.00	16.07	0.01
LEIXLIP_CK	7707	16.06	16.38	0.32	16.51	0.45	16.06	0.00	16.07	0.01
LEIXLIP_CK	7707	16.06	16.38	0.32	16.51	0.45	16.06	0.00	16.07	0.01
LEIXLIP_CK	7927	16.06	16.38	0.32	16.51	0.45	16.06	0.00	16.07	0.01
LEIXLIP_CK	7927	16.06	16.38	0.32	16.51	0.45	16.06	0.00	16.07	0.01
LEIXLIP_CK	8035	16.06	16.38	0.32	16.50	0.44	16.05	-0.01	16.06	0.00
LEIXLIP_CK	8172	16.06	16.37	0.31	16.50	0.44	16.05	-0.01	16.06	0.00
LEIXLIP_CK	8290	16.06	16.37	0.31	16.50	0.44	16.05	-0.01	16.06	0.00
LEIXLIP_CK	8463	16.05	16.37	0.32	16.49	0.44	16.05	0.00	16.06	0.01
LEIXLIP_CK	8590	16.05	16.36	0.31	16.49	0.44	16.05	0.00	16.05	0.00
LEIXLIP_CK	8742	16.05	16.36	0.31	16.49	0.44	16.04	-0.01	16.05	0.00
LEIXLIP_CK	8742	16.05	16.36	0.31	16.49	0.44	16.04	-0.01	16.05	0.00
LEIXLIP_CK	8992	16.05	16.36	0.31	16.49	0.44	16.04	-0.01	16.05	0.00
LEIXLIP_CK	9128	16.05	16.36	0.31	16.49	0.44	16.04	-0.01	16.05	0.00
LEIXLIP_CK	9261	16.05	16.36	0.31	16.49	0.44	16.04	-0.01	16.05	0.00

Appendix H
Road and Rail Crossing Immunity

Current Immunity Levels Roads and Crossings

Flowpath	Road/Rail Crossing	MIKE 11 Chainage m	Crossing Level	Flood Immunity	Approx. closure duration in 10 Year ARI event	Peak Flood Level (m AHD) for ARI (Years)			
			m AHD	Years	Hours	10	20	50	100
Calliope River	Blackgate Rd/ Ferguson Rd	324	2.5	<<10	>72	14.6	16.0	17.7	18.9
	Old Bruce Highway Crossing	9413	2.0	<<10	>72	10.4	12.0	14.2	15.7
	Bruce Highway Bridge	9907	15.24	>100	N/A	9.0	10.3	11.7	12.5
	Rail Bridge 1	22576	8.35 abutments ~6	50	N/A	4.4	5.2	6.1	6.7
	Rail Bridge 2	22770	9 abutments ~8	>100	N/A	4.0	4.6	5.4	5.9
	Port Curtis Way	30721	8.32 abutment ~6	>100	N/A	2.8	3.0	3.3	3.5
Leixlip Creek	Dawson Highway	1062	29.5	<10	3	30.4	30.6	30.8	30.9
	Stowe Rd	2924	25.0	<10	12	25.8	26.0	26.2	26.3
	Hookes Rd	4466	18.5	<10	24	21.5	22.1	22.4	22.8
	Rail Crossing	4813	22	20	N/A	21.5	22.1	22.4	22.8
	Schilling Lane	6332	12.7	<10	27	15.3	15.7	16.1	16.5
Clyde Creek	Dawson Highway	953	20.82	50	N/A	19.0	19.8	20.8	21.1
	Rail Crossing	973	20.5	>100	N/A	17.8	18.7	19.2	19.6
	Wyndham Rd	3820	10.4	<10	15	11.6	11.9	12.2	12.5
	Jefferis Rd	6100	4	<10	26	5.4	6.1	7.0	7.7
Deep Ck	Dawson Highway	47	16.15	10	N/A	15.9	18.0	18.5	18.9
Double Ck	Railway Crossing	3100	15.9	50	N/A	11.6	13.1	15.2	16.6
	Dawson Highway	-440	14	<<10	24	16.6	17.1	17.6	18.0
Anabranch	Port Curtis Way	2630	5.17	>100	N/A	3.0	3.3	3.7	4.0

