Condamine River Flood Study

Kogan Creek Mine – Levee Assessment

Palaris

0892-02-E3, 25 July 2017

For and on behalf of WRM Water & Environment Pty Ltd
Level 9, 135 Wickham Tce, Spring Hill
PO Box 10703 Brisbane Adelaide St Qld 4000
Tel 07 3225 0200

Greg Roads
Principal Engineer
RPEQ #6413

FORM OF CERTIFICATION

Name of Registered Professional Engineer providing certification:

Greg Roads RPEQ No 6413

Employed by WRM Water & Environment Pty Ltd

Address of Registered Professional Engineer providing certification:

WRM Water & Environment

Level 9, 135 Wickham Terrace, Spring Hill

PO Box 10703

Adelaide St Brisbane QLD 4000

Statement of Relevant Experience:

I hereby state that I am a Registered Professional Engineer of Queensland and meet the requirements of the definition of 'suitably qualified and experienced person'.

Statement of Certification:

All relevant material relied upon by me, including subsidiary certifications of specialist components, where required by the environmental authority, is provided in the attached report "Condamine River Flood Study, Kogan Creek Mine – Levee Assessment", dated 25 July 2017 (the report).

I hereby certify that:

- The report has been prepared in accordance with the engineering practice consistent with the standards required for this assessment, and in accordance with the regulatory guideline document "Manual for assessing consequence categories and hydraulic performance of structures", released by Department of Environment and Heritage Protection (DEHP) in March 2016.
- All relevant aspects are properly addressed in the report.

I, Greg Roads, declare that the information provided as part of this certification is true to the best of my knowledge. I acknowledge that it is an offence under Section 480 of the Environmental Protection Act 1994 to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

Signed: Greg Roads

Date: 25 July 2017

Contents

List of Figures

List of Tables

1 Introduction

Kogan Creek Mine is the primary supplier of coal to CS Energy's Kogan Creek Power Station. The mine is located about 25 km south-east of Chinchilla between the small townships of Brigalow and Kogan. The Condamine River, which drains in a westerly direction, is located to the north of the site. Kogan Creek and its tributary Eastern Branch Creek, flow through the site in a northerly direction towards the Condamine River. The locality of the Kogan Creek Coal Mine and the Condamine River catchment are shown in Figure 1.1.

Kogan Creek Mine is affected by flooding from the Condamine River and Kogan Creek systems. Earthen levees have been constructed around the mine to protect the mine infrastructure from flooding. As mining progresses southwards, a new levee is required to protect the open cut and existing levees are proposed to be modified as they are no longer protecting the pit. The layout of the Kogan Creek Mine and the locations of the existing and proposed flood protection levees are shown in Figure 1.2.

The regulatory requirements for levees constructed as part of an environmentally relevant activity pursuant to the *Environmental Protection Act 1994* (EPAct), such as those on Kogan Creek Mine must have their hazard category assessed. A dam or levee is assigned a high, significant or low hazard based on its potential consequence to the environment, humans or general economic loss if the dam overflows or the dam wall fails. A dam or levee must be regulated by the Department of Environment and Heritage Protection (DEHP) if it falls into the high or significant hazard category. Regulated levees are required to prevent the inundation of the open cut pit for the 0.1% Annual exceedance probability (AEP) (1 in 1000 year) event (DEHP, 2016).

WRM Water & Environment was commissioned by Palaris on behalf of CS Energy to undertake a consequence assessment of the levees to determine whether the levees would be regulated under the EPAct. A flood study of the Condamine River (and Kogan Creek) has also been undertaken to determine the flood immunity of the existing levees and to assess the impact, if any, on raising the levees. To undertake the study, design discharges have been estimated by the development and calibration of an URBS rainfall runoff routing model of the Condamine River and Kogan Creek systems. The model was calibrated to three historical flood events. A TUFLOW fully two-dimensional hydraulic model was developed to estimate design flood levels adjacent to the levees. The model was calibrated to the March 2010 and December 2010 events, the latter of which almost overtopped the existing levees.

The report is structured as follows:

- Section 2 describes the characteristics of the Condamine River and Kogan Creek catchments upstream of the Kogan Creek Mine as well as outlines the regulatory requirements of the levee;
- Section 3 describes the data available for the calibration of the hydrologic and hydraulic models, including a review of available rating curves;
- Section 4 describes the configuration of the URBS hydrologic model and presents the results of model calibration;
- Section 5 presents the design discharges estimated by the URBS model and compares them to design discharges estimated using the flood frequency analysis approach.
- Section 6 describes the development and calibration of the hydraulic model of the Condamine River and Kogan floodplains;

- Section 7 presents the design flood levels and extents for the study area under existing conditions;
- Section 8 outlines the consequence category assessment of the levels and the impact associated with raising the levees;
- Section 9 summarises the findings of the study; and
- Section 10 is a list of references.

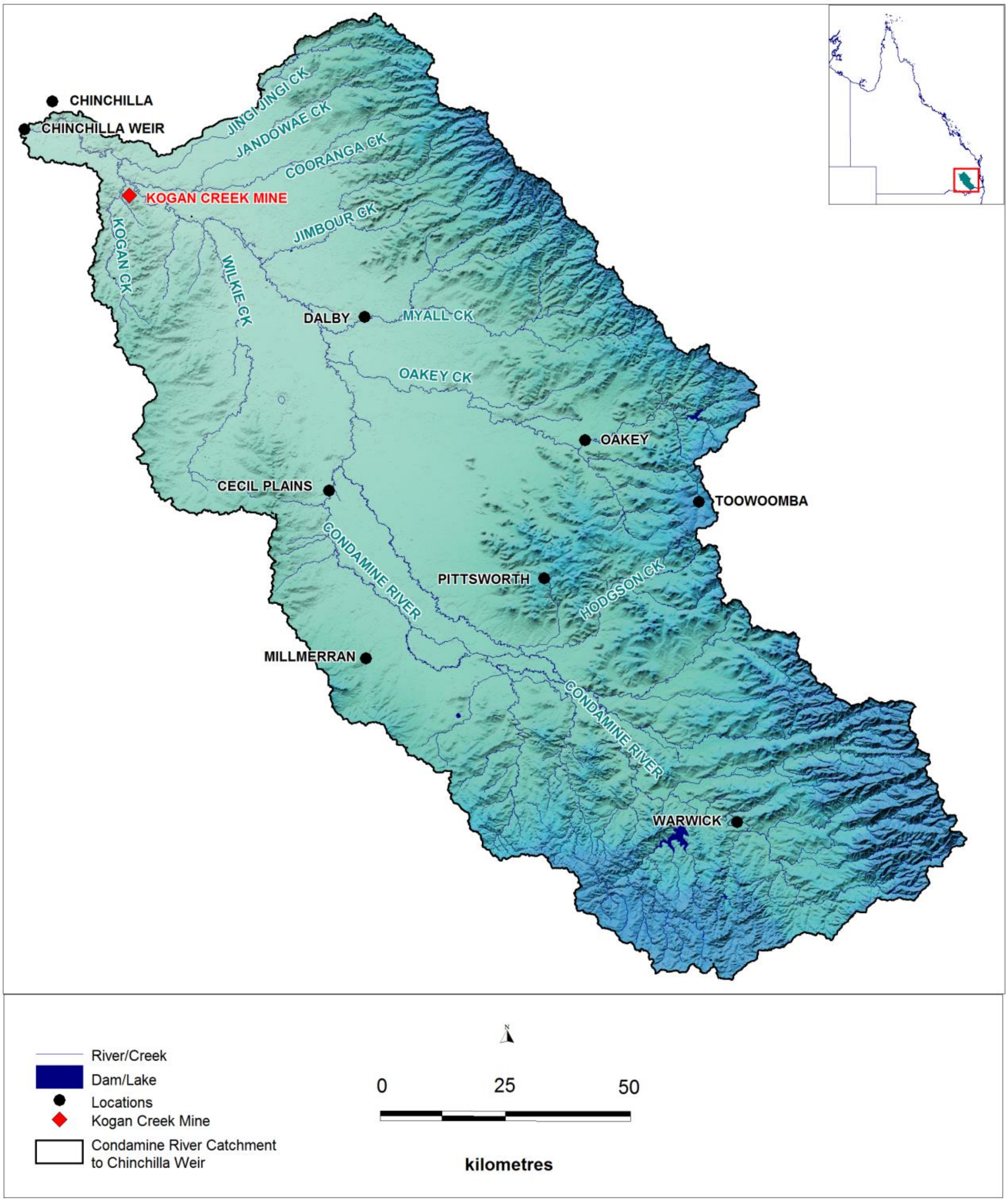

Figure 1.1 – Location of Kogan Creek Coal Mine and the Condamine River catchment

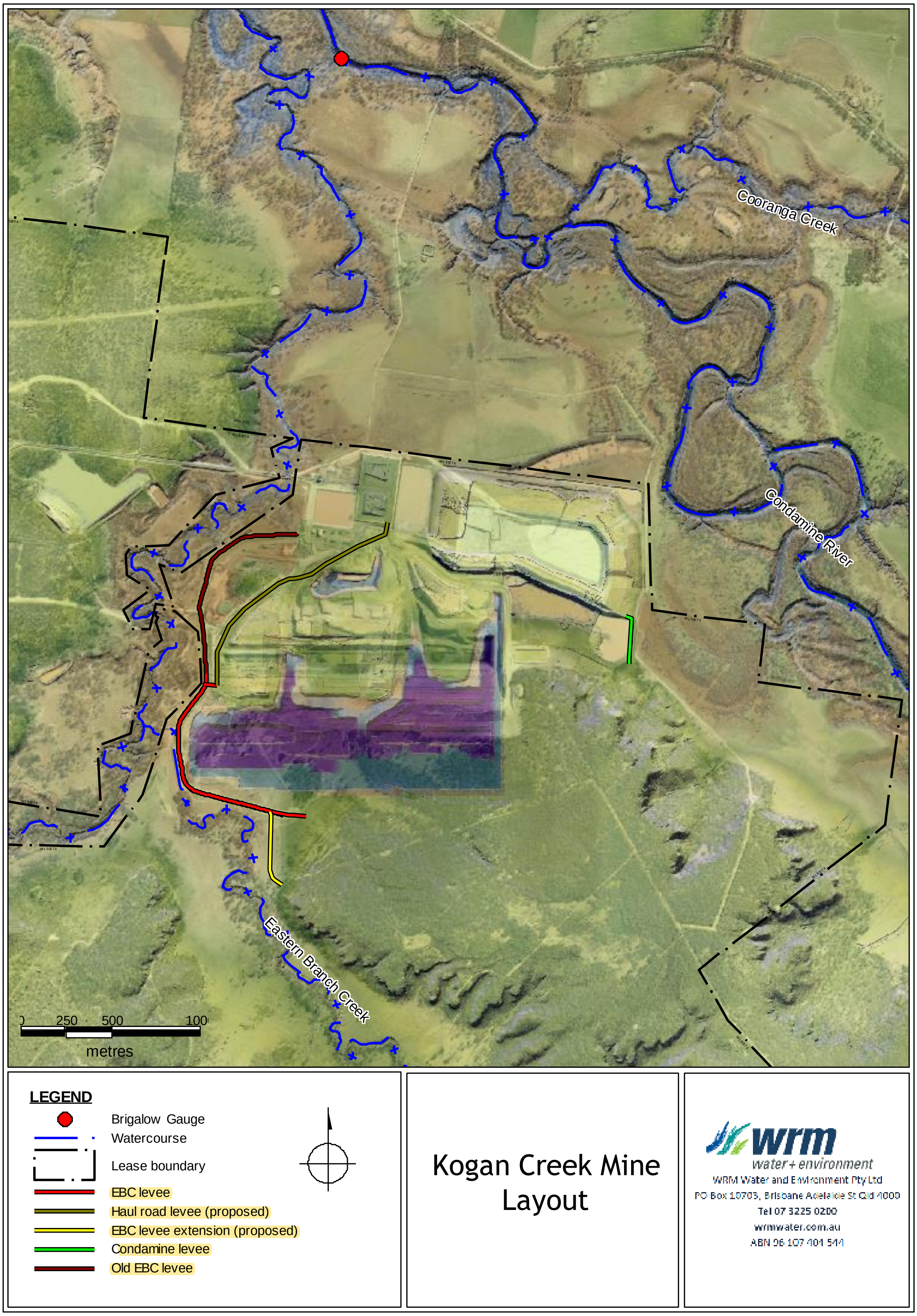

Figure 1.2 – Kogan Creek Mine Layout

2 Background

2.1 CATCHMENT CHARACTERISTICS

The Condamine River forms part of the Murray-Darling Basin and originates in the Great Dividing Range to the east of Warwick. It flows in a north-westerly direction from Warwick to Kogan Creek Mine collecting runoff from several watercourses draining the range including, Glengallan Creek, Dalrymple Creek, Hodgson Creek, Oakey Creek, Myall Creek and Jimbour Creek. The total catchment area of the Condamine River to Chinchilla Weir is approximately 19,200 km^2.

Figure 1.1 shows the drainage network and the topographic relief of the Condamine River catchment and its major tributaries. The headwaters upstream of Warwick and the north-eastern boundary of the catchment along the Great Dividing Range are relatively steep and have well defined drainage channels. The Condamine River floodplain downstream of Warwick is topographically flat with the majority of flows draining over bank during flood events.

Kogan Creek drains in a northerly direction towards the Condamine River, to the west of Kogan Creek Mine, as shown in Figure 1.2. Kogan Creek has a catchment of approximately 295 km^2, which is 1.5% of the Condamine river catchment to Chinchilla Weir. The flood peak from the Kogan Creek catchment is unlikely to coincide with the peak in the Condamine River, due to the faster flood response of Kogan Creek. As a result, this study focuses on the flooding resulting from high Condamine River flows.

2.2 REGULATORY REQUIREMENTS FOR LEVEES

The Qld government is in the process of regulating the flood immunity level of levees constructed as part of an environmentally relevant activity (ERA). This requirement has emerged as a result of the January 2008 flood, which inundated the Ensham Mine and others. Following this event, the Qld government prepared a draft manual in August 2008 for consultation with the industry. The manual was initially approved by the Minister in February 2012 and has been recently updated in March 2016 (DEHP, 2016).

Where a levee is designed to prevent ingress of non-mine affected flood water into an operational area, or catchment of a containment system, the levee would be a regulated structure where the flood modelling shows that the pit would be encroached by a flood event with a probability more likely than or equal to 1:1000 AEP. Under this circumstance, the levee would be a regulated structure and must be constructed to protect an open cut pit to have a flood immunity of at least the 0.1% AEP event.

2.3 PREVIOUS INVESTIGATIONS

At the time the Kogan Mine levees were constructed there was no specific flood immunity requirement for flood protection levees constructed as part of an ERA. The crest level of the existing levees were based on flood modelling of the Condamine River to provide flood protection up to and including the 0.2% annual exceedance probability (AEP) (1 in 500 year) event (Water Studies, 2003). The levees in Figure 1.2 that were proposed to prevent ingress to the open cut pit were the Eastern Branch Creek levees (EBC levee and Old EBC levee) and Condamine Levee. These have been identified as the existing levees in this report. The remaining levees in Figure 1.2 (ROM levee and OPAC levee) protect mine infrastructure and were not considered in the previous study.

WRM (2011) prepared a review of the existing flood protection levees at Kogan Creek mine following major flooding in December 2010 and January 2011, which came within 0.5 m of overtopping the levee. The review found that the existing mine does not have 0.2% AEP flood immunity from the Condamine River. The 0.2% AEP event would overtop the Eastern Branch Creek levee and may also breach the Condamine River levee. The study recommended raising the levees by over 2 m to improve the flood immunity. This included a 1 m freeboard to account for the significant uncertainties associated with the 0.1% AEP design discharge estimate, which was based on an extrapolation of a flood frequency analysis of the recorded flows in the Condamine River at Chinchilla Weir. To reduce the uncertainty with the design discharge estimates, the review recommended the development of a calibrated rainfall runoff routing model of the Condamine River catchment. This report has been prepared in response to this recommendation.

3 Available data

3.1 GENERAL

Available data for the calibration of hydrologic and hydraulic models consists of:

- recorded rainfalls (daily and pluviometer records);
- recorded water levels at stream gauging stations within the catchment;
- rating curves to convert recorded water levels to discharge at stream gauges; and
- topographic data.

A summary of the available data is provided in the following sections.

3.2 SELECTION OF CALIBRATION EVENTS

The URBS model was calibrated against recorded stream flows within the catchment for the following historical flood events:

- May 1996;
- December 2010 and
- January 2013.

3.3 RAINFALL DATA

Table 3.1 provides details of the available rainfall stations in and around the Condamine River catchment for the three selected calibration events. Note that the December 2010 event included two relatively separate rainfall events, and the 7-day rainfall totals for both events are provided Table 3.1. The rainfall data for the three selected events was obtained from the Bureau of Meteorology (BOM) and Department of Natural Resources and Mines (DNRM). The locations of the rainfall stations are shown in Figure 3.1. Note that Station ID's in Figure 3.1 and Table 3.1 have been assigned in a generally north-west to south-east direction.

The available rainfall data provides a reasonable coverage of the catchment-wide rainfalls for the selected calibration flood events. Data is available from both pluviograph stations, which record rainfall continuously, and daily rainfall stations which generally record rainfall over a 24-hr period to 0900 hours. Table 3.1 also shows the total rainfall for each event:

- The May 1996 rainfall event occurred within the 7 day period to 0900 hours 7 May 1996;
- The December 2010 flood event occurred as a results of 2 rainfall events, the first within the 7 day period to 0900 hours 28 December 2010 and the second within the 7 day period to 0900 hours 12 January 2011; and
- The January 2013 rainfall event occurred within the 7 day period to 0900 hours 29 January 2013.

