Sarah has a long connection with the Northern Midlands through the Heritage Highway Tourism Region Association, with whom she was originally employed in 1999. She continued to work for the HHTRA on a part-time, contractual basis until 2005, and remains involved with the Association informally. Earlier this year, Bill Fox & Associates invited her to assist with the Longford Visitor Appeal Study.

While Sarah is considered an expert in regional tourism, she has developed a particular interest in visitor information services. Both her research and project work in this area has been widely acknowledged, culminating in her keynote presentation at the Victorian Tourism Industry Council, Victorian Visitor Information Centre Summit in 2014. Her paper was entitled, *Effective and Contemporary Visitor Services: Some Perspectives from Around the World.* Other examples of her work in this area include:

- Hobart Visitor Information Services Review 2014
- Tasmanian Travel and Information Centre Discussion Paper 2013
- Launceston Travel and Information Centre Review (with Bill Fox & Associates) 2012
- Tasmanian Visitor Information Network Business Structure and Financial Management Review (with David Reed Consulting) 2011
- Cradle Coast Tasmanian Visitor Information Centre Online Business Modelling (with Kingthing Marketing) 2010
- People and Processes Toolkit for the Launceston Travel and Information Centre 2010
- Marketing Plan for the Tasmanian Visitor Information Network 2010.

She also collaborated with Tourism Tasmania to:

- Develop a database of current research and best practice in visitor information centres, both nationally and internationally
- Develop the content for Tourism Tasmania's corporate website which outlined the processes and requirements for recognised visitor information providers.

Sarah is recognised as a skilled writer, who delivers well-researched and engaging reports. She is also in demand as a successful submission writer, securing substantial Government funding - and multiple tourism awards, for industry.

Sarah is a past Chair of Judges for the Tasmanian Tourism Awards (2007-2010) and was a Judge for the Australian Tourism Awards for several years. In January 2012, she was appointed to represent the Tourism Industry Council on the Tasmanian Heritage Council.

Additional key projects

The following provides a selection of tourism-related projects that Sarah has undertaken in recent years, which illustrates her wide-ranging experience working with the tourism industry in Tasmania and elsewhere:

- Longford Visitor Appeal Study 2015
- Review of the Business Plan for the Northern Midlands Council Visitor Information Centre 2015
- Review of the West Coast Heritage Centre 2015
- Review of Victorian Regional Tourism Boards and Destination Management Plans (Tourism Victoria and in collaboration with Claire Ellis Consulting) 2014

- Industry Development Project, Tourism Northern Tasmania 2014
- Destination Management Plan, Southern Tasmania 2013 – 2014
- North Coast Destination Network, DMP Stakeholder Consultation 2013
- Local Tourism Association capacity building (Tourism Tasmania) 2012-2014
- Great Ocean Road Region Print Collateral Review 2013
- Derwent Valley Social, Tourism, Economic and Physical Structure Plan 2013 (creating Preferred Futures - lead consultancy)
- Launceston Travel and Information Centre Review (LCC) 2012
- Local Tourism Association guidelines for development (Tourism Tasmania) 2012
- Marketing King Island (Tourism Tasmania) 2012
- Successful TQUAL Grants submissions 2012
- Southern Tasmanian Regional Tourism Strategy (STCA) 2011-12
- Break O'Day Tourism Development Strategy 2011-12
- Derby Tin Centre Business Case Development (Dorset Council) 2011
- Trail of the Tin Dragon, Marketing and Promotions Strategy (Dorset Council) 2011
- Tasman Tourism Development Strategy 2010
- Innovative Arts-based and Heritage Tourism Experiences for Northern Tasmania 2010
- Marketing the Tasmanian Visitor Information Network 2010
- Bay of Fires Brand Development Strategy 2009
- Food and Beverage Tourism Market Assessment (Tourism Tasmania) 2009
- Rail Tourism Market Assessment (Tourism Tasmania) 2009
- Review of Tasmanian regional tourism infrastructure priorities (Tourism Tasmania) 2009
- Tasmanian Caravan and Holiday Park Product and Analysis (Tourism Tasmania) 2009
- Signature Experiences Development Program (Tourism Tasmania) 2009.

W+I 1

Australian Government
Attorney-General's Department

Tasmanian Government

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NATIONAL PARTNERSHIP AGREEMENT ON NATURAL DISASTER RESILIENCE

TASMANIAN NDRGP/SEMP/EVF

Quarterly Performance Report

Project Name Longford-Hadspen- Flood Risk Study

Funding Recipient: Northern Midlands Council in cooperation with Meander Valley Council

Project Manager: Jonathan Galbraith/Terry Eaton

Reporting period: 30th June 2015

Expected completion date: 31st March 2016

Performance Assessment (use colour wheel below):

1. Brief Project Description
(Include objectives)

The project outputs will enable Council to develop flood plain maps of major communities in the South River catchment for the 20 year, 50 year, 100 year and for the future period 2070 to 2099, 100 year climate change flow estimate. The study will also allow the Council to develop flood evacuation plans in conjunction with the SES and will inform future planning decisions.

The principal objectives of the study are:

- To develop revised flood plain maps for Longford for the 20 year, 50 year, 100 year and for the future period 2070 to 2099, 100 year climate change flow estimate. Other useful flood layer can be provided.
- To develop flood plain maps for Hadspen for the 20 year, 50 year, 100 year and for the future period 2070 to 2099, 100 year climate change flow estimate

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2. Summary of progress and performance for this reporting period

Progress to date:

1. Acquisition of aerial imagery and LIDAR contour information at a cost of $24,200 covering most of the floodplain surrounding Longford has been completed. This contract was an extension of an existing contract run by Northern Midlands Council. Adverse weather conditions caused a significant delay in the delivery of the LIDAR data which was delivered in late May.
2. Bathymetric surveys of specific reaches of the river beds of the lower Meander, South Esk and Macquarie Rivers have been undertaken with Launceston City Councils Spatial Information officers and our project officer using a boat and canoe mounted GPS linked to an echo sounder. The bathymetry is required to enhance the LIDAR information and the combined digital terrain model will be used in the hydraulic flood modelling.
3. The hydrology report produced by Entura the consulting arm of Hydro Tasmaina have bas completed for Hadspen - Longford funded under the Natural Disaster Resilience Grants Program (NDRGP) for a joint project undertaken with North Midland Council with some financial support from Meander Valley Council.
4. Outputs from these hydrological studies will be used as inputs to the 2D hydraulic model which will be constructed for Longford-Hadspen once the LIDAR data has been configured and manipulated. The hydraulic model is being developed by Hydrodynamica Consulting & JMG Pty Ltd by their

joint project engineer Steve Ratcliffe who is also coordinating various spatial data services providers under joint Northern Midlands Council - Meander Valley Council initiative funded through the SES under the Commonwealth Governments NDRGP.

5. Construction of the large Longford - Hadspen 2D model will commence in the new financial year as soon as the processed data is available, we anticipate the data manipulation which includes integration of bathymetric and LIDAR data will be completed by 1/10/2015. This model will provide the required project outputs for Hadspen in the Meander Valley Council and Longford for the Northern Midlands Council. MVC and NMC entered into a joint project in consultation with the SES to exploit synergies between the two projects by building one model for Hadspen and Longford.

6. The overall project has been principally resourced by Tasmanian firms including Hydrodynamica Consulting, JMG Pty Ltd, Esk Mapping, Entura (Hydro Consulting), Woolcott Surveys and LCC's specialist bathymetric surveyors under a Municipal resource sharing agreement. We anticipate that the flood maps and the associated report will be delivered by 31/03/2015.

7. Scoping of ADMS flood warning web site for Longford has been completed by Entura and forwarded to NMC we are now waiting for a Council authorisation to proceed with the ADMS development. The current estimate is under budget but the balance can be used to refine the site and or add more functionality.

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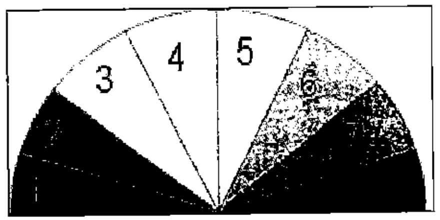
3. Project Status Overview

Key Area	Yes / No	Comments
Scope - *Is the scope of the project consistent with the project plan?*	**Yes**	The project plan outcomes or principal deliverables are flood maps and supporting reports for floodplain mapping work at Longford and Hadspen. The scope of the project in relation to GIS data acquisition, hydrological inputs and the extent of the hydraulic modelling is entirely consistent with the projects deliverables. However the original project as described in the application was only partially funded under the Natural Disaster Resilience Grants Program. The original proposal included automation and upgrading of the Back Creek Floodgate.
Budget - *Is the budget on track?*	**Yes**	The GIS data has now been acquired, hydrological reports completed and the hydraulic modelling and mapping will commence as soon as the LIDAR and bathymetric data have been manipulated and integrated. There have been no cost overruns to date. Full expenditure has not reached anticipated amounts at the present time due to delays encountered through Council's LIDAR data acquisition contract and the late delivery of Entura's Hydrological Report.

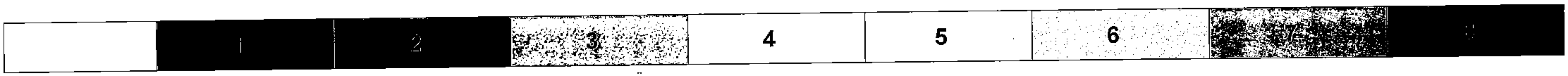
Resources - *Are there any significant resource implications?*	**No**	The project is adequately resourced.
Stakeholders - *Has there been a change to or issues with stakeholders?*	**Yes**	As indicated above the work at Hadspen provided an opportunity to run a jointly funded project with Northern Midlands and Meander Valley Council to achieve outcomes that benefited both Council's while reducing input costs to each Council through cost sharing in the provision of hydrological studies and hydraulic analysis and data gathering.
Schedule - *Has there been a change to the project schedule?*	**Yes**	The nature of the joint project with Northern Midlands Council (NMC) caused the schedule for completion of Meander Valley Council's original project grant to be extended. The difficulties encountered by NMC's LiDAR data acquisition contractor were due to cloud cover which rendered data acquisition impossible. This has caused the schedule to be extended with a completion date in the next financial year.
Risk – *Are there any emerging or significant risks to the project? How will they be addressed?*	**No**	
1_106 **Capital works** – *Details of any capital work carried out to date (photos can be included)*	**Not applicable**	

4. Project Finance			
Total Project Budget:	$	**Budget Spent to Date:**	$
Budget Remaining:	$	**Anticipated expenditure next quarter:**	$

NATIONAL PARTNERSHIP AGREEMENT ON NATURAL DISASTER RESILIENCE



Performance Assessment Model



Projects / Initiatives	Project is not delivering intended results or is significantly behind schedule for more than two reporting periods. Cannot be achieved without significantly modifying the project plan.	Project is not delivering intended results or is significantly behind schedule for two reporting periods or more. Cannot be achieved without a management intervention plan and modifying the project plan.	Project is delivering intended results or is recovering the schedule for more than one reporting period. Management intervention plan has been implemented.	Several challenges in delivering some results to the required standard and has nearly recovered schedule to the required timeframe. Assigned resources and authority levels bedding down and delivering results.	Some challenges in delivering some results to the required standard or timeframe. These are being managed with assigned resources and authority levels.	Few challenges in delivering some results to the required standard or timeframe. These are being managed with assigned resources and authority levels.	There are only a few minor challenges in delivering some results. These are being managed with assigned resources and authority levels.	Results are being delivered to the required standard on time.

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NDRGP Longford-Hadspen Flood Risk Study

Supply of Lidar Data NMC Towns Flood Modelling	$27,714.50	$25,195.00	-$2,519.50	134	Cohen & Associates Pty Ltd	1572	17-Jun-15	9-Jun-15	$59,977.50	Paid	15/06/2015 16:36	56991	E.F.T.	15/06/2015 16:37	gail.murfet	247822
Supply Lidar Data for NMC Towns	$32,263.00	$29,330.00	-$2,933.00	134	Cohen & Associates Pty Ltd	1571	17-Jun-15	9-Jun-15	$59,977.50	Paid	15/06/2015 16:35	56991	E.F.T.	15/06/2015 16:36	gail.murfet	247821
Flood Modelling Date	$121.00	$110.00	-$11.00	3781	Esk Mapping & GIS	3416	17-Jun-15	31-May-15	$121.00	Paid	15/06/2015 14:21	57037	E.F.T.	15/06/2015 14:21	gail.murfet	247622
Longford & Hadspen Hydrology Report	$25,850.00	$23,500.00	-$2,350.00	1114	Hydro Tasmania	514242	28-May-15	30-Apr-15	$25,850.00	Paid	26/05/2015 11:51	56791	E.F.T.	26/05/2015 11:52	gail.murfet	246551
Preparation of Flood Model - Claim 2	$5,940.00	$5,400.00	-$540.00	211	Johnstone McGee & Gandy Pty Ltd	133902	28-May-15	30-Apr-15	$7,634.00	Paid	26/05/2015 11:47	56759	E.F.T.	26/05/2015 11:47	gail.murfet	246548
Preparation of Flood Model	$6,534.00	$5,940.00	-$594.00	211	Johnstone McGee & Gandy Pty Ltd	133615	15-Apr-15	26-Mar-15	$6,534.00	Paid	14/04/2015 11:16	56377	E.F.T.	14/04/2015 11:16	gail.murfet	244266
Lford & Surrounds 2011 Flood Level Survey	$786.50	$715.00	-$71.50	3781	Esk Mapping & GIS	3375	15-Apr-15	31-Mar-15	$786.50	Paid	14/04/2015 11:12	56449	E.F.T.	14/04/2015 11:11	gail.murfet	244264
NMC Flood Modelling Data Management	$665.50	$605.00	-$60.50	3781	Esk Mapping & GIS	3322	11-Feb-15	31-Jan-15	$665.50	Paid	9/02/2015 14:07	55918	E.F.T.	9/02/2015 14:07	gail.murfet	240324
Flood Modelling Services	$3,850.00	$3,500.00	-$350.00	211	Johnstone McGee & Gandy Pty Ltd	132553	19-Nov-14	31-Oct-14	$7,271.00	Paid	18/11/2014 9:48	54984	E.F.T.	18/11/2014 9:49	gail.murfet	236539
Total of Selected Rows	$103,724.50	$94,295.00	-$9,429.50						$168,817.00							

PROJECTED CASH FLOW NORTHERN MIDLANDS FLOOD PLAIN MAPPING PROJECT				
Time line		**Project milestones**		**Notes**
1/11/2015	Actual 1/05/2015	**Milestone 1**: Hydrological report.	$ 22,000.00	Total cost $33,000; $22,000 NMC & $11,000 NMC Entura have been engaged for this part of the project. The Hydrological Report was delivered 5 months late.
		Milestone 2: Acquisition of spatial data and bridge information		
22/01/2015	Actual 20/05/2015	LIDAR	$ 24,200.00	LIDAR data was delivered 3 months late
12/01/2015	6/02/2015	Bathymetric survey (Estimate)	$ 5,000.00	
		Bridge data acquisition		Part of project management
		Terrestrial survey (Bridges and flood marks)	$ 8,000.00	Registered surveyor
01/6/2015	1/10/2015	LIDAR & Bathymetric Data Processing		Esk Mapping/LCC
1/10/2015	31/03/2016	**Milestone 3**: Hydraulic modelling reports, input and project management of flood maps.		Part of project management
1/10/2015	31/03/2016	**Milestone 4**: Flood maps for Longford, Hadspen.	$ 9,000.00	Esk Mapping have been engaged for this part of the project
1/11/2015	30/06/2015	**Milestone 5**: Scoping of ADMS flood warning web site for Longford (and implementation depending on Council authorization to proceed).	$ 6,600.00	Entura's Stream Gauging Dept have been engaged for this part of the project
1/11/2015	31/03/2016	Project Management and Hydraulic Modelling	$ 36,800.00	JMG (S.Ratcliffe) is the PM and principal modeller
		Cash Total	**$ 111,600.00**	
1/11/2015	31/03/2016	In kind	$ 36,300.00	
		Total	**$ 147,900.00**	

Projected cash estimate 21/06/2015

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Hydro Tasmania | The power of natural thinking

Longford and Hadspen Flood Hydrology
Final Report

ENTURA-95886
24 April 2015

Prepared by Hydro-Electric Corporation ABN48 072 377 158
t/a Entura 89 Cambridge Park Drive, Cambridge TAS 7170 Australia

Entura in Australia is certified to the latest version of ISO9001, ISO14001, and OHSAS18001.

Document information

Document title	Longford and Hadspen Flood Hydrology Final Report
Client organisation	Northern Midlands Council/Meander Valley Council
Client contact	Steve Ratcliffe/Jonathan Galbraith/Dino de Paoli
ConsultDM number	ENTURA-95886
Project Manager	William Cohen
Project number	E304794 - P509375

Revision history

Draft 0.0

Revision description	Draft 0		
Prepared by	William Cohen	WCohen	22/1/2015
Reviewed by	Fiona Ling	FLing	22/1/2015
Approved by	Fiona Ling	FLing	22/1/2015
	(name)	(signature)	(date)
Distributed to	Steve Ratcliffe/Jonathan Galbraith/Dino de Paoli (name)	Northern Midlands Council/Meander Valley Council (organisation)	22/1/2015 (date)

Revision 1.0

Revision description	Revision 1		
Prepared by	William Cohen	WCohen	5/3/2015
Reviewed by	Fiona Ling	FLing	5/3/2015
Approved by	Fiona Ling	FLing	5/3/2015
	(name)	(signature)	(date)
Distributed to	Steve Ratcliffe/Jonathan Galbraith/Dino de Paoli (name)	Northern Midlands Council/Meander Valley Council (organisation)	5/3/2015 (date)

Revision 2.0

Revision description	Final		
Prepared by	William Cohen	WCohen	24/4/2015
Reviewed by	Jayson Peterson	Peterson	24/4/2015
Approved by	Jayson Peterson	Peterson	24/4/2015
	(name)	(signature)	(date)
Distributed to	Steve Ratcliffe/Jonathan Galbraith/Dino de Paoli	Northern Midlands Council/Meander Valley Council	24/4/2015
	(name)	(organisation)	(date)

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Executive summary

A review of previous flood studies at Longford and Hadspen has been carried out at the request of Northern Midlands Council and Meander Valley Council. Flood frequency analysis had been undertaken at sites throughout the catchment; results on the Meander were similar to findings from a previous flood study at Deloraine. A flood model of the South Esk has been reinstated from a previous study. This model has been recalibrated at sites on the South Esk River (Perth) and Meander River (Strathbridge), and used to develop flood hydrographs for key reporting sites in the catchment. Model parameters were similar to those found in previous studies for Longford, Deloraine and Trevallyn. Probabilities for concurrent peaks at tributaries of the South Esk were estimated Design flood hydrographs under climate change scenarios have also been produced.

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1. Introduction

Northern Midlands Council and Meander Valley Council have requested design flood hydrographs for sites within the South Esk catchment to be used as inputs to a hydraulic model in this region. This report outlines the review of previous hydrological studies in the area, flood frequency analysis at key sites, the reinstatement and recalibration of a rainfall runoff model to recent recorded flood events, and the use of this model to produce design flood hydrographs under current and future climate scenarios. Concurrent tributary inflow analysis has also been undertaken to estimate annual exceedance probabilities of hydrographs in tributaries to the main stream of the South Esk River.

1.1 Considerations for modelling design flood hydrographs

An important consideration when producing design flood hydrographs from a rainfall-runoff model is the selection of a main reporting site. This is of particular importance for the South Esk catchment as it has a large catchment area, and different reporting sites within the catchment will have considerably different catchment areas.

Output hydrographs have been produced for design floods at Trevallyn, just downstream of Hadspen. Individual design floods for key reporting sites within the catchment will have different shapes and peaks, due to different catchment design rainfall and areal reduction factors.