Current and Proposed Flood Immunity

Flowpath	MIKE 11 Chainage m	Road/Rail Crossing	Structure	Current Crossing Level	Approx Current Immunity Level ARI (Years)	Flood Level m AHD for ARI (Years)				Proposed Immunity (Years)	Proposed Upgrade or Comment	Min Road/Deck Level Required m AHD (assume deck 0.8 m above soffit)	Increase in Height m	Additional Waterway Area sq.m.	10Yr ARI flood level with proposed upgrade m AHD	Difference m	50Yr ARI flood level with proposed upgrade m AHD	Difference m
				m AHD		10	20	50	100									
Calliope River	324	Blackgate Rd/ Ferguson Rd	Ford	2.5	<<10	14.6	16.0	17.7	18.9	<<10	No proposed change High risk crossing Upgrade impractical Recommend closure or as min. warning signs	-	-	-		-	-	-
	9413	Old Bruce Highway Crossing	Low level Causeway	2.0	<<10	10.4	12.0	14.2	15.7	<<10	No proposed change High risk crossing Upgrade impractical Recommend closure or as min. warning signs	-	-	-		-	-	-
	9907	Bruce Highway Bridge	Bridge	15.24	>100	9.0	10.3	11.7	12.5		No upgrade required	-	-	-		-	-	-
	22576	Rail Bridge 1	Bridge	8.35 abutments ~6	100	4.4	5.2	6.1	6.7		No upgrade required	-	-	-		-	-	-
	22770	Rail Bridge 2	Bridge	9 abutments ~8	>100	4.0	4.6	5.4	5.9		No upgrade required	-	-	-		-	-	-
	30721	Port Curtis Way	Bridge	8.32 abutment ~6	>100	2.8	3.0	3.3	3.5		No upgrade required	-	-	-		-	-	-
Leixlip Creek	1062	Dawson Highway	Culverts	29.5	<10	30.4	30.6	30.8	30.9	50	Raise min road level to 31.2m Increase main culvert from 5 to 15 cells (3.0w x 2.4h)	31.20	1.70	72	30.4	-0.1	31.1	0.4
	2924	Stowe Rd	Culvert	25.0	<10	25.8	26.0	26.2	26.3	10	Raise min road level to 26.8m Increase main culvert from 5 to 10 cells (3.6w x 3.0h)	26.80	1.80	54	26.0	0.2	26.3	0.2
	4466	Hookes Rd	Ford	18.5	<<10	21.5	22.1	22.4	22.8	10	Raise min road level to 22.1m New 10 cell culvert (3.6w x 2.1h) Low priority as alternative access/egress route available. Warning signs recommended	22.10	3.60	75.60	21.3	-0.1	22.4	-0.1
	4813	Rail Crossing	Bridge	22	50	21.5	22.1	22.4	22.8		No upgrade required	-	-	-		-	-	-
	6332	Schilling Lane	Causeway with low flow culvert	12.7	<10	15.3	15.7	16.1	16.5	10	Raise min road level to 16.0m New 10 cell culvert (3.6w x 3.0h) Low priority as alternative access/egress route available. Warning signs recommended.	16.00	3.30	108.00	15.2	-0.1	16.3	0.2
Clyde Creek	953	Dawson Highway	Bridge	20.82	50	19.0	19.8	20.8	21.1		No upgrade required	-	-	-			-	
	973	Rail Crossing	Bridge	20.5	>100	17.8	18.7	19.2	19.6		No upgrade required	-	-	-		-	-	-
	3820	Wyndham Rd	Proposed Bridge	10.4	<10	11.6	11.9	12.2	12.5	10	Increase bridge deck level and approaches to 12.2m. An alternative high immunity acess route is being considered. Warning signs recommended.	12.20	1.80	Bridge raised to soffit 11.4	11.4	-0.2	12.1	-0.1
	6100	Jefferis Rd	Culvert	4	<10	5.4	6.1	7.0	7.7	10	Raise min road level to 7.1m Additional 5 cells to culvert (3.6w x 2.1h)	7.10	3.10	75.60	6.3	0.9	7.5	0.4
Deep Ck	47	Dawson Highway	Bridge	16.15	10	15.9	18.0	18.5	18.9	-	Increase bridge deck level and approaches to 18.5m	18.50	2.35	Bridge raised to soffit 17.7	15.9	-	-	-
Double Ck	3100	Railway Crossing	Causeway	15.9	>100	11.6	13.1	15.2	16.6	-	No upgrade required	-	-	-		-	-	-
	-440	Dawson Highway	Bridge	14	<<10	16.6	17.1	17.6	18.0	50	Increase bridge deck level and approaches to 18.1m	18.10	4.10	Bridge raised to soffit 17.6	16.2	-0.4	17.3	-0.3
Anabranch	2630	Port Curtis Way	Bridge	5.17	>100	3.0	3.3	3.7	4.0	-	No upgrade required	-	-	-		-	-	-