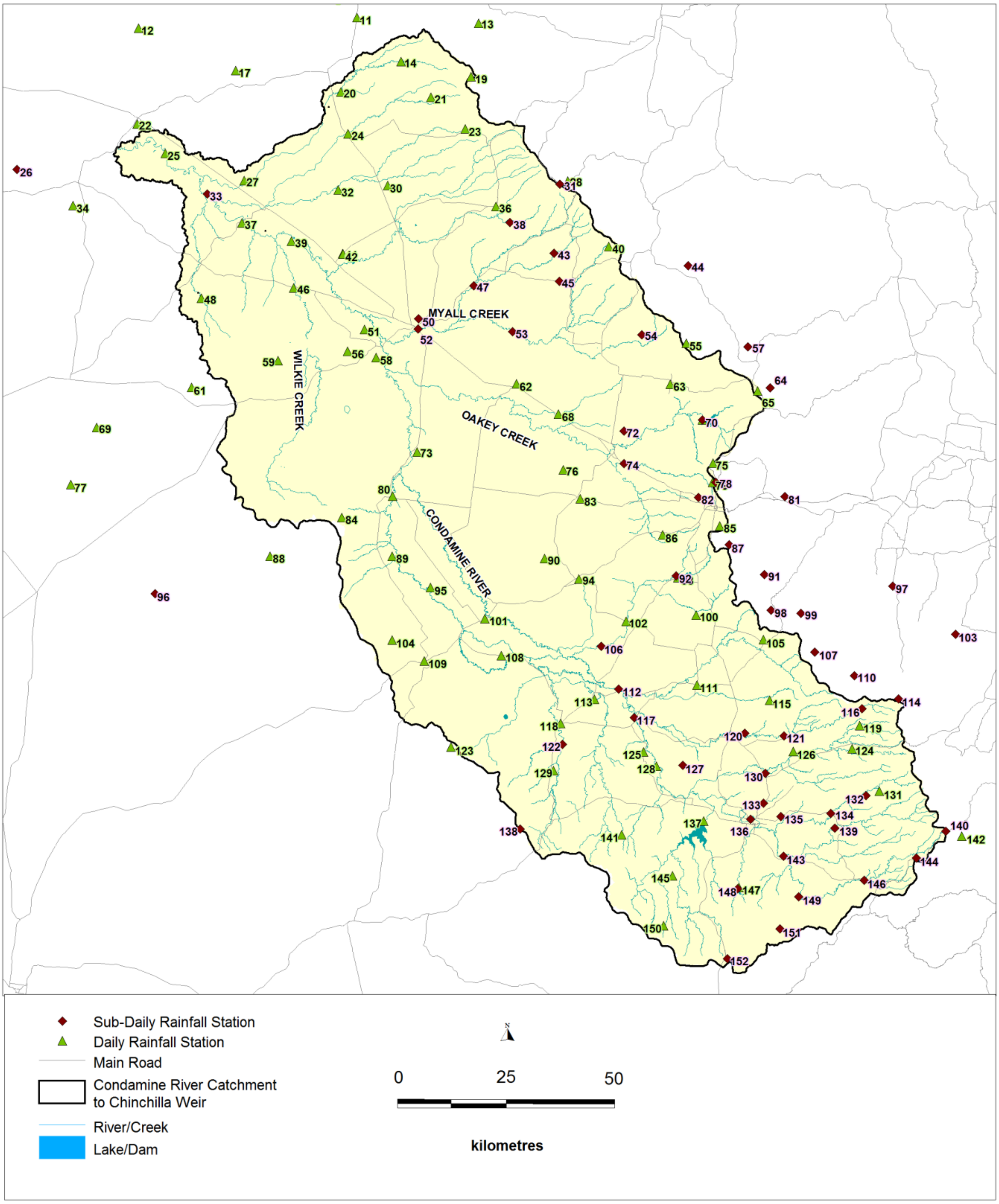

Figure 3.1 – Rainfall station locations

Table 3.1 – Rainfall data availability for calibration events

Station ID in Figure 3.1	Station Number	Station Name	Observation Period	7-day Rainfall Total to 9am (mm)			
				7 May '96	28 Dec '10	12 Jan '11	29 Jan '13
11	41090	Darr Creek TM	Daily	-	137	111	-
12	42025	Horse Creek TM	Daily	-	127	130	-
13	40246	Warragai	Daily	125	166	160	280
14	41483	Wonga	Daily	-	121	124	-
17	41409	Beruna	Daily	-	145	6	128
19	41086	Quendon	Daily	152	168	166	250
20	41052	Jingi Jingi	Daily	145	137	135	168
21	41168	Rosevale	Daily	138	-	-	198
22	41017	Chinchilla Zeller Street	Daily	172	138	190	128
23	41131	Cooranga North	Daily	138	104	112	182
24	41050	Jandowae Post Office	Daily	144	162	134	141
25	41215	Riverview Hopeland	Daily	160	132	137	-
26	542008	Bedarra TM	Pluvio	-	-	-	107
27	41291	Ehlma Park	Daily	110	-	-	147
28	40435	Mt. Mowbullan	Daily	261	-	-	-
30	41310	Kuyura	Daily	144	149	104	140
31	541046	Mt. Mowbullan ALERT	Pluvio	205	-	-	312
32	41179	Wyobie	Daily	141	-	-	-
33	41490	Brigalow Bridge TM	Pluvio	151	135	74	144
34	42078	Harewood	Daily	156	-	-	-
36	41005	Bell	Daily	124	-	-	-
37	41486	Warra-Kogan Road Bridge	Daily	155	134	66	157
38	41551	Belgrae Park ALERT	Pluvio	-	105	162	158
39	41187	Waverley	Daily	160	-	-	-
40	41202	Talgai	Daily	178	124	201	240
41	23100	Waronga	Daily	154	-	-	-
42	41469	Macalister	Daily	-	116	122	143
43	41514	Leyburn TM	Pluvio	264	121	122	-
44	540144	St. Aubyns ALERT	Pluvio	225	112	301	317
45	541044	Cooringa ALERT	Pluvio	205	99	174	142
46	41297	Daandine	Daily	193	-	-	168
47	541042	Moffatt ALERT	Pluvio	146	109	138	99
48	41261	Kia Ora	Daily	160	-	-	170
49	42086	Woodlea	Daily	125	163	70	136
50	41522	Dalby APT SYN	Pluvio	-	117	122	133
51	41240	Hereward	Daily	180	121	126	-
52	541041	Dalby ALERT	Pluvio	-	111	131	130
53	541043	Clydesdale ALERT	Pluvio	164	118	162	129
54	541045	Mt. Brigalow ALERT	Pluvio	46	93	245	207
55	41042	Haden	Daily	-	123	269	187
56	41257	Kupunn	Daily	169	-	-	-
57	540161	Crows Nest ALERT	Pluvio	-	104	328	348
58	41236	Westfields	Daily	180	-	-	-
59	41221	Karawatha Park	Daily	184	-	-	-
61	41135	Broadacres	Daily	155	-	-	-

Station ID in Figure 3.1	Station Number	Station Name	Observation Period	7-day Rainfall Total to 9am (mm)			
				7 May '96	28 Dec '10	12 Jan '11	29 Jan '13
62	41008	Bowenville	Daily	232	135	192	-
63	41037	Goombungee Post Office	Daily	201	94	280	155
64	541057	Mt. Pechey ALERT	Pluvio	-	89	283	-
65	40170	Pechey	Daily	-	-	-	-
68	41053	Jondaryan Post Office	Daily	206	112	155	95
69	41108	Beau Maison	Daily	-	153	65	137
70	541031	Cooby Creek Dam ALERT	Pluvio	-	-	-	-
71	41512	Cooby Creek Dam	Daily	213	109	316	236
72	41359	Oakey AWS	Pluvio	175	114	319	127
73	41358	Tipton Bridge	Daily	169	-	-	-
74	541058	Oakey TM	Pluvio	176	-	-	-
75	41510	Tamba	Daily	469	-	-	402
76	41072	Mount Irving	Daily	226	131	165	107
77	41493	The Deep Crossing	Daily	-	145	54	156
78	540162	Toowoomba ALERT	Pluvio	-	130	315	417
79	41069	Millmerran	Daily	-	-	-	163
80	41016	Cecil Plains Homestead	Daily	200	185	131	-
81	40829	Helidon TM	Pluvio	556	-	-	-
82	41529	Toowoomba AP	Pluvio	-	131	346	364
83	41170	Aubigny Purrawunda	Daily	-	163	186	114
84	41025	Dunmore State Forest	Daily	192	162	111	235
85	41553	Middle Ridge	Daily	-	159	363	408
86	41126	Westbrook	Daily	296	-	-	-
87	540521	Gormans Gap ALERT	Pluvio	-	-	-	289
88	41545	Dunmore Exchange TM	Daily	-	173	83	126
89	41061	Kurrowah	Daily	184	-	-	155
90	41219	Redbank	Daily	245	130	117	130
91	540170	Little Egypt ALERT	Pluvio	-	138	232	233
92	541077	Cambooya TM	Pluvio	-	189	175	-
93	41011	Cambooya	Daily	-	-	-	147
94	41082	Pittsworth	Daily	-	242	126	132
95	41019	Condamine Plains	Daily	214	168	77	134
96	41508	O'Connor TM	Pluvio	140	112	83	158
97	540528	Mulgowie ALERT	Pluvio	-	-	-	409
98	541106	West Haldon ALERT	Pluvio	-	-	-	242
99	540166	West Woodbine ALERT	Pluvio	-	174	72	267
100	41040	Greenmount Post Office	Daily	338	221	166	134
101	41250	Pampas	Daily	235	162	96	123
102	41405	Felton	Daily	234	236	131	71
103	540068	Adams Bridge TM	Pluvio	463	-	-	-
104	41110	Turallin	Daily	228	173	94	-
105	41225	Mirrabooka	Daily	276	-	-	-
106	41515	Felton TM	Pluvio	-	172	99	61
107	540600	Goltz Road ALERT	Pluvio	-	-	-	327
108	41306	Tosari	Daily	258	119	83	106
109	41096	Mt. Kynoch	Daily	-	-	-	502

Station ID in Figure 3.1	Station Number	Station Name	Observation Period	7-day Rainfall Total to 9am (mm)			
				7 May '96	28 Dec '10	12 Jan '11	29 Jan '13
110	540570	Upper Blackfellow Creek Alert	Pluvio	-	-	-	557
111	41018	Clifton	Daily	-	154	143	-
112	541050	Millbrook TM	Pluvio	-	-	-	108
113	41404	Ellangowan	Daily	277	54	147	137
114	540171	Mt. Castle ALERT	Pluvio	-	257	534	1216
115	41106	Upper Forest Springs	Daily	189	241	120	122
116	541105	Upper Dalrymple Creek ALERT	Pluvio	-	-	-	452
117	541038	Talgai Weir TW TM	Pluvio	-	146	130	97
118	41060	Leyburn	Daily	264	-	-	-
119	41323	Mandala	Daily	487	249	285	591
120	41516	Allora TM	Pluvio	-	204	137	91
121	541101	Goomburra ALERT	Pluvio	-	-	-	108
122	541104	Torridon ALERT	Pluvio	-	-	-	134
123	41388	Murralah	Daily	233	143	101	122
124	41229	Maryvale	Daily	-	232	245	381
125	41083	Pratten	Daily	-	-	-	125
126	41259	Clintonvale	Daily	169	229	149	118
127	541092	Bony Mountain ALERT	Pluvio	-	-	-	152
128	41473	Pratten Condamine River	Daily	203	122	139	161
129	41315	Brigalow Park	Daily	214	122	126	122
130	41531	Glengallan Creek ALERT	Pluvio	-	157	147	71
131	41464	Oakington	Daily	-	215	337	450
132	541062	Mosely's ALERT	Pluvio	282	215	263	421
133	541103	Campbells Gully ALERT	Pluvio	-	-	-	114
134	41530	Yangan ALERT	Pluvio	146	151	149	89
135	41525	Warwick AWS	Pluvio	-	154	132	89
136	41534	Warwick ALERT	Pluvio	152	125	142	126
137	41445	Leslie Dam	Daily	158	122	170	150
138	541080	Warahgai ALERT	Pluvio	-	90	108	90
139	41533	Emu Vale ALERT	Pluvio	148	130	156	100
140	540207	Wilsons Peak ALERT	Pluvio	-	-	-	727
141	41041	Coolesha	Daily	228	126	150	112
142	40485	Wilsons Peak	Daily	361	228	305	-
143	41536	Murrays Bridge ALERT	Pluvio	116	129	170	102
144	541064	Carrs Lookout ALERT	Pluvio	459	210	315	510
145	41285	Fairleigh	Daily	144	115	173	111
146	41537	Killarney ALERT	Pluvio	48	134	243	115
147	41438	Silverwood Dam	Daily	-	-	-	182
148	41532	Connolly Dam ALERT	Pluvio	91	101	172	-
149	41535	Elbow Valley ALERT	Pluvio	49	116	223	127
150	41251	Palgrove	Daily	140	96	125	81
151	541061	Cherrabah ALERT	Pluvio	178	108	229	197
152	541063	Dalveen ALERT	Pluvio	186	84	187	145

3.4 STREAM FLOW DATA

Table 3.2 shows the water level data available for the various model calibration events. The locations of streamflow gauges used in model calibration are shown in Figure 3.2. Recorded water level data was obtained from DNRM and BOM. Due to the discontinuation or commencement of stations, equipment malfunctions or other recording problems, recorded water level data was not available at all monitoring sites for all events.

Table 3.2 - Streamflow data availability for model calibration

Station Number	Station Name	Stream	Data Available		
			1996	2010b	2013
422334A	Aides Bridge TM	Kings Creek	Y	Y	Y
422319B	Allora TM	Dalrymple Creek	Y	Y	Y
422336A	Brigalow Bridge TM	Condamine River	Y	Y	Y
422341A	Brosnans Barn TM	Condamine River	Y	Y	Y
422316A	Cecil Plains TM	Condamine River	Y	Y	Y
41472[1]	Centenary Bridge	Condamine River	Y	Y	Y
422308C	Chinchilla Weir TM	Condamine River	Y	Y	Y
541043[1]	Clydesdale Alert	Myall Creek	Y	Y	Y
41532[1]	Connolly Dam Alert	Rosenthal Creek	Y	Y	Y
541041[1]	Dalby Alert	Myall Creek	Y	Y	Y
422394A	Elbow Valley Alert	Condamine River	Y	Y	Y
41404[1]	Ellangowan	Thanes Creek	Y	Y	Y
422313B	Emu Vale Alert	Emu Creek	Y	Y	Y
422350A	Fairview TM	Oakey Creek	Y	Y	Y
422352A	Felton TM	Hodgson Creek	Y	Y	Y
41531[1]	Glengallan Creek Alert	Backwater Creek	N	Y	Y
422359A	Jondaryan	Oakey Creek	N	N	Y
41537[1]	Killarney Alert	Condamine River	Y	Y	Y
422321B	Killarney	Spring Creek	Y	Y	Y
422338A	Leyburn TM	Canal Creek	Y	Y	Y
422345A	Lone Pine TM	North Condamine River	Y	Y	Y
422333A	Loudouns Bridge TM	Condamine River	Y	Y	Y
541042[1]	Moffat Alert	North Myall Creek	Y	Y	Y
41536[1]	Murrays Bridge Alert	Condamine River	Y	Y	Y
422332B	Oakey	Gowrie Creek	Y	Y	Y
422347B	Pampas Bridge Alert	North Condamine River	Y	Y	Y
41473[1]	Pratten	Condamine River	N	Y	Y
41501[1]	Pratten TM	Condamine River	Y	N	Y
41346[1]	Ranges Bridge	Condamine River	Y	Y	N
422310C	Scots College TM	Condamine River	Y	Y	Y
422306A	Swanfels TM	Swan Creek	Y	Y	Y
422355A	Talgai Weir TW TM	Condamine River	Y	Y	Y
41046[1]	The Head	Condamine River	Y	Y	Y
41358[1]	Tipton Bridge	Condamine River	Y	N	N
422323A	Tummaville TM	Condamine River	Y	Y	Y
541048[1]	Victoria Hill Alert	Dalrymple Creek	N	Y	Y
41486[1]	Warra-Kogan Rd Bridge	Condamine River	Y	Y	Y
422310B[2]	Warwick Alert	Condamine River	Y	Y	Y
41530[1]	Yangan Alert	Swan Creek	Y	Y	Y
422353A[2]	Yarramalong TM	Condamine River	Y	N	N

1. BOM streamflow station only 2. DERM station now closed

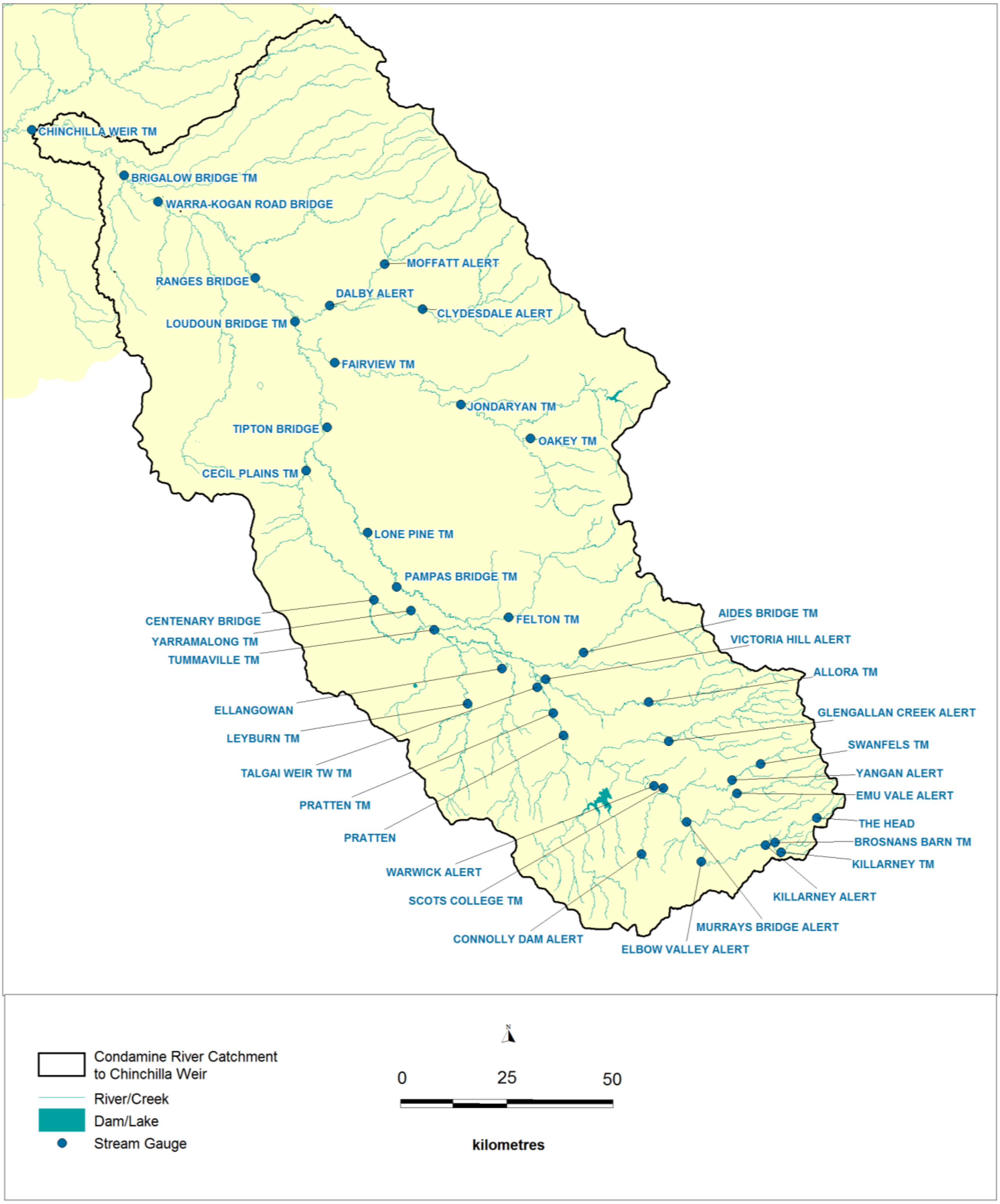

Figure 3.2 – Stream gauging station locations

3.5 RATING CURVES

Rating curves are used to convert the recorded water levels to discharges and are derived by taking direct measurements of stream flows at various water levels to derive a water level/discharge relationship.

Rating curves for key stations throughout the Condamine catchment were obtained from DNRM. These curves were reviewed and checked against actual stream gauging data. Table 3.3 summarises the rating curve data available, including the maximum recorded discharge and the maximum gauged discharge at each gauge. The recorded flows at each station are potentially more reliable for flows up to the maximum gauged discharge. The rating curves have been extrapolated above this level and are therefore potentially less reliable.