This study sets the main reporting site at Hadspen/Trevallyn. It is important to note that the flood peak at Longford modelled using a 1% AEP design storm for Hadspen will differ from a 1% flood peak at Longford design storm derived using design storms centred over the Longford catchment. This is discussed further in concurrent tributary inflow analysis (Appendix E).

1.2 Acknowledgements

Thanks are due to Hydro Tasmania Dam Safety for permission to use the Trevallyn/South Esk design event flood model, Hydro Tasmania Wholesale Energy Services (HT) for permission to use hydrometric data, and to the Department of Primary Industry, Parks, Water and Environment (DPIPWE) also for permission to use hydrometric data. Thanks are due to the Bureau of Meteorology (BoM) for permission to use rain gauge data in the South Esk catchment.

Thanks are also to the Tasmanian State Emergency Service (SES) and the Natural Disaster Resilience Grants Program (NDRGP) for funding for this project.

1.3 Note on convention

This report uses the modern style of referring to frequency of storm/flood occurrence as Annual Exceedance Probability (AEP), which is expressed as a percentage; this indicates the probability of a storm/flood being exceeded in any given year. This contrasts with the older terminology of 'average recurrence interval' (ARI), as this term can be slightly misleading. A lookup of the equivalent ARI and AEP is given in Table 1.1.

Table 1.1: ARI – AEP lookup table

ARI	AEP
2	50%
5	20%
10	10%
20	5%
50	2%
100	1%
200	0.5%
500	0.2%

2. Previous studies

Previous flood studies in the South Esk catchment were reviewed. These studies included the Longford Flood Study (Hydro Tasmania 2002), Perth-Longford Flood Plain Study (Wilson 1992) and Deloraine Flood Plain Study (Hydro-Electric Corporation 1997). Hydro Tasmania (2002) focussed on a hydraulic investigation of Longford and its levee system, and provided hydrograph inputs to this study. The upstream boundaries of the hydraulic model were identified as:

- South Esk River at Perth
- Macquarie River at Brumbys Creek
- Back Creek at Longford
- Meander River at Deloraine Bridge

Peak discharges for design events at this site are given in Table 2.1. This 2002 study used design flood hydrographs developed by Parkyn (1994), which were based on work done by Wilson (1992). Hydro Tasmania (2002) found that when the South Esk is in flood, inflows from Back Creek are minimal. Its significance is as hydraulic storage during a flood event.

Table 2.1: Peak discharges for design inflow events in m^3/s (Hydro Tasmania 2002)

AEP	South Esk Peak	Macquarie	Meander
1:20 (5% AEP)	2678	1588	1083
1:50 (2% AEP)	3537	2355	1905
1:100 (1% AEP)	4083	2917	2403

Wilson (1992) gives a flood frequency analysis at Perth, which included significant pre-record floods of 1852, 1863, and 1929. A section of the frequency analysis from a Log Pearson Type III distribution is given in Table 2.2. A different convention of confidence limits is used by Wilson (1992); the reverse of what has been used in this report.

Table 2.2: Flood frequency at Perth from a Log Pearson Type III distribution, adapted from Wilson (1992); a different convention of confidence limits is used here

ARI	Flood Peak (m^3/s)	5% confidence limit	95% confidence limit
10	1623	2170	1214
50	3750	6250	2250
100	5147	9619	2754

The flood study at Deloraine (Hydro-Electric Corporation 1997) presented a rigorous hydrological analysis of design flood on the Meander River at Deloraine. It found a good agreement for design flood peaks from two methods: annual series analysis from at-site records and a rainfall runoff model. Results from the rainfall-runoff model were preferred for larger events. Design peaks from the rainfall-runoff model are given in Table 2.3.

Table 2.3: Design flow peaks (m^3/s) from rainfall runoff analysis for Meander at Deloraine (Hydro-Electric Corporation 1997)

AEP	Meander at Deloraine Design Flow
1:20 (5% AEP)	395
1:50 (2% AEP)	485
1:100 (1% AEP)	555

This study also calibrated a design event flood model to Deloraine. Parameters for this model are given in Table 2.4. The model used by HEC (1997) was developed using Hydrol Modelling, a precursor to Hydstra Modelling used in this study.

Table 2.4: Parameters of Meander design flood model (Hydro-Electric Corporation 1997) used in Hydrol Modelling/Hydstra Modelling

Parameter	Description	Value
α	Channel routing	2.2
m	Channel storage degree of non-linearity	0.8
IL	Initial loss	20 mm
CL	Continuing loss	1.0 mm/hour

The catchment model uses non-linear channel routing, which relates outflow to reach storage using the equation adapted from Kisters (2003) in (2.1).(2.1

$$S = (\alpha * L) * Q^m \qquad (2.1)$$

where:
S = reach storage (m^3)
α = channel routing parameter

L = reach length (km)
Q = outflow (m^3/s)
m = non-linearity parameter; this is given as n by Hydro Tasmania (2003b)

There is a significant discrepancy between results from HEC (1997, see Table 2.3) and Hydro Tasmania (2002, see Table 2.1) for design peaks of the Meander River at Deloraine. Design flood peaks from the Longford study were obtained from design flood hydrographs, from a design event model. Due to this discrepancy, it was decided to undertake a separate calibration for the Meander catchment to the remainder of the South Esk/Macquarie catchments.

Hydro Tasmania (2003b) developed a semi-distributed flood model of the South Esk catchment for the purposes of assessing flood hydrology at Trevallyn Dam. This model is ideally suited for the purposes of producing design flood hydrographs at key locations within the South Esk catchment, and is therefore suitable for use in this study. Calibrated parameters of the South Esk flood model for Trevallyn Dam are given in Table 2.5.

Table 2.5: Parameters of South Esk design flood model (Hydro Tasmania 2003b)

Parameter	Description	Value
α	Channel routing	1.055
n	Channel storage degree of non-linearity	0.8
IL	Initial loss	35 mm
CL	Continuing loss	0.8 mm/hour

A uniform rainfall spatial pattern for AEPs of 1% and more frequent was adopted. For rainfalls rarer than 1% AEP, a defined spatial pattern was used (Hydro Tasmania 2003b). Hydro Tasmania (2003b) used GSAM temporal patterns for AEPs rarer than 1%. For AEPs of 1% and more frequent, unfiltered pre-burst temporal patterns were used for durations of 72 hours and shorter. For the 92 and 120 hour duration events, temporal patterns without pre-burst had been used (Hydro Tasmania 2003b).

3. Data

Streamflow data used in this project was sourced from various agencies. Gauges used in this study are shown in Table 3.1. Catchment areas have been obtained from Hydro Tasmania's HydstraTSM database where this information is available; otherwise areas have been obtained through terrain analysis of the CFEV digital elevation model (DPIW 2006). For database entries that do have catchment areas listed, there is generally good agreement between these values and the CFEV values.

Table 3.1: Gauge sites used in this study

Site ID	Site Name	Location	Custodian	Catchment Area (km^2)	Period of record
18218	Back Creek	Longford	HT	131	1979 - 1990

181	South Esk	ab Macquarie (Perth)	DPIPWE	3278	1956 - current
852	Meander	at Strathbridge	DPIPWE	1012	1985 - current
164	Liffey	Carrick	DPIPWE	224	2009 - current
733	Macquarie River	Cressy Pumps	HT	3764	1985 - current
89[1]	South Esk	Longford	BoM	7143	1999 - current
162	Meander	Deloraine Rail Bridge	HT	474	1996 - current
541	Meander	bl Deloraine Weir	HT	474	1968 - 1996

Site metadata records (DPIPWE 2009) were reviewed to determine the suitability of key sites for flood frequency analysis and potential model calibration. As of 2009 at South Esk at Perth (site 181), 285 gaugings had been undertaken and 16 ratings had been applied to this site. At Meander at Strathbridge (site 852), 116 gaugings had been undertaken and 7 ratings had been applied to this site. Discussions with hydrographers have determined that these sites have several high flow gaugings, and should therefore provide a reliable record for flood estimation purposes.

Data used for flood frequency analysis at Deloraine came from two records:

- Site 541 (Meander River below Deloraine); 1968 - 1996
- Site 162 (Meander River at Deloraine Bridge); 1996 – current

For the purposes of this study, sites 541 and 162 are treated as having the same location and catchment area. These records were merged resulting in a 46 year period of record.

4. Study area

The study area for this project is in the Northern Midlands of Tasmania in the lower South Esk catchment. The towns of interest are Longford (Northern Midlands Council) at the confluence of the South Esk and Macquarie Rivers, and Hadspen (Meander Valley Council) at the confluence of the South Esk and Meander Rivers. The locations of flow gauges within this area are shown in Figure 4.1. Site 541 has the same location as site 162 (see Section 3).

[1] No stage-discharge rating available

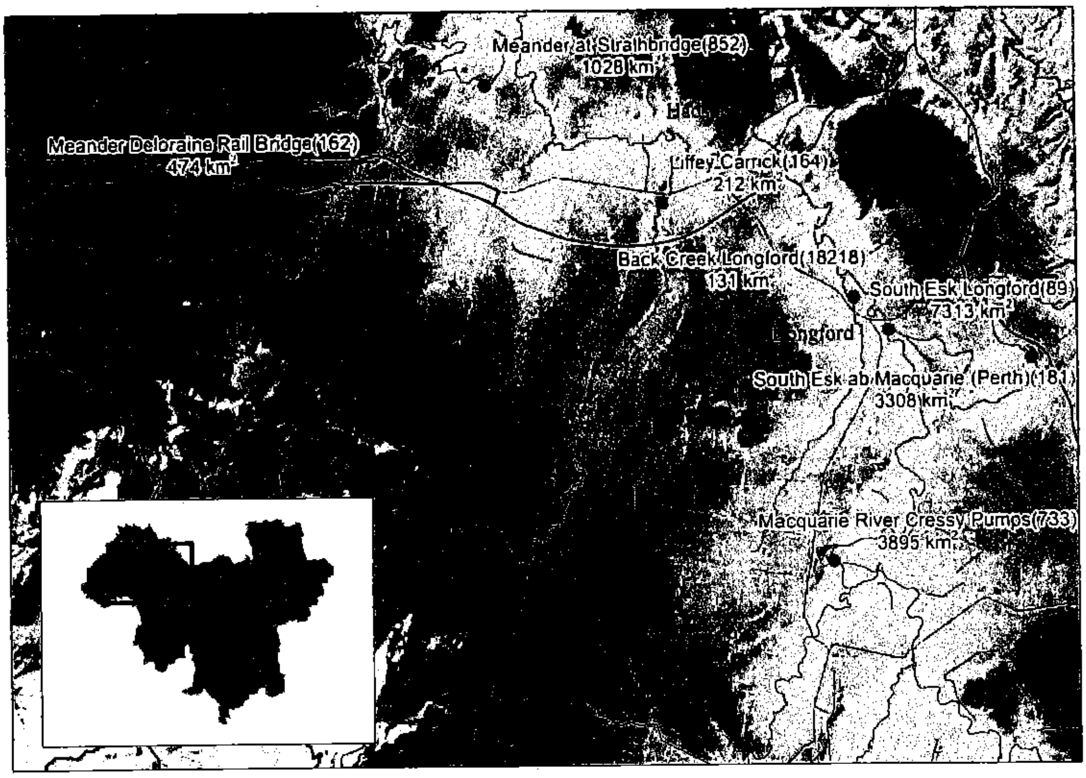

Figure 4.1: Key locations and study area within the South Esk Catchment; the location of site 541 is coincident with site 162

5. Flood frequency analysis

Flood frequency analysis was required at three sites: Meander River at Deloraine, South Esk at Longford and Meander River at Strathbridge. The gauged site at South Esk at Longford had no suitable rating available, so no flood frequency analysis was undertaken at this site.

5.1 Meander River at Deloraine

An annual series (Engineers Australia 1998) was created from records at sites 541 and 162 (catchment area 474 km^2) with a combined period of record of 46 years. Flike software (University of Newcastle 2013) was used to fit several distributions to this series using L2 moments and Bayesian methods. A GEV (generalised extreme value) distribution fitted with L2 moments was determined to be a suitable fit. This distribution is plotted in Figure 5.1 and results are presented in Table 5.1. The values show good agreement with peaks obtained from HEC (1997), with all peaks from the 1997 study falling within the given confidence limits.

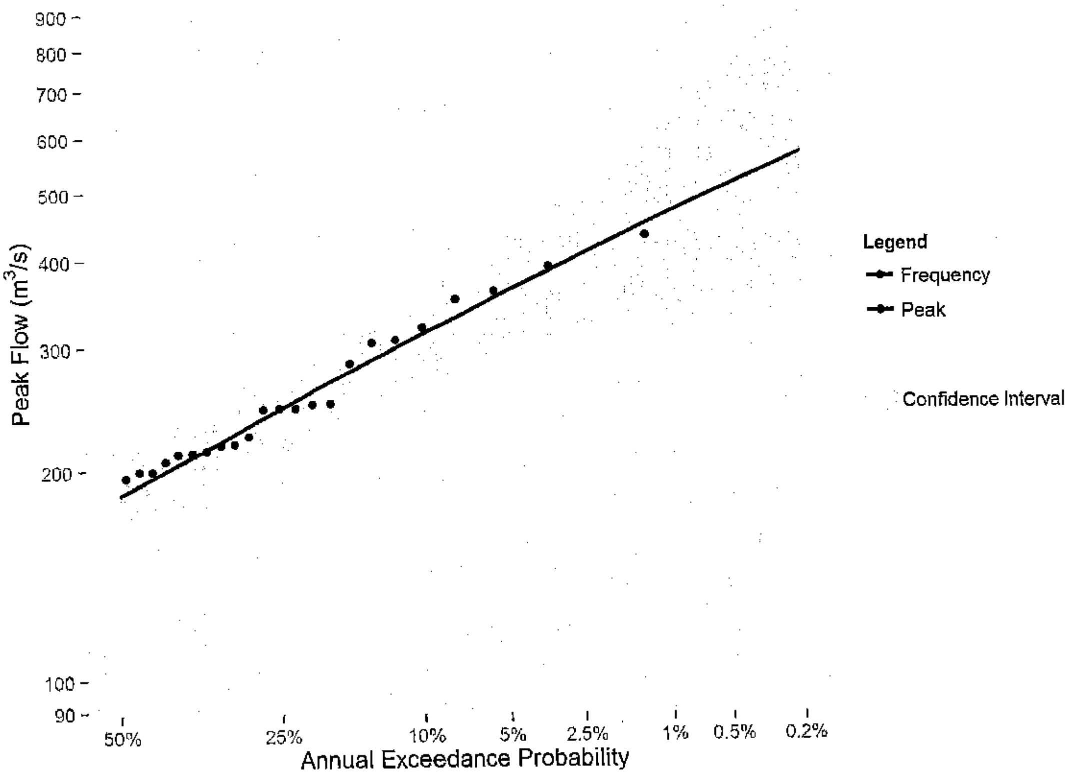

Figure 5.1: Flood frequency on the Meander River at Deloraine

Table 5.1: Flood quantiles for Meander River at Deloraine from a GEV distribution fitted using L2 moments compared with results from HEC (1997) where available; values in m^3/s

		Confidence limits (m^3/s)		
AEP	**Peak (m^3/s)**	**5%**	**95%**	**HEC 1997 Peaks (m^3/s)**
50%	184	160	211	
20%	262	225	302	
10%	312	265	364	
5%	360	296	430	395
2%	421	326	534	485
1%	466	343	632	555
0.5%	510	356	751	
0.2%	567	368	943	

These results are consistent with those found by the Hydro-Electric Corporation (1997). Note that the Meander Dam was commissioned part way through the period of record of Meander River at Deloraine. The dam has a considerable catchment area (156.3 km^2) compared with the catchment area at Deloraine (474 km^2). The impact of this dam has not been considered in the flood frequency analysis because there was no discernable difference in the flood characteristics from visual inspection of the hydrograph record.

An additional check for significance of the dam on floods at key downstream locations was made by comparing the volume of the dam at full supply level (FSL, 42.8 Mm^3, see Table A.1), with the volume at Deloraine of the 1% AEP design event (at Trevallyn) for a 24 hour storm (in the first 48 hours of storm runoff), 113,223 Mm^3. The ratio of the dam capacity to storm runoff volume was 0.04%, which is a negligible contribution to storm volume. As such, it was decided to proceed without additional investigation into the significance of Meander Dam.

5.2 Macquarie River at Cressy Pumps

Hydro Tasmania maintains a gauge on the Macquarie River at Cressy Pumps (site 733, catchment area 3764 km^2). It is understood that this site has a good rating, with gaugings at the high end (L. Salkeld pers. Comms 9 April 2015). This site has 30 years of record. A flood frequency curve was produced by fitting a GEV distribution using L2 moments. This curve is shown in Figure 5.2, and quantiles are provided in Table 5.2. The plot shows that the curve has a poor fit over the six largest flood events, which show a much lower rate of increase in the plotting space. However, the adopted GEV distribution provides the best fit compared to all other distributions that are recommended for use in Australian river systems. Therefore the curve is deemed appropriate.

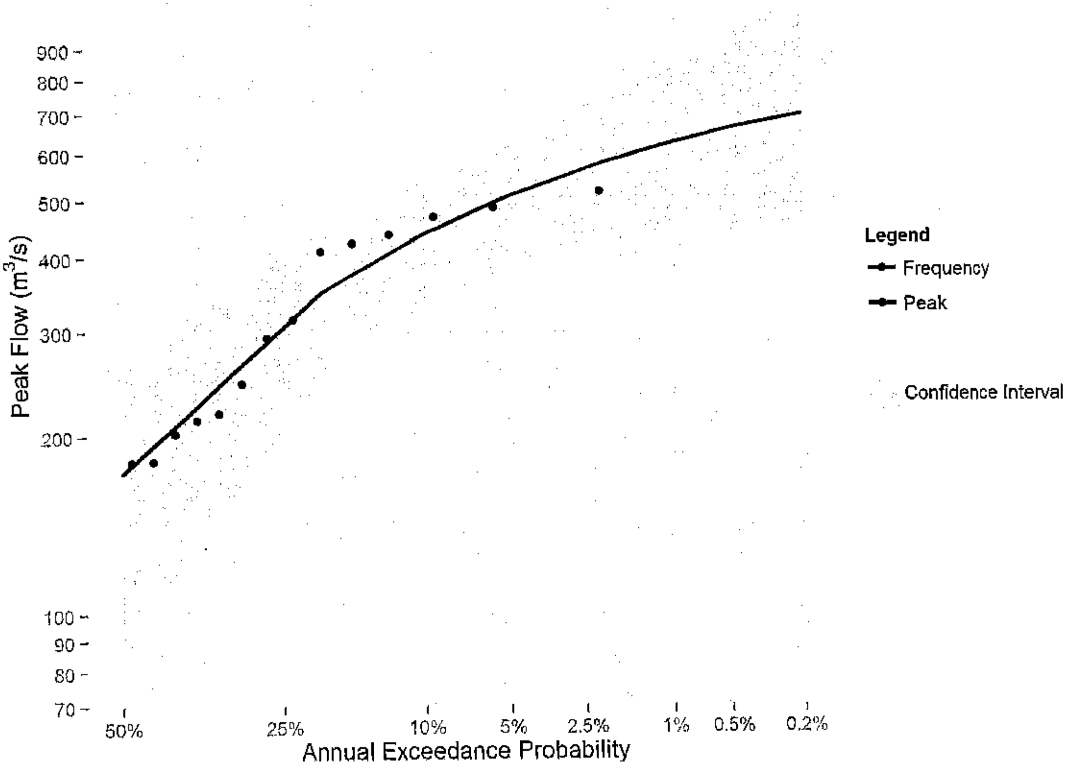

Figure 5.2: Flood frequency on the Macquarie River at Cressy Pumps; a GEV distribution fitted with L2 moments

There is a possibility that this site is susceptible to backwater effects at the high end, though the high gaugings should alleviate this concern somewhat. If this were the case, it is expected that the highest annual peaks would be proportionally lower, making for a worse fit of the GEV distribution.