Appendix I
Potential Levee – Leixlip Creek

Flowpath	Chainage m	Bed Level m AHD	Peak Flood Level (m AHD) for ARI (Years) Existing Conditions				Mitigation Runs - Levee Calliope Township 100 Year ARI only						
			10	20	50	100	3 hr storm	6 hr storm	12 hr storm	18 hr storm	24 hr storm	Envelope	Difference m
LEIXLIP_CK	0	29.91	32.93	33.03	33.11	33.19	33.21	33.12	33.13	32.97	33.15	33.21	0.02
LEIXLIP_CK	241	27.38	32.27	32.38	32.46	32.53	32.56	32.46	32.47	32.31	32.50	32.56	0.03
LEIXLIP_CK	493	26.65	31.40	31.51	31.61	31.70	31.72	31.61	31.62	31.45	31.65	31.72	0.02
LEIXLIP_CK	721	26.50	30.79	30.97	31.09	31.21	31.23	31.08	31.09	30.85	31.11	31.23	0.02
LEIXLIP_CK	858	27.26	30.57	30.76	30.91	31.03	31.04	30.87	30.89	30.62	30.91	31.04	0.01
LEIXLIP_CK	957	26.69	30.45	30.65	30.79	30.91	30.91	30.74	30.76	30.49	30.78	30.91	0.00
LEIXLIP_CK	1062	25.81	30.42	30.61	30.75	30.87	30.86	30.70	30.72	30.45	30.74	30.86	0.00
LEIXLIP_CK	1062	25.81	30.42	30.61	30.75	30.87	30.86	30.70	30.72	30.45	30.74	30.86	0.00
LEIXLIP_CK	1115	25.42	29.58	29.76	29.91	30.03	30.07	29.90	29.92	29.64	29.96	30.07	0.04
LEIXLIP_CK	1115	25.42	29.58	29.76	29.91	30.03	30.07	29.90	29.92	29.64	29.96	30.07	0.04
LEIXLIP_CK	1160	25.09	29.49	29.66	29.80	29.92	29.97	29.80	29.82	29.54	29.86	29.97	0.05
LEIXLIP_CK	1253	25.42	29.23	29.37	29.50	29.61	29.68	29.52	29.53	29.27	29.57	29.68	0.07
LEIXLIP_CK	1418	25.32	28.66	28.88	29.06	29.22	29.33	29.14	29.16	28.82	29.22	29.33	**0.11**
LEIXLIP_CK	1521	25.16	28.52	28.76	28.95	29.12	29.24	29.05	29.07	28.71	29.13	29.24	**0.12**
LEIXLIP_CK	1711	24.32	28.33	28.56	28.76	28.93	29.04	28.86	28.87	28.51	28.93	29.04	**0.11**
LEIXLIP_CK	1891	24.41	28.00	28.23	28.42	28.58	28.66	28.49	28.50	28.16	28.57	28.66	0.08
LEIXLIP_CK	2002	24.31	27.60	27.79	27.96	28.10	28.15	28.00	28.01	27.73	28.07	28.15	0.05
LEIXLIP_CK	2099	23.68	27.12	27.37	27.59	27.77	27.77	27.61	27.62	27.28	27.70	27.77	0.00
LEIXLIP_CK	2148	22.74	27.03	27.30	27.53	27.72	27.72	27.55	27.56	27.20	27.65	27.72	0.00
LEIXLIP_CK	2236	22.39	26.98	27.25	27.49	27.68	27.67	27.50	27.51	27.15	27.60	27.67	-0.01
LEIXLIP_CK	2366	22.05	26.83	27.09	27.32	27.50	27.48	27.32	27.33	26.99	27.42	27.48	-0.02
LEIXLIP_CK	2493	21.26	26.46	26.70	26.91	27.09	27.11	26.96	26.96	26.64	27.06	27.11	0.02
LEIXLIP_CK	2632	22.17	26.16	26.38	26.57	26.73	26.77	26.63	26.63	26.34	26.73	26.77	0.04
LEIXLIP_CK	2735	20.84	26.02	26.20	26.38	26.53	26.57	26.44	26.44	26.17	26.54	26.57	0.04
LEIXLIP_CK	2902	22.32	25.78	25.94	26.13	26.27	26.33	26.18	26.19	25.92	26.29	26.33	0.06
LEIXLIP_CK	2902	22.32	25.78	25.94	26.13	26.27	26.33	26.18	26.19	25.92	26.29	26.33	0.06
LEIXLIP_CK	2946	22.32	25.51	25.64	25.75	25.88	25.89	25.80	25.81	25.62	25.89	25.89	0.01
LEIXLIP_CK	2946	22.32	25.51	25.64	25.75	25.88	25.89	25.80	25.81	25.62	25.89	25.89	0.01
LEIXLIP_CK	3014	19.81	25.08	25.25	25.42	25.56	25.59	25.48	25.48	25.24	25.56	25.59	0.04
LEIXLIP_CK	3225	20.06	24.51	24.68	24.84	24.97	25.01	24.90	24.90	24.66	24.98	25.01	0.04
LEIXLIP_CK	3320	19.71	24.21	24.38	24.53	24.64	24.67	24.58	24.57	24.36	24.66	24.67	0.03
LEIXLIP_CK	3483	19.25	23.58	23.77	23.90	24.05	24.06	23.96	23.95	23.74	24.08	24.08	0.03
LEIXLIP_CK	3635	18.84	23.12	23.37	23.53	23.70	23.68	23.57	23.55	23.33	23.74	23.74	0.04
LEIXLIP_CK	3749	19.40	22.91	23.18	23.35	23.52	23.48	23.37	23.38	23.14	23.57	23.57	0.05
LEIXLIP_CK	3925	18.53	22.35	22.76	23.00	23.23	23.15	23.01	23.06	22.67	23.29	23.29	0.06
LEIXLIP_CK	4167	17.77	21.94	22.42	22.69	22.97	22.86	22.71	22.77	22.34	23.04	23.04	0.07