Table 3.3 - Stream gauge rating data availability

Station Number	Station Name	Stream	Maximum Gauged Discharge (m^3/s)	Maximum Recorded Discharge (m^3/s)
422334A	Aides Bridge TM	Kings Creek	287	1621
422319B	Allora TM	Dalrymple Creek	76.1	653
422336A	Brigalow Bridge TM	Condamine River	3388	4817
422341A	Brosnans Barn TM	Condamine River	66.4	279
422316A	Cecil Plains TM	Condamine River	2757[1]	2047
422308C	Chinchilla Weir TM	Condamine River	2721[2]	4499
422394A	Elbow Valley Alert	Condamine River	114	790
422313B	Emu Vale Alert	Emu Creek	51.3	689
422350A	Fairview TM	Oakey Creek	422[3]	418
422352A	Felton TM	Hodgson Creek	291	1442
422359A	Jondaryan	Oakey Creek	308	409
422321B	Killarney	Spring Creek	3.3	142
422338A	Leyburn TM	Canal Creek	255	612
422345A	Lone Pine TM	North Condamine River	21.6	620
422333A	Loudouns Bridge TM	Condamine River	636	3124
422332B	Oakey	Gowrie Creek	122	482
422347B	Pampas Bridge Alert	North Condamine River	16.2	52.9
422310C	Scots College TM	Condamine River	363	1519
422306A	Swanfels TM	Swan Creek	50.1	380
422355A	Talgai Weir TW TM	Condamine River	701	2375
422323A	Tummaville TM	Condamine River	666	1788

1. Maximum gauged discharge in 1983 appears to relate to older rating curve
2. Maximum gauged discharge in 1996, maximum observed discharge in 2011
3. Maximum gauged discharge in 1981, maximum observed discharge in 1995

3.6 TOPOGRAPHIC DATA

Topographic data was used to define the drainage network and catchment boundary of the Condamine River. The following topographic data were available for the study:

- Digital Elevation Model derived from the NASA Shuttle Radar Topographic Mission (SRTM) data from Geosciences Australia was used to define the URBS model catchments;
- Light Detection and Ranging (LiDAR) aerial survey along the Condamine River floodplain, adjacent to Kogan Creek Mine, was obtained from Cameron Cotterell and Steen for the hydraulic modelling. The data was flown in March and April 2008 at a vertical accuracy of ±0.15 m.

4 Hydrologic model development and calibration

4.1 METHODOLOGY

The URBS runoff-routing model (Carroll, 2014) was used to estimate flood discharges in the Condamine River catchment. URBS is a runoff-routing computer model that uses a network of conceptual storages to represent the routing of rainfall excess through a catchment. URBS is used extensively throughout Australia by the Bureau of Meteorology for flood forecasting on major river systems.

The URBS model was used in the "split mode" which enables the separate simulation of catchment and channel routing. Adopted rainfall losses are subtracted from the total rainfall hyetograph to obtain rainfall excess. The rainfall excess is then routed through conceptual catchment storage to determine the local runoff hydrograph for the sub-catchment. The storage - discharge relationship for catchment routing is:

$$S_{catch} = \left\{ \frac{\beta \sqrt{A}\,(1 + F)^2}{(1 + U)^2} \right\} Q^m$$

where S_{catch} is the catchment storage (m^3 h/s);
β is the catchment lag parameter;
A is the area of sub-catchment (km^2);
U is the fraction urbanisation of sub-catchment;
F is the fraction of sub-catchment forested; and
m is the catchment non-linearity parameter.

In the above equation, β and m are determined during model calibration and are global parameters.

The local runoff hydrograph is then combined with runoff from the upstream sub-catchment and routed through a channel storage to obtain the outflow hydrograph for the sub-catchment. Channel routing is based on the non-linear Muskingum Model. The channel routing storage-discharge relationship is given by:

$$S_{chnl} = \alpha f \frac{n^* L}{\sqrt{S_c}} \left(x Q_u + (1 - x) Q_d \right)^n$$

Where S_{chnl} is the channel storage (m^3 h/s);
α is the channel lag parameter
f is the reach length factor;
L is the length of reach (km);
S_c is the channel slope (m/m);
Q_U is the inflow at upstream end of reach (includes catchment inflow) (m^3/s);
Q_d is the outflow at downstream end of the channel reach (m^3/s);
x is the Muskingum translation parameter;
n is the Muskingum non-linearity parameter (exponent); and
*n** is the Manning's 'n' or channel roughness.

In the above equation, α and *f* are the principal calibration parameters. Note also that α is a global parameter, whereas f can be varied for each channel reach.

URBS allows the user to select one of several standard loss models. The available options are: initial and continuing loss model, proportional loss model, Manley-Phillips infiltration model and water balance model. The initial and continuing loss model was adopted for the Condamine River catchment. This model assumes that there is an initial loss of '**il**' mm before any rainfall becomes runoff. After this, a continuing loss rate of '**cl**' mm per hour is applied to the rainfall, subject to the limit of the soil infiltration capacity (IF_{max}). The loss rates can be specified 'globally' to the entire catchment or 'individually' to each sub-catchment. An initial loss recovery factor is also applied for long duration events (such as the December 2010/January 2011 events)

Full details of the URBS model and its features are given in the URBS User Manual (2012).

4.2 CATCHMENT DELINEATION

Catchment delineation of the Condamine River URBS model has been determined using the CatchmentSim software (Catchment Simulation Solutions Pty Ltd, 2013) and SRTM data. CatchmentSIM allows for automatic catchment delineation and stream length generation for input to URBS. CatchmentSim also provides a tool to output the catchment and stream network information in the required format for direct input to URBS. Catchment slope was also obtained from CatchmentSim and, while not used directly in the URBS model, was used to approximate regions where different reach length factors could be applied.

The process for automatically delineating catchments and streams required importing topographic data (SRTM data) and further processing the DEM to ensure hydrological connectivity. Catchments were then created based on user defined outlet locations.

It should be noted that the direct output from CatchmentSim to URBS file format assumes that the "centroid" is halfway along the main stream length, where the main stream length is the longest flow path in that catchment.

4.3 URBS MODEL CONFIGURATION

4.3.1 Sub-catchment models

The Condamine River URBS model covers the entire catchment upstream of Chinchilla Weir. The URBS model was broken into 5 sub-models, as shown in Figure 4.1. The configuration of the individual sub-models is shown in Figure 4.2 to Figure 4.6. Appendix A provides the areas and main stream lengths (defined as the longest flow path through the catchment) for each sub-catchment in each sub-model.

4.3.2 Bypass flows

It is possible that under high flow situations in the Condamine River, floodwater may break out of the main channel at a number of locations, diverting flow around stream gauges. Based on comparisons with the recorded stream flow and as part of the calibration process, channel bypasses were include at a number of locations to simulate these breakout flows occurring:

- at Tummaville stream gauge, 90% of the Condamine River flow for discharges greater than 700 m^3/s was assumed to bypass the gauge, re-joining downstream of the Tummaville gauge; and
- at Fairview stream gauge,100% of the Oakey Creek flow for discharges greater than 300 m^3/s was assumed to bypass the gauge, re-joining the Condamine River downstream of the Loudoun Bridge gauge.

4.3.3 Floodplain storage

Floodplain storage areas were added to the model upstream of the Centenary Bridge stream gauge, Loudoun Bridge stream gauge and Warra Kogan stream gauge to better model the floodplain storage at very high discharges. Table 4.1 shows the storage-discharge curve adopted for these storage areas. Note that these storage-discharge curves have been derived from the three calibration events. They can be improved by calibration to more flood events. These floodplain storage nodes primarily affect flood events below the December 2010 event discharges for which data is available. Peak flows above these levels are generally not mitigated by these nodes.

Table 4.1 - Adopted Storage-Discharge Curves

Upstream of Centenary Bridge		Upstream of Loudoun Bridge		Upstream of Warra Kogan	
Storage (ML)	Discharge (m^3/s)	Storage (ML)	Discharge (m^3/s)	Storage (ML)	Discharge (m^3/s)
0	0	0	0	0	0
50,000	450	5,000	200	5,000	250
60,000	5,000	40,000	500	60,000	650
		270,000	5,000	160,000	2,000
				170,000	5,000
				180,000	15,000