Table 5.2: Flood quantiles for Macquarie River at Cressy Pumps from GEV distribution fitted using L2 moments

		Confidence limits (m^3/s)	
AEP	**Peak (m^3/s)**	**5%**	**95%**
50%	172	89	259
20%	347	250	442
10%	436	329	535
5%	505	383	618
2%	577	422	732
1%	620	438	828
0.5%	655	449	935
0.2%	692	456	1089

5.3 Meander River at Strathbridge

The Department of Primary Industries, Parks, Water and the Environment (DPIPWE) maintain a gauge on Meander at Strathbridge (site 852, catchment area 1012 km^2) with a record from 1985 – current. An annual series of 28 years was extracted from this record and distributions were fitted using the Flike software. A Generalised Extreme Value (GEV) distribution fitted with L2 moments was found to give a suitable fit (plotted in Figure 5.3 and results in Table 5.3).

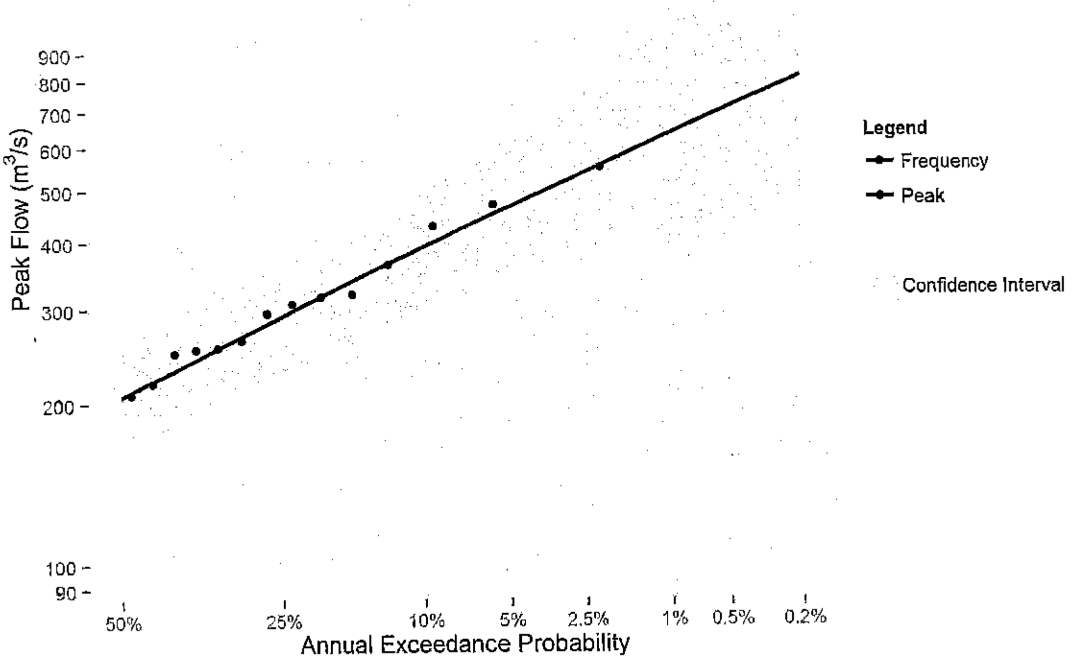

Figure 5.3: Flood frequency on the Meander River at Strathbridge

Table 5.3: Flood quantiles for Meander River at Strathbridge from GEV distribution fitted using L2 moments

		Confidence limits (m^3/s)	
AEP	**Peak (m^3/s)**	**5%**	**95%**
50%	205	163	255
20%	315	248	393
10%	390	300	492
5%	463	341	605
2%	560	377	799
1%	634	395	1004
0.5%	709	408	1271
0.2%	810	420	1754

Note that the Meander Dam was commissioned part way through the period of record of Meander River at Strathbridge. The dam has a considerable catchment area (156.3 km^2) compared with the catchment area at Strathbridge (1012 km^2), though is less significant than at the Deloraine site. The impact of this dam has not been considered in the flood frequency analysis.

5.4 South Esk River at Perth

DPIPWE's gauge at South Esk at Perth (site 181) has a considerable period of record of 57 years. The catchment area at this site is 3278 km^2. The flood frequency curve was developed using a GEV distribution fitted with L2 moments (see Figure 5.4 and Table 5.4). A gauging was made at around the second largest event on record, during March 2011 (pers. Comms K. Adams 13 April 2015). This additional gauging did not affect the rating for this site by much, indicating that the site already had a rating suitable for observing high level flows.

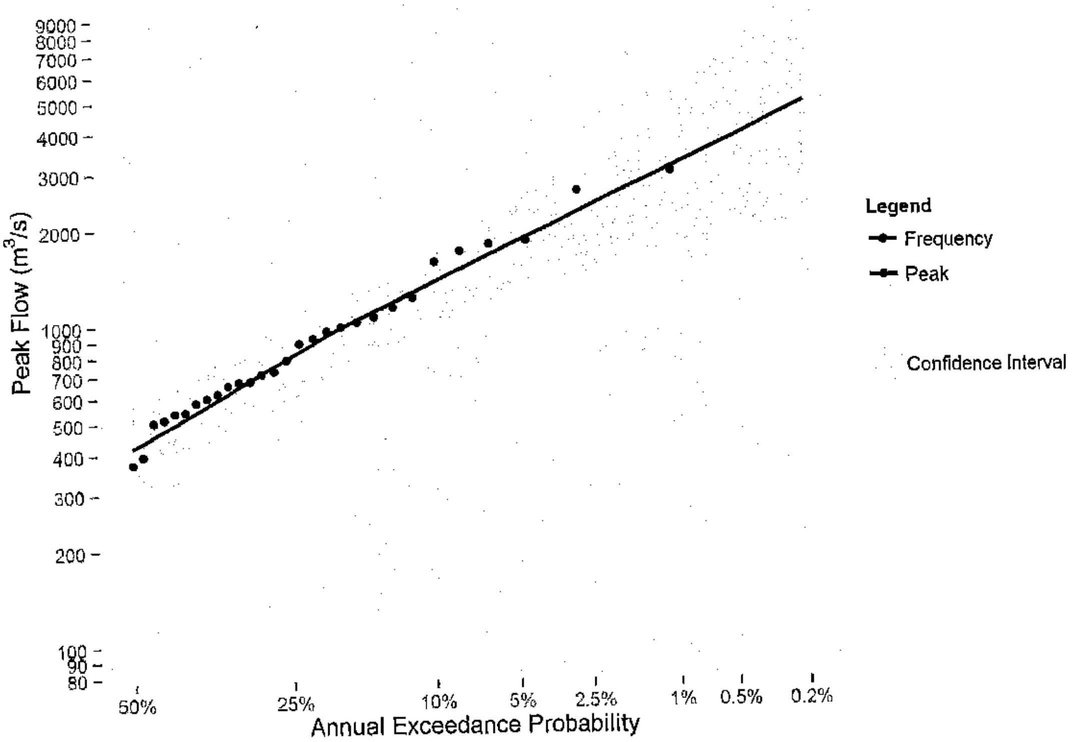

Figure 5.4: Flood frequency at South Esk at Perth (GEV distribution fitted with L2 moments)

Table 5.4: Flood quantiles for South Esk at Perth from GEV distribution fitted using L2 moments; compared with results from Wilson (1992) where available; values in m^3/s

		Confidence limits (m^3/s)		Wilson 1992 Peaks (m^3/s)
AEP	Peak (m^3/s)	5%	95%	
50%	418	291	566	
20%	937	697	1224	
10%	1350	989	1773	1623
5%	1807	1256	2470	
2%	2501	1559	3796	3750
1%	3110	1752	5274	5147
0.5%	3805	1923	7310	
0.2%	4878	2118	11347	

5.4.1 Comparison with Wilson (1992)

A comparison plot with the flood frequency derived from Wilson (1992, also see section 2, Table 2.2) is given in Figure 5.5. The differences in these studies are explained by the different methods used (including the incorporation of the large historic events by Wilson), different distributions fitted, and different periods of record.

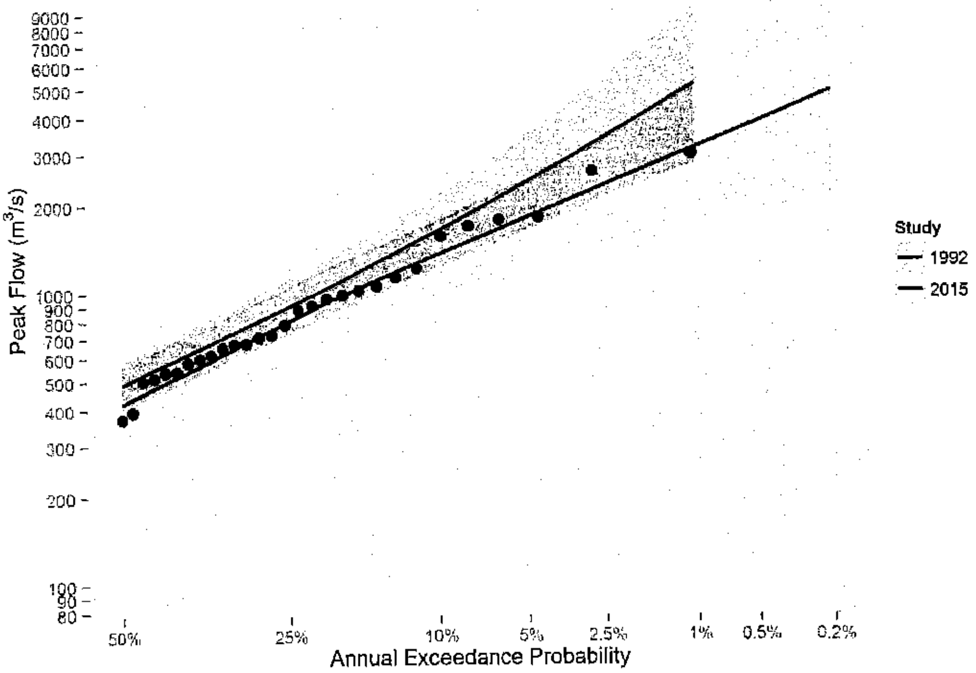

Figure 5.5: Comparison between flood frequency distributions at Perth: Wilson (1992, Log Pearson Type III distribution, including large pre-record events) and the current study (labelled as '2015', GEV distribution fitted with L2 moments). The annual series (black dots) peaks and plotting positions relate to the current study and distribution only

5.5 Back Creek at Longford

Hydro Tasmania's flow gauge at Back Creek at Longford (site 18218) has 9 years of usable data to produce an annual series. This is generally considered to be a short period of record for deriving flood frequency; it is always desirable to have at least 10 to 15 years of recorded flows (Engineers Australia 1998a). As such, uncertainty for discharge peaks at less frequent AEPs will be significant. A Generalised Pareto distribution fitted with the Bayesian method was found to provide a good fit for the annual series (see Figure 5.6 and Table 5.5).

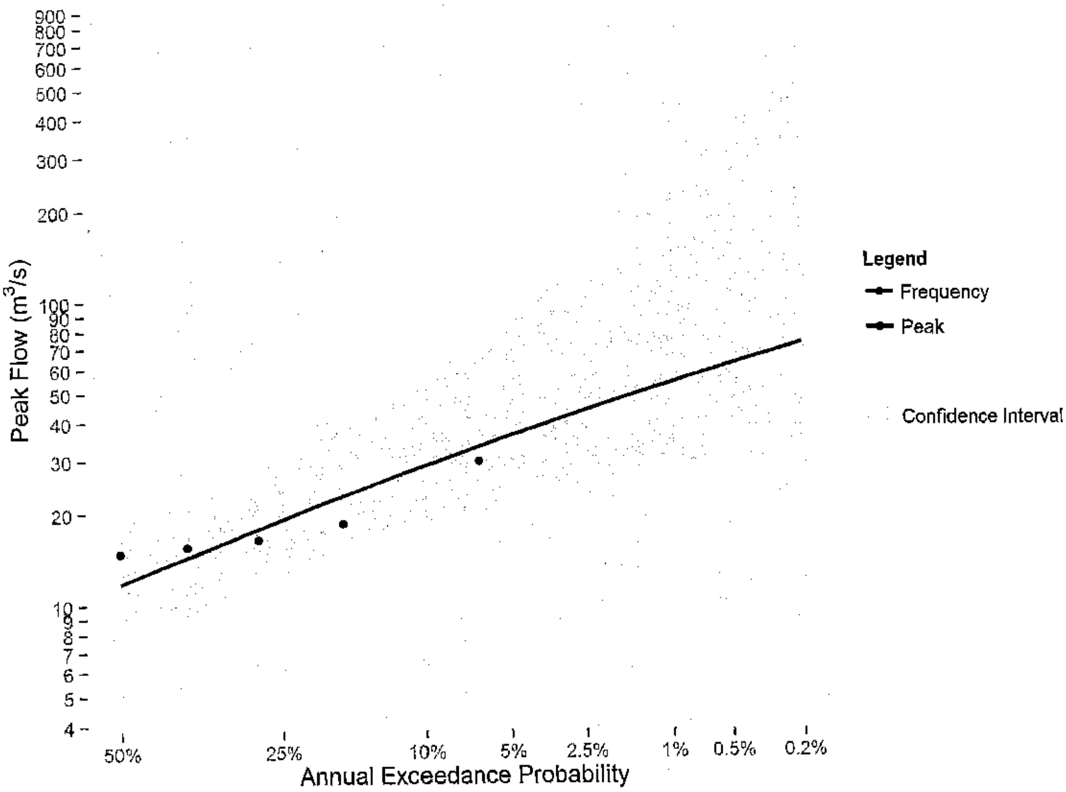

Figure 5.6: Flood frequency for Back Creek at Longford (Generalised Pareto Distribution fitted with the Bayesian method)

A search was made to find suitable sites nearby that had longer periods of record; however none were found that could provide a significant improvement on the results obtained from the at-site record. As Back Creek is not expected to contribute significantly to any flood events in the South Esk River (Section 2, Hydro Tasmania 2002), it was decided use the at-site flood frequency for this project.

Table 5.5: Flood quantiles for Back Creek at Longford from Generalised Pareto distribution fitted using the Bayesian method

		Confidence limits (m^3/s)	
AEP	**Peak (m^3/s)**	**5%**	**95%**
50%	12	7	18
20%	21	14	36
10%	29	19	55
5%	36	22	85
2%	46	26	156
1%	53	28	237
0.5%	61	30	367
0.2%	72	32	639

6. South Esk flood hydrology model

Hydro Tasmania's flood model for Trevallyn Dam (Hydro Tasmania 2003b) was reinstated for the purposes of this study. This model is an initial loss/continuing loss flood model for the South Esk catchment and is ideally suited to deriving peak flood estimates and hydrographs for a range of design storm durations and annual exceedance probabilities. Hydro Tasmania (2003b) outlined model assumptions specific to the South Esk model, summarised as follows:

- The Arthur's Lake catchment is not included in the model, as its storage capacity is large in terms of its catchment area, and it is not anticipated that it will spill in modelled events
- Outflow from Poatina Power Station is not modelled, as its historic average discharge of approximately 30 m^3/s is assumed insignificant for large events in the South Esk catchment
- Additional baseflow into the Hadspen Basin (at the Liffey confluence on the Meander River, approximately 4.5 km upstream of the South Esk catchment) has been determined to be 60 m^3/s
- The Hadspen Basin, downstream of Hadspen, is modelled as a storage to account for the observed attenuation in flood peaks

The 2003 model was modified to include the Meander Dam storage in the upper reaches of the Meander River. This storage has a catchment area of 156.3 km^2, and is modelled with starting storage at full supply level (FSL). Storage and spillway ratings for Meander Dam were obtained from Hydro Tasmania Consulting (2006).

The original model had a spatial pattern for events less frequent than 1% AEP. During calibration, this introduced inconsistencies in results (ie 1% AEP peaks were greater than peaks for 0.5% and 0.2% AEPs); therefore an additional change to the model has been to adopt uniform spatial rainfall patterns for all modelled events.

Due to the differences in calibrated model parameters for the Deloraine flood study and the Longford flood study discussed in Section 2, the calibration of this model was performed at two sites: South Esk at Perth and Meander River at Strathbridge.

6.1 Modelling approach

The sites of interest for this study are Longford and Hadspen, which have significantly different catchment areas (approximately 7000 km^2 and 9000 km^2 respectively) and catchment centroids. Accordingly, flood studies unique to each of these sites will have different point rainfall intensity, areal reduction factors and design rainfall depths. Two approaches for determining inflow design flood hydrographs for Longford and Hadspen were considered:

- Unified model of the whole catchment
- A separate targeted model over the Longford subcatchment with concurrent tributary inflow calculations for downstream tributaries

After careful consideration, it was decided to proceed with the unified model of the whole catchment for both townships. Though this approach results in lower inflow peaks for Longford (lower by approximately 7% - 10%), it has been adopted for the following reasons:

- It is assumed that a more homogenous catchment response would be more representative than the statistical ARR concurrent tributary inflows for the South Esk
- The already conservative approach from some factors (including Macquarie calibration against flood frequency curve at this site) should compensate for the reduction in inflow peaks
- Although inflow peaks at Longford are lower when using a unified model approach, the concurrent flood peak from the Meander River is higher; this may cause more significant backwater impacts, therefore compensating for the reduced inflows.
- The maintenance of a single model makes it easier to ensure that consistent results can be provided.

Concurrent tributary analysis was conducted, but since the unified model approach has been adopted, it is not required. Information relating to this has been included in Appendix E.

6.2 Design rainfall

The South Esk flood model (Hydro Tasmania 2003b) used point rainfall depths averaged across the catchment, obtained from the FORGE Viewer (Hydro Tasmania 2003a). This provides design rainfall depths for durations between 24 hours and 120 hours and AEPs between 1:50 (2% AEP) and 1:2000 (0.05%).

Areal reduction factors based on catchment area were then used to produce catchment design rainfalls.

Rainfall depths were then extrapolated in log space to AEPs more frequent than 2%. For the calibration at the Meander River site, rainfall depths were also extrapolated to durations shorter than 24 hours.

This method was used to derive design rainfalls for calibration at both sites (South Esk at Perth and Meander River at Strathbridge), as well as for the full catchment for hydrograph output. Catchment boundaries were obtained from GIS.

6.3 Design storm temporal patterns

Pre-burst temporal patterns were taken from the Trevallyn flood model (Hydro Tasmania 2003b) and were used for all calibration and hydrograph production events for durations of 72 hours or less. No pre-burst pattern had been added to the 96 and 120 hour duration temporal patterns, as used in the original model (Hydro Tasmania 2003b, Section 2).

Several durations were found to contain 'embedded storms' at specific AEPs; that is, for a given AEP, a long duration rainfall contains a burst that exceeds the design rainfall depth of a shorter duration at the same AEP. This is an issue for modelling, as it directly contradicts the IFDs supplied by the Bureau of Meteorology. These temporal patterns have been filtered to remove these embedded storms as shown in Figure 6.1.