LEIXLIP_CK	4260	17.62	21.58	22.15	22.45	22.80	22.66	22.49	22.55	22.05	22.90	22.90	0.10
LEIXLIP_CK	4466	17.17	21.33	21.98	22.30	22.67	22.54	22.35	22.42	21.89	22.79	22.79	0.12
LEIXLIP_CK	4602	17.65	21.27	21.91	22.23	22.60	22.46	22.28	22.35	21.83	22.72	22.72	0.12
LEIXLIP_CK	4710	16.80	21.13	21.79	22.09	22.50	22.34	22.15	22.22	21.72	22.64	22.64	0.14
LEIXLIP_CK	4813	16.75	21.04	21.70	22.00	22.42	22.26	22.06	22.14	21.65	22.57	22.57	0.15
LEIXLIP_CK	4862	16.13	20.87	21.57	21.85	22.32	22.14	21.92	22.01	21.54	22.49	22.49	0.17
LEIXLIP_CK	4909	15.87	20.10	20.47	20.78	21.06	20.89	20.78	20.82	20.3	21.12	21.12	0.07
LEIXLIP_CK	5100	16.76	19.37	19.75	20.07	20.34	20.17	20.08	20.1	19.56	20.4	20.40	0.06
LEIXLIP_CK	5198	15.61	19.03	19.39	19.69	19.94	19.78	19.71	19.72	19.21	19.99	19.99	0.05
LEIXLIP_CK	5353	14.72	18.55	18.95	19.28	19.52	19.37	19.30	19.31	18.74	19.57	19.57	0.05
LEIXLIP_CK	5469	14.50	18.28	18.69	19.04	19.29	19.13	19.06	19.08	18.47	19.34	19.34	0.05
LEIXLIP_CK	5657	14.66	17.71	18.06	18.36	18.66	18.45	18.39	18.4	17.91	18.72	18.72	0.06
LEIXLIP_CK	5758	13.81	17.43	17.78	18.10	18.44	18.21	18.14	18.15	17.68	18.5	18.50	0.06
LEIXLIP_CK	5886	13.65	17.13	17.52	17.87	18.23	17.97	17.91	17.92	17.46	18.29	18.29	0.06
LEIXLIP_CK	6106	12.32	16.15	16.62	17.04	17.42	17.14	17.09	17.09	16.79	17.5	17.50	0.08
LEIXLIP_CK	6199	11.37	15.65	16.16	16.60	17.00	16.70	16.67	16.66	16.58	17.08	17.08	0.08
LEIXLIP_CK	6332	10.04	15.23	15.67	16.06	16.41	16.13	16.14	16.11	16.36	16.48	16.48	0.07
LEIXLIP_CK	6370	11.50	15.02	15.45	15.84	16.29	15.90	15.93	15.88	16.29	16.27	16.29	0.00
LEIXLIP_CK	6390	11.50	15.00	15.43	15.82	16.29	15.89	15.91	15.87	16.28	16.26	16.28	-0.01
LEIXLIP_CK	6545	9.76	13.79	14.36	14.87	16.10	14.87	15.03	15.21	16.1	15.42	16.10	0.00
LEIXLIP_CK	6666	9.74	13.27	13.84	14.35	16.09	14.33	14.51	15.21	16.08	15.34	16.08	-0.01
LEIXLIP_CK	6829	9.17	12.85	13.43	13.96	16.08	13.93	14.13	15.2	16.08	15.3	16.08	0.00
LEIXLIP_CK	7001	8.44	12.48	13.05	13.56	16.07	13.54	13.75	15.2	16.07	15.25	16.07	0.00
LEIXLIP_CK	7124	8.43	12.16	12.71	13.21	16.07	13.18	13.41	15.2	16.07	15.21	16.07	0.00
LEIXLIP_CK	7237	8.04	11.80	12.35	12.95	16.07	12.83	13.08	15.2	16.07	15.19	16.07	0.00
LEIXLIP_CK	7441	6.51	11.71	12.25	12.92	16.07	12.73	12.99	15.2	16.06	15.18	16.06	-0.01
LEIXLIP_CK	7542	7.38	11.67	12.20	12.91	16.06	12.68	12.95	15.2	16.06	15.17	16.06	0.00
LEIXLIP_CK	7707	6.26	11.43	11.99	12.87	16.06	12.51	12.92	15.2	16.06	15.17	16.06	0.00
LEIXLIP_CK	7707	6.26	11.43	11.99	12.87	16.06	12.51	12.92	15.2	16.06	15.17	16.06	0.00
LEIXLIP_CK	7927	5.13	10.83	11.54	12.79	16.06	12.16	12.92	15.2	16.06	15.15	16.06	0.00
LEIXLIP_CK	7927	5.13	10.83	11.54	12.79	16.06	12.16	12.92	15.2	16.06	15.15	16.06	0.00
LEIXLIP_CK	8035	4.58	10.71	11.41	12.77	16.06	12.02	12.92	15.2	16.06	15.13	16.06	0.00
LEIXLIP_CK	8172	5.02	10.48	11.16	12.72	16.06	11.79	12.92	15.2	16.06	15.12	16.06	0.00
LEIXLIP_CK	8290	4.04	10.06	11.00	12.67	16.06	11.47	12.92	15.2	16.06	15.1	16.06	0.00
LEIXLIP_CK	8463	4.26	9.51	10.96	12.59	16.05	10.76	12.92	15.2	16.05	15.07	16.06	0.01
LEIXLIP_CK	8590	3.15	9.36	10.93	12.54	16.05	10.68	12.92	15.2	16.05	15.05	16.06	0.01
LEIXLIP_CK	8742	2.09	9.29	10.70	12.54	16.05	10.68	12.92	15.2	16.05	15.04	16.06	0.01
LEIXLIP_CK	8742	2.09	9.29	10.70	12.53	16.05	10.68	12.92	15.2	16.05	15.04	16.06	0.01
LEIXLIP_CK	8992	1.50	9.25	10.70	12.52	16.05	10.68	12.92	15.2	16.05	15.03	16.06	0.01
LEIXLIP_CK	9128	-0.96	9.25	10.65	12.51	16.05	10.68	12.92	15.2	16.05	15.03	16.06	0.01
LEIXLIP_CK	9261	-0.04	9.25	10.60	12.50	16.05	10.68	12.92	15.2	16.05	15.03	16.06	0.01