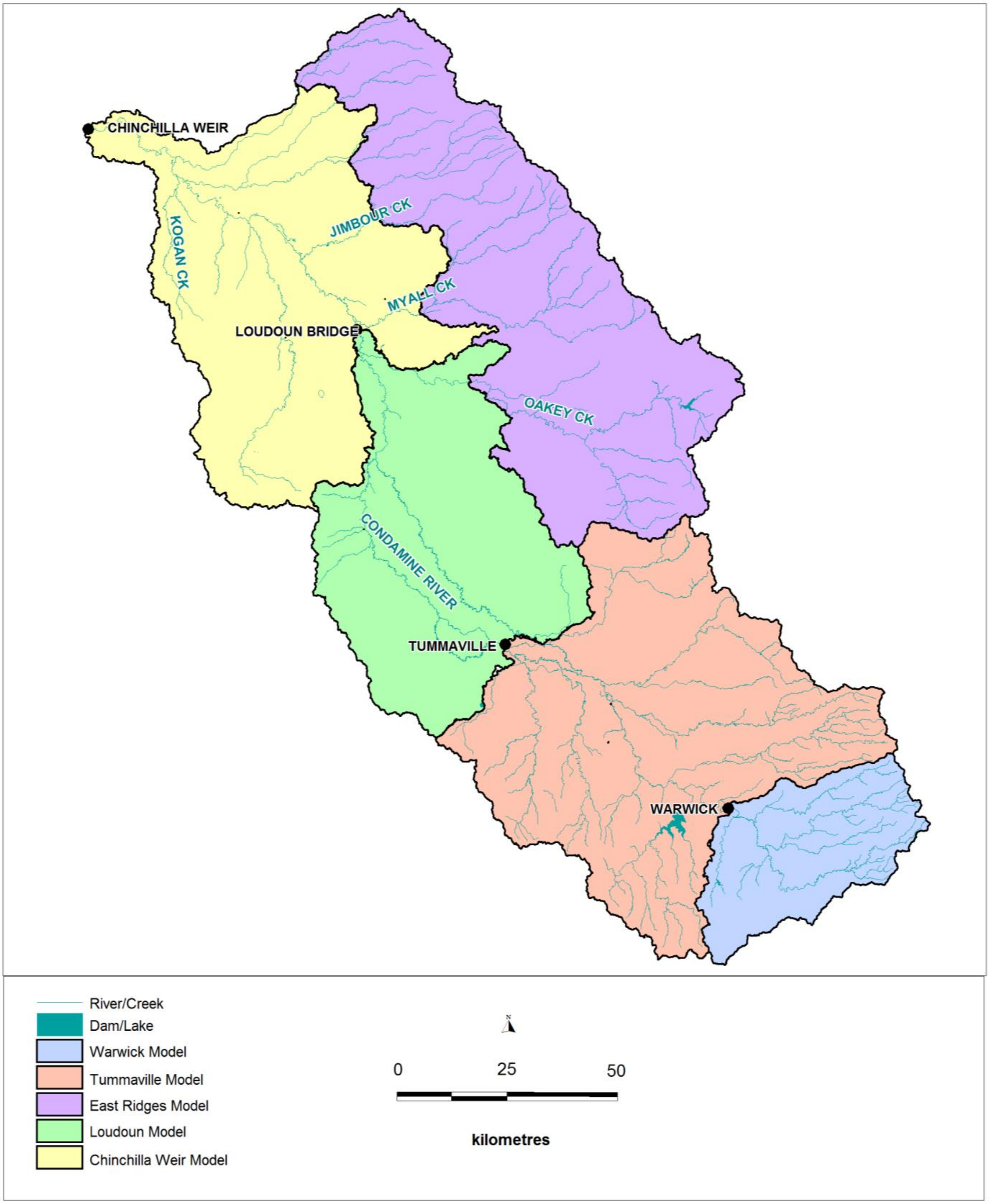

Figure 4.1 - Condamine URBS sub-model configuration

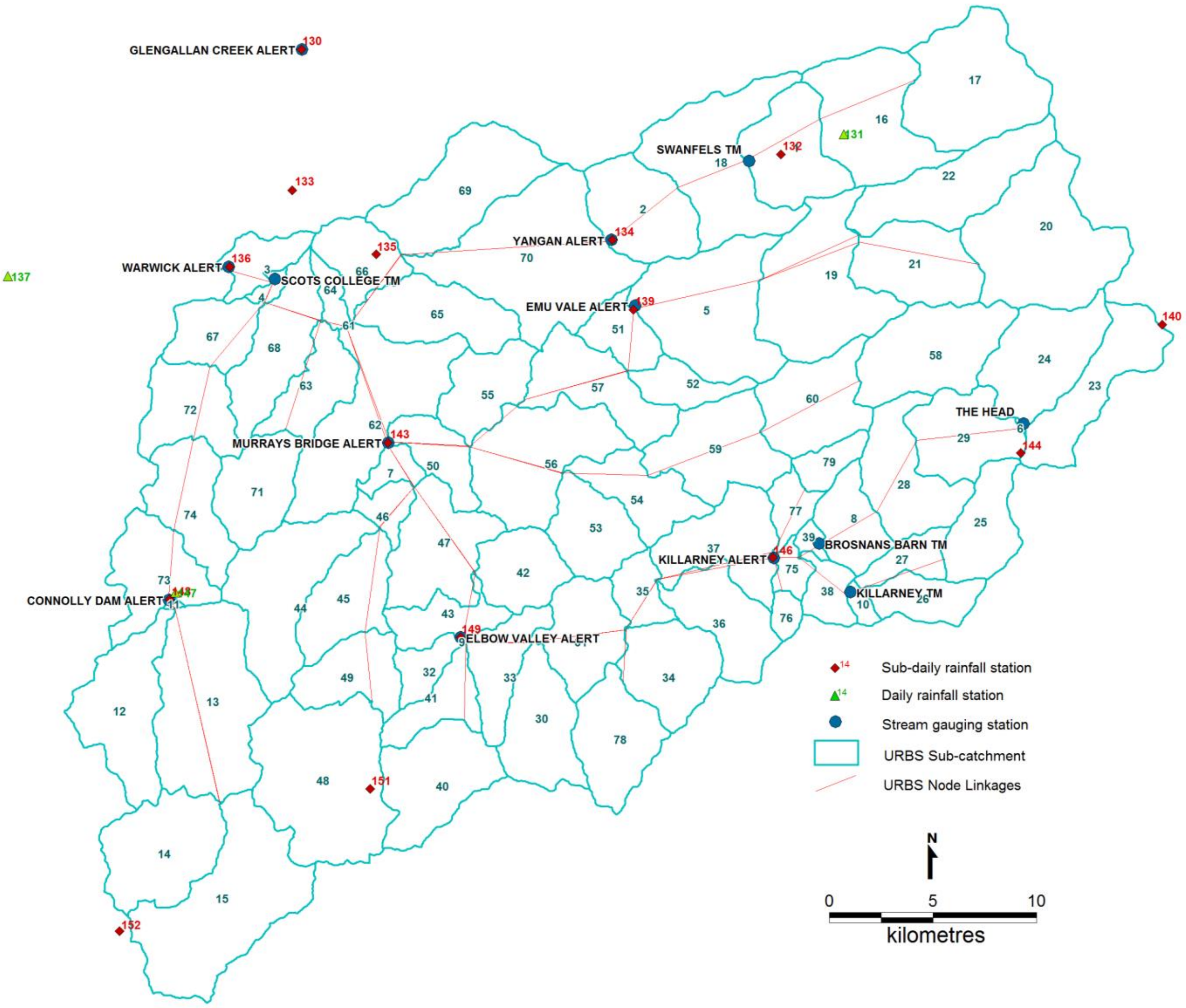

Figure 4.2 - Warwick URBS model configuration

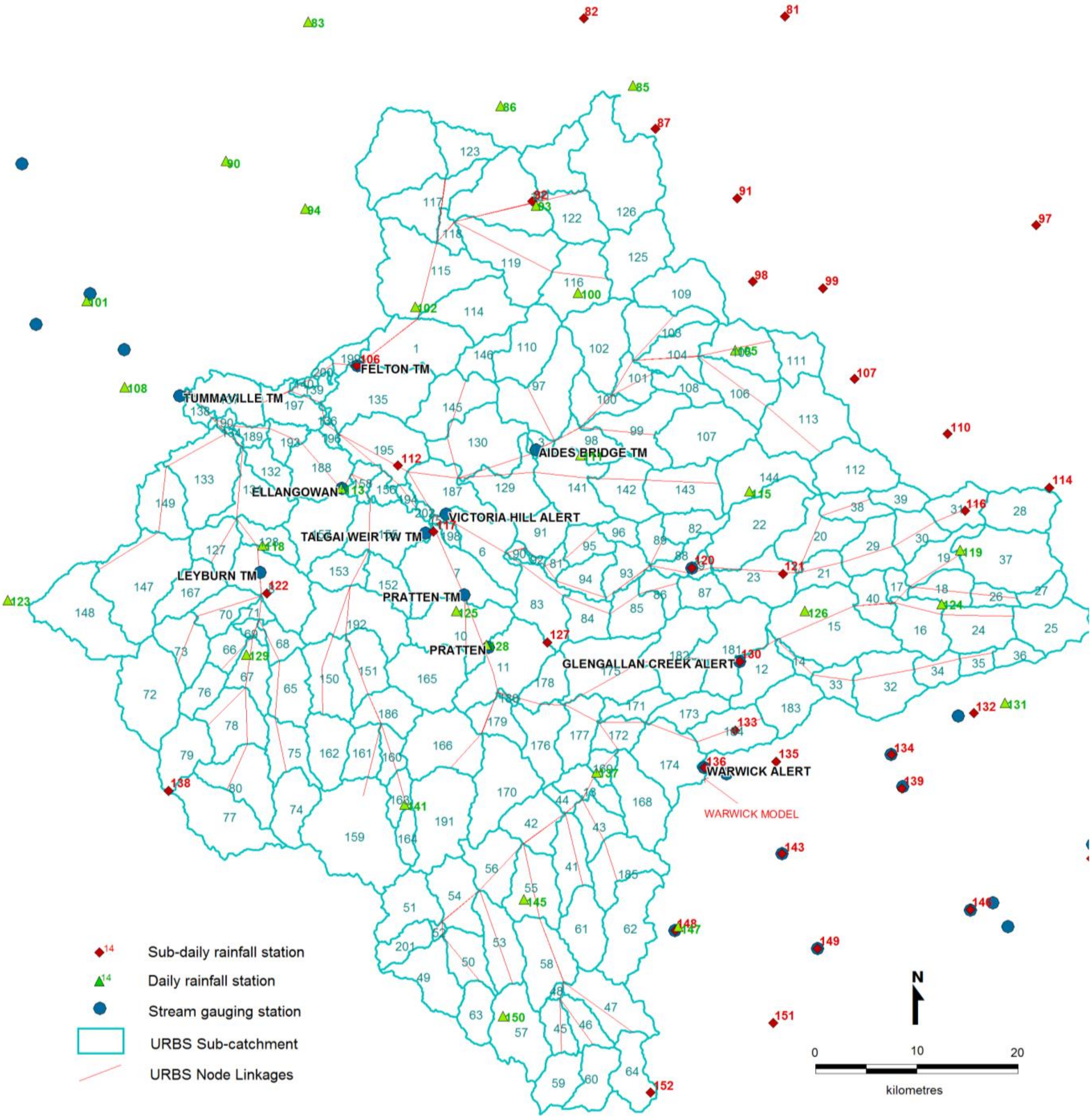

Figure 4.3 - Tummaville URBS model configuration

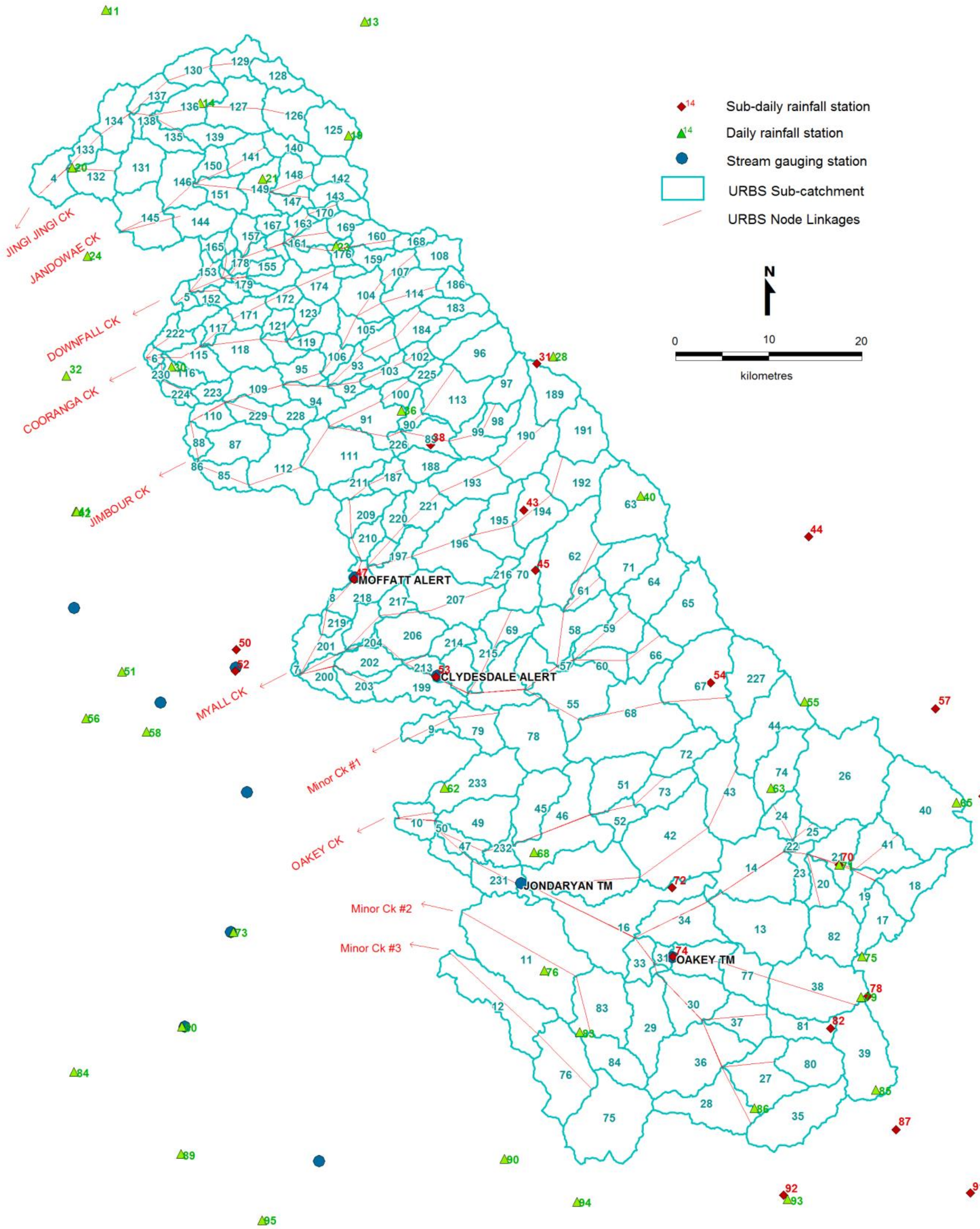

Figure 4.4 – East Ridges URBS model configuration

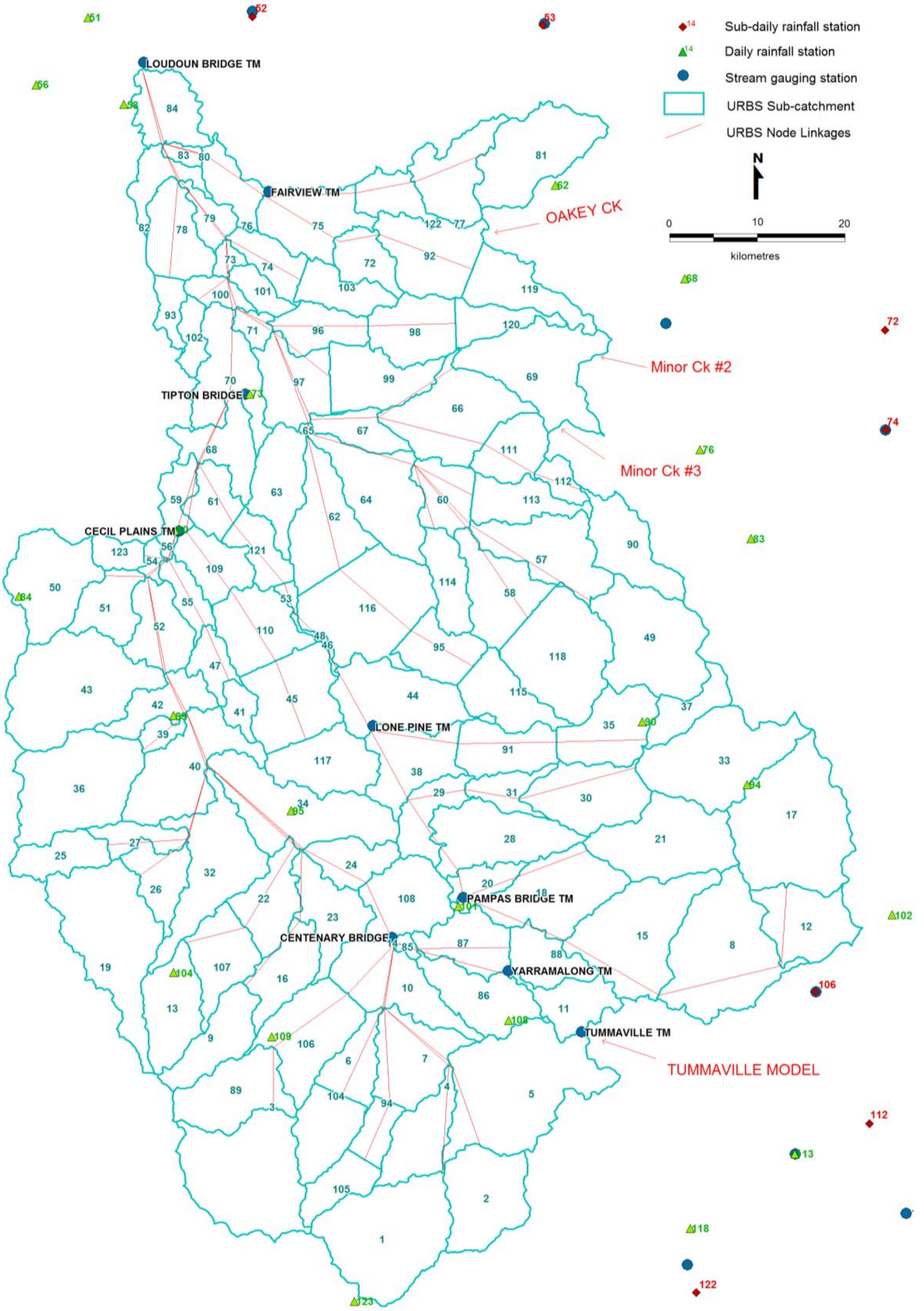

Figure 4.5 - Loudoun URBS model configuration

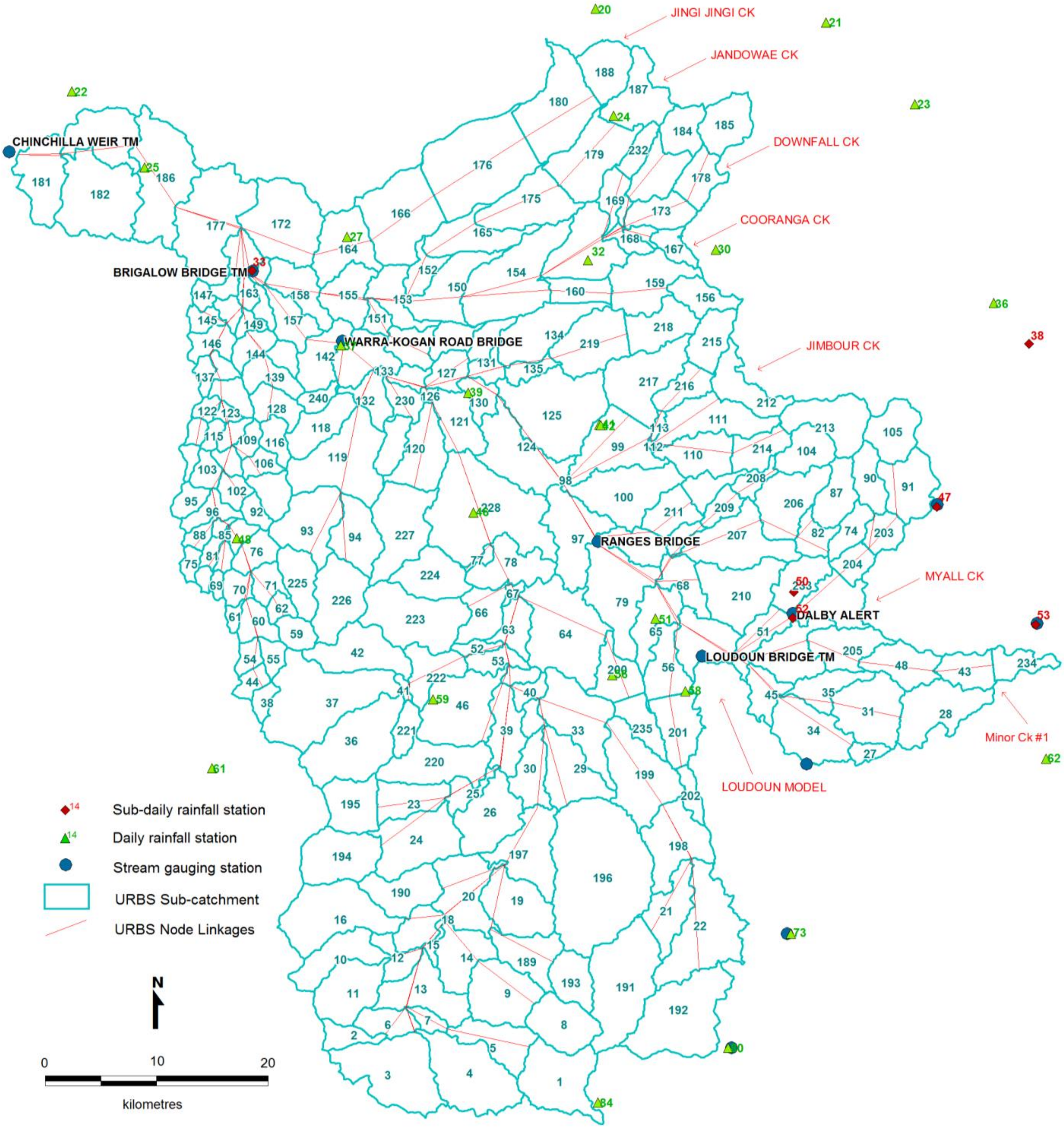

Figure 4.6 – Chinchilla Weir URBS model configuration

4.3.4 Stream length factors

Table 4.2 shows the adopted stream length factors for all calibrations events for the Condamine River sub-models. Subcatchments were assigned stream length factors, approximately based on catchment slope. Figure 4.7 to Figure 4.11 show the regions of catchments where the different stream length factors were applied for each sub-model.

Table 4.2 - Adopted Stream Length Factors

Model	Catchment Slope	Stream Length Factor
Warwick Model	>1.0%	0.9
	<1.0%	1.0
Tummaville Model	>1.0%	0.7
	0.2%-1.0%	1.2
	<0.2% & Condamine R channel d/s of Talgai Weir	1.9
	Condamine R channel u/s of Talgai Weir	1.6
East Ridges Model	>1.0%	0.3
	0.5%-1.0%	1
	<0.5%	3
Loudoun Model	>0.5%	0.8
	Condamine R channel	1.0
	0.1%-0.5%	1.2
	<0.1%	2.5
Chinchilla Weir Model	>0.5%	0.8
	0.1%-0.5%	1.6
	<0.1%	2.5