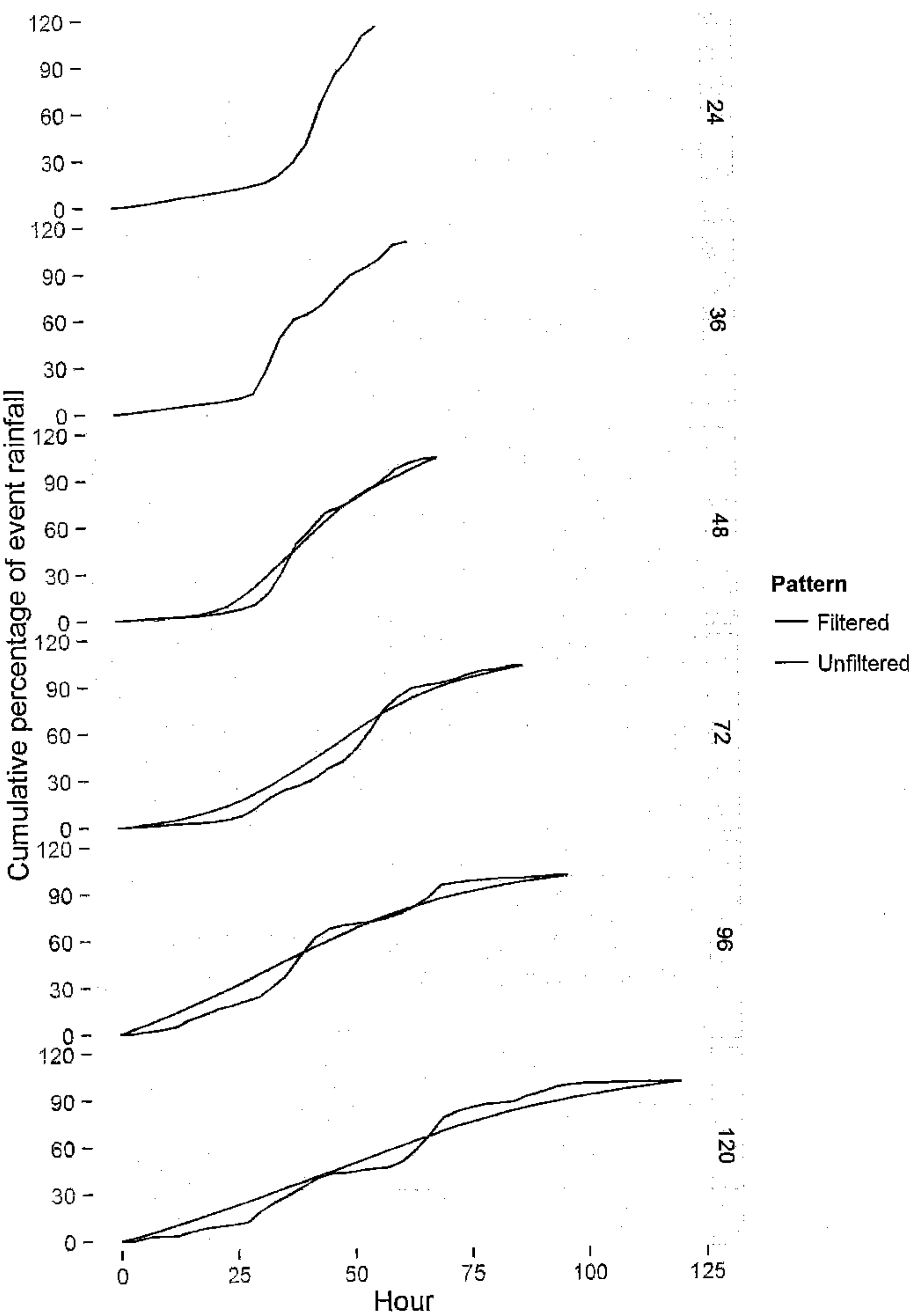

Figure 6.1: Filtering of temporal patterns for longer durations. Note temporal patterns exceed their nominated duration and 100% of storm depth: this is a feature of the pre-burst temporal patterns and is addressed in the calibration of the initial loss parameter of the model

6.4 Model calibration at South Esk at Perth

It has previously been determined that the record at South Esk at Perth (site 181) is suitable for flood model calibration (Section 3). The model was therefore recalibrated at this site. The recalibration involved a two-step process:

1. Event calibration, to determine the alpha (channel routing attenuation) parameter of the model
2. Calibration to the flood frequency derived from observed records, to determine the initial loss and continuing loss parameters of the model

The non-linearity parameter (m, n, refer Section 2) was fixed at 0.8.

6.4.1 Event calibration

Six events from the flow record at South Esk at Perth (site 181) were used to determine the alpha parameter for the model. Observed rainfall records were taken from rain gauges upstream of the site at Perth. These rain gauges are shown in Figure 6.2 and Table 6.1. The hydrographs for these event calibrations are given in Appendix C, Figure C.1.

Table 6.1: Rain gauges used for calibration of the South Esk model

Site	Name	Custodian
150	South Esk at Llewellyn	HT
1746	Gray	BoM
997	Mt Victoria	BoM
18506	South Esk at Mathinna	BoM
2000	Upper Esk	BoM

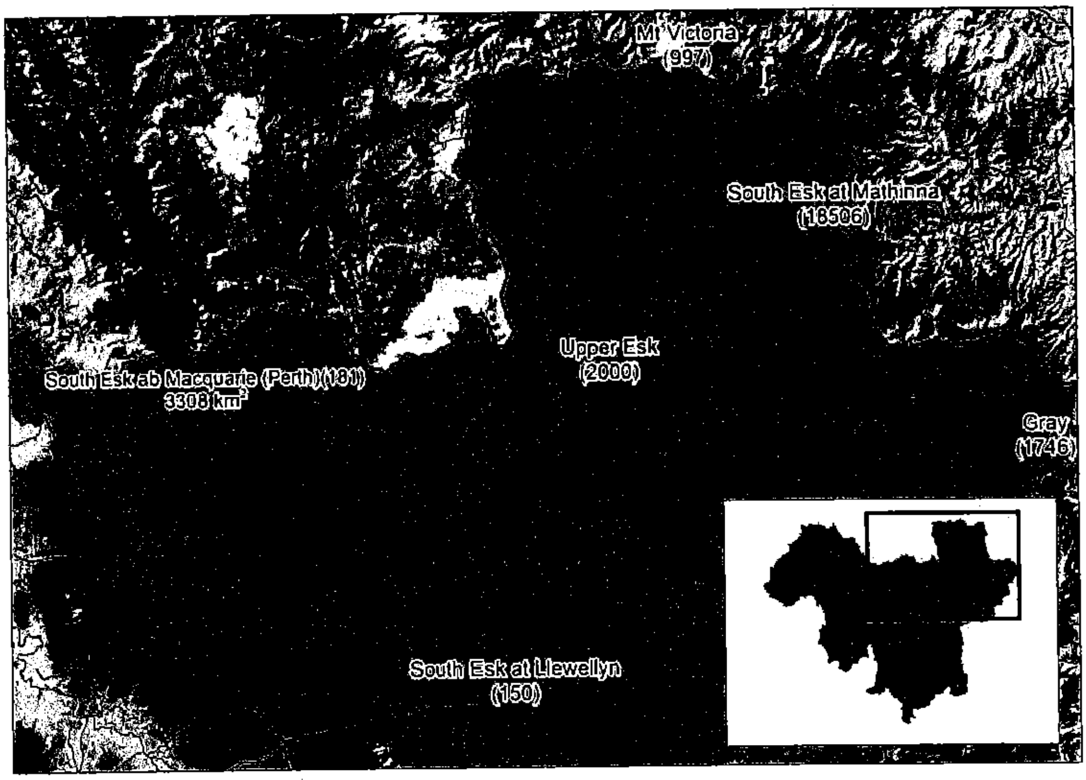

Figure 6.2: Map of rain gauges used for calibration. Area upstream of calibration site 181 at Perth is shaded

The results of this calibration are presented in Table 6.2 and hydrographs for these events are given in Figure C.1. The calibration for event 5 was determined to be unacceptable. The other events were accepted and were used to determine an appropriate value of alpha of **1.055**. This is the same as when the model had previously been calibrated for Trevallyn design flood events (Hydro Tasmania 2003b); see Section 2, Table 2.5.

Table 6.2: Performance statistics of model event calibration at South Esk River at Perth (site 181)

	Parameter	Event 1	Event 2	Event 3	Event 4	Event 5	Event6
Event perio	Start	30/5/1969	21/3/2011	5/8/2011	27/1/2004	11/8/2009	20/8/2003
	End	5/6/1969	30/3/2011	16/8/2011	5/2/2004	17/8/2009	30/8/2003
Performance statistics	obs_avg	803.39	381.11	239.99	231.86	303.42	187.46
	mod_avg	711.62	408.85	187.73	227.42	327.01	142.81
	Bias	0.89	1.07	0.78	0.98	1.08	0.76
	r-sq	0.92	0.89	0.91	0.69	0.17	0.94
	obs_peak	2941	2577	1231	1205	1118	1048
	Mod_peak	2930	2583	1218	1286	1348	1051
	% diff peak	0.39	-0.25	1.09	-6.74	-20.62	-0.34
Calibration parameters	Alpha	1	1.055	1.3	1.055	0.8	1.055
	IL	35	35	80	100	0	37
	CL	2.1	2.8	0.85	4	0	0.8
	BaseFlow	0	0	0	0	25	0

Events 3 and 4 have particularly high initial losses, indicating that the catchment should be relatively dry prior to the events. The rainfall in the 30 days leading up to the calibration events is given in Figure 6.3. The immediate lead up to events 3 and 4 is quite dry, indicating a high initial loss would be appropriate. This is in contrast with event 5 which has some rainfall immediately prior to it, supporting the initial loss value of 0 mm for this event.

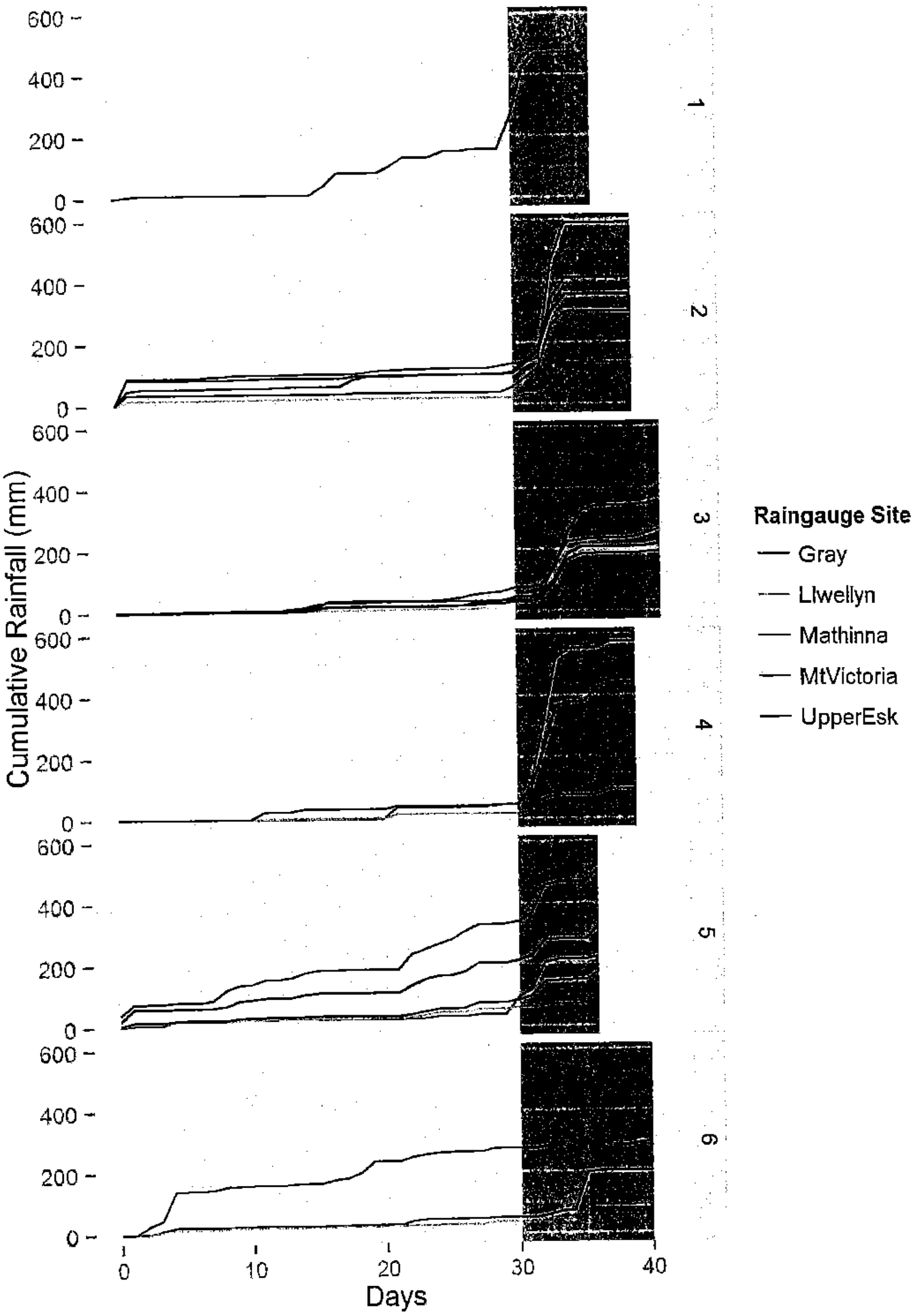

Figure 6.3: Catchment rainfall in the 30 days leading up to the calibration events. Event numbers are on the side (1-6); the shaded area is the event being calibrated

6.4.2 Flood frequency calibration

Design rainfalls for the flood frequency calibration were obtained using the method outlined in Section 6.2 and are presented in Table 6.3.

Table 6.3: Design rainfall depths (mm) used for the frequency calibration at South Esk at Perth by AEP and Duration. Extrapolated values are in grey.

AEP	24	36	48	72	96	120
50%	63.5	77.9	88.2	105.1	113.5	120.7
20%	75.9	92.3	103.8	122.6	131.5	138.8
10%	86.8	104.8	117.4	137.7	146.9	154.3
5%	99.3	119.2	132.8	154.8	164.2	171.6
2%	118.7	141.1	156.3	180.6	190.3	197.4
1%	135.7	160.4	176.8	202.9	212.6	219.5
0.5%	154.1	180.7	198.3	226.1	235.6	242.2
0.2%	181.2	210.0	228.8	258.4	267.2	273.0

A flood frequency was fitted to the record at site 181 (South Esk at Perth, see section 5.4), and the initial loss and continuing loss parameters of the South Esk model were calibrated so that flood peak quantiles at that site matched the observed flood frequency as closely as possible. A visual fit was used to achieve this (Figure 6.4). Loss parameters differed to those provided by Hydro Tasmania (2003) (see Table 6.4).

Table 6.4: Loss parameters for South Esk model excluding the Meander River

Parameter	Value
Initial loss	25 mm
Continuing loss	0.8 mm/hour

These loss parameters are similar to those derived when the South Esk model was calibrated for Trevallyn design flood events (Hydro Tasmania 2003b); see Section 2, Table 2.5.

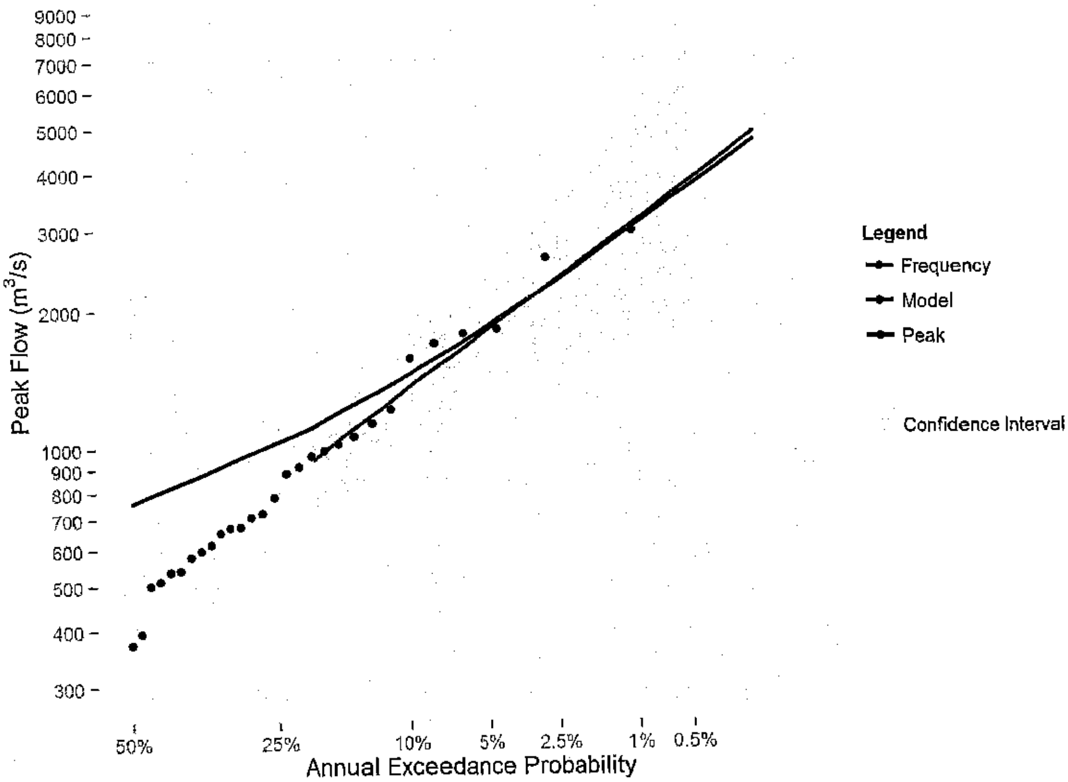

Figure 6.4: Frequency calibration of South Esk model at South Esk at Perth (site 181)

Though the frequency calibration does not give a good fit at the 50% and 20% AEPs, there is a good fit for storms less frequent than 10%. Note that rainfall depths used in the calibration of the South Esk model differ from the rainfall depths used for producing hydrographs. This is because the catchment area of site 181 is substantially less than the catchment area of Trevallyn, resulting in lower areal reduction factors, meaning rainfall depth is higher when used for calibration. Model calibration at Meander at Strathbridge

As there were differences in model parameters for the Deloraine (Meander River) and Longford (South Esk and Macquarie Rivers) flood studies (see Section 2), it was decided to perform a separate calibration at the Meander at Strathbridge site. This site had previously been found suitable for flood model calibration (Section 3). For this calibration, no changes were made to the modelling of the Meander Dam Storage, as the volume of the storage was found to be negligible when compared with the runoff volume of a 1% AEP event (Section 5.1).

6.5 Model calibration at Macquarie at Cressy Pumps

A separate calibration, undertaken for the Macquarie subcatchment, is outlined in the following sections.

6.5.1 Event calibration

Seven events were used in the calibration of the Macquarie River section of the model, outlined in Table 6.5.

Table 6.5: Performance statistics of model event calibration at Macquarie River at Cressy Pumps (site 733)

	Parameter	Event 1	Event 2	Event 3	Event 4	Event 5	Event6	Event 7
Event period	Start	05/08/2011	9/8/2009	22/12/1993	22/09/1998	29/08/2005	22/08/2003	28/7/1996
	End	15/08/2011	18/8/2009	03/01/1994	27/09/1998	5/9/2005	29/08/2003	10/8/1996
Performance statistics	obs_avg	16.01	40.10	122.01	161.96	132.38	52.70	37.23
	mod_avg	15.00	43.88	90.01	146.51	161.84	60.80	43.20
	Bias	0.94	1.09	0.74	0.90	1.22	1.15	1.16
	r-sq	0.94	0.81	0.97	0.89	0.87	0.76	0.77
	obs_peak	510.29	481.81	465.06	433.38	420.53	402.90	311.41
	Mod_peak	504.55	427.25	493.95	369.90	412.39	416.77	312.35
	% diff peak	1.12	11.33	-6.21	14.65	1.94	-3.44	-0.30
Calibration parameters	Alpha	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	IL	12	12	20	5	10	10	0
	CL	0	0	0.2	2.3	2.1	2	0.8
	BaseFlow	15	30	0	25	10	15	20

Five rain gauges were used in the event calibration for Macquarie, given in Table 6.6. A map of these rain gauges is given in Appendix D, Figure D.1.

Table 6.6: Additional rain gauges used for calibration at Macquarie at Cressy Pumps

Site	Name	Custodian
687	Tooms Lake	BoM
259	Macquarie River at Morriston	BoM
1009	Palmerston	HT
941	Great Lake East	HT
597	Pine Tree Rivulet at Lake Highway	HT

6.5.2 Flood frequency calibration

Design rainfalls for the flood frequency calibration were obtained using the method outlined in Section 6.2 and are presented in Table 6.7.