Appendix J
Flood Mitigation Measures - Storage Options

Detention Basin Elevation – Storage Characteristics
Flood Levels with Storages in Place

Detention Basin Elevation – Area – Storage Relationships

Detention Basin LC1
eixlip CK (sub area CD)

RL	Area	Volume	CumVol
m AHD	km2	m3	m3
58	0	0	0
60	0.01768	17680	17680
70	0.2117	1146900	1164580
80	0.7711	4914000	6078580
90	1.678	12245500	18324080

Detention Basin CC1
Clyde Ck (sub area CX)

RL	Area	Volume	CumVol
m AHD	km2	m3	m3
54	0	0	0
60	0.07693	230790	230790
70	0.3712	2240650	2471440

Detention Basin CC2
Clyde Ck (sub area CY)

RL	Area	Volume	CumVol
m AHD	km2	m3	m3
50	0	0	0
60	0.1433	716500	716500
70	0.7926	4679500	5396000
80	1.6457	12191500	17587500

Flood Levels Clyde Creek with Detention Basins

Flowpath	Chainage m	Peak Flood Level (m AHD) for ARI (Years) Existing Conditions				Mitigation Runs - Detention Basins Run 2								
		10	20	50	100	10 yr 3hr	10 yr 24hr	10 yr Diff	50 yr 3hr	50 yr 24hr	50 yr Diff	100 yr 3hr	100 yr 24hr	100 yr Diff
CLYDE_CK	0	20.28	20.98	21.64	21.96	18.55	18.86	-1.42	19.64	19.91	-1.73	19.97	20.34	-1.62
CLYDE_CK	233	19.85	20.57	21.31	21.61	18.09	18.39	-1.46	19.15	19.45	-1.86	19.52	19.91	-1.70
CLYDE_CK	522	19.72	20.41	21.15	21.43	17.98	18.28	-1.44	19.03	19.32	-1.83	19.39	19.77	-1.66
CLYDE_CK	780	19.37	20.12	20.96	21.24	17.66	17.94	-1.43	18.68	18.97	-1.99	19.04	19.44	-1.80
CLYDE_CK	953	19.01	19.84	20.83	21.11	17.30	17.58	-1.43	18.30	18.60	-2.23	18.67	19.09	-2.02
CLYDE_CK	973	17.81	18.69	19.16	19.55	15.89	16.25	-1.56	17.10	17.49	-1.67	17.52	18.05	-1.50
CLYDE_CK	1066	17.73	18.59	19.06	19.46	15.79	16.15	-1.58	17.00	17.39	-1.67	17.44	17.95	-1.51
CLYDE_CK	1262	16.95	17.84	18.37	18.91	15.01	15.38	-1.57	16.23	16.63	-1.74	16.66	17.20	-1.71
CLYDE_CK	1508	15.94	16.82	17.49	18.25	14.08	14.48	-1.46	15.26	15.70	-1.79	15.68	16.24	-2.01
CLYDE_CK	1761	15.20	16.03	16.65	17.36	13.39	13.84	-1.36	14.56	15.04	-1.61	14.97	15.56	-1.80
CLYDE_CK	2011	14.56	15.31	15.87	16.50	12.85	13.30	-1.26	13.96	14.44	-1.43	14.35	14.91	-1.59
CLYDE_CK	2261	13.99	14.68	15.17	15.73	12.33	12.81	-1.18	13.43	13.92	-1.25	13.81	14.36	-1.37
CLYDE_CK	2513	13.61	14.23	14.67	15.18	11.98	12.48	-1.13	13.08	13.58	-1.09	13.44	13.98	-1.20
CLYDE_CK	2560	13.55	14.16	14.59	15.08	11.93	12.44	-1.11	13.02	13.52	-1.07	13.39	13.92	-1.16
CLYDE_CK	2634	13.41	13.99	14.40	14.87	11.79	12.32	-1.09	12.89	13.40	-1.00	13.25	13.78	-1.09
CLYDE_CK	2696	13.31	13.87	14.25	14.70	11.70	12.24	-1.07	12.80	13.31	-0.94	13.16	13.68	-1.02
CLYDE_CK	2768	13.19	13.71	14.06	14.47	11.61	12.14	-1.05	12.69	13.19	-0.87	13.04	13.54	-0.93
CLYDE_CK	2989	12.53	12.99	13.34	13.75	11.15	11.64	-0.89	12.10	12.54	-0.80	12.40	12.84	-0.91
CLYDE_CK	3237	12.01	12.53	12.94	13.37	10.88	11.31	-0.70	11.66	12.04	-0.90	11.90	12.37	-1.00
CLYDE_CK	3489	11.84	12.30	12.67	13.04	10.80	11.21	-0.63	11.53	11.88	-0.79	11.74	12.17	-0.87