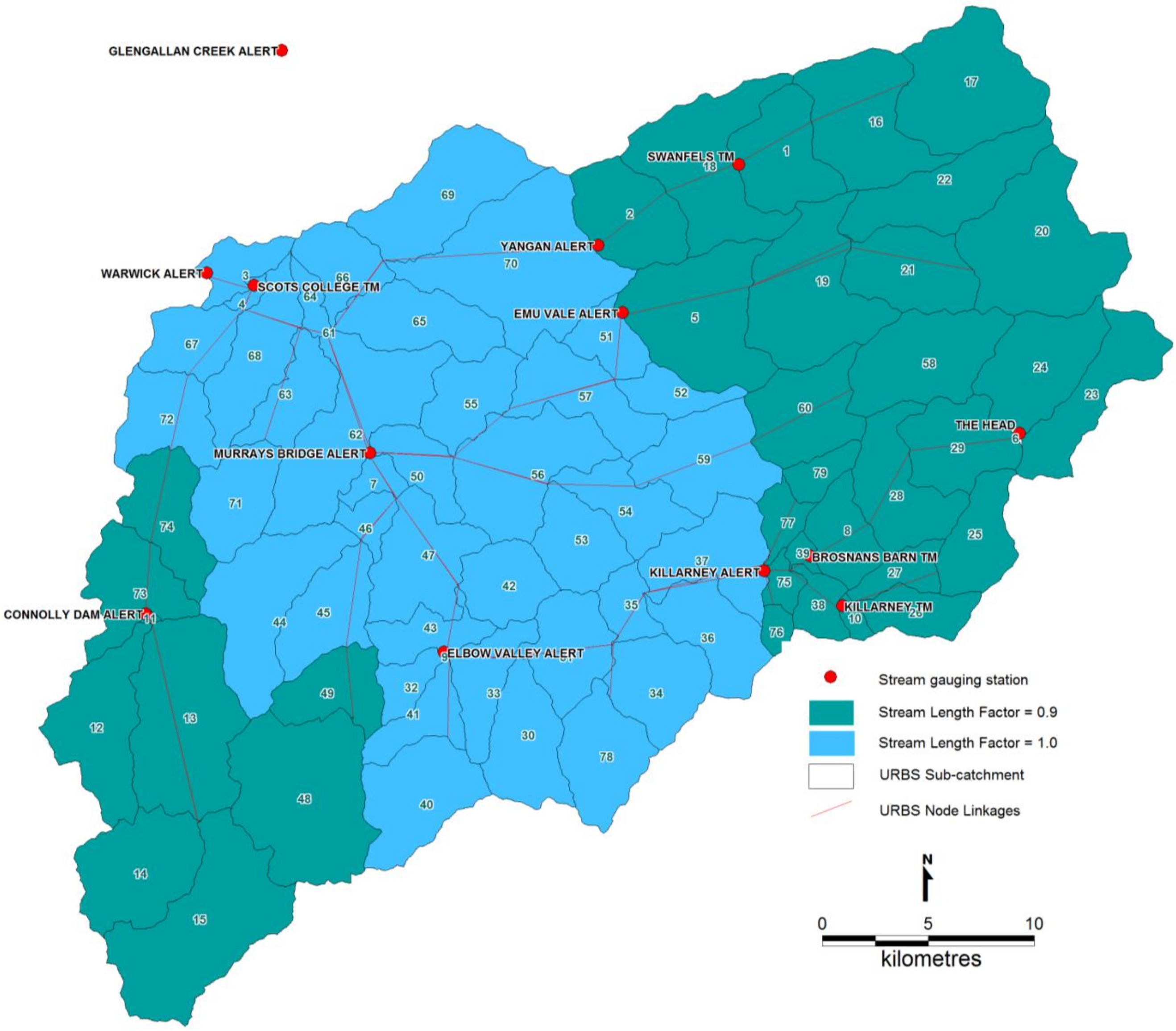

Figure 4.7 - Adopted stream length factors – Condamine River to Warwick

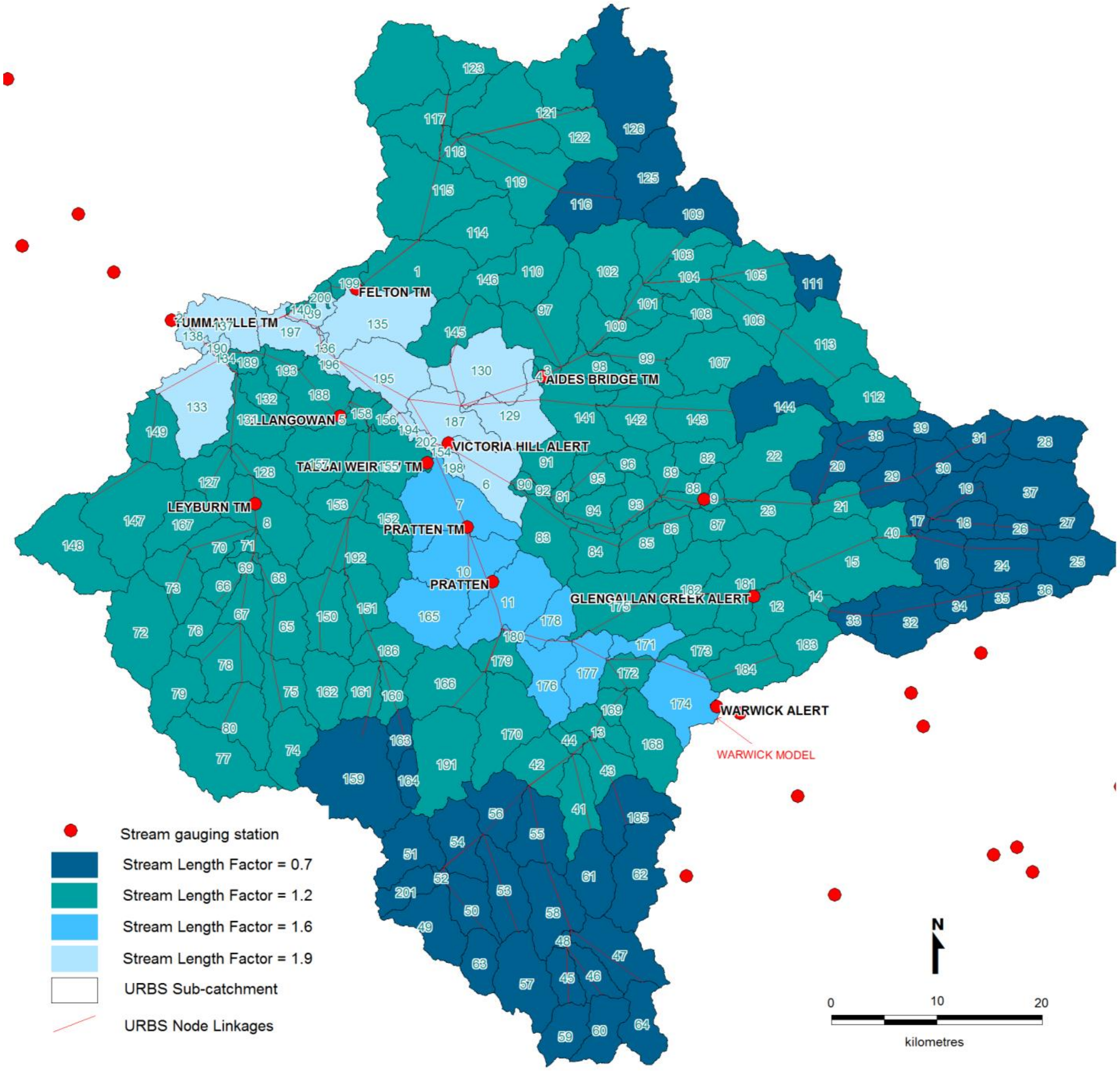

Figure 4.8 – Adopted stream length factors – Condamine River to Tummaville

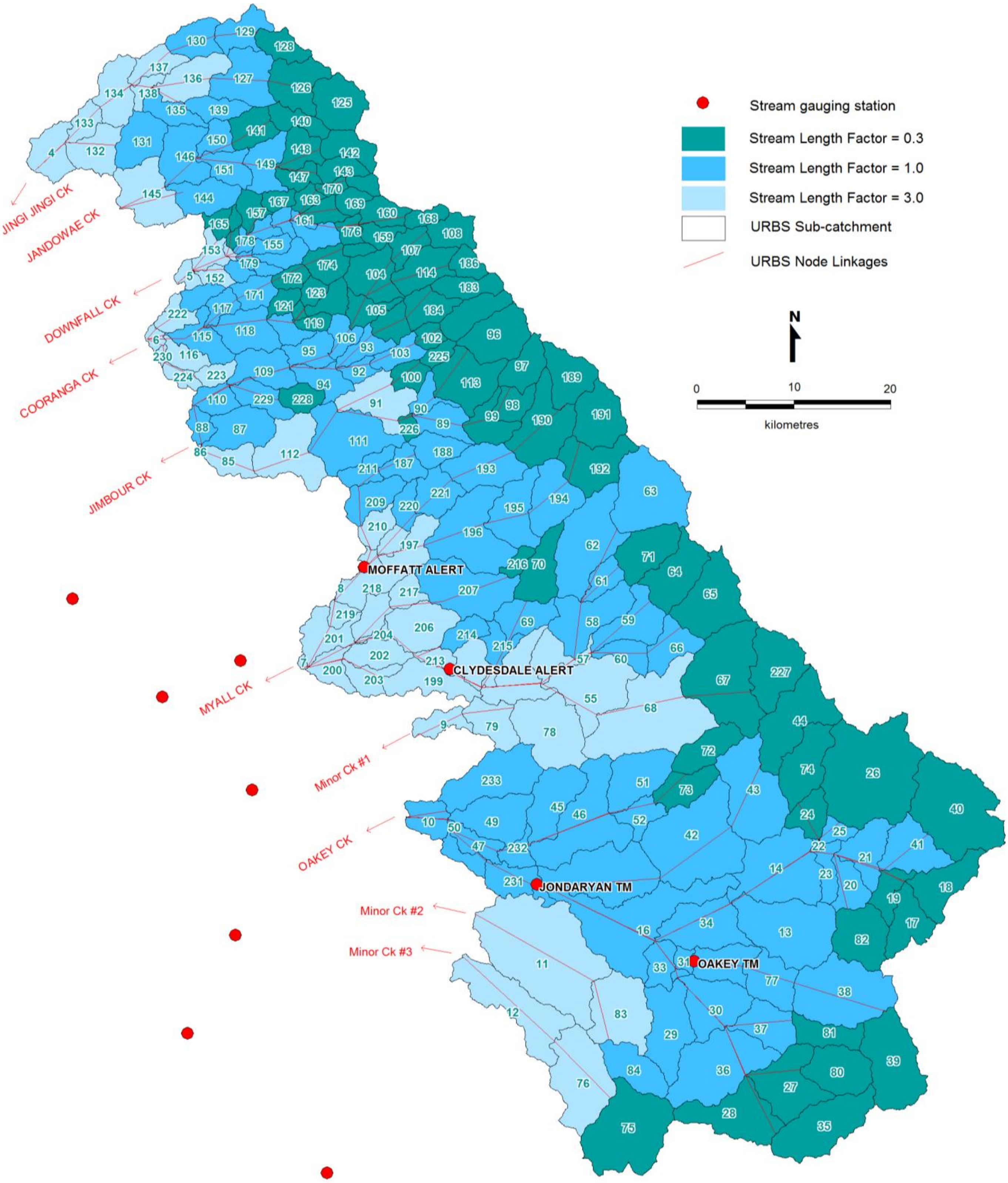

Figure 4.9 - Adopted stream length factors – East Ridges tributaries

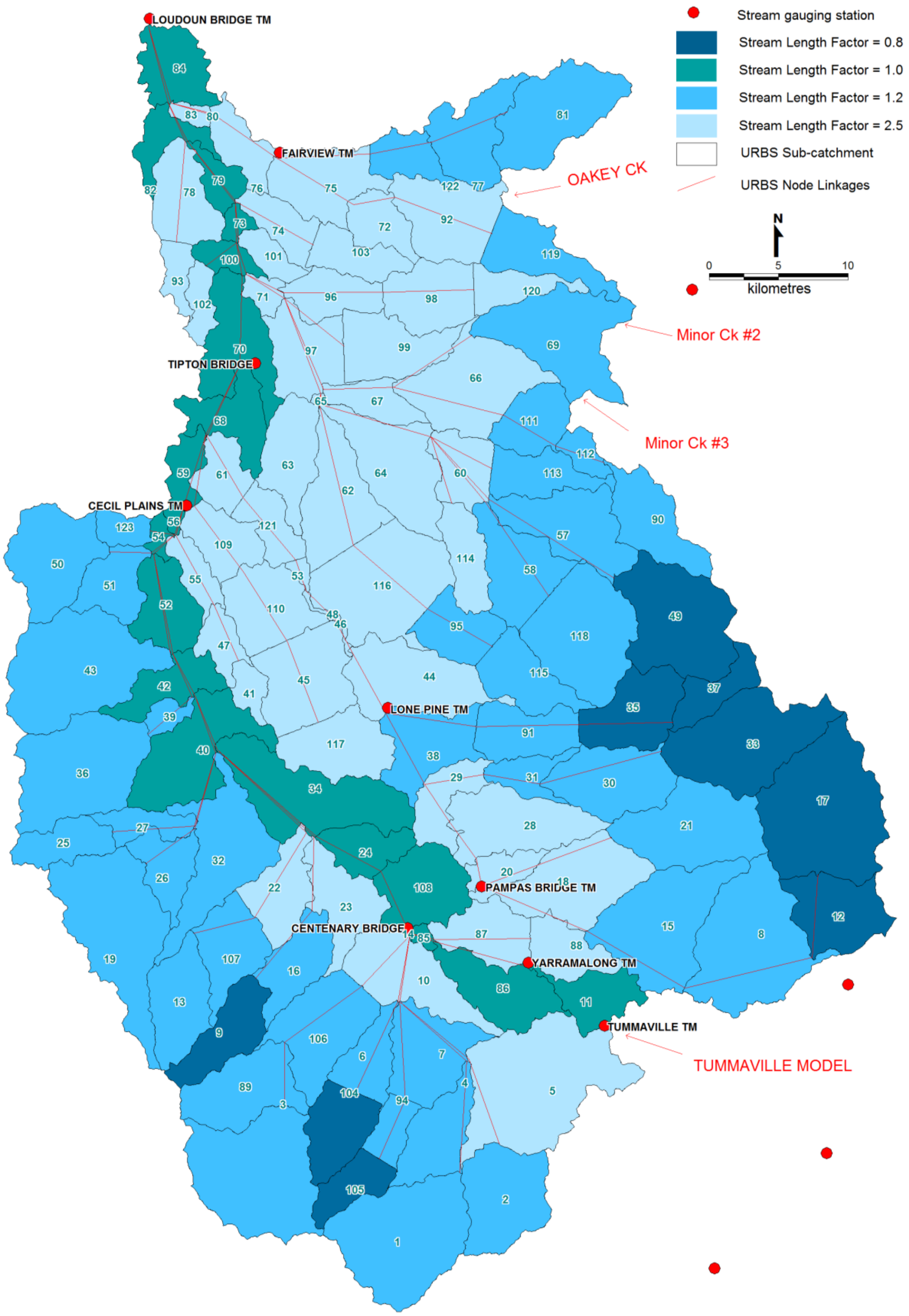

Figure 4.10 - Adopted stream length factors – Condamine River to Loudoun Bridge

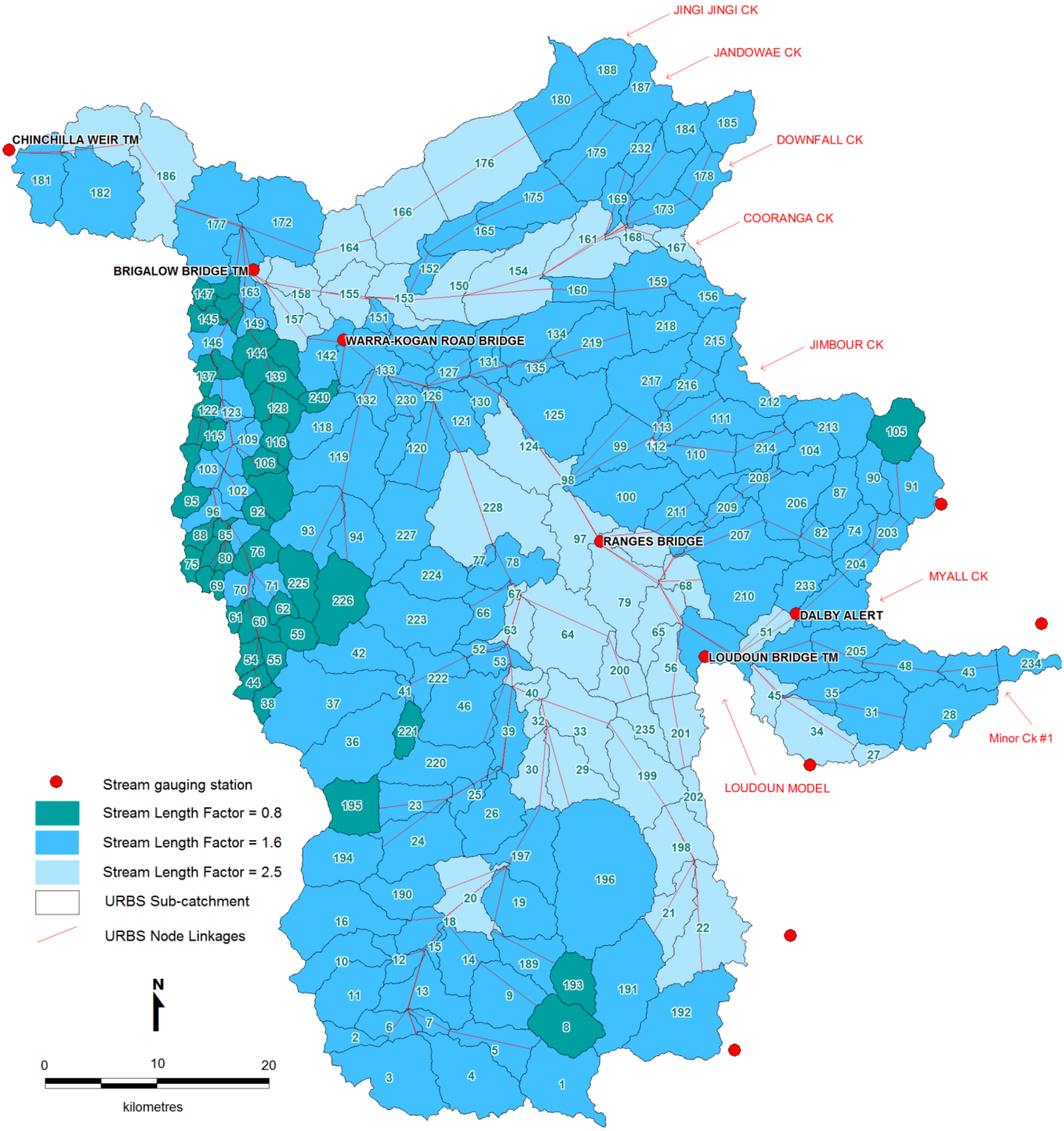

Figure 4.11 - Adopted stream length factors – Condamine River to Chinchilla Weir

4.4 ASSIGNMENT OF TOTAL RAINFALLS AND TEMPORAL PATTERNS

Total event rainfalls for each sub-catchment of the URBS sub-models were estimated by weighting recorded data (both daily and pluviograph stations) based on the square of the inverse distance from the centroid of each sub-catchment to the nearest four rainfall stations, using the method described by Malone (2000). The rainfall temporal pattern for each sub-catchment was then obtained by applying the temporal rainfall distribution derived from the nearest pluviograph station. Note parts of the Condamine River catchment, particularly for the May 1996 calibration event, have relatively limited coverage by pluviograph stations, resulting in substantial reliance on daily rainfalls in some areas of the catchment.

Details of available rainfall stations and rainfall totals for each rainfall event are given in Section 3.3.

4.5 MODEL CALIBRATION PARAMETERS

A single set of model parameters was adopted for each of the URBS sub-models (except for rainfall losses), and maintained for all calibration events. The model parameters were adjusted to achieve the best calibration across all events, resulting in a compromise between model accuracy and model simplicity. It is noted that calibration of the models for individual events can be improved by adopting a different set of model parameters for each of the different events.

4.5.1 URBS parameters

Table 4.3 shows the adopted URBS model parameters for all calibration events for the Condamine River sub-models.

Table 4.3 - Adopted URBS Model Parameters for Calibration Events

Parameter	Value				
	Warwick Model	Tummaville Model	East Ridges Model	Loudoun Model	Chinchilla Weir Model
α (channel lag parameter)	0.6	0.4	0.6	0.4	0.4
β (catchment lag parameter)	4.0	4.0	4.0	4.0	4.0
m (catchment non-linearity parameter)	0.6	0.6	0.6	0.6	0.6
n (channel non-linearity parameter)	0.9	0.9	0.8	0.9	0.9

4.5.2 Initial and continuing losses

Table 4.4 shows the adopted initial loss, continuing loss and initial loss recovery factors for the Condamine River sub-models for the different calibration events. It is of note that the amount and quality of available rainfall data will have some effect on the adopted initial and continuing losses. The commencement of the model run, which often does not relate to the commencement of the flood producing storm burst, will also impact on the adopted initial losses.

Table 4.4 - Adopted Initial and Continuing Losses for Calibration Events

Model	Event	Initial Loss (mm)	Continuing Loss (mm/hr)	Initial Loss Recovery Factor
Warwick Model	1996	90	1.0	0.2
	2010	15	1.5	0.2
	2013	100	1.5	0.2
Tummaville Model	1996	100	1.5	0.2
	2010	15	1.0	0.2
	2013	120	2.0	0.2
East Ridges Model	1996	100	1.5	0.2
	2010	15	1.5	0.2
	2013	130	1.5	0.2
Loudoun Model	1996	60	1.5	0.2
	2010	15	1.5	0.2
	2013	100	1.5	0.2
Chinchilla Weir Model	1996	60	1.0	0.2
	2010	15	1.5	0.2
	2013	50	1.5	0.2

4.6 MODEL CALIBRATION RESULTS

4.6.1 General

The main objective of the model calibration was to achieve the best possible fit between the predicted and recorded discharge hydrographs at key stations in the vicinity of Kogan Creek Mine and in particular the Condamine River at Brigalow Bridge and Chinchilla Weir gauges for each of the calibration events. For these stations, the calibration attempted to match the predicted and recorded flood peaks and volumes. For the upstream stations, model calibration focussed on ensuring the timing of the flood peaks and flood volumes were well represented. Further calibration of these upstream stations could be undertaken to improve the overall calibration of the model.

Due to the large catchment and the limited rainfall data, the URBS models cannot accurately reproduce flood behaviour for all events and at all gauging stations. As such, calibration emphasis was placed more on large events and on stream gauges along the main river channel, as the accuracy of small events and on smaller tributary catchments are impacted significantly by spatial and temporal variation in rainfall.

4.6.2 May 1996

Figure 4.12 and Figure 4.13 show comparisons of predicted and recorded flood discharge hydrographs at Brigalow Bridge and Chinchilla Weir, respectively, for the May 1996 event. The comparisons at the upstream gauges are shown in Appendix B.

There is significantly less short duration rainfall data available for this event and therefore model calibration primarily focussed on the flood volumes. Notwithstanding, the URBS models satisfactorily reproduce the flood peaks, flood volumes and the timing and shapes of the hydrographs at most gauges for this event.

- The Warwick model satisfactorily reproduces the flood peak at the Scots College gauge (Warwick). However, there appears to be some issues with the timing and flood volumes at the upstream gauges most likely due to the poor rating of the upstream gauges and the use of daily rainfall.
- The Tummaville model under predicts the flood peaks and volumes for all of the side tributary gauges, possibly due to the lack of rainfall stations and the use of the same initial losses for the entire Tummaville model. However, the flood peaks and volumes are satisfactorily reproduced along the Condamine River with the exception of the early flood peak on 3 May 1996 early in the flood event.
- The predicted flows at the only gauge in the East Ridges model (Gowrie Creek) matches reasonably well to the recorded data.
- For the Loudoun model, the modelled flow at Pampas stream gauge is not a good fit for the recorded data. The data at this station is not consistent with the gauge immediately downstream at Lone Pine. It is also poorly rated (see Table 3.3) and has therefore been assumed to be a data error. The URBS model underestimated the peak and flow volumes at the Cecil Plains gauge, which appears to be partially due to the missed flows from the upstream catchment.
- The predicted flows at Loudon correspond well to the recorded flows for this event. However, these flows are not consistent with the upstream flows at Cecil Plains or the downstream gauges, which suggests that its rating at high flows may be questionable.
- The Fairview gauge should be ignored because Oaky Creek at this station is 'perched' above the floodplain so the rating curve does not change significantly above the bank full flow.

The model under predicts peak flows and volumes at the downstream end of the URBS model at the Brigalow Bridge and Chinchilla Weir stream gauges. The calculated peak flood discharge at Chinchilla Weir was within 15% of the recorded peak flood discharge. The loss of flow appears to be related to the limited rainfall data available for this event.

4.6.3 December 2010

Figure 4.14 and Figure 4.15 show comparisons of predicted and recorded flood discharge hydrographs at the Brigalow Bridge and Chinchilla Weir gauges, respectively, for the December 2010 event. The comparisons at the upstream gauges are shown in Appendix B.

The model of this event was extended to include the January 2011 event, which was higher in some of the upstream gauges but ultimately lower in the area of interest. The flood peaks for both of these events were much higher than for the other calibration events and therefore a higher emphasis was placed in defining model parameters for this event. Overall, a good calibration was achieved for these events, with the URBS models satisfactorily reproducing the flood peaks, flood volumes and the timing and shapes of the hydrographs at most gauges.