Table 6.7: Design rainfall depths (mm) used for the frequency calibration at Macquarie at Cressy Pumps by AEP and Duration. Extrapolated values are in grey.

AEP	24	36	48	72	96	120
50%	50.4	63.6	70.4	81.4	87.7	91.5
20%	59.8	73.8	81.6	94.0	100.7	105.0
10%	68.1	82.7	91.3	104.8	111.9	116.5
5%	77.5	92.7	102.0	116.9	124.3	129.3
2%	92.0	107.7	118.3	135.0	142.8	148.4
1%	104.8	120.6	132.3	150.6	158.6	164.7
0.5%	118.7	134.1	146.7	166.4	174.6	181.4
0.2%	138.7	152.5	166.4	188.0	196.2	204.4

The flood frequency calibration was performed to match modelled flood quantiles to the flood frequency curve at Meander at Strathbridge (Figure 6.6).

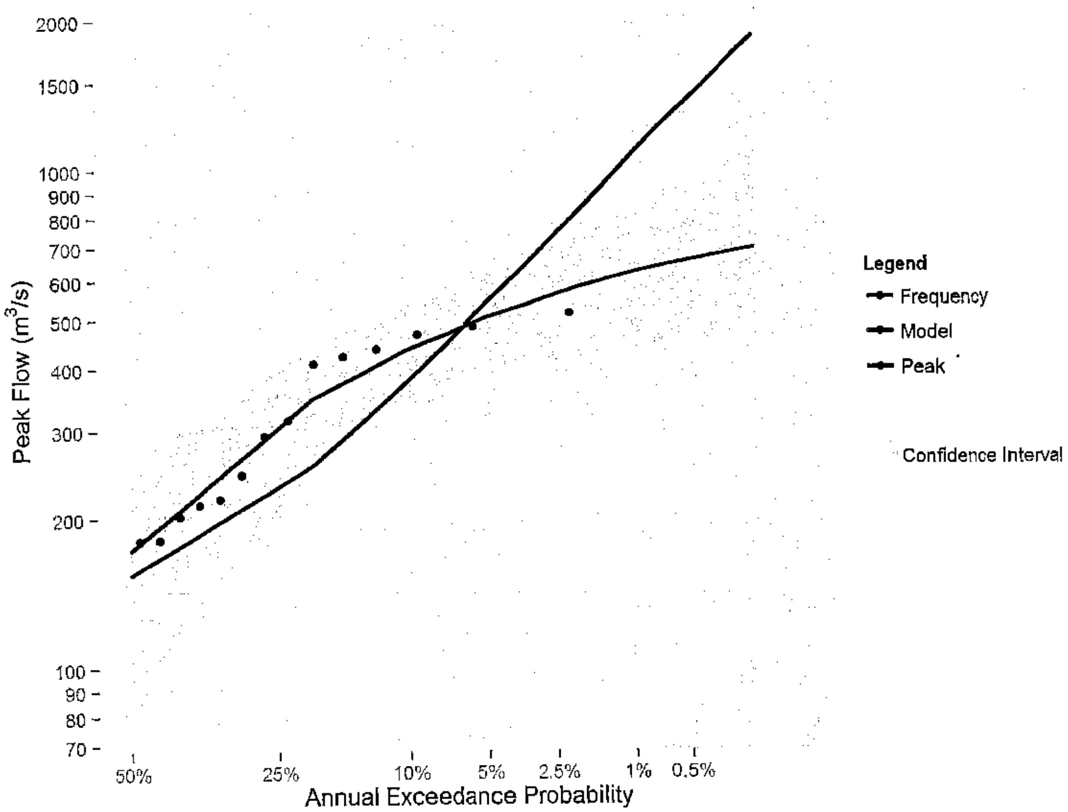

Figure 6.5: Frequency calibration at Macquarie River at Cressy Pumps (site 733)

There is a poor fit between the flood frequency curve and the model calibration, particularly at the high end. No combination of rainfall losses (IL and CL) could improve the fit to the frequency curve. Discussions with hydrographers suggest that this site has a good rating, including a recent flood gauging (2011). The discrepancy between the model and the at-site record could be due to a number of factors, including:

- The possibility that more flood gaugings would affect the rating at this site, especially given the vast wetted cross section of this location when in flood
- The suitability of the design flood modelling assumptions and inputs including:
  - catchment averaged FORGE rainfalls for the Macquarie River,
  - the suitability of the temporal patterns used,
  - a uniform spatial pattern in the modelling approach

A decision was made to adopt rainfall loss parameters which are near the upper bound of the range of values used during event calibration. An alternative consideration of scaling back the modelled design flows in the Macquarie to match the measured flood frequency was not chosen as it is less conservative. The adopted parameters for the Macquarie catchment of the model are given in Table 6.8.

Table 6.8: Calibrated model parameters for Macquarie catchment

Parameter	Value
Initial loss	20 mm
Continuing loss	2.0 mm/hour
α	1.5

6.6 Model calibration at Meander at Strathbridge

The model had a separate event/frequency calibration for the Meander subcatchment, which is outlined in the following sections.

6.6.1 Event calibration

Seven events were selected from the Meander at Strathbridge record to calibrate the alpha (channel lag) parameter (Table 6.9). The hydrographs for these event calibrations are given in Appendix C, Figure C.3.

Table 6.9: Performance statistics of model event calibration at Meander River at Strathbridge (site 852)

	Parameter	Event 1	Event 2	Event 3	Event 4	Event 5	Event6	Event 7
Event period	Start	22/09/1998	30/8/2005	08/10/1992	18/07/2000	01/05/1997	28/07/1996	04/09/2010
	End	28/09/1998	05/09/2005	14/10/1992	28/07/2000	11/05/1997	08/08/1996	14/09/2010
Performance statistics	obs_avg	217.88	217.20	181.34	112.55	27.66	58.99	105.16
	mod_avg	194.47	234.48	177.54	110.35	41.39	65.24	108.96
	Bias	0.89	1.08	0.98	0.98	1.50	1.11	1.04
	r-sq	0.92	0.77	0.96	0.79	-1.04	0.78	0.78
	obs_peak	547.01	466.64	426.21	318.74	152.53	123.85	167.83
	Mod_peak	559.79	561.63	498.38	417.44	222.48	110.23	186.01
	% diff peak	-2.34	-20.36	-16.93	-30.96	-45.86	11.00	-10.83
Calibration parameters	Alpha	1.8	2	2	2.5	2	2.5	4
	IL	7	15	5	25	5	0	10
	CL	0.5	0.3	0.5	0.2	1.2	0.2	0.5
	BaseFlow	15	0	10	20	0	25	40

Additional observed rain gauges to those listed in Table 6.1 were used for event calibration at Strathbridge; these are listed in Table 6.10. A map of these gauges is given in D, Figure D.1.

Table 6.10: Additional rain gauges used for calibration at Meander River at Strathbridge

Site	Name	Custodian
18907	Meander River at Meander Bridge	BoM
852	Meander River at Strathbridge	DPIPWE
22	Mersey River at Kimberley	BoM
162	Meander River at Deloraine Bridge	HT

6.6.2 Flood frequency calibration

Design rainfalls for the flood frequency calibration were obtained using the method outlined in Section 6.2 and are presented in Table 6.11.

Table 6.11: Design rainfall depths (mm) used for the frequency calibration at Meander at Strathbridge by AEP and Duration. Extrapolated values are in grey.

AEP	24	36	48	72	96	120
50%	61.3	72.2	78.4	88.2	97.6	102.6
20%	72.0	84.5	91.9	103.4	113.5	119.7
10%	81.4	95.1	103.5	116.6	127.3	134.6
5%	92.0	107.1	116.6	131.4	142.7	151.3
2%	108.1	125.4	136.6	154.1	165.9	176.6
1%	122.2	141.2	153.9	173.7	186.0	198.5
0.5%	138.2	158.8	173.1	195.5	208.4	223.6
0.2%	162.5	185.7	202.2	228.1	241.8	262.0

The flood frequency calibration was performed to match modelled flood quantiles to the flood frequency curve at Meander at Strathbridge (Figure 6.6).

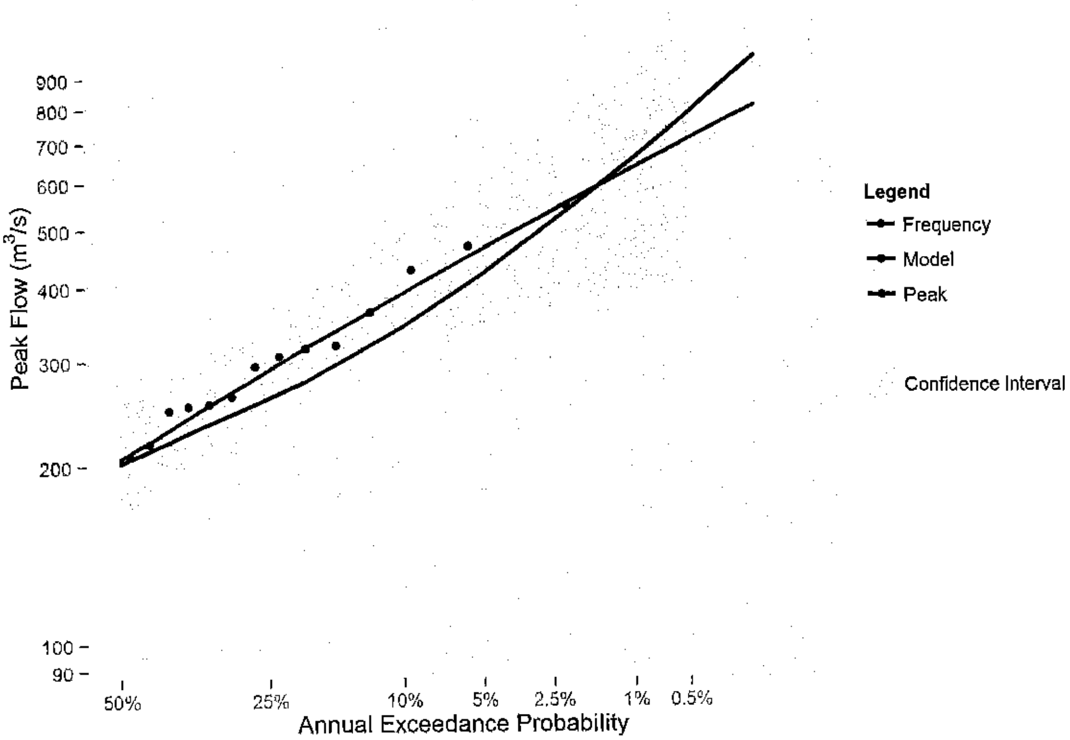

Figure 6.6: Frequency calibration at Meander River at Strathbridge (site 852)

The adopted parameters for the Meander catchment of the model are given in Table 6.12.

Table 6.12: Calibrated model parameters for Meander catchment

Parameter	Value
Initial loss	20 mm
Continuing loss	1.0 mm/hour
α	2.2

6.7 Event timing

In order to achieve a good fit of event calibration, additional lag was introduced into the model in order to achieve suitable calibration. This varied for each site, and also for each event. As peak discharges at each reporting site could be affected by varying the timing of the input hydrographs, it was decided to determine whether adjusting the timing of different catchments would have a significant impact on the total hydrograph peaks at each town.

The introduction of delays caused approximately a 5% decrease in hydrograph peak. It was decided not to include this affect in the modelling of design hydrographs, as this difference was considered insignificant.

6.8 Hydrographs

The model was used to produce design flood hydrographs at key points within the catchment for a series of annual exceedance probabilities and design storm durations. These locations are given in Figure 6.7 and Table 6.13.

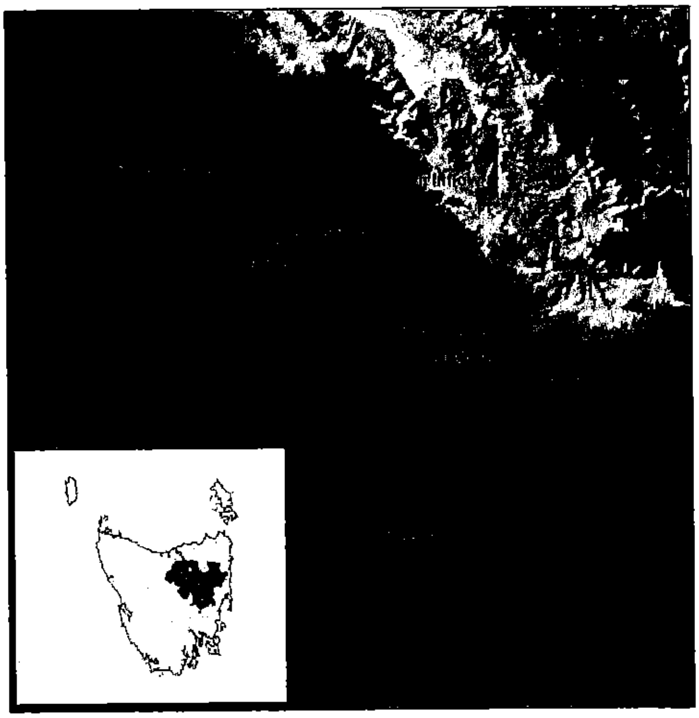

Figure 6.7: Hydrograph reporting locations

Table 6.13: Hydrograph reporting locations; coordinates in GDA94 MGA Zone 55

Site	Easting	Northing	Catchment Area (km^2)
Back Creek	508925	5397512	131
Cressy (Macquarie River)	507836	5385492	3895
Hadspen (South Esk River, ds Meander)	504375	5405110	9000
Liffey at Carrick	500057	5401790	212
Longford (South Esk River, ds Macquarie)	510588	5396023	7143
Perth (South Esk River)	517096	5394753	3308
Strathbridge (Meander River)	492067	5407135	1012
Trevallyn Inflow (South Esk River)	506426	5406410	9092
Westwood (Meander River)	502850	5403384	1556

Design rainfalls used to produce hydrographs were obtained using the method outlined in Section 6.2 for the catchment above Trevallyn and are presented in Table 6.14.

Table 6.14: Design rainfall depths (mm) used to output hydrographs by AEP and Duration. Extrapolated values are in grey.

AEP	24	36	48	72	96	120
50%	52.6	65.6	73.4	86.0	93.4	98.4
20%	62.1	76.5	85.3	99.5	107.3	112.8
10%	70.5	85.9	95.6	111.0	119.2	125.0
5%	80.1	96.5	107.1	123.9	132.4	138.6
2%	94.6	112.6	124.4	143.2	152.1	158.8
1%	107.4	126.5	139.4	159.9	168.9	176.0
0.5%	121.3	141.2	155.1	177.1	186.2	193.8
0.2%	141.6	162.0	177.2	201.1	209.9	218.6

Hydrographs for a range of annual exceedance probabilities, design storm durations, and output sites are presented in Figure 6.8. Modelled peaks are given in Table 6.15 and critical durations are given in Table 6.16.

The use of different temporal patterns at different AEPs as used in the original model (see Section 2, Hydro Tasmania 2003b) was found to produce inconsistent results for the smaller catchments of Back Creek and Liffey; peaks for the 1% AEP event were greater than the peaks for the 0.5% and 0.2% AEPs for these small catchments. As such, the GSAM temporal patterns have not been used and the filtered pre-burst temporal patterns[2] were used for all AEPs (see Section 6.3).

[2] With the following exceptions: 96 and 120 hour durations were not pre-burst (Section 2); 24 and 36 hour durations were not filtered (Section 6.3)

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Table 6.15: Peak inflows for modelled design events

AEP	ARI	Back Creek	Cressy	Hadspen	Liffey	Longford	Perth	Strathbridge	Trevallyn Inflow	Westwood
50%	2	47	175	785	76	615	460	145	736	270
20%	5	66	287	1213	105	986	729	209	1084	361
10%	10	83	420	1611	132	1332	953	266	1395	444
5%	20	104	584	2105	162	1762	1229	334	1765	542
2%	50	136	855	2913	208	2466	1680	439	2347	694
1%	100	165	1129	3687	251	3142	2096	539	2889	838
0.5%	200	196	1439	4559	298	3905	2564	648	3465	995
0.2%	500	241	1916	5870	367	5051	3258	810	4256	1229

Table 6.16: Critical durations for modelled design events

AEP	ARI	Back Creek	Cressy	Hadspen	Liffey	Longford	Perth	Strathbridge	Trevallyn Inflow	Westwood
50%	2	24	24	24	24	24	24	24	24	24
20%	5	24	24	24	24	24	24	24	24	24
10%	10	24	24	24	24	24	24	24	24	24
5%	20	24	24	24	24	24	24	24	24	24
2%	50	24	24	24	24	24	24	24	24	24
1%	100	24	24	24	24	24	24	24	24	24
0.5%	200	24	24	24	24	24	24	24	24	24
0.2%	500	24	24	24	24	24	24	24	24	24

To validate these values, peak flows and critical durations were compared against those found by Hydro Tasmania (2003b). This study is reporting inflows to Trevallyn Dam and the 2003 study reported outflows, which would have been attenuated by being routed through the storage; the attenuation should lower peaks and potentially increase critical durations, so only an approximate comparison has been made. At the 1% AEP, Hydro Tasmania (2003b, p. 15 Figure 5.9) had found the critical outflow duration to be 72 hours, however there was little difference between peaks across durations less than 72 hours (24, 36 and 48 hours).

Though the peak discharge at the 1% AEP for Trevallyn (2889 m^3/s inflow) are less than those at the same AEP from the Trevallyn report (3776 m^3/s outflow), it is within the 90% confidence interval. This difference is due to the recalibration of the Macquarie and Meander subcatchments.

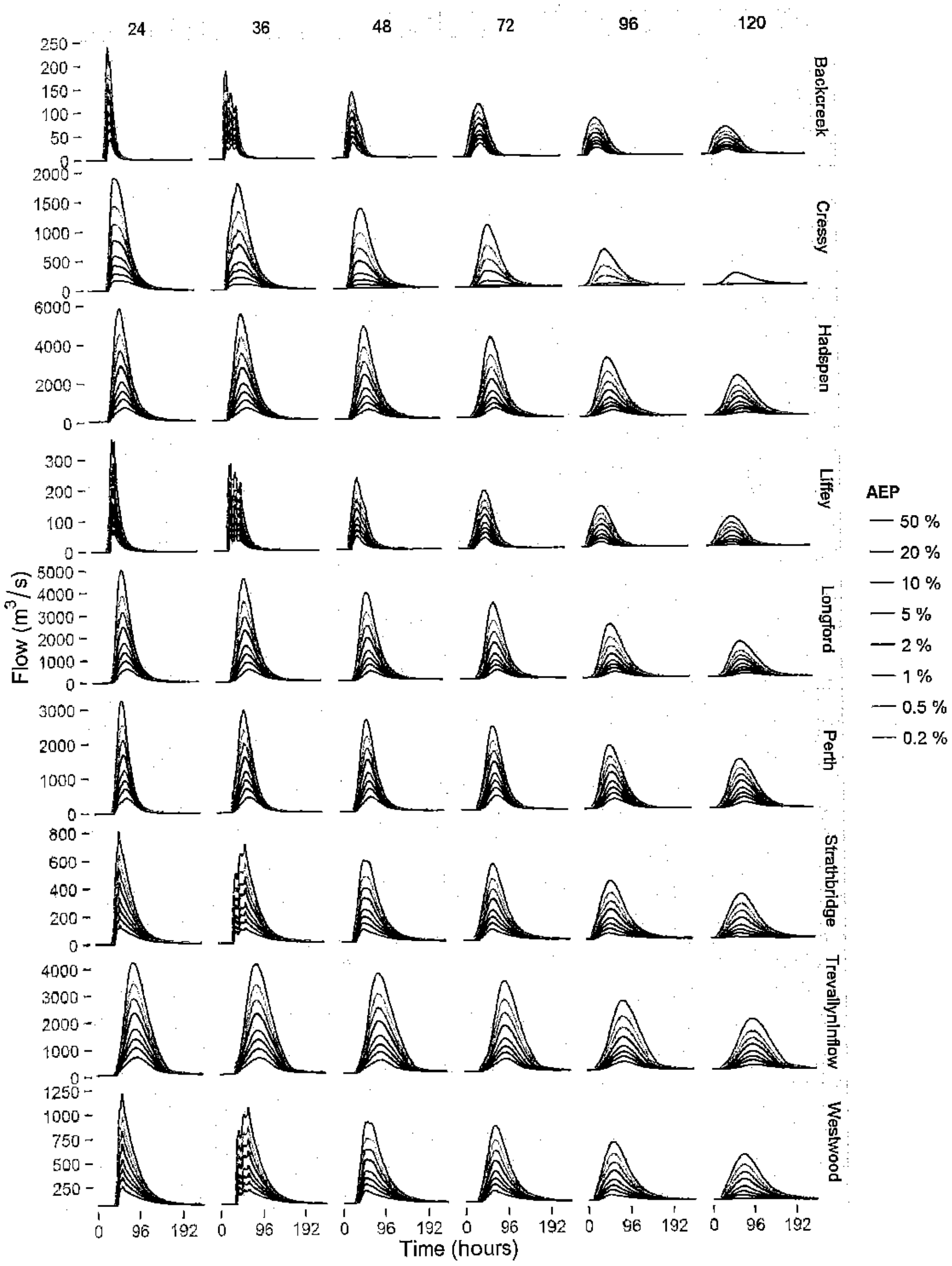

Figure 6.8: Model output hydrographs for each site (vertical facets), design storm duration (horizontal facets, in hours), and annual exceedance probability (colour)

6.9 Discussion

There is some discrepancy between hydrograph peaks obtained from the model and peak discharges obtained through flood frequency analysis at Back Creek at Longford. The model gives consistently higher peak discharges. The most likely reasons for this discrepancy is the short period of record used to derive the flood frequency at Back Creek and that the model may not be representative for such a small component of the catchment at Back Creek (ie the catchment conditions at Back Creek may differ to those of the remainder of the South Esk, and the model has not been designed to give critical flows at Back Creek).