CLYDE_CK	3733	11.65	12.03	12.32	12.62	10.72	11.11	-0.54	11.38	11.69	-0.63	11.56	11.94	-0.68
CLYDE_CK	3800	11.57	11.93	12.20	12.48	10.69	11.06	-0.51	11.32	11.61	-0.59	11.49	11.84	-0.64
CLYDE_CK	3855	10.82	11.26	11.56	11.88	9.50	10.06	-0.76	10.47	10.88	-0.68	10.70	11.17	-0.71
CLYDE_CK	3980	10.40	10.80	11.04	11.29	9.22	9.72	-0.68	10.08	10.46	-0.58	10.30	10.72	-0.57
CLYDE_CK	4229	9.22	9.68	9.96	10.28	8.34	8.62	-0.60	8.90	9.30	-0.66	9.12	9.61	-0.67
CLYDE_CK	4361	8.66	9.09	9.42	9.81	7.63	8.03	-0.63	8.33	8.76	-0.66	8.57	9.05	-0.76
CLYDE_CK	4646	8.28	8.66	8.94	9.30	7.05	7.62	-0.66	7.95	8.39	-0.55	8.19	8.66	-0.64
CLYDE_CK	4898	8.16	8.49	8.73	9.05	6.98	7.54	-0.62	7.85	8.27	-0.46	8.08	8.51	-0.54
CLYDE_CK	5048	8.08	8.39	8.60	8.90	6.92	7.46	-0.62	7.78	8.18	-0.42	8.01	8.40	-0.50
CLYDE_CK	5089	7.95	8.25	8.45	8.75	6.83	7.34	-0.61	7.66	8.06	-0.39	7.88	8.27	-0.48
CLYDE_CK	5141	7.72	8.01	8.19	8.51	6.61	7.10	-0.62	7.40	7.84	-0.35	7.64	8.03	-0.48
CLYDE_CK	5338	6.82	7.16	7.45	8.00	5.69	6.19	-0.63	6.46	7.03	-0.42	6.72	7.42	-0.58
CLYDE_CK	5519	6.21	6.69	7.18	7.88	5.32	5.72	-0.49	5.93	6.67	-0.51	6.13	7.35	-0.53
CLYDE_CK	5726	5.87	6.45	7.13	7.81	5.14	5.48	-0.39	5.65	6.61	-0.52	5.82	7.32	-0.49
CLYDE_CK	5898	5.68	6.27	7.08	7.77	5.02	5.32	-0.36	5.48	6.57	-0.51	5.63	7.29	-0.48
CLYDE_CK	5967	5.62	6.22	7.07	7.76	4.98	5.27	-0.35	5.43	6.56	-0.51	5.57	7.28	-0.48
CLYDE_CK	6000	5.56	6.18	7.06	7.75	4.94	5.23	-0.33	5.38	6.55	-0.51	5.52	7.27	-0.48
CLYDE_CK	6090	5.40	6.07	7.04	7.74	4.86	5.10	-0.30	5.24	6.54	-0.50	5.37	7.26	-0.48
CLYDE_CK	6110	5.20	5.87	6.79	7.34	4.03	4.46	-0.74	4.84	6.42	-0.37	5.17	7.05	-0.29
CLYDE_CK	6266	5.05	5.80	6.74	7.30	3.68	4.39	-0.66	4.54	6.39	-0.35	4.83	7.02	-0.28
CLYDE_CK	6473	4.95	5.73	6.69	7.25	3.45	4.34	-0.61	4.27	6.35	-0.34	4.59	6.98	-0.27
CLYDE_CK	6731	4.93	5.71	6.68	7.25	3.35	4.33	-0.60	4.20	6.34	-0.34	4.59	6.98	-0.27
CLYDE_CK	6983	4.92	5.71	6.68	7.25	3.31	4.32	-0.60	4.20	6.34	-0.34	4.59	6.97	-0.28
CLYDE_CK	7076	4.92	5.71	6.68	7.25	3.30	4.32	-0.60	4.20	6.34	-0.34	4.59	6.97	-0.28
CLYDE_CK	7288	4.91	5.70	6.67	7.24	3.27	4.31	-0.60	4.20	6.34	-0.33	4.59	6.97	-0.27
CLYDE_CK	7551	4.91	5.70	6.67	7.24	3.25	4.31	-0.60	4.20	6.33	-0.34	4.59	6.97	-0.27
CLYDE_CK	7670	4.91	5.70	6.67	7.24	3.25	4.31	-0.60	4.20	6.33	-0.34	4.59	6.96	-0.28
CLYDE_CK	7872	4.90	5.69	6.67	7.23	3.25	4.31	-0.59	4.20	6.33	-0.34	4.59	6.96	-0.27
CLYDE_CK	7965	4.90	5.69	6.67	7.24	3.25	4.31	-0.59	4.20	6.33	-0.34	4.59	6.96	-0.28
CLYDE_CK	8131	4.90	5.69	6.66	7.23	3.25	4.30	-0.60	4.20	6.33	-0.33	4.59	6.96	-0.27
CLYDE_CK	8189	4.90	5.69	6.66	7.23	3.25	4.30	-0.60	4.20	6.33	-0.33	4.59	6.96	-0.27
CLYDE_CK	8234	4.90	5.69	6.66	7.23	3.25	4.30	-0.60	4.20	6.33	-0.33	4.59	6.96	-0.27
CLYDE_CK	8484	4.89	5.69	6.66	7.23	3.25	4.30	-0.59	4.20	6.33	-0.33	4.59	6.96	-0.27
CLYDE_CK	8667	4.88	5.68	6.66	7.23	3.25	4.29	-0.59	4.20	6.32	-0.34	4.59	6.95	-0.28
CLYDE_CK	8964	4.87	5.67	6.65	7.22	3.25	4.29	-0.58	4.20	6.32	-0.33	4.59	6.95	-0.27