- The Warwick model marginally over predicts the flood peaks at the Scots College Gauge (Warwick) but marginally under predicts the flood peaks at most upstream gauges.
- The Tummaville model accurately predicts the flood peaks and volumes at the Tummaville gauge but marginally under predicts the peaks at the upstream gauges. None of the upstream gauges are well rated at these high flows.
- The East Ridges model under predicts the peak flows at the Gowrie Creek gauge. However the flood volumes are reasonable.

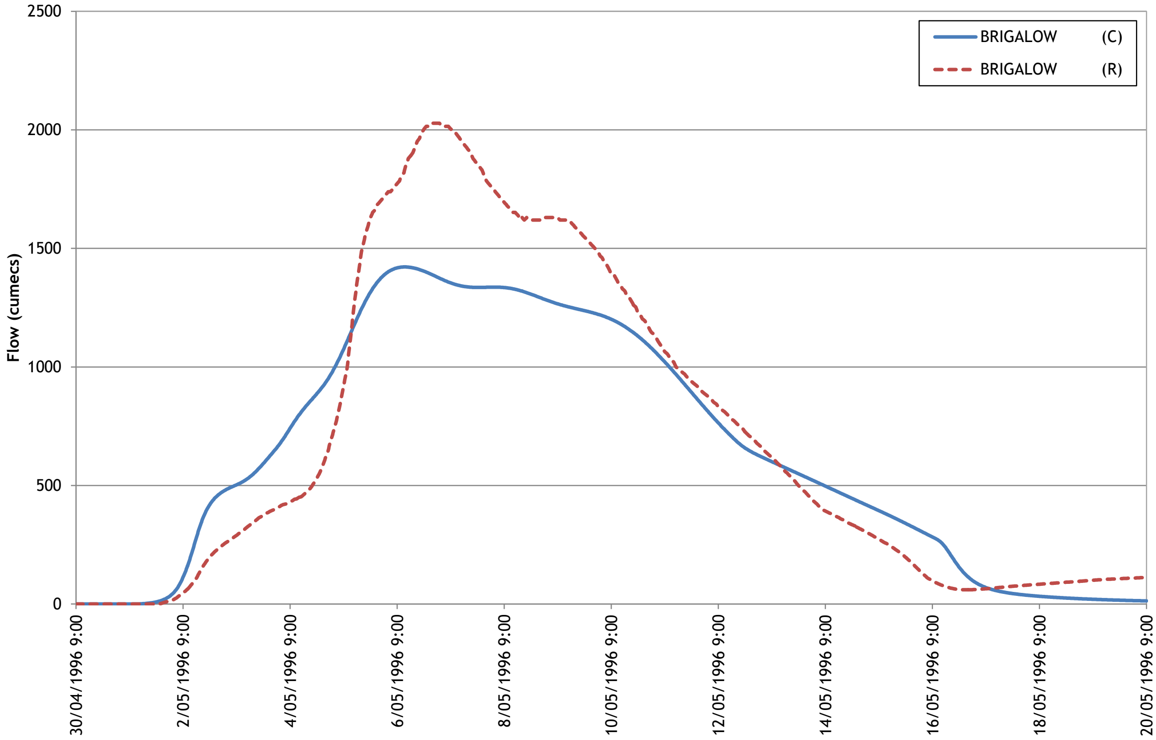

Figure 4.12 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Brigalow Bridge, May 1996

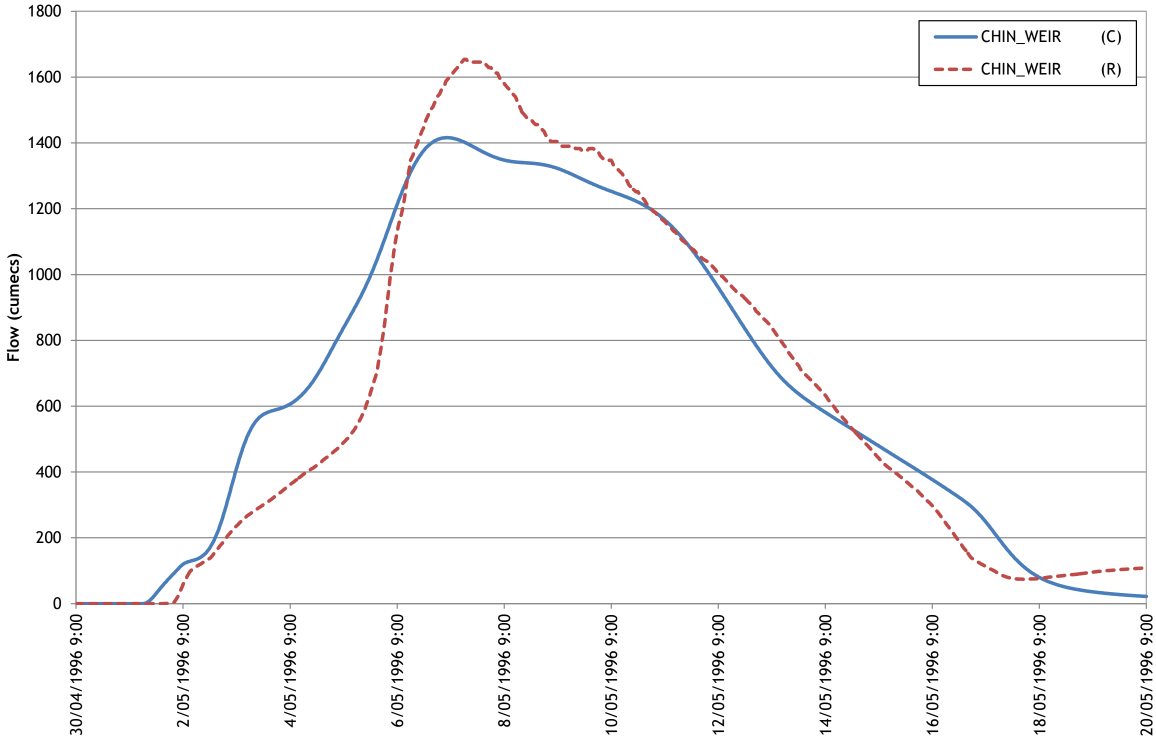

Figure 4.13 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Chinchilla Weir, May 1996

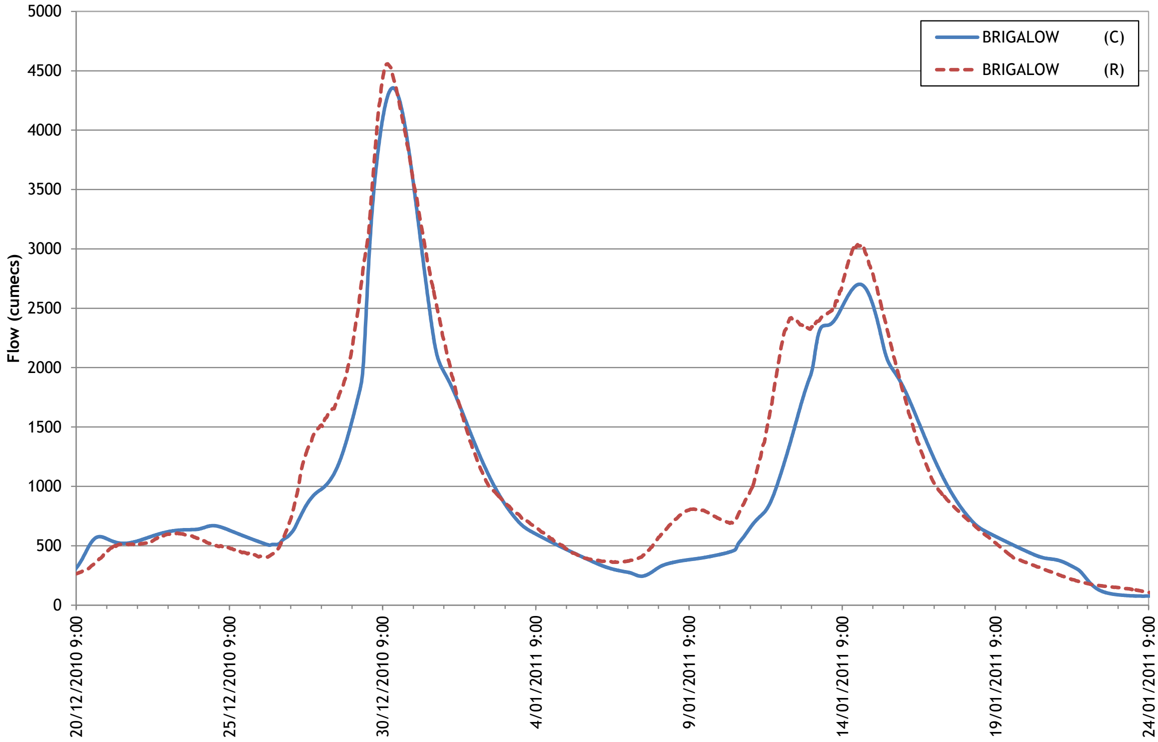

Figure 4.14 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Brigalow Bridge, Dec 2010

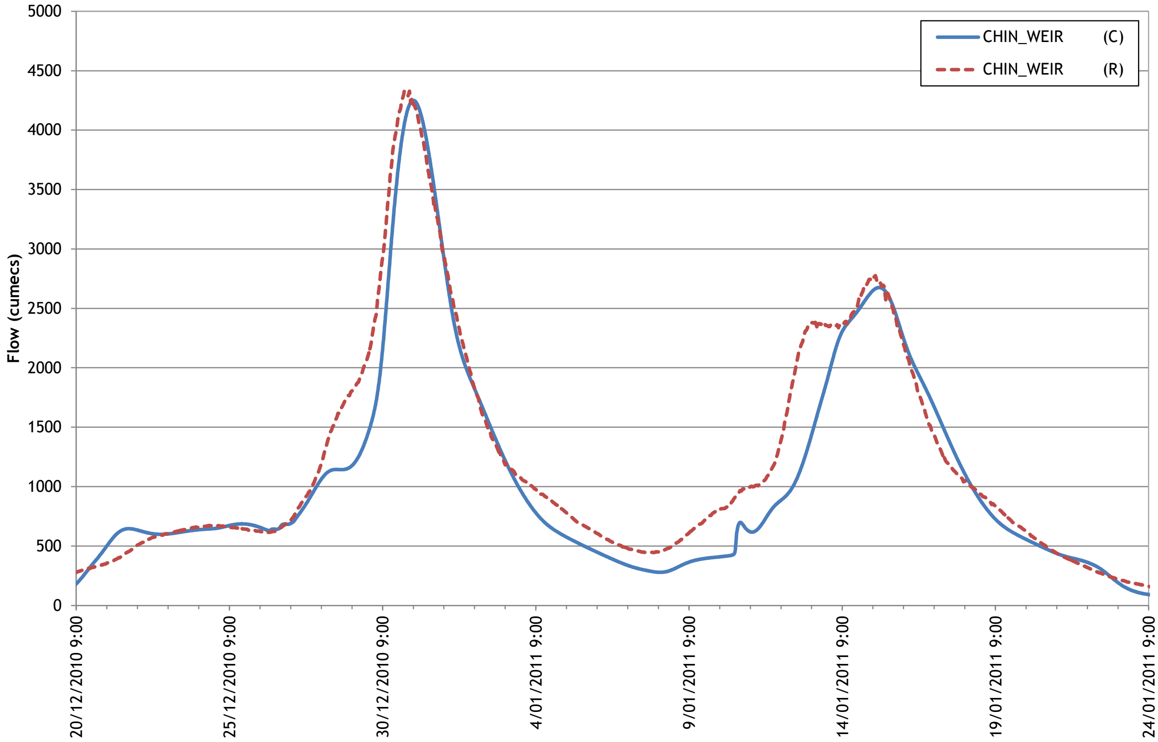

Figure 4.15 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Chinchilla Weir, Dec 2010

- The Loudoun model over predicted the flood peaks at both Cecil Plains and Loudon Bridge. Given the good match that occurs at the downstream gauges, it is likely that the stream gauge rating curves at both of these stations are not accurate at high flows.
- The calibration at both of the downstream gauges (Brigalow and Chinchilla Weir) is excellent for both the December 2010 and January 2011 events.

4.6.4 January 2013

Figure 4.16 and Figure 4.17 show comparisons of predicted and recorded flood discharge hydrographs at Brigalow the Bridge and Chinchilla Weir gauges, respectively, for the January 2013 event. The comparisons at the upstream gauges are shown in Appendix B.

The calibration of the January 2013 event is reasonable. This event is smaller than the other two events and therefore a lower emphasis was placed on refining the model parameters to suit this event.

- The Warwick model marginally over predicts the flood peak at the Scots College gauge but adequately predicts the timing of the flood peak.
- The Tummaville model significantly under predicts the flood peaks (and volumes) at the upstream gauges and as a result marginally under predicts the flood peak at Tummaville. It is expected that the under prediction is due to the lack of rainfall data in these catchments.
- The East Ridges model adequately predicts the flows at the Gowrie Creek gauge but over predicts the flows and the timing of flows at the new Jondaryan gauge.
- The Loudoun model representation of the timing of catchment flows is poor. However, the predicted flood peak is in reasonable agreement. The channel lag parameters in this reach were determined from the larger events. A better representation could have been achieved if the purpose was to calibrate the model to these smaller events.
- The recorded and predicted flood peaks at the Brigalow Bridge and Chinchilla Weir gauges are in reasonable agreement. The calculated peak flood discharge at Chinchilla Weir was within 6% of the recorded peak flood discharge.

4.7 SUMMARY OF MODEL CALIBRATION

Overall the URBS models have been adequately calibrated to the three historical events. The flood peaks for the calibration events at the key gauges of Brigalow Bridge and Chinchilla weir have been well produced and is therefore suitable to estimate design discharges at Kogan Creek Mine.

Further refinement of the model, particularly the East Ridges model, could be undertaken to improve the model calibration. However, it appears that reasonable estimates can be made of the peak discharges in the vicinity of Kogan Creek Mine when the flood peaks at the Tummaville gauge are well reproduced.

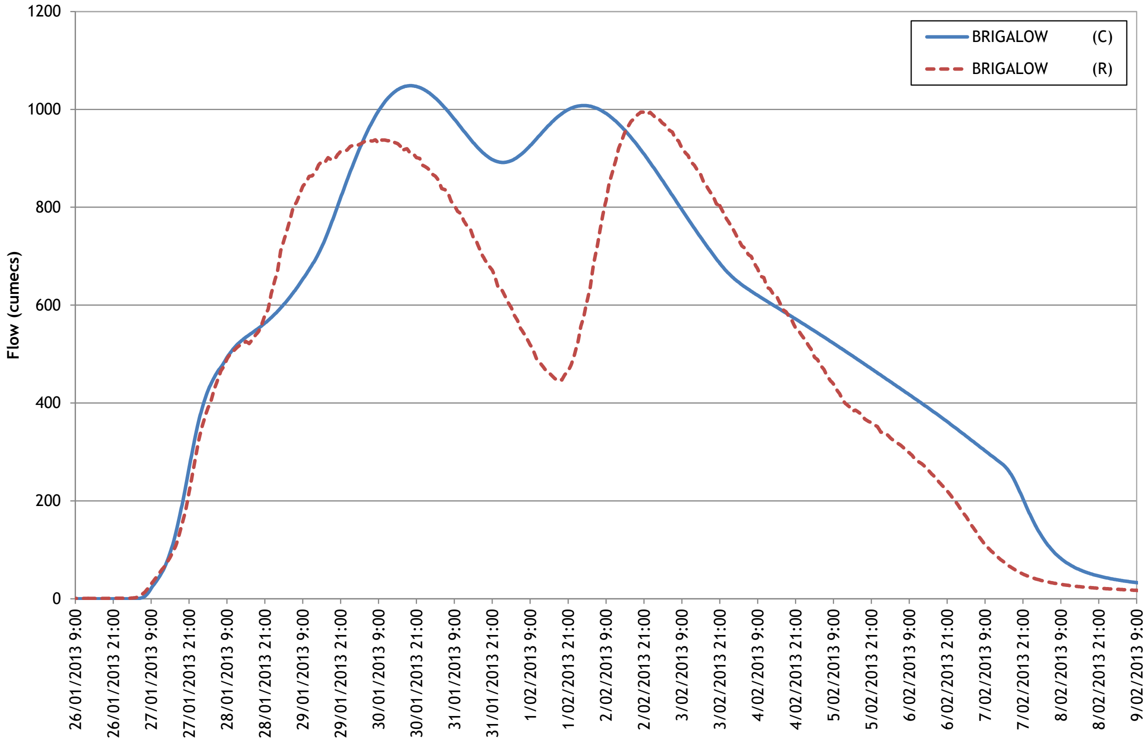

Figure 4.16 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Brigalow Bridge, Jan 2013

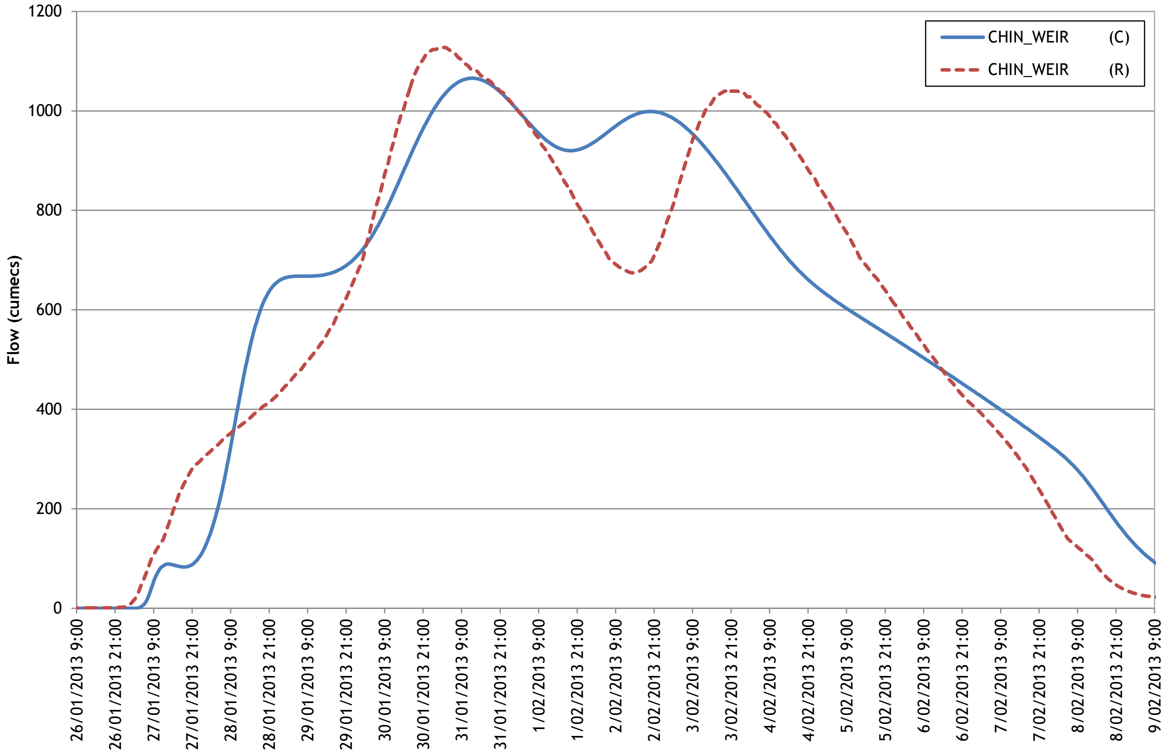

Figure 4.17 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Chinchilla Weir, Jan 2013

5 Estimation of design flood discharges

5.1 OVERVIEW

The calibrated URBS model described in Section 4 was used to estimate design flood discharge hydrographs for the 5%, 1% and 0.1% AEP events. The discharges estimated by the URBS model were compared with peak design discharges estimated by Flood Frequency Analysis at the Chinchilla Weir gauge.