7. Future flood estimates under climate change

The recently published interim guidelines for rainfall and runoff under climate change have been adopted for this study (Engineers Australia 2014). These guidelines recommend a simple approximation of an increase in rainfall intensity of 5% per degree Celsius of global warming. Warming by the year 2085 (median year of the target period of the study, 2070 - 2099) in the midlands region of Tasmania has been taken under the A2 climate scenario (high emissions scenario) provided by Grose et al, (2010) as 3°C. This results in a rainfall intensity increase of 15%. When this is run through the model, this gives increases of peak discharge between 14% and 49% across all AEPs, durations and reporting sites. Hydrographs under climate change are shown in Figure 7.1.

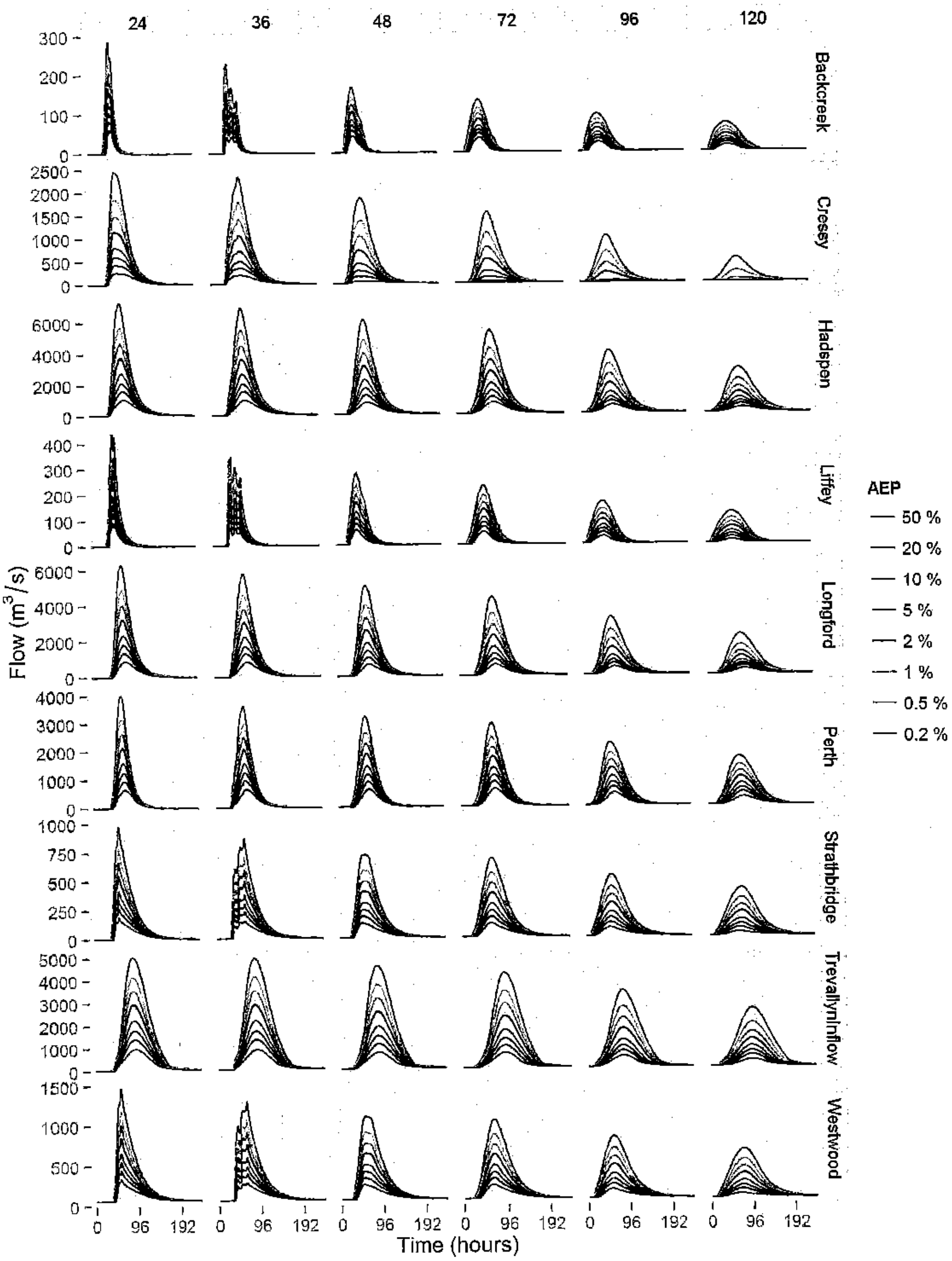

Figure 7.1: Model output hydrographs under climate change scenario for each site (vertical facets), design storm duration (horizontal facets, in hours), and annual exceedance probability (colour)

Table 7.1: Peak inflows for modelled design events under climate change

AEP	ARI	Back Creek	Cressy	Hadspen	Liffey	Longford	Perth	Strathbridge	Trevallyn Inflow	Westwood
50%	2	63	262	1128	100	913	680	196	1016	343
20%	5	85	439	1657	135	1371	974	273	1431	454
10%	10	106	602	2155	165	1805	1255	340	1802	551
5%	20	130	806	2769	200	2341	1600	421	2245	667
2%	50	168	1160	3778	257	3221	2146	551	2952	855
1%	100	201	1490	4703	306	4033	2644	665	3558	1019
0.5%	200	236	1866	5736	360	4933	3187	794	4178	1205
0.2%	500	288	2463	7335	440	6333	4023	984	5056	1480

Table 7.2: Critical durations for modelled design events under climate change

AEP	ARI	Back Creek	Cressy	Hadspen	Liffey	Longford	Perth	Strathbridge	Trevallyn Inflow	Westwood
50%	2	24	24	24	24	24	24	24	24	24
20%	5	24	24	24	24	24	36	24	24	24
10%	10	24	24	24	24	24	24	24	24	24
5%	20	24	24	24	24	24	24	24	24	24
2%	50	24	24	24	24	24	24	24	24	24
1%	100	24	24	24	24	24	24	24	24	24
0.5%	200	24	24	24	24	24	24	24	24	24
0.2%	500	24	24	24	24	24	24	24	24	24

As well as increasing flood peaks, modelling under climate change suggests that the critical duration may be 36 hours for some of the sites with large catchment areas (Perth, Cressy, Longford, Hadspen and Trevallyn), at certain AEPs.

8. References

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A Tables used in modelling application

A.1 Meander Dam Tables

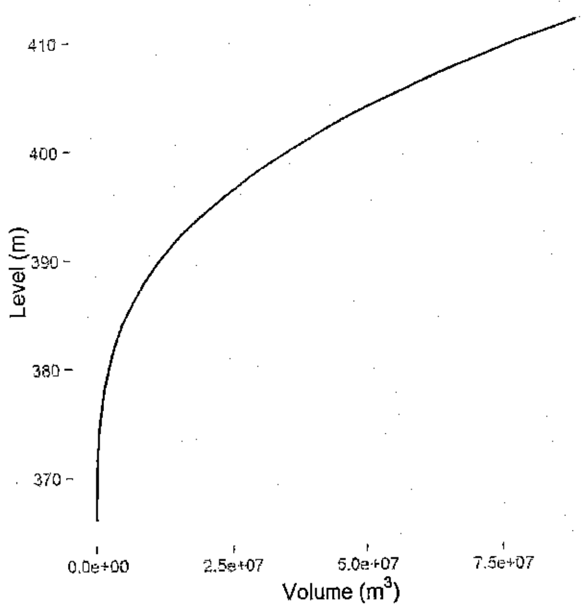

Figure A.1: Meander Dam Storage Curve (Hydro Tasmania Consulting 2006)

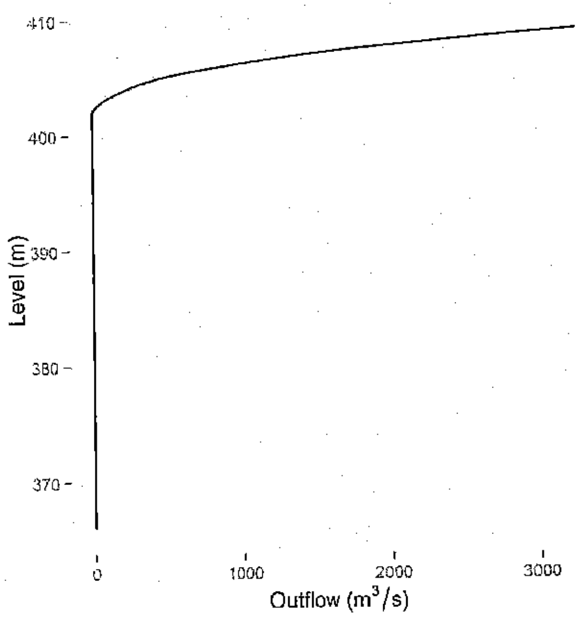

Figure A.2: Meander Dam Spill Curve (Hydro Tasmania Consulting 2006)

Table A.1: Meander Dam Storage Curve (Hydro Tasmania Consulting 2006)

Level (m)	Volume (m^3)
366	45515
368	89014.02
370	165912.1
372	313138
374	573107
376	996998.4
378	1601997
380	2397570
382	3454555
384	4896483
386	6768953
388	9142388
390	12067949
392	15594618
394	19699778
396	24429881
398	29848507
400	35985228
402[3]	42849540
404	50488377
406	58969991
408	68264231
410	78377298
412	89344917

[3] Full supply level

Table A.2: Meander Dam Spill Curve (Hydro Tasmania Consulting 2006)

Level (m)	Outflow (m^3/s)
402.0	0
402.2	6
402.4	17
402.6	32
402.8	50
403.0	71
403.4	122
403.8	184
404.2	256
404.6	338
405.0	454
405.4	600
405.8	770
406.2	962
406.6	1172
406.9	1340
407.1	1472
407.6	1831
408.0	2148
408.4	2496
408.8	2863
409.2	3254

A.2 Hadspen retarding basin tables

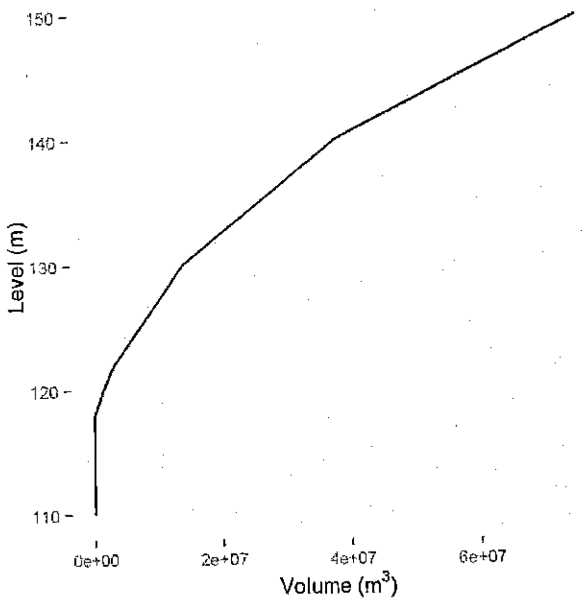

Figure A.3: Hadspen Basin Storage Curve (Hydro Tasmania 2003)

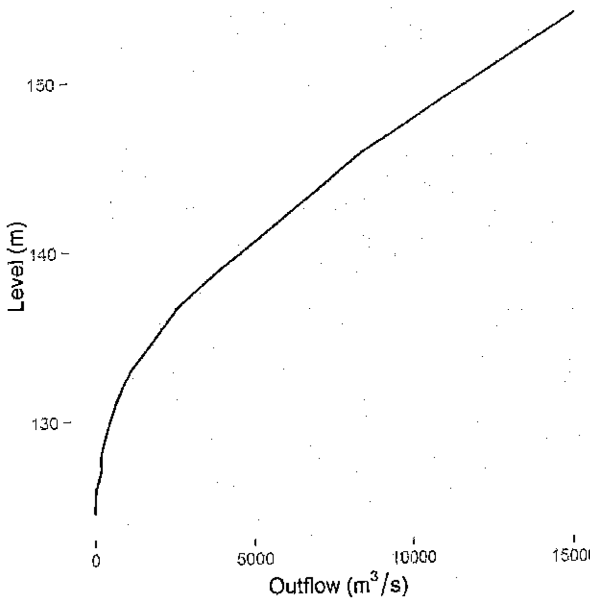

Figure A.4: Hadspen Basin Outflow Curve (Hydro Tasmania 2003)

Table A.3: Hadspen Basin Storage Curve (Hydro Tasmania 2003)

Level (m)	Volume (m^3)
110	0
118	9
120	1414997
122	3101005
130	13860000
140	37456070
150	75020000

Table A.4: Hadspen Basin Storage Curve (Hydro Tasmania 2003)

Level (m)	Outflow (m^3/s)
125	0
125	4
126	38
127	186
128	209
129	341
130	500
131	685
132	904
133	1169
137	2670
139	3964
146	8500
154	15200

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B Annual series used in flood frequency analysis

Note that while the aggregation period is 1 year for the annual series, it is not necessarily a calendar year (1 Jan – 31 Dec); appropriate water years have been selected based on the input data.

Table B.1: Annual series used to derive flood frequency distribution at Meander at Deloraine

Year	Peak (m^3/s)
1970	306
1971	431
1972	146
1973	195
1974	283
1975	199
1976	167
1977	87
1978	199
1979	158
1980	218
1981	248
1982	140
1983	79
1984	116
1985	245
1986	156
1987	244
1988	146
1989	245
1990	248
1991	211
1992	101
1993	350
1994	206
1995	107
1996	159

Year	Peak (m^3/s)
1997	223
1998	319
1999	389
2000	213
2001	212
2002	150
2003	106
2004	171
2005	156
2006	359
2007	113
2008	149
2009	50
2010	217
2011	303
2012	122
2013	100
2014	166
2015	186

Table B.2: Annual series used to derive flood frequency distribution at Meander River at Strathbridge

Year	Peak (m^3/s)
1987	315
1988	132
1989	362
1990	252
1991	161
1992	155
1993	427
1994	175
1995	67
1996	152
1997	294
1998	306
1999	547
2000	168
2001	319
2002	207
2003	105
2004	254
2005	176
2006	468
2007	83
2008	185
2009	59
2010	218
2011	262
2012	183
2013	125
2014	248

Table B.3: Annual series used to derive flood frequency distribution at South Esk at Perth

Year	Peak (m^3/s)
1958	1565
1959	669
1960	958
1961	393
1962	578
1963	141
1964	372
1965	215
1966	706
1967	879
1968	172
1969	2965
1970	1810
1971	511
1972	122
1973	305
1974	984
1975	616
1976	320
1977	313
1978	1771
1979	151
1980	293
1981	672
1982	124
1983	720
1984	779
1985	261
1986	1686
1987	172
1988	340
1989	597

Year	Peak (m^3/s)
1990	161
1991	163
1992	536
1993	83
1994	908
1995	540
1996	361
1997	151
1998	141
1999	74
2000	500
2001	282
2002	55
2003	1057
2004	1213
2005	653
2006	148
2007	298
2008	43
2009	1130
2010	1020
2011	2591
2012	79
2013	226
2014	203

Table B.4: Annual series used to derive flood frequency distribution at Back Creek at Longford

Year	Peak (m^3/s)
1982	15
1983	8
1984	4
1985	29
1986	11
1987	15
1988	6
1989	16
1990	18

Table B.5: Annual series used to derive flood frequency distribution at Macquarie at Cressy

Year	Peak (m^3/s)
1988	57
1989	213
1990	158
1991	92
1992	69
1993	201
1994	466
1995	54
1996	218
1997	313
1998	101
1999	435
2000	88
2001	180
2002	154
2003	55
2004	408
2005	181

Year	Peak (m^3/s)
2006	421
2007	52
2008	78
2009	53
2010	483
2011	292
2012	513
2013	89
2014	244
2015	85

C Event calibration hydrographs

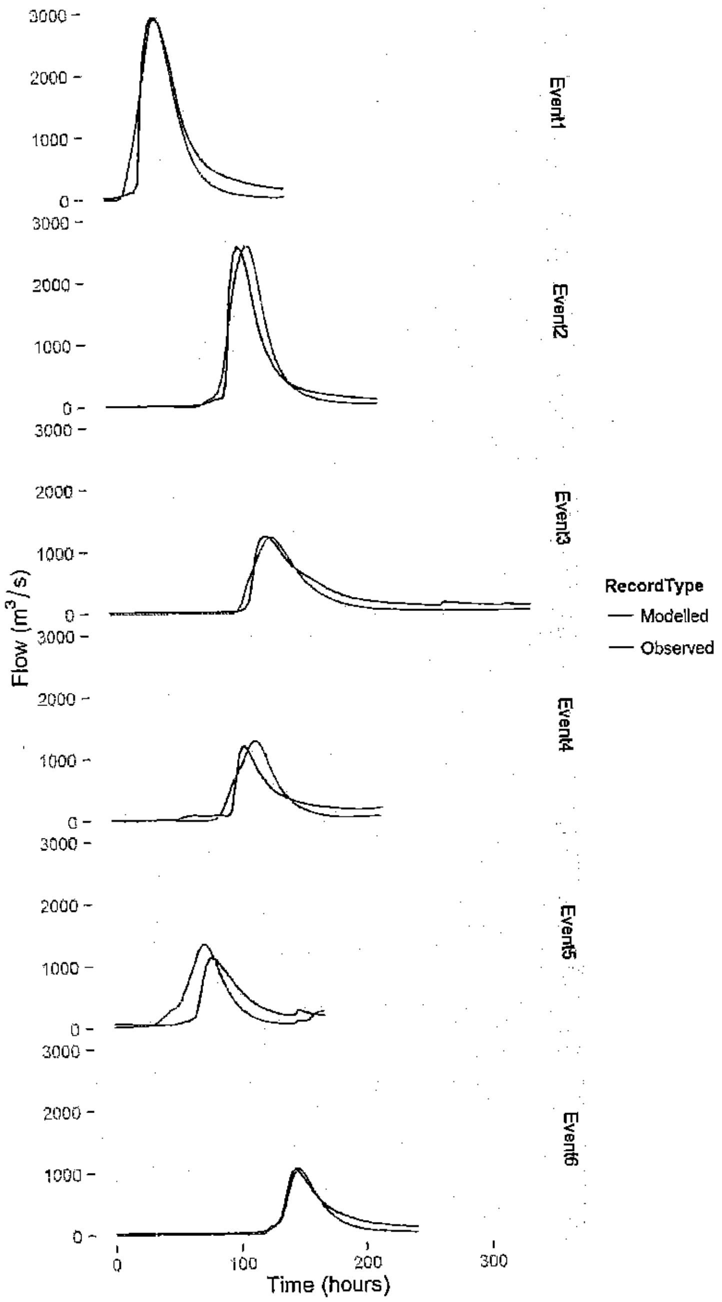

Figure C.1: Hydrographs for event calibrations at South Esk at Perth (site 181)