Flood Levels Leixlip Creek with Detention Basins

Flowpath	Chainage m	Peak Flood Level (m AHD) for ARI (Years) Existing Conditions				Mitigation Runs - Detention Basins Run 2								
		10	20	50	100	10 yr 3hr	10 yr 24hr	10 yr Diff	50 yr 3hr	50 yr 24hr	50 yr Diff	100 yr 3hr	100 yr 24hr	100 yr Diff
LEIXLIP_CK	0	32.94	33.05	33.13	33.21	30.68	30.74	-2.20	30.78	30.86	-2.27	30.82	30.90	-2.31
LEIXLIP_CK	241	32.29	32.40	32.48	32.56	30.09	30.08	-2.21	30.37	30.23	-2.11	30.47	30.34	-2.09
LEIXLIP_CK	493	31.42	31.53	31.63	31.72	30.07	29.91	-1.51	30.35	30.19	-1.28	30.44	30.30	-1.28
LEIXLIP_CK	721	30.80	30.98	31.11	31.23	30.07	29.90	-0.90	30.34	30.18	-0.77	30.43	30.30	-0.80
LEIXLIP_CK	858	30.58	30.77	30.92	31.04	30.07	29.90	-0.68	30.34	30.18	-0.58	30.43	30.29	-0.61
LEIXLIP_CK	957	30.46	30.65	30.79	30.91	30.07	29.90	-0.56	30.34	30.18	-0.45	30.43	30.29	-0.48
LEIXLIP_CK	1062	30.42	30.61	30.75	30.87	30.06	29.90	-0.52	30.33	30.18	-0.42	30.42	30.29	-0.45
LEIXLIP_CK	1062	30.42	30.61	30.75	30.87	30.06	29.90	-0.52	30.33	30.18	-0.42	30.42	30.29	-0.45
LEIXLIP_CK	1115	29.60	29.79	29.93	30.06	29.28	29.15	-0.45	29.52	29.38	-0.41	29.61	29.48	-0.45
LEIXLIP_CK	1115	29.60	29.79	29.93	30.06	29.28	29.15	-0.45	29.52	29.38	-0.41	29.61	29.48	-0.45
LEIXLIP_CK	1160	29.51	29.68	29.82	29.95	29.20	29.08	-0.43	29.44	29.30	-0.38	29.52	29.40	-0.43
LEIXLIP_CK	1253	29.24	29.39	29.52	29.64	28.99	28.88	-0.36	29.19	29.06	-0.33	29.25	29.15	-0.39
LEIXLIP_CK	1418	28.69	28.91	29.09	29.25	28.31	28.23	-0.46	28.56	28.45	-0.53	28.67	28.57	-0.58
LEIXLIP_CK	1521	28.55	28.79	28.98	29.15	28.09	27.99	-0.56	28.40	28.27	-0.58	28.53	28.41	-0.62
LEIXLIP_CK	1711	28.35	28.59	28.79	28.96	27.88	27.79	-0.56	28.20	28.08	-0.59	28.33	28.22	-0.63
LEIXLIP_CK	1891	28.03	28.26	28.46	28.62	27.53	27.43	-0.60	27.88	27.76	-0.58	28.01	27.90	-0.61
LEIXLIP_CK	2002	27.62	27.82	27.99	28.14	27.14	27.05	-0.57	27.49	27.39	-0.50	27.60	27.52	-0.54
LEIXLIP_CK	2099	27.15	27.40	27.62	27.80	26.60	26.56	-0.59	26.96	26.90	-0.66	27.10	27.05	-0.70
LEIXLIP_CK	2148	27.06	27.33	27.57	27.76	26.47	26.43	-0.63	26.85	26.79	-0.72	27.01	26.95	-0.75
LEIXLIP_CK	2236	27.01	27.28	27.52	27.71	26.39	26.36	-0.65	26.80	26.73	-0.72	26.95	26.90	-0.76
LEIXLIP_CK	2366	27.01	27.28	27.52	27.71	26.27	26.26	-0.75	26.66	26.60	-0.86	26.81	26.76	-0.90
LEIXLIP_CK	2493	26.48	26.73	26.95	27.12	25.88	25.91	-0.57	26.29	26.25	-0.66	26.43	26.39	-0.69
LEIXLIP_CK	2632	26.18	26.40	26.59	26.76	25.61	25.66	-0.52	26.01	25.98	-0.58	26.13	26.11	-0.63
LEIXLIP_CK	2735	26.03	26.22	26.41	26.56	25.51	25.56	-0.47	25.88	25.85	-0.53	25.98	25.97	-0.58
LEIXLIP_CK	2902	25.79	25.97	26.15	26.31	25.32	25.38	-0.41	25.64	25.62	-0.51	25.73	25.73	-0.58
LEIXLIP_CK	2902	25.79	25.97	26.15	26.31	25.32	25.38	-0.41	25.64	25.62	-0.51	25.73	25.73	-0.58
LEIXLIP_CK	2946	25.52	25.65	25.78	25.89	25.01	25.09	-0.43	25.32	25.34	-0.44	25.45	25.46	-0.43
LEIXLIP_CK	2946	25.52	25.65	25.78	25.89	25.01	25.09	-0.43	25.32	25.34	-0.44	25.45	25.46	-0.43
LEIXLIP_CK	3014	25.11	25.28	25.45	25.58	24.04	24.19	-0.92	24.79	24.84	-0.61	25.01	25.03	-0.55
LEIXLIP_CK	3225	24.53	24.71	24.87	25.00	23.50	23.65	-0.88	24.25	24.30	-0.57	24.43	24.46	-0.54
LEIXLIP_CK	3320	24.23	24.40	24.55	24.66	23.29	23.42	-0.81	23.94	23.99	-0.56	24.12	24.16	-0.50
LEIXLIP_CK	3483	23.60	23.80	23.93	24.08	22.67	22.79	-0.81	23.20	23.27	-0.66	23.41	23.50	-0.58
LEIXLIP_CK	3635	23.17	23.41	23.57	23.74	22.05	22.17	-1.00	22.63	22.72	-0.85	22.86	23.00	-0.74
LEIXLIP_CK	3749	22.97	23.22	23.39	23.56	21.94	22.06	-0.91	22.45	22.54	-0.85	22.64	22.77	-0.79
LEIXLIP_CK	3925	22.44	22.82	23.06	23.28	21.29	21.42	-1.02	21.83	21.96	-1.10	22.04	22.21	-1.07
LEIXLIP_CK	4167	22.06	22.50	22.77	23.04	20.60	20.78	-1.28	21.31	21.50	-1.27	21.58	21.80	-1.24
LEIXLIP_CK	4260	21.68	22.26	22.55	22.89	20.34	20.51	-1.17	21	21.18	-1.37	21.25	21.47	-1.42