5.2 ESTIMATION OF DESIGN RAINFALL DEPTHS

Design rainfall depths for the 5%, 1% and 0.1% AEP events were estimated for a range of storm durations using the CRC Forge method (Hargraves, c2004). Design rainfalls were spatially weighted across 5 sub-areas in the Condamine River catchment, corresponding to the 5 URBS sub-models shown in Figure 4.1.

Spatial weighting was determined by adjusting CRC Forge point rainfall estimates for each sub area to ensure the total volume of sub-area rainfall was equivalent to the volume of areally reduced rainfall estimated by CRC Forge for the entire Condamine river catchment. The adopted rainfall depths for various sub-areas are shown in Table 5.1 to Table 5.3.

Table 5.1 - Sub-model design rainfall depths, 5% AEP events

Storm Duration (h)	Chinchilla Weir	East Ridges	Loudoun	Tummaville	Warwick
24	103.9	93.62	90.91	100.3	93.70
48	137.5	125.1	120.8	134.5	130.0
72	156.7	143.0	138.4	152.7	147.4
96	168.5	154.1	150.7	168.0	159.9
120	175.5	160.7	159.5	177.5	163.4

Table 5.2 - Sub-model design rainfall depths, 1% AEP events

Storm Duration (h)	Chinchilla Weir	East Ridges	Loudoun	Tummaville	Warwick
24	139.8	125.4	121.7	133.3	123.8
48	186.1	167.8	162.0	178.4	171.0
72	211.7	192.0	186.1	203.2	194.2
96	228.6	207.0	202.4	223.8	210.4
120	237.8	216.3	214.4	236.1	214.9

Table 5.3 - Sub-model design rainfall depths, 0.1% AEP events

Storm Duration (h)	Chinchilla Weir	East Ridges	Loudoun	Tummaville	Warwick
24	195.5	174.2	175.9	186.1	173.4
48	264.2	235.0	235.2	250.6	239.0
72	299.8	270.4	268.0	287.3	270.4
96	324.6	292.8	291.2	315.2	292.3
120	337.3	308.1	307.7	333.9	299.3

5.3 TEMPORAL PATTERNS

The Zone 2 temporal patterns provided in ARR (Pilgrim, 1998) were adopted for 5% and 1% AEP events for durations up to 72 hours. For durations greater than 72 hours and for the 0.1% AEP events, the average variability method temporal patterns given in BOM (2005) were adopted.

5.4 FLOOD FREQUENCY ANALYSIS

5.4.1 Methodology

Flood frequency analysis (FFA) was undertaken using the TUFLOW FLIKE package, in accordance with the revised ARR guidelines (Engineers Australia, 2012). FLIKE was used to fit a Log-Pearson Type III distribution to recorded annual maximum flows from the Condamine River gauging station at Chinchilla Weir (gauge number 422308C).

5.4.2 Available data

The Chinchilla Weir gauge was selected for the analysis because it has a much longer period of record when compared with the nearby Brigalow Gauge (94 years compared to 44 years). Given the proximity of the Chinchilla gauge to the Kogan Creek Mine, flows at Chinchilla would be representative of flows at the mine.

The Chinchilla Weir gauge was relocated in 1924 (422308A) and again in 1955 (422308B). However the catchment area upstream of the gauge has remained constant and three records can be combined to provide a complete record extending back to 1921. Appendix C lists the annual maximum flows at the Chinchilla Weir gauges.

5.4.3 Results

Figure 5.1 and Table 5.4 show the results of the FFA for the Condamine River at Chinchilla Weir gauge. All flows less than 20 m^3/s were censored for the analysis to improve the fit at high flows.

Table 5.4 - Flood Frequency Analysis results, Condamine River at Chinchilla

AEP (%)	Design Discharge (m^3/s)		
	Lower 90% Confidence Limit	Estimated Peak Discharge	Upper 90% Confidence Limit
5%	1467	1927	2705
1%	2626	3820	6507
0.1%	4233	7516	17742

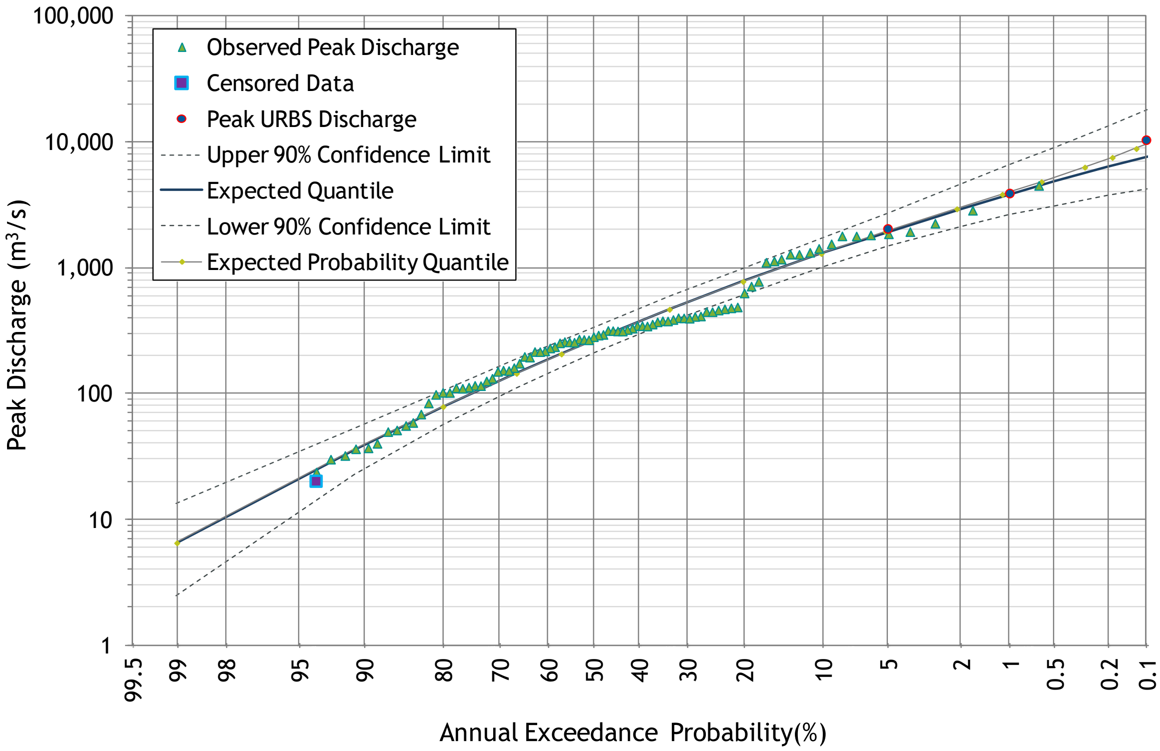

Figure 5.1 - Flood Frequency Analysis plot, Condamine River at Chinchilla Weir

5.5 URBS PEAK DESIGN DISCHARGES

The calibrated URBS model was run for a number of storm durations for each AEP event to determine the peak discharges at the Chinchilla Weir stream gauge.

The URBS model results for the 5% and 1% AEP events were reconciled with the FFA results by adjusting the adopted rainfall loss values:

- a continuing loss of 1.5 mm/hour was adopted for all design events;
- an initial loss of 25.0 mm was adopted for the 5% AEP event;
- an initial loss of 35.0 mm was adopted for the 1% AEP event; and
- an initial loss of 0.0 mm was adopted for the 0.1% AEP event.

Note that the reconciliation against 0.1% AEP event was not made because it is beyond the credible limit to extrapolate the FFA analysis based on 94 years of data to 1000 years.

Table 5.5 lists the critical durations and peak discharges for the 5%, 1% and 0.1% AEP events. A comparison of URBS model and FFA peak design discharges is shown in Figure 5.1.

Table 5.5 - Peak discharge and critical duration at Chinchilla Weir

AEP (%)	Peak Discharge (m^3/s)	Critical Duration (h)
5%	2047	48
1%	3914	72
0.1%	10395	48

A good agreement was achieved for the 5% and 1% AEP events (albeit higher initial losses were used for the 1% event than the 5% event due to the different storm duration). The URBS 0.1% AEP event peak flow is much higher than the FFA estimate but is well within the 90% confidence limits. Note that previous study by Water Studies (2003) estimated peak design discharges of 1730 m^3/s and 3140 m^3/s for the 5% and 1% AEP events, respectively.

Based on the results, the December 2010 flood, which almost breached the Kogan Creek levees, had an estimated AEP of between 1% and 0.5%.

6 Hydraulic model development and calibration

6.1 OVERVIEW

The TUFLOW hydrodynamic model (WBM, 2010, 2014a) was used to simulate the behaviour of the Condamine River, Kogan Creek and Eastern Branch Creek flows at the Kogan Creek Mine. TUFLOW represents hydraulic conditions on a fixed grid by solving the full two dimensional depth and averaged momentum and continuity equations for free surface flow.

The TUFLOW model was calibrated against recorded water levels at the Brigalow gauge and surveyed peak flood levels at the Kogan Creek Mine levees for the following historical flood events:

- March 2010; and
- December 2010.

The March 2010 event was a relatively small event for which only gauged water levels at the Brigalow gauge were available. Due to its size it was suitable for calibrating in-bank flows. The December 2010 event was a large event for which both gauged water levels at Brigalow and surveyed water levels at the Kogan Creek mine levees were available.

TUFLOW model calibration was undertaken by using the recorded hydrographs at the Brigalow gauge, applied at the upstream boundary of the model. The calibrated TUFLOW model was then used to predict design event flood depths, levels and extents using URBS model inflows for the design events described in Section 5.

6.2 HYDRAULIC MODEL CONFIGURATION

6.2.1 Model extent

Figure 6.1 shows the extent of the TUFLOW model covering a total area of 83.1km^2. The model extent commences approximately 3.5km upstream of Kogan Creek Mine and extends 16km downstream of the mine. The upstream boundary has been defined by the limit of the available survey, which has meant that assumptions on the upstream boundary distribution were required. A review of the model results suggests that this limitation and assumption does not have a significant impact on the predicted flood levels at the Kogan Creek Mine.

6.2.2 Model grid size, topography and time step

A 10m grid size was adopted in the TUFLOW model. This allowed good representation of ground levels and river channels, while ensuring model run times remained reasonable.

Model topography was extracted from LiDAR data, while ‘z-shapes’ (a feature within TUFLOW to adjust model topography) were used to ensure the finer details of drainage in Kogan and East Branch creeks were represented. A z-shape was also used to improve the representation of the Condamine River channel for in-bank flows.

The model uses adaptive time stepping where the model may iteratively reduce the time step as necessary to ensure a stable solution is found while maintaining target courant number criteria.

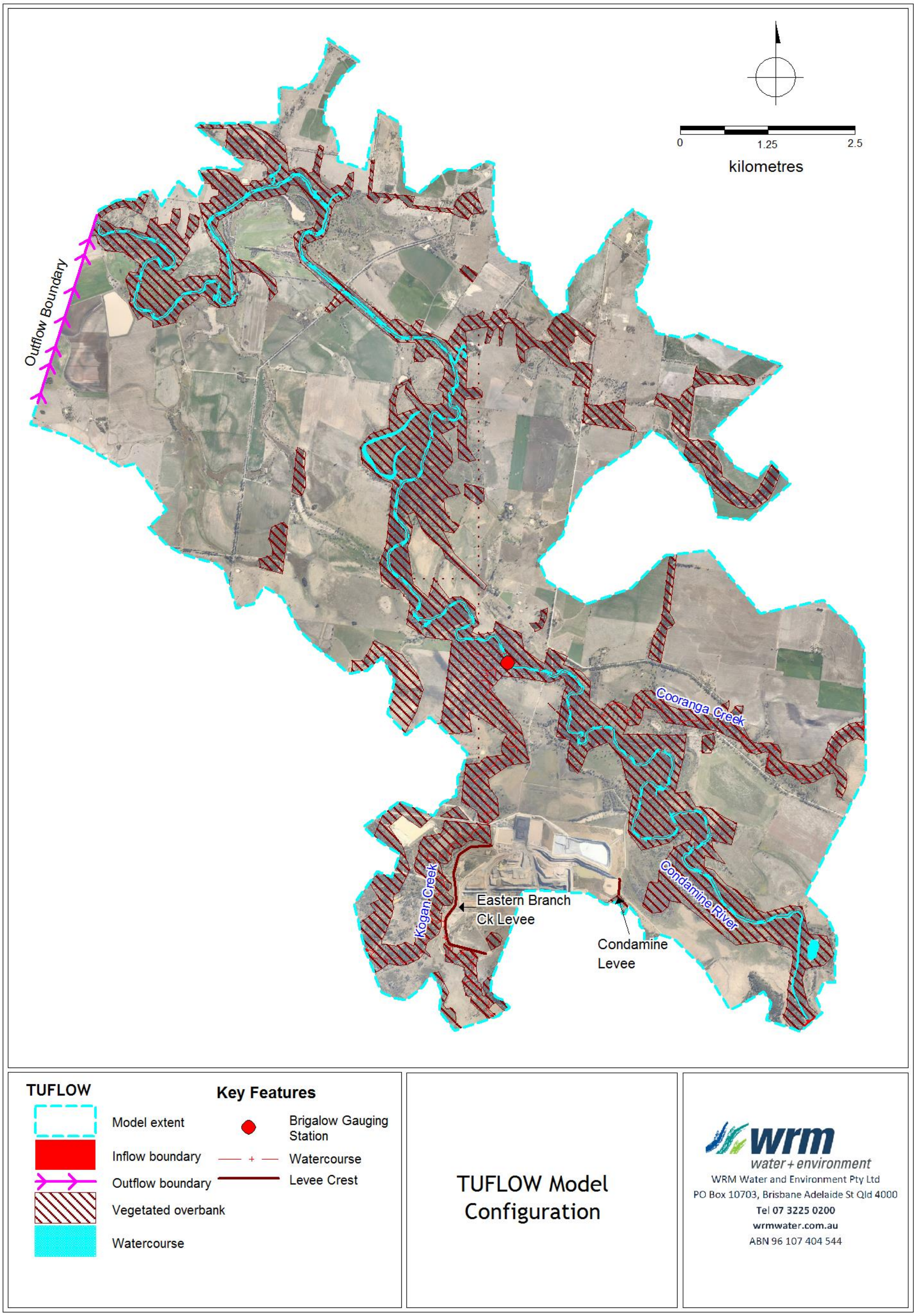

Figure 6.1 - TUFLOW model configuration

6.2.3 Adopted Manning's 'n' values

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance (notionally channel or floodplain roughness). Discrete regions of continuous vegetation types and land uses were mapped, and appropriate roughness values assigned to each region, as shown in Figure 6.1. Vegetation and land use mapping was undertaken using aerial imagery of the area.

The Manning's 'n' values were selected during model calibration and applied to all model scenarios. Agricultural land was adopted for the unspecified area. Table 6.1 lists the adopted Manning's 'n' values for different material types.

Table 6.1 - Adopted TUFLOW model Manning's 'n'

Land Use Type	Adopted Mannings 'n'
Agricultural Land / Scattered Vegetation	0.05
Vegetated Overbank	0.075
Watercourse (in-bank)	0.035

6.2.4 Inflow and outflow boundaries

Figure 6.1 shows the locations of the inflow and outflow boundaries used in the TUFLOW model. Inflow hydrographs were applied to the model at the upstream boundaries on the Condamine River, Cooranga Creek, Kogan Creek and Eastern Branch Creek. The model applies flow equally to all cells along the inflow boundary.

Outflow boundaries were located across the floodplain at the downstream model extent. A normal depth boundary condition was applied to the outflow boundaries. The downstream boundary location was selected to ensure that the normal depth assumptions did not impact on peak flood levels at the Kogan Creek Mine.

6.2.5 Hydraulic structures

There are no bridge or culvert structures represented in the model. Bridges across the Condamine River at Healys Crossing Road and Banana Bridge Road are unlikely to have any impact on water levels at the Kogan Creek Mine as these are low level structures. The previous assessment of the Smiths Road Bridge across Kogan Creek found that it does not affect peak flood levels as flooding there is dominated by slow moving backwater from the Condamine River.

Figure 6.1 shows the existing Condamine River and Eastern Branch Creek levees. Surveyed details of the existing levee crests are represented in the model using 'z-shapes'. These levees were in place during the calibration events.

6.3 MODEL CALIBRATION RESULTS

6.3.1 March 2010 event

Figure 6.2 shows a comparison of predicted and recorded flood level hydrographs at the Brigalow gauge together with the gauged discharge hydrographs adopted for model calibration. The recorded and predicted peak flood levels are shown in Table 6.2.

Predicted flood levels for the March 2010 event are within 0.18m of recorded flood levels at the Brigalow gauge.

6.3.2 December 2010 event

Figure 6.3 shows a comparison of predicted and recorded flood level hydrographs at the Brigalow gauge together with the gauged discharge hydrograph adopted for calibration. Table 6.2 compares predicted and surveyed peak flood level hydrographs at the Condamine River and East Branch Creek levees and at the Brigalow gauge.

Predicted flood levels for the December 2010 event are generally in good agreement with the recorded peak flood levels. Predicted peak flood levels match recorded peak levels at the Brigalow gauge, while peak flood levels are within 0.04m of surveyed peak flood levels at the Eastern Branch Creek levee and 0.19m above the level at the Condamine River levee. Given the predicted levels are in good agreement to the recorded levels, the calibration is considered reasonable and suggest that it is suitable to estimate design flood levels at Kogan Creek Mine.