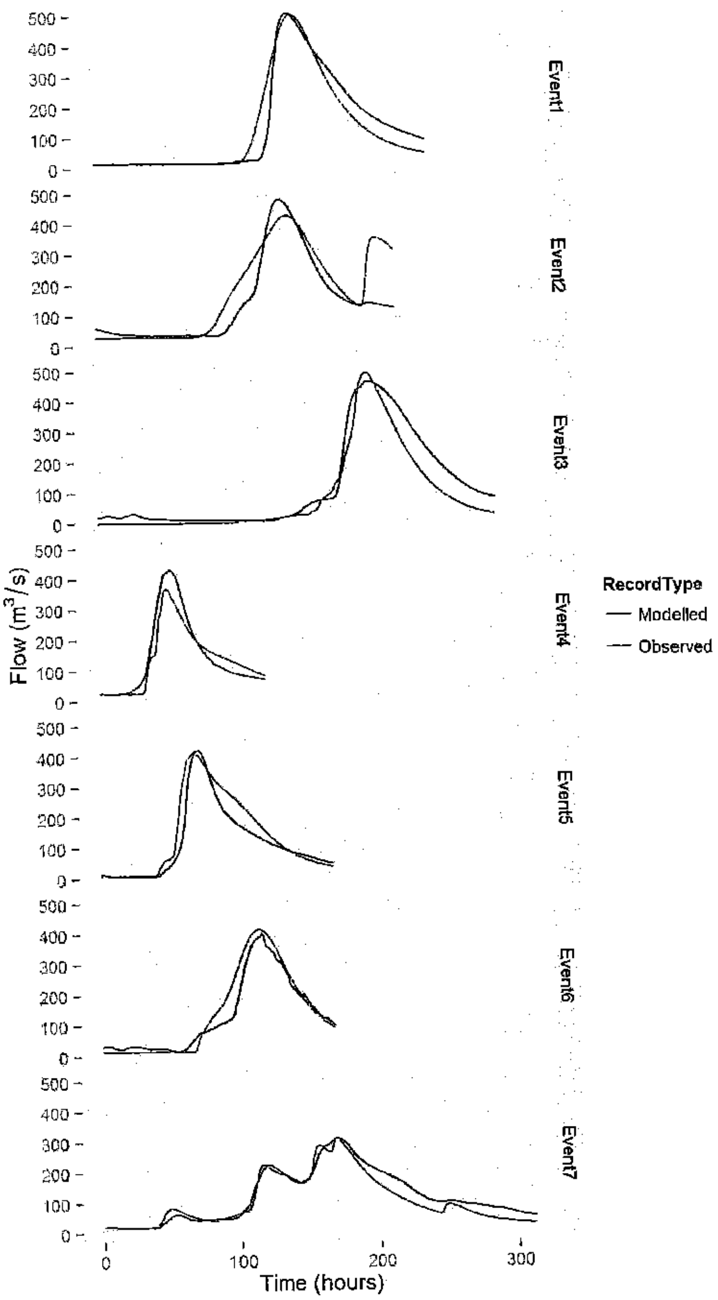

Figure C.2: Hydrographs for event calibrations at Macquarie at Cressy Pumps (site 733)

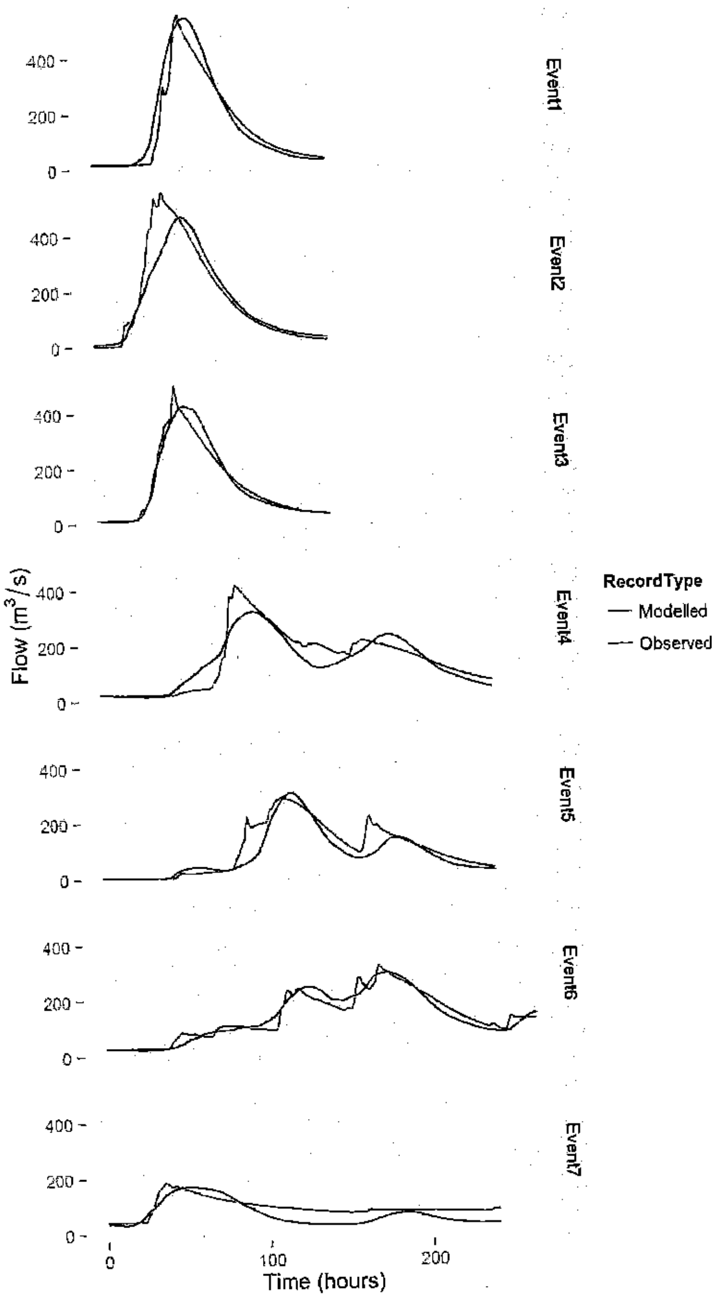

Figure C.3: Hydrographs for event calibrations at Meander at Strathbridge (site 852)

D Full catchment rain gauge map

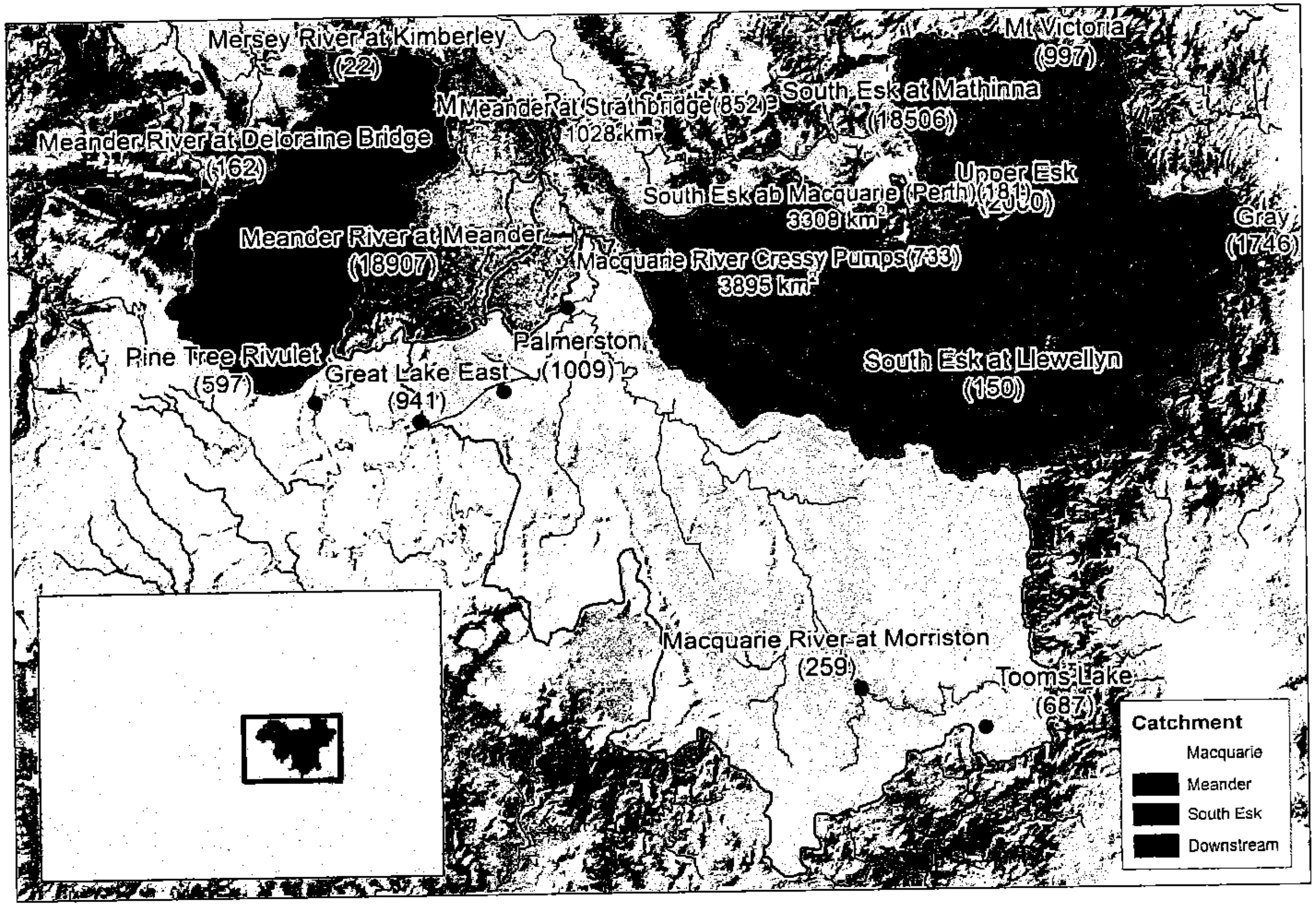

Figure D.1: Catchment map of all rain gauges used in calibrations

E Concurrent inflows at Tributaries

The concurrent inflows analysis determines annual exceedance probabilities of peaks in subcatchment tributaries that can be expected to occur simultaneously with the design storm for the main stream reporting station (South Esk at Hadspen, downstream of the Meander confluence). For example, for a design storm of 1% Annual Exceedance Probability (AEP) at Hadspen, the concurrent inflows analysis will determine the AEP of peaks occurring at each reporting node in the model. In general, it is expected that concurrent tributary AEPs will be more frequent than the AEP of the main stream; this because the spatial pattern of the storm will not be centred on the tributary catchment, and also due to the relatively smaller size of the tributary catchments.

Concurrent inflows and their annual exceedance probabilities for sites within the South Esk catchment were determined using two approaches. In the first method (Modelled) the modelled peak outflows are looked up for given AEPs against the quantile peaks/frequency distribution derived using flood frequency analysis (Section 5) to determine the concurrent AEP of tributary hydrographs.

The second approach (ARR approximation) uses the approximation method defined by Engineers Australia (1998b, section 7.3.2). This approach compares peak discharges of the main stream with peak discharges at the target tributary of the main stream. The correlation of concurrent inflows (rho, ρ) is dependent upon the distance between catchment centroids of the main stream and the target stream, and is determined using the distance-correlation plot shown in Figure E.1. The correlation is then applied to determine concurrent tributary inflow peaks using (E.1). These peaks are then looked up against the quantiles for the tributary site to obtain the AEP of the concurrent peak.

$$m_{y/x} = m_y + \rho \frac{s_y}{s_x}(x - m_x) \qquad \text{(E.1)}$$

where m and s are the mean and standard deviation of the marginal distributions, ρ is the correlation between the two sites obtained from the distance relationship in Figure E.1, x and y are the flows at the mainstream and tributary sites respectively; all flows and statistics are in log space. This method is designed for determining downstream tributary inflows, rather than for inflows from tributaries within the design catchment, however it does provide a check for figures derived using the modelling method.

In this study, the main stream peak discharges were taken from modelled outflows at Hadspen. It was decided that the routing of the Hadspen Basin could have an effect on these calculations, so the Trevallyn inflows (downstream of the Hadspen Basin) was rejected on this assumption. It can be seen that there is little correlation when catchment centroids are greater than about 20 km apart.

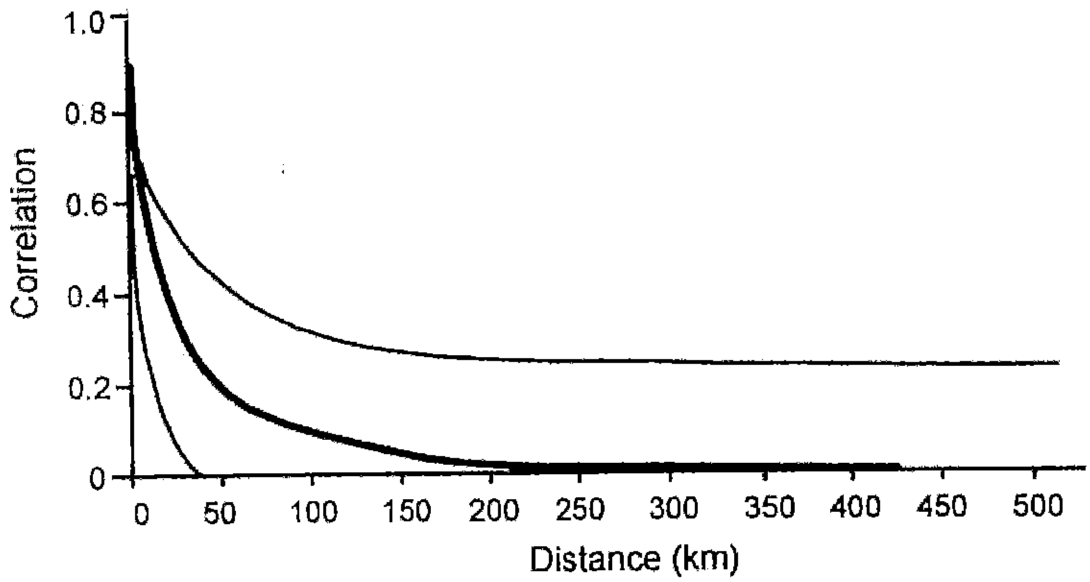

Figure E.1: Concurrent tributary flows: variations in correlation between the logarithm of point rainfall maxima and distance for Tasmania; thick line is median relationship, thin lines indicate 90% prediction limits (Engineers Australia 1998b)

Concurrent inflow estimates were determined for four sites. A GIS map of the region was used to approximate catchment centroids of the main stream and tributaries; distances are summarised in Table E.1.

Table E.1: Distances between mainstream catchment centroid (South Esk below Hadspen) and tributaries in the South Esk catchment

		Catchment Centroid		Catchment Area (km^2)	Distance between centroids (km)
Site	**Name**	**Easting**	**Northing**		
	South Esk below Hadspen	*530611*	*5371832*	*9000*	*NA*
181	Perth	561302	5388554	1028	35
18218	Back Creek	504370	5390534	131	32
162	Deloraine	466687	5390036	474	66
852	Strathbridge	474307	5399138	1028	63
733	Macquarie at Cressy Pumps	529220	5350002	3764	22

Results of concurrent peak flow analysis are shown in Table E.2, Table E.3, Table E.4, Table E.5, and Table E.6. As there are significant distances between the catchment centroids, there is little correlation between inflows at less frequent annual exceedance probabilities.

Table E.2: Concurrent tributary inflows for South Esk at Perth. Distance of 35 km between centroids

Hadspen		ARR Approximation		Modelled Flow	
ARI	**AEP**	**Peak (m^3/s)**	**AEP**	**Peak (m^3/s)**	**AEP**
2	50%	495	48%	460	52%
5	20%	590	40%	729	31%
10	10%	656	35%	953	21%
20	5%	725	31%	1229	13%
50	2%	820	26%	1680	7%
100	1%	896	23%	2096	4%
200	0.5%	971	20%	2564	2.3%
500	0.2%	1069	17%	3258	1.2%

Table E.3: Concurrent tributary inflows for Back Creek at Longford. Distance of 32 km between centroids

Hadspen		ARR Approximation		Modelled Flow	
ARI	**AEP**	**Peak (m^3/s)**	**AEP**	**Peak (m^3/s)**	**AEP**
2	50%	13	48%	47	1.67%
5	20%	15	39%	66	0.369%
10	10%	16	34%	83	0.1141%
20	5%	17	30%	104	0.03288%
50	2%	19	25%	136	0.006245%
100	1%	21	21%	165	0.001698%
200	0.5%	22	18%	196	0.000484%
500	0.2%	24	15%	241	0.0000989%

Table E.4: Concurrent tributary inflows for Meander at Deloraine. Distance of 66 km between centroids

Hadspen		ARR Approximation		Modelled Flow	
ARI	**AEP**	**Peak (m^3/s)**	**AEP**	**Peak (m^3/s)**	**AEP**
2	50%	189	49%	107	92%
5	20%	197	45%	151	71%
10	10%	202	42%	191	48%
20	5%	207	40%	237	27%
50	2%	214	37%	309	10%
100	1%	218	35%	377	4%
200	0.5%	222	33%	452	1.2%
500	0.2%	228	31%	563	0.2%

Modelled flows for Meander at Deloraine are unavailable at this stage as hydrograph outputs have not been prepared at this site.

Table E.5: Concurrent tributary inflows for Meander at Strathbridge. Distance of 63 km between centroids

Hadspen		Concurrent Flow		Modelled Flow	
ARI	AEP	Peak (m^3/s)	AEP	Peak (m^3/s)	AEP
2	50%	212	49%	145	78%
5	20%	224	45%	209	50%
10	10%	231	42%	266	31%
20	5%	238	39%	334	16.4%
50	2%	247	36%	439	6.0%
100	1%	254	34%	539	2.3%
200	0.5%	260	32%	648	0.9%
500	0.2%	268	30%	810	0.2%

Table E.6: Concurrent tributary inflows for Macquarie River at Cressy Pumps. Distance of 22 km between centroids

Hadspen		Concurrent Flow		Modelled Flow	
ARI	AEP	Peak (m^3/s)	AEP	Peak (m^3/s)	AEP
2	50%	218	47%	175	66%
5	20%	248	36%	287	25%
10	10%	269	30%	420	7%
20	5%	290	25%	584	1.4%
50	2%	318	19%	855	0.1%
100	1%	339	15%	1129	0.01%
200	0.5%	361	12%	1439	0.002%
500	0.2%	388	9%	1916	0.0001%

E.1 Discussion

There is a notable difference in AEPs derived from the ARR approximation and modelling methods. Much of this difference derives from the discrepancy between modelled peaks and flood frequency analysis described in Section 6.9. Some additional difference may also be explained by possible limitations of the approximation method described by Engineers Australia, in particular the distance-correlation curve in Figure E.1 , when applied to the South Esk catchment. This approach is a regional method for Tasmania, and the correlations have been derived from statistical relationships between rain gauge recordings across the state, which can give significant difference across short distances, given Tasmania's size, terrain, and effects from different weather systems. It is suspected that rainfall across the South Esk catchment would be more homogenous than that indicated in Figure E.1, and therefore AEPs of concurrent tributary inflows would more closely match the AEP of mainstream flows. To assess this, however, would take considerable effort which is beyond the scope of this study.