LEIXLIP_CK	4466	21.46	22.11	22.42	22.79	20.18	20.35	-1.11	20.81	20.99	-1.43	21.05	21.26	-1.53
LEIXLIP_CK	4602	21.40	22.05	22.35	22.72	20.15	20.31	-1.09	20.77	20.94	-1.41	21	21.20	-1.52
LEIXLIP_CK	4710	21.27	21.93	22.22	22.63	20.06	20.22	-1.05	20.66	20.83	-1.39	20.89	21.09	-1.54
LEIXLIP_CK	4813	21.46	22.11	22.42	22.79	20.02	20.17	-1.29	20.6	20.76	-1.66	20.82	21.01	-1.78
LEIXLIP_CK	4862	21.05	21.73	22.01	22.49	19.93	20.07	-0.98	20.48	20.63	-1.38	20.68	20.87	-1.62
LEIXLIP_CK	4909	20.13	20.52	20.82	21.12	19.10	19.22	-0.91	19.6	19.75	-1.07	19.8	19.99	-1.13
LEIXLIP_CK	5100	19.40	19.80	20.10	20.39	18.20	18.39	-1.01	18.85	19.05	-1.05	19.1	19.31	-1.08
LEIXLIP_CK	5198	19.06	19.43	19.72	19.98	17.82	18.06	-1.00	18.55	18.76	-0.96	18.8	19.01	-0.97
LEIXLIP_CK	5353	18.58	19.00	19.31	19.56	17.41	17.63	-0.95	18.07	18.26	-1.05	18.3	18.52	-1.04
LEIXLIP_CK	5469	18.31	18.75	19.07	19.34	17.21	17.41	-0.90	17.81	17.98	-1.09	18.02	18.25	-1.09
LEIXLIP_CK	5657	17.74	18.10	18.40	18.71	16.88	17.04	-0.70	17.34	17.48	-0.92	17.51	17.69	-1.02
LEIXLIP_CK	5758	17.45	17.83	18.15	18.49	16.54	16.72	-0.73	17.05	17.19	-0.96	17.22	17.41	-1.08
LEIXLIP_CK	5886	17.16	17.57	17.92	18.28	15.99	16.26	-0.90	16.69	16.87	-1.05	16.9	17.12	-1.16
LEIXLIP_CK	6106	16.18	16.68	17.09	17.48	14.79	15.05	-1.13	15.57	15.82	-1.27	15.86	16.14	-1.34
LEIXLIP_CK	6199	15.68	16.22	16.66	17.07	14.36	14.60	-1.08	15.07	15.32	-1.34	15.34	15.66	-1.41
LEIXLIP_CK	6332	15.26	15.72	16.11	16.47	14.14	14.35	-0.91	14.73	14.96	-1.15	14.97	15.26	-1.21
LEIXLIP_CK	6370	15.05	15.50	15.89	16.29	14.02	14.21	-0.84	14.56	14.78	-1.11	14.78	15.14	-1.15
LEIXLIP_CK	6390	15.03	15.48	15.87	16.29	14.00	14.20	-0.83	14.54	14.77	-1.10	14.76	15.13	-1.16
LEIXLIP_CK	6545	13.83	14.43	14.94	16.10	12.63	12.77	-1.06	13.15	13.67	-1.27	13.49	15.04	-1.06
LEIXLIP_CK	6666	13.32	13.91	14.78	16.09	12.04	12.28	-1.04	12.64	13.59	-1.19	12.98	15.01	-1.08
LEIXLIP_CK	6829	12.90	13.51	14.73	16.08	11.46	11.80	-1.10	12.19	13.55	-1.18	12.54	15.00	-1.08
LEIXLIP_CK	7001	12.53	13.12	14.69	16.07	11.00	11.42	-1.11	11.82	13.53	-1.16	12.19	14.99	-1.08
LEIXLIP_CK	7124	12.21	12.82	14.67	16.07	10.63	11.09	-1.12	11.52	13.52	-1.15	11.89	14.98	-1.09
LEIXLIP_CK	7237	11.87	12.74	14.67	16.07	10.13	10.70	-1.17	11.19	13.51	-1.16	11.6	14.97	-1.10
LEIXLIP_CK	7441	11.78	12.73	14.66	16.07	10.02	10.61	-1.17	11.11	13.51	-1.15	11.53	14.97	-1.10
LEIXLIP_CK	7542	11.74	12.72	14.66	16.06	9.99	10.58	-1.16	11.08	13.50	-1.16	11.5	14.97	-1.09
LEIXLIP_CK	7707	11.51	12.69	14.66	16.06	9.79	10.38	-1.13	10.9	13.50	-1.16	11.32	14.97	-1.09
LEIXLIP_CK	7707	11.51	12.69	14.66	16.06	9.79	10.38	-1.13	10.9	13.50	-1.16	11.32	14.97	-1.09
LEIXLIP_CK	7927	11.22	12.65	14.65	16.06	9.36	10.12	-1.10	10.42	13.49	-1.16	10.84	14.96	-1.10
LEIXLIP_CK	7927	11.22	12.65	14.65	16.06	9.36	10.12	-1.10	10.42	13.49	-1.16	10.84	14.96	-1.10
LEIXLIP_CK	8035	11.20	12.63	14.65	16.06	9.29	10.11	-1.09	10.33	13.49	-1.16	10.75	14.96	-1.10
LEIXLIP_CK	8172	11.15	12.61	14.65	16.06	9.13	10.09	-1.06	10.16	13.48	-1.17	10.67	14.95	-1.11
LEIXLIP_CK	8290	11.10	12.58	14.64	16.06	8.65	10.06	-1.04	9.87	13.48	-1.16	10.67	14.95	-1.11
LEIXLIP_CK	8463	11.02	12.54	14.63	16.05	7.88	10.05	-0.97	9.87	13.46	-1.17	10.67	14.94	-1.11
LEIXLIP_CK	8590	10.97	12.52	14.63	16.05	7.88	10.05	-0.92	9.87	13.46	-1.17	10.67	14.93	-1.12
LEIXLIP_CK	8742	10.96	12.51	14.62	16.05	7.88	10.04	-0.92	9.87	13.45	-1.17	10.67	14.93	-1.12
LEIXLIP_CK	8742	10.96	12.51	14.62	16.05	7.88	10.04	-0.92	9.87	13.45	-1.17	10.67	14.93	-1.12
LEIXLIP_CK	8992	10.94	12.51	14.62	16.05	7.88	10.04	-0.90	9.87	13.45	-1.17	10.67	14.93	-1.12
LEIXLIP_CK	9128	10.94	12.51	14.62	16.05	7.88	10.04	-0.90	9.87	13.45	-1.17	10.67	14.93	-1.12
LEIXLIP_CK	9261	10.94	12.51	14.62	16.05	7.88	10.04	-0.90	9.87	13.45	-1.17	10.67	14.93	-1.12