A particular discrepancy is with concurrent tributary inflow at Back Creek. Likely reasons for this are the same as those presented in Section 6.9. Additionally, the Macquarie River at Cressy Pumps has a large discrepancy; this is due to the poor calibration results at this site against the at-site flood frequency (Section 6.5.2).

It is recommended that the results of the modelling approach be used for evaluation of concurrent inflows. The check using the ARR approximation method shows that the modelling approach is conservative, in terms of giving higher concurrent flows.

W+I 2

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TASMANIA
53 BRISBANE STREET
LAUNCESTON.

HONG KONG OFFICE
ROOM 605 PARK TOWER
15 AUSTIN ROAD
KOWLOON. HONG KONG

8th March 2015

Wayne Chellis
Works & Infrastructure Manager
Northern Midlands Council
PO Box 156
Longford, Tasmania 7301

Dear Wayne

Re – Reconstruction of Macquarie Road,

I refer to a site meeting last Thursday afternoon to inspect a planting of *Cupressus macrocarpa*.

The plantation assessed is on private land directly adjacent to Macquarie Road between Ashby Road to the Morningside Bridge. The road reconstruction is approximately 1.275 kilometres in length and the plantation of trees is affected by this road redevelopment.

The plantation of trees is considered to be in an over-mature state with an age of approximately 80 years. From the site inspection it is estimated the trees have a useful life expectancy of approximately 15 years. The trees vary in height from approximately 10 metres to 15 metres on average.

I was advised at the site inspection that council will need to rip a line to break tree roots approximately one metre from the fence line on council land to a depth of 1.5 metres. The purpose of this proposed action is to ensure the trees' root system does not damage the new road as they have in the past. At the site visit it was evident the uneven surface is a result of the tree roots underneath the bitumen surface. This has resulted in an unacceptable uneven surface causing multiple traffic hazards along the section of road. The two photos below show the uneven service and the picture to the left side of the page shows the bitumen breaking up.

When the ripping of the tree roots occur as a preventive measure this will have three detrimental affects to the plantation. Firstly this activity will take place in the Structural Root Zone of the trees resulting in the structural roots being severed. This will make the trees unstable in the future and could result in root plate failure occurring to individual trees. Secondly the damage to the root plate will allow rapid access for any wood decaying pathogen such as *Ganoderma* sp. to destroy the remaining roots and trunks of the tree rendering the trees structurally unsound.

The ripping will also result in a 40% reduction of the water and nutrients absorption area of the trees' root systems, shortening the life expectancy of the trees and could contributing to premature large branch failure or the death of the trees.

Further reading of the specification shows that the tree branches above the road and out to near the ripped line on the boundary will need to be pruned up to 6 metres in height above ground to allow the trucks to tip their loads of gravel. Such pruning works will result in altering the canopy of the tree allowing large openings for wind to enter into the once enclosed protected canopy. This will result in large branch failures in wind events.

The photo below on the left page side shows the end tree of the plantation having multiple large branch failures already. The photo on the right side of the page below shows the canopy of this tree starting to open up due to a large branch failure, which now allows for wind tunnelling to occur, placing the canopy under different wind loading stresses to which it is adapted.

Once the pruning works are complete to allow access for 6 metres above the highway that is intended for use as a carriage-way, the plantation is at a very high risk of failure. These failures will occur over the road which could result in serious injury or death to drivers and occupants of vehicles using this road.

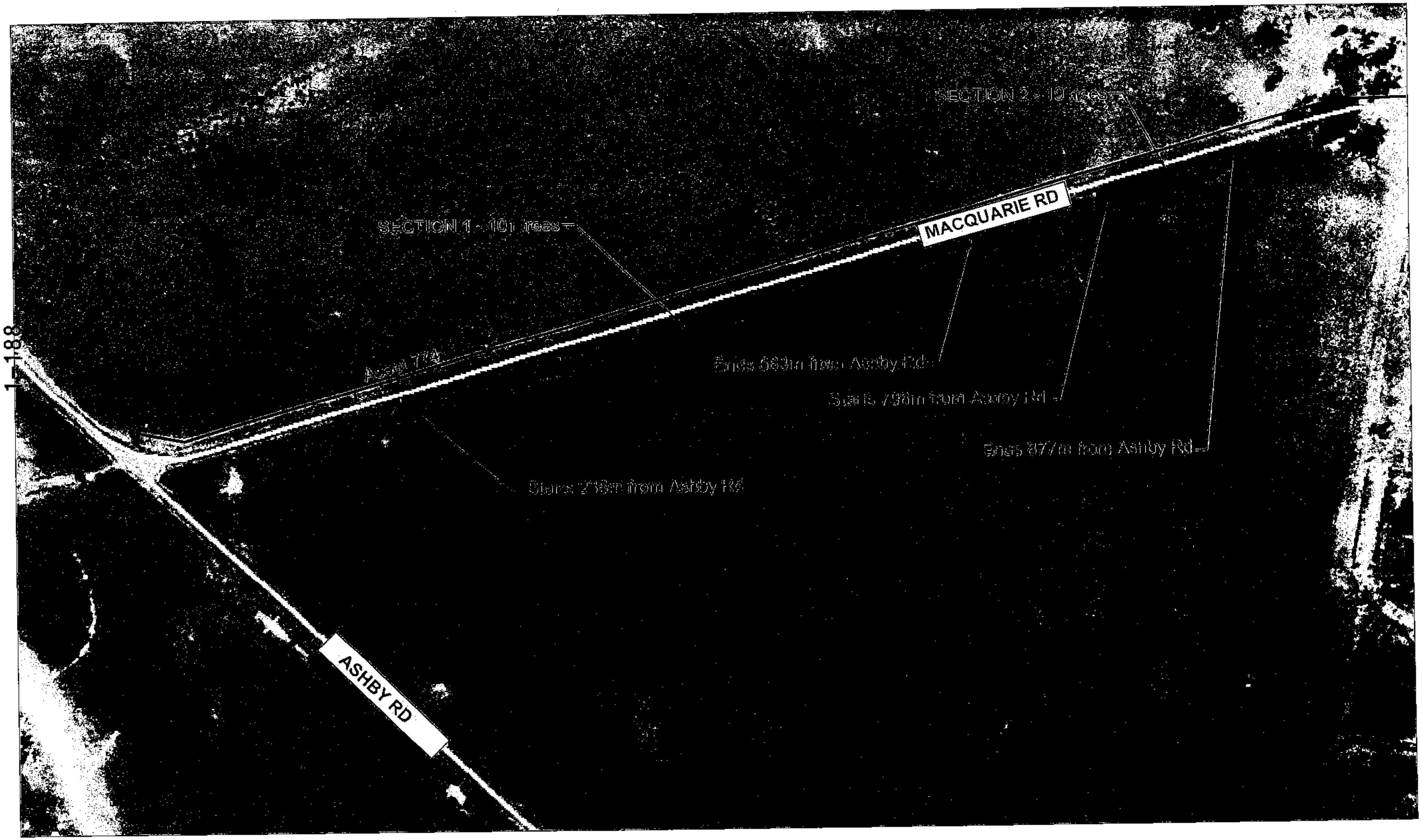
It is recommended that the trees are removed on private land prior to any construction works taking place. This will eliminate any future risk to users of the road and future damage to the road at a later date.

If you require any further information please do not hesitate to contact me at your earliest convenience via email or 0417027152.

Yours sincerely

Craig Hallam
Managing Director
ENSPEC Pty Ltd
Advanced Diploma Horticulture Arboriculture
Diploma Arboriculture.

LOCATION OF MACRACARPA TREES, MACQUARIE RD



Gov 7

NORTHERN
TASMANIA
DEVELOPMENT

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www.northerntasmania.org.au

NORTHERN MIDLANDS COUNCIL					
Location					
File No.					
Property					
Attachments					
REC'D - 8 JUL 2015					
GM	✓		MYR	✓	
P&DM			CRS	✓	
CSM			PLAN		
E&DM			BLD		
WM			HLT		
HR					

6 July 2015

Mr Des Jennings
General Manager
Northern Midlands Council
PO Box 156
LONGFORD TAS 7301

Dear Des

COUNCIL ELECTED MEMBER REPRESENTATION ON THE C8 WORKING GROUP

This letter is sent to you on behalf of the C8 Working Group, who after their meeting on 4 March 2015, would like to formally request the nomination of an elected member representative from the Northern Midlands Council to become a member and participant on the C8 Working Group.

With the changes made to Northern Tasmania Development's corporate structure in late 2012 to that of a regional collaboration and co-ordination model, the provision to have committees formed under the Local Government Committee to deal with specific issues and projects became available.

Endorsement from the Local Government Committee for the C8 to become a formal sub-committee was carried at its meeting held on 27 August 2014, and as such it is essential to the success of the C8 that elected member representation from across all northern councils is achieved on its working group.

The Role of C8
It is important to note that the C8 has not been established to burden itself with time consuming research projects that are best left to other better resourced groups who have administrative resourcing and capacity for this.

Any outcomes or initiatives raised or achieved by the C8 will now be documented and reported back to Councils. However it is worth noting that the C8 is not about building –

a) a bureaucracy and an overly administrative structure
b) an un-elected decision making body
c) a body seen to be competing with those or at odds with existing organisations.

C8 Structure
It is important that the C8 is driven by the elected members of the eight northern Councils. To assist with this a C8 Working Group (WG) has been established, which is endorsed annually, and should ideally consist of elected members from all eight Councils. The C8 Working Group is the conduit and platform for elected members to become more involved in the regional direction setting through the Local Government Committee.

A C8 Working Group Co-ordinator is elected annually to facilitate meetings and agendas and act as spokesperson for the group. The role is rotated between the different Councils every 12 months. The C8 WG appointed Tim Woinarski from West Tamar Council as its Co-ordinator at its last meeting held on 4 March 2015.

In addition to the above request, please also find attached a background paper outlining the aim and objectives of the C8 and further clarification around its role.

We look forward to hearing back on your nominated elected member representative at your earliest convenience.

Yours sincerely

Derek Le Marchant
EXECUTIVE OFFICER

(ON BEHALF OF THE C8 WORKING GROUP)

NETWORKING THE NORTH

Background
In 2012 Councillors from across Northern Tasmania proposed the idea to create an informal network of elected members – an 'Assembly' of Councillors (C8 = Councillors of the eight northern LGA's. There were existing networks for General Managers and Mayors, but no regular forums for Councillors.

Overview
From this proposal, in conjunction with Northern Tasmania Development (NTD), the first inaugural C8 Summit was held in October 2013 and following its success another was held in December 2014.

The goal of the C8 is to give elected members an opportunity to better understand local challenges and opportunities faced by Councils in a regional context by aiming to:

- Share challenges and opportunities experienced in each Local Government Area;
- Increase awareness of the key regional challenges and the evidence behind them;
- Build trust and respect amongst councillors;
- Focus on areas of agreement rather than areas of conflict;
- Invigorate and inspire Councillors to work together; and
- Gain consensus on a path to regional understanding and cooperation.

The C8 is building:

- a strong yet informal information sharing and knowledge building network amongst elected representatives of the eight northern Councils;
- an understanding of ourselves and our region (its challenges and opportunities);
- an understanding of what works for others in regions around Australia through research and presentation of case studies;
- an annual schedule of gathering; and
- collaboration between ourselves and our region.

Elected members can attend any of the C8 summits and meetings to meet, network and gain something of value. Two key roles for the C8 are:

- to present case studies and invite speakers from around the region (and occasionally outside of the region) to share case studies and projects that have involved collaboration, working across municipal boundaries, working with multiple stakeholders, had positive and practical outcomes from around the region in areas that have relevance to all northern councils.

- Specific project champions (including current elected members) who could coordinate activities where they have major interests or expertise, and feedback through NTD, reflecting the premise that the project has a regional priority.

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Gov 8

Tasmanian Electoral Commission

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Hobart Tasmania 7000

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Reference F 84.88

Mayor David Downie
Northern Midlands Council
PO Box 156
LONGFORD TAS 7301

Dear Mayor David Downie

Local Government Association of Tasmania — 2015 by-election

The Tasmanian Electoral Commission has been asked to conduct a by-election for President of the Local Government Association of Tasmania (LGAT).

Election timetable

Nominations open	Friday 26 June 2015
Nominations close	5 pm Thursday 30 July 2015
Ballot material posted (if a ballot is required)	Tuesday 4 August 2015
Close of postal ballot	10 am Tuesday 8 September 2015
Declaration of result	Tuesday 8 September 2015

A nomination form and reply paid envelope are enclosed.

If you would like further information or assistance, please call Rod Huskins of this office on 6208 8716.

Yours sincerely

Julian Type
ELECTORAL COMMISSIONER
25 June 2015

1-193

GOV 10

Tasmanian Government

Treasurer
Minister for Planning and Local Government

Level 9 15 Murray Street HOBART TAS 7000 Australia
GPO Box 123 HOBART TAS 7001 Australia
Ph: +61 3 6165 7670
Email: Peter.gutwein@dpac.tas.gov.au

6 July 2015

Cr David Downie
Mayor
Northern Midlands Council
PO Box 156
LONGFORD TAS 7301

Dear Mayor

I want to acknowledge the positive approach taken by Councils across the State when considering either improved shared services and/or voluntary amalgamations as a way to improve benefits to ratepayers.

Almost all councils have informed me of the proposals they wish to put forward. However many of the proposals are at an early stage and need further development. While it has been a very positive start, I am keen to maintain the goodwill and momentum that has been built up.

I fully understand that you are considering fundamental and in some cases challenging reforms, and to assist in this process I have requested that the Department of Premier and Cabinet - Local Government Division (LGD) contact you directly in coming weeks to discuss the details of council proposals and the way forward from here. As it is approaching six months since I addressed councils in each region of the State, I am keen to get feasibility studies underway.

Without pre-empting outcomes, I note that a number of councils are now prepared to engage in feasibility studies at a regional level. Given the potential benefits of a much broader, regional approach to resource sharing, it would be disappointing if there were a small number of councils in each region not participating in such a major reform.

If you have been a council that has chosen to stay out of the process, I ask that you reconsider on the back of the emergence of significant proposals that are being considered in all three regions.

Following discussions with the LGD, and if your council thought it worthwhile, I would welcome the opportunity to meet with you and your partner councils to discuss the proposals you may wish to progress.

Furthermore as I have received a number of requests regarding the process to be followed in order to secure State Government funding. The process would be as follows:

1. Final detailed proposal submitted to Minister for Planning and Local Government.

2. State Government approves funding for the proposal.

15/43573

3. The councils and the State Government sign a Memorandum of Understanding related to the project requirements and use of funds.

4. The partner councils would select the companies to tender for feasibility studies from a list of preferred providers established by the State Government following a rigorous tendering process.

5. In close consultation with the relevant council(s) a contract would be drawn up between the successful tenderer, the Council(s) and the State Government.

6. The partner councils would work closely with the successful consultancy to undertake the feasibility study.

7. The findings of the feasibility study would be presented to the partner councils and the State Government for consideration.

8. Pending the outcome of the feasibility study, the partner councils would then consult with their communities before making a final decision on whether to implement any changes.

Thank you taking this opportunity to investigate new and better ways of operating. I look forward to discussing your proposals in the near future.

Yours sincerely

Peter Gutwein MP
Minister for Planning and Local Government

15/044424

Gov II

Brief Introdution on Liupanshui City

Lying in the western Guizhou, Liupanshui is a city that connects provinces of Sichuan, Yunan, Guizhou and Guangxi Zhuang Autonomous Region. It is an industrial city in energy raw material developed during the "Three-line Construction" period. Liupanshui city is known as the Western Region of Panzhihua city ---Liupanshui Resources

Comprehensive Development Zone approved by the state; it is also the "Bijie,Shuicheng and Xingyi Economic Belt" approved by the provincial party committee and the provincial government. Liupanshui city consists of four county-level administrative districts, namely, Liuzhi, Panxian, Shuicheng and Zhongshan, covering an area of 9,965 square kilometers with a total population of 3.2million, in which ethnic groups of Miao, Yi and Buyi takes up 27.4%.

Liupanshui, known as "the Ideal Summer Resort of China", is famous for its pleasant climate which characterizes cool, comfort, moist and moderate ultraviolet radiation. The annual average temperature here is 12.3-15.2℃ and the average temperature of the hottest month in summer is 19.7℃.In August 2005, Liupanhsui was awarded the name of " the Ideal Summer Resort in China " by the Chinese Meteorological Society. In 2006, it was appraised as one of the top ten Chinese summer resorts by China Institute of City Competition and other agencies, and listed as one of the national top ten model cities of the green environmental protection by China Circular Economy Development Forum in May 2009 .

Liupanshui city, the coal city of southern China, is rich in resources, which has more than 30 varieties of resources including coal, manganese, zinc and other mineral resources. The prospective reserves of coal is 84.4 billion tons. And the proved reserves of it is 18 billion tons. Over the past 30 years of reform and opening up, Liupanshui has become an industrial city depending on coal, electric power, metallurgy and building materials. In September 2009, the State Council listed Liupanshui city into the pilot cities of resources-abundant area and circular economic area.

Liupanshui, located in the junction of Sichuan, Yunnan, Guizhou and Guangxi provinces, is about 300-500 km away from the five capital cities: Kunming, Chengdu, Chongqing, Guiyang, and Nanning. With Guiyang-Kunming railway, Zhuzhou-Liupanshui double track line linking the east and west, and with Nanning-Kunming railway, Shuicheng - Baiguo railway and Neijiang-Kunming railway connecting the north and south. Liupanshui has become an important railway transportation hub in the southwestern China. Moreover, with the highways of Zhenning-Shengjingguan, Shuicheng-Panxian and Liuzhi-Zhenning completed years ago, and with Hangzhou-Ruili, Liupanshui-Liuzhi, Shuicheng- Xichang, and Liupanshui airport under construction, all these advantages of location and transportation will make Liupanshui more prominent.

In 2014, the city's GDP completed 104.273 billion RMB, an increase of 14.1%.Public Finance budget revenue completed 12.874 billion RMB, an increase of 4.2%. Fixed asset investment of above 500 thousand RMB completed 133.627 billion RMB , an increase of 26.7%. Large-scale industrial increase completed 45.636 billion RMB , an increase of 11.5%. The total retail sales of social consumer goods completed 23.69 billion yuan, an increase of 13.2%. Farmers per capita disposable income reached 6,791 RMB,an increase of 12.9%.Urban residents per capita disposable income reached 21,168 RMB,an increase of 11.1%. The rate of realizing overall well-off society reached 77.4%.

In 2015, led by the spirit of the 18th National Congress of the CPC, the third and the fourth plenary plenary session of the 18th CPC Central Committee and the fifth plenary session of the 11th CPC Guizhou Provincial Committee, Liupanshui will conscientiously carry out the decisions and arrangements of Guizhou Provincial Party Committee and provincial government, focus on the idea of building regional central city, international standard tourism leisure and holiday-spending city and national circular economy model city, and will uphold the banner of circular economy, firmly hold the three baselines of development, ecology and safety, and insist on the main keynote and the main strategy, actively adapt to the new normalization,actively grasp the new opportunity, actively realize new accomplishment, Liupanshui city will grasp the big tendercy, make overall plans,keep people's livelihood in mind,speed up and transformation,press ahead with the development of economy, society and eco- civilization to open up a new prospect.

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Local Government Association Tasmania

ANNUAL GENERAL MEETING

AGENDA

To be submitted to the

ONE HUNDRED AND THIRD SESSION OF THE ASSOCIATION

Will be held on
22 July 2015

Commencing
10.30am

The Tramsheds
Launceston

Local
Government
Conference

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* Denotes Attachment