Table 6.2 - Predicted and observed peak water levels for calibration events

Location	Predicted Peak Water Level (mAHD)	Observed Peak Water Level (mAHD)	Difference (m)
March 2010			
Brigalow gauge	307.23	307.05	0.18
December 2010			
Brigalow Gauge	311.94	311.94	0.00
Condamine River Levee	313.59	313.40	0.19
Eastern Branch Creek Levee	312.23	312.19	0.04

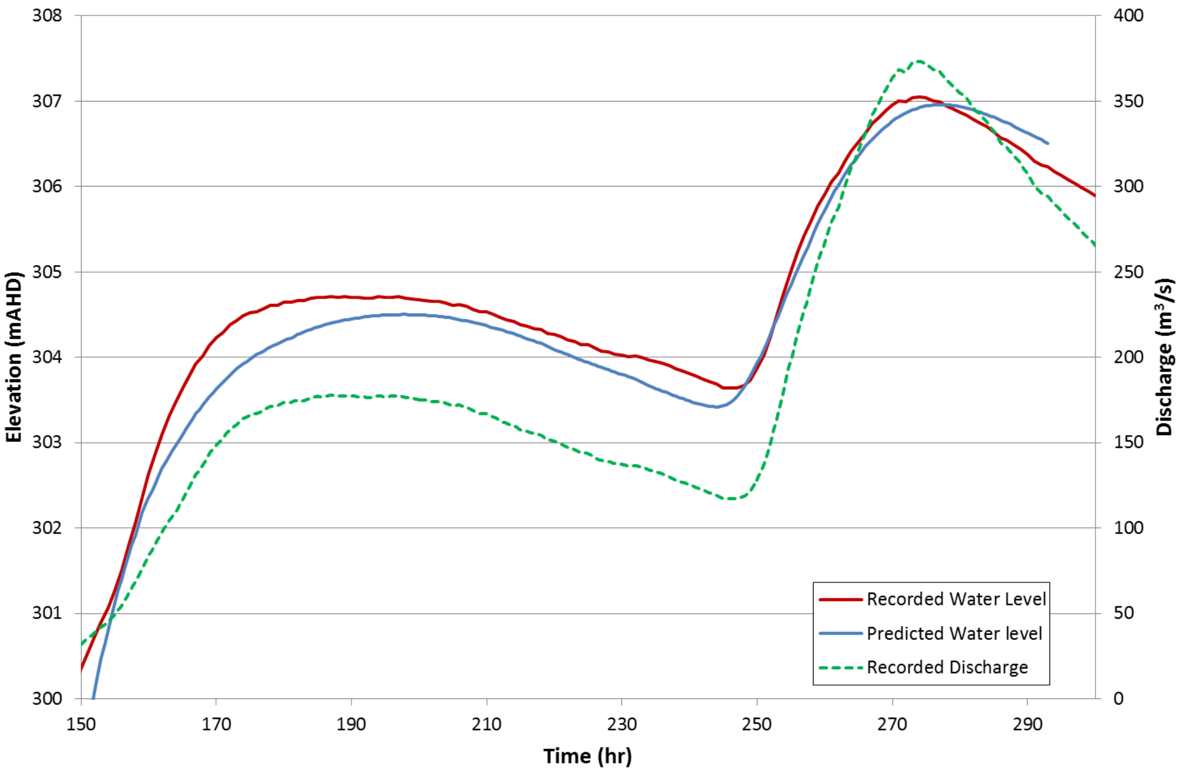

Figure 6.2 - Comparison of predicted and recorded water levels at Brigalow Gauge. March 2010

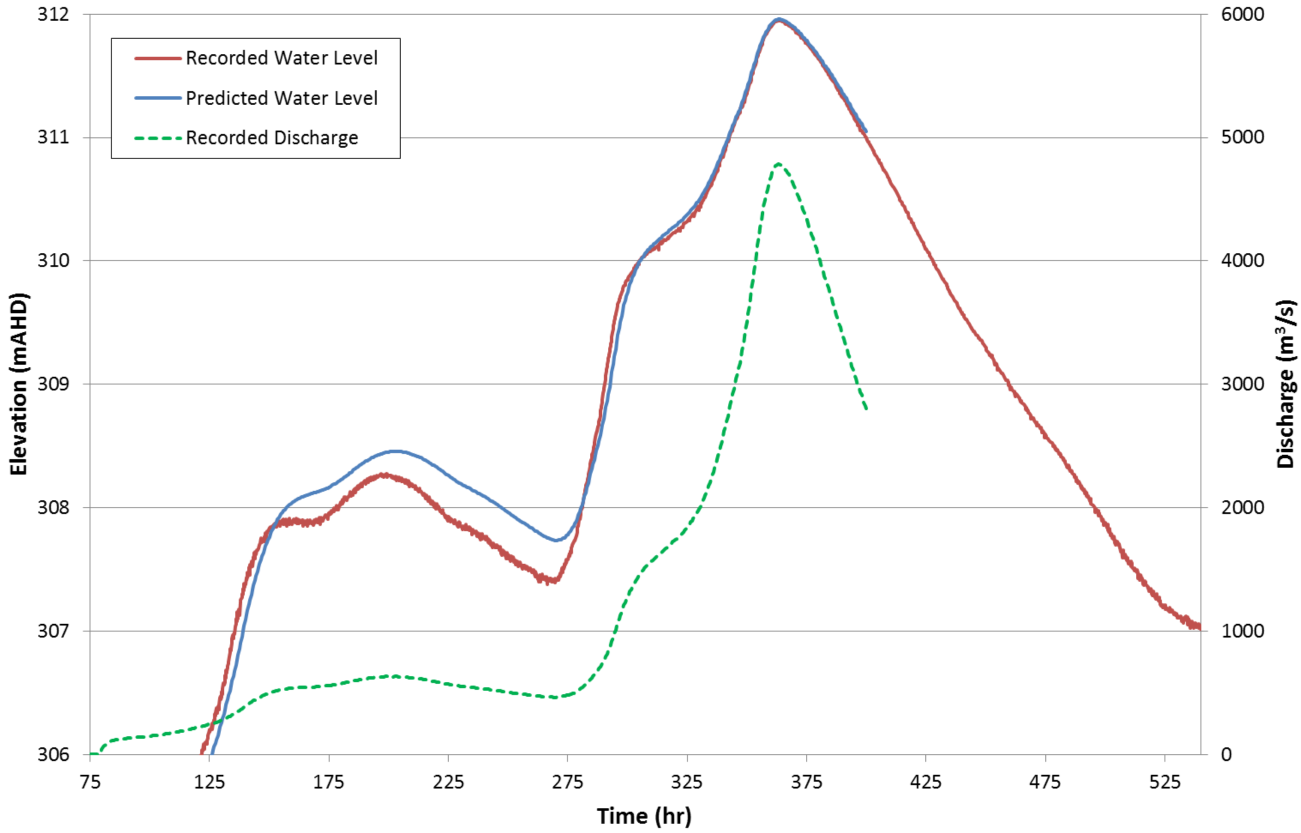

Figure 6.3 - Comparison of predicted and recorded water levels at Brigalow Gauge. December 2010

7 Existing conditions design flood depths, levels and extents

7.1 OVERVIEW

The calibrated TUFLOW model described in Section 6 was used to predict peak depths, levels, extents and velocities of flooding for the 5% AEP (1 in 20 year), 1% AEP (1 in 100 year) and 0.1% AEP (1 in 1000 year) design events for existing conditions including the existing Eastern Branch Creek and Condamine River levees.

7.2 DESIGN EVENT TUFLOW INFLOWS

Table 7.1 provides the peak discharges at the inflow locations shown in Figure 6.1, estimated by the URBS hydrologic model for each design event.

The selected storm duration for each AEP event was determined based on the peak event in the Condamine River at the Chinchilla Weir stream gauge, not in Kogan Creek or Eastern Branch Creek, as it was found that Condamine River flows dominate flood levels at the levees.

Table 7.1 - Peak discharge at TUFLOW inflow locations

TUFLOW Inflow Location	Design Event Peak Discharge (m^3/s)		
	5% AEP, 48H	1% AEP, 72H	0.1% AEP, 48H
Condamine River	2,117	3,973	10,569
Cooranga Creek	442	780	1,083
Kogan Creek	188	341	354
Eastern Branch Creek	69	133	120

7.3 DESIGN FLOOD DEPTH, LEVELS AND EXTENTS

Predicted flood extent, depth and peak flood water surface elevation contours are shown for all design events in Figure 7.1 to Figure 7.3. Table 7.2 lists peak flood water surface elevations at the Condamine River levee, Eastern Branch Creek levee and Brigalow gauge.

Table 7.2 - Predicted peak water surface elevation at key locations

Location	Peak WL (mAHD)		
	5% AEP	1% AEP	0.10% AEP
Brigalow gauge	310.59	311.62	313.62
Condamine River Levee	312.20	313.30	315.26
Eastern Branch Creek Levee	310.70	311.85	314.23

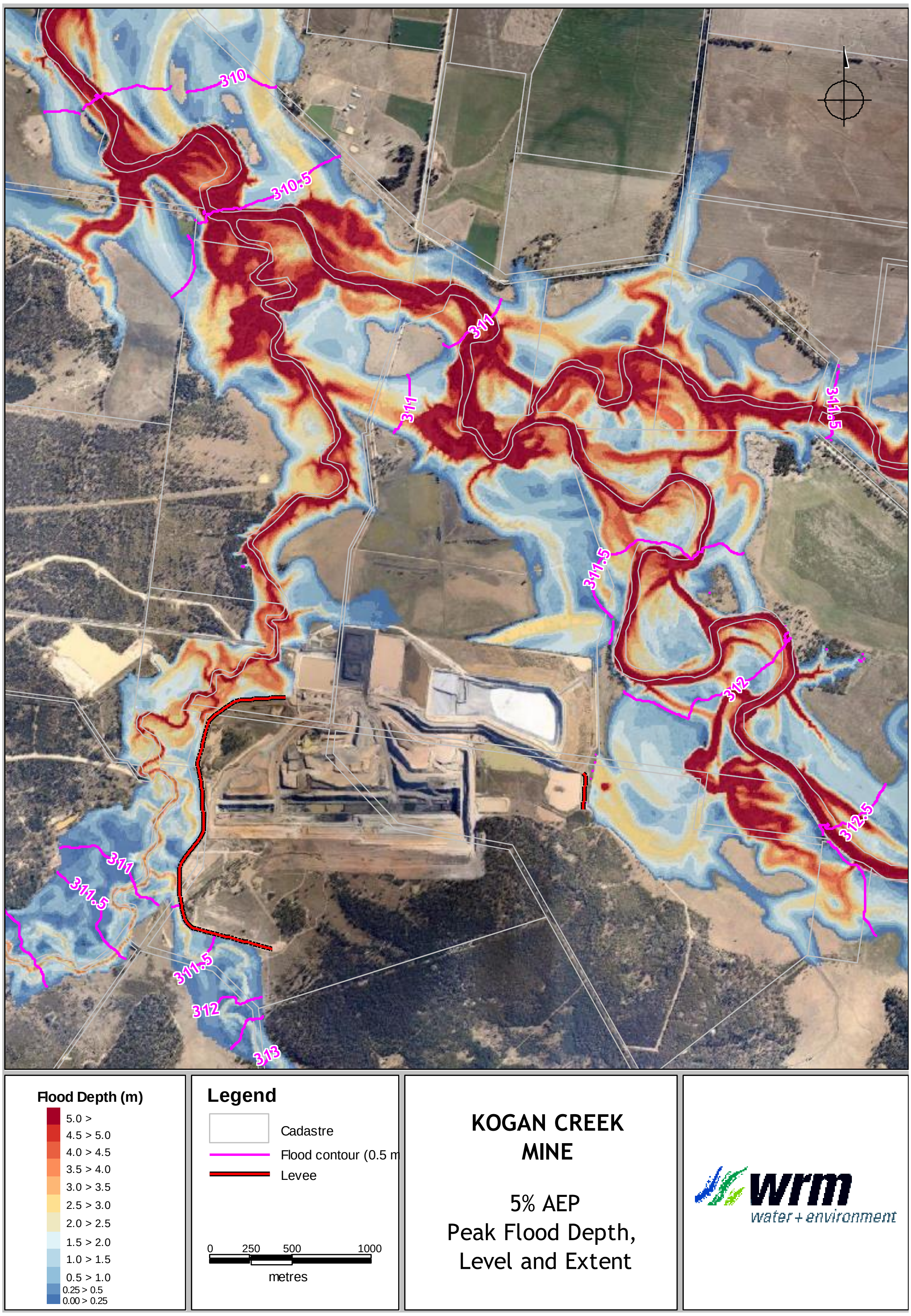

Figure 7.1 - Condamine River Peak flood depth and extent, 5% AEP event

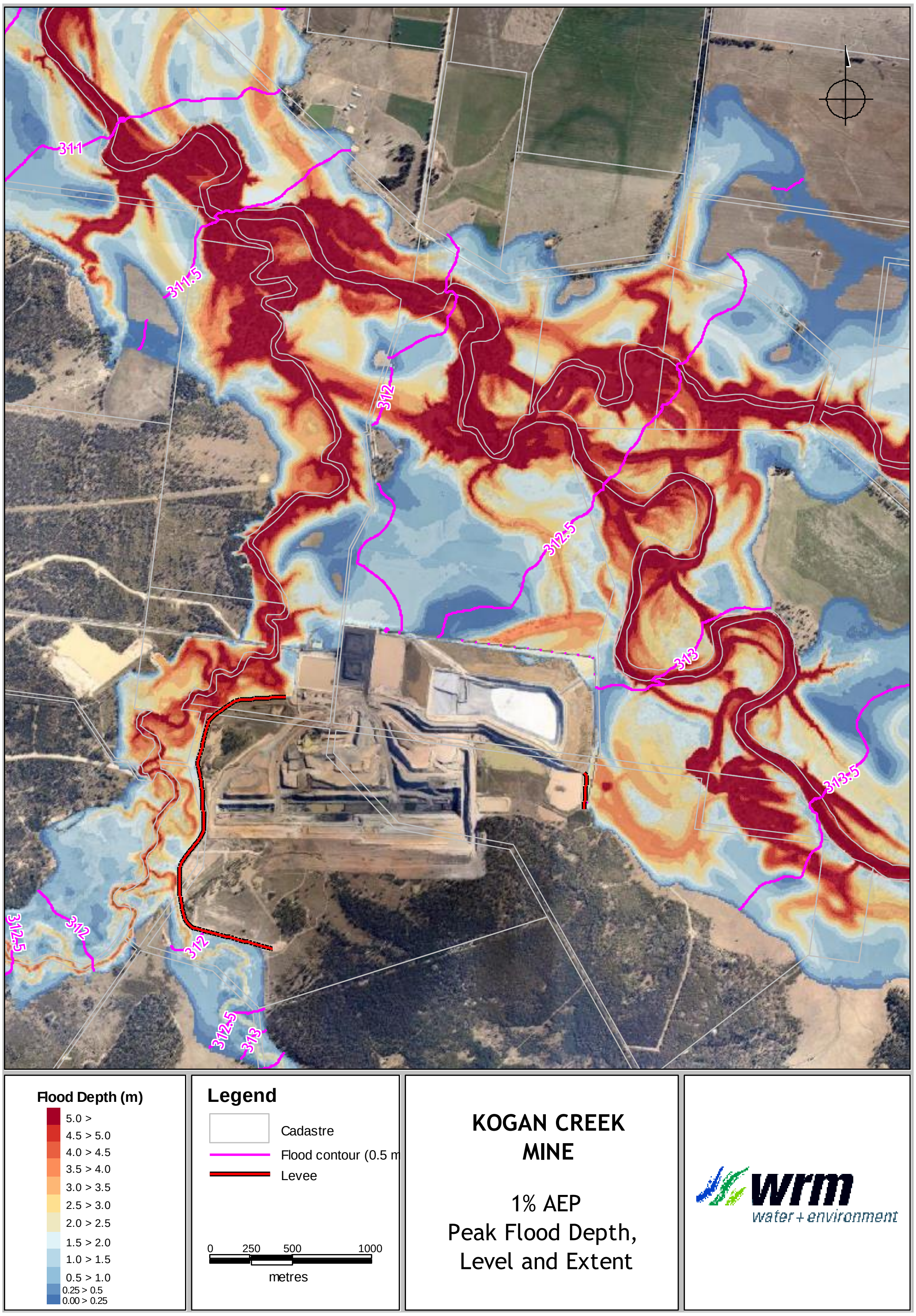

Figure 7.2 - Condamine River Peak flood depth and extent, 1% AEP event

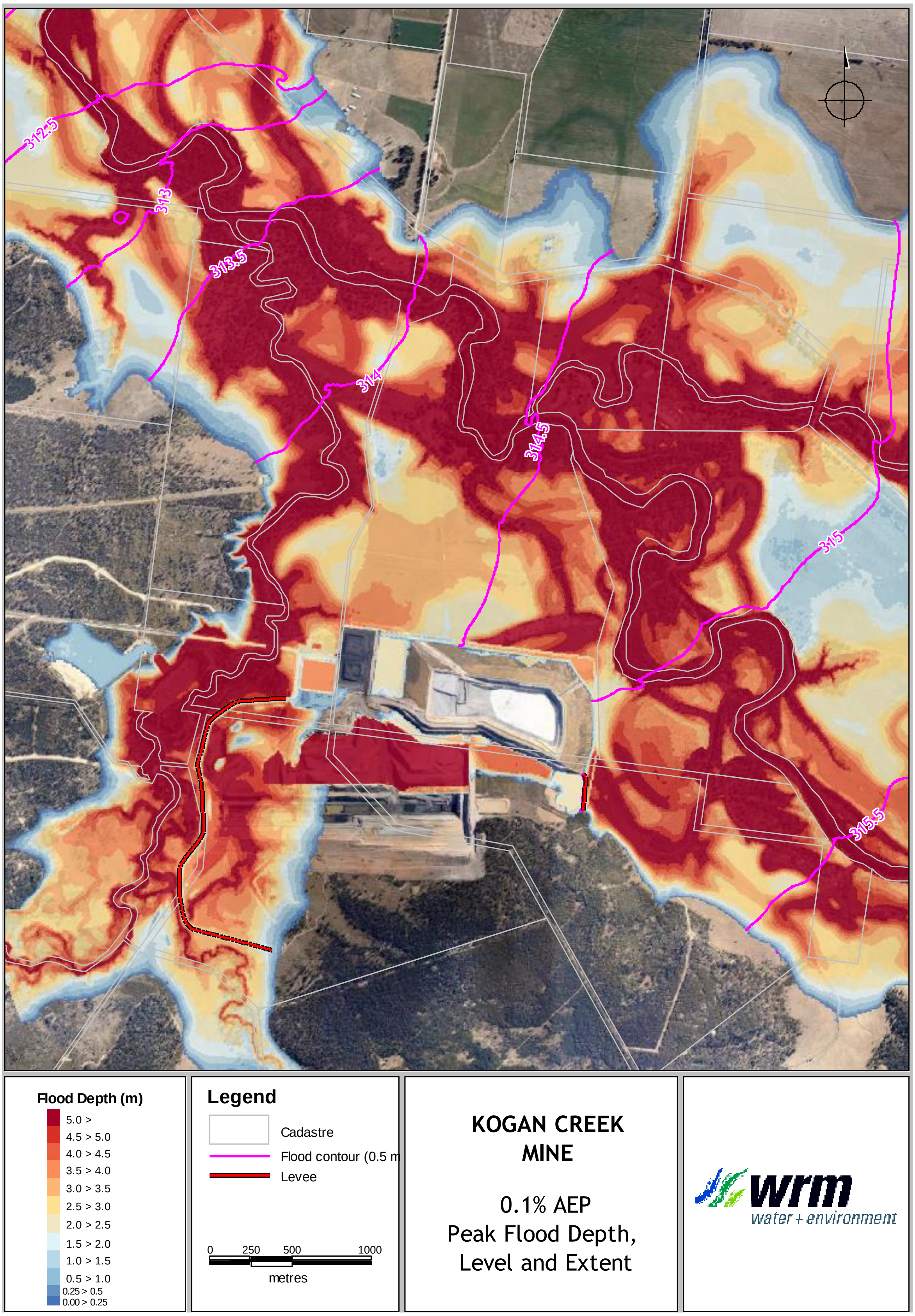

Figure 7.3 - Condamine River Peak flood depth and extent, 0.1% AEP event

Modelling of the 5%, 1% and 0.1% AEP events showed the following:

- The Eastern Branch Creek and Condamine River levees provide immunity for floods up to and including the 1% AEP event;
- Both levees are overtopped during the 0.1% AEP event. The Eastern Branch Creek levee is overtopped to an average depth of 0.73m, while the Condamine River levee is overtopped to an average depth of 0.16m; and
- The Eastern Branch Creek levee is overtopped prior to the overtopping of the Condamine River levee. Overtopping occurs for a sufficient length of time to inundate the entire open cut pit.

Figure 7.4 and Figure 7.5 show longitudinal sections along the two levees with peak flood surface elevation for each design event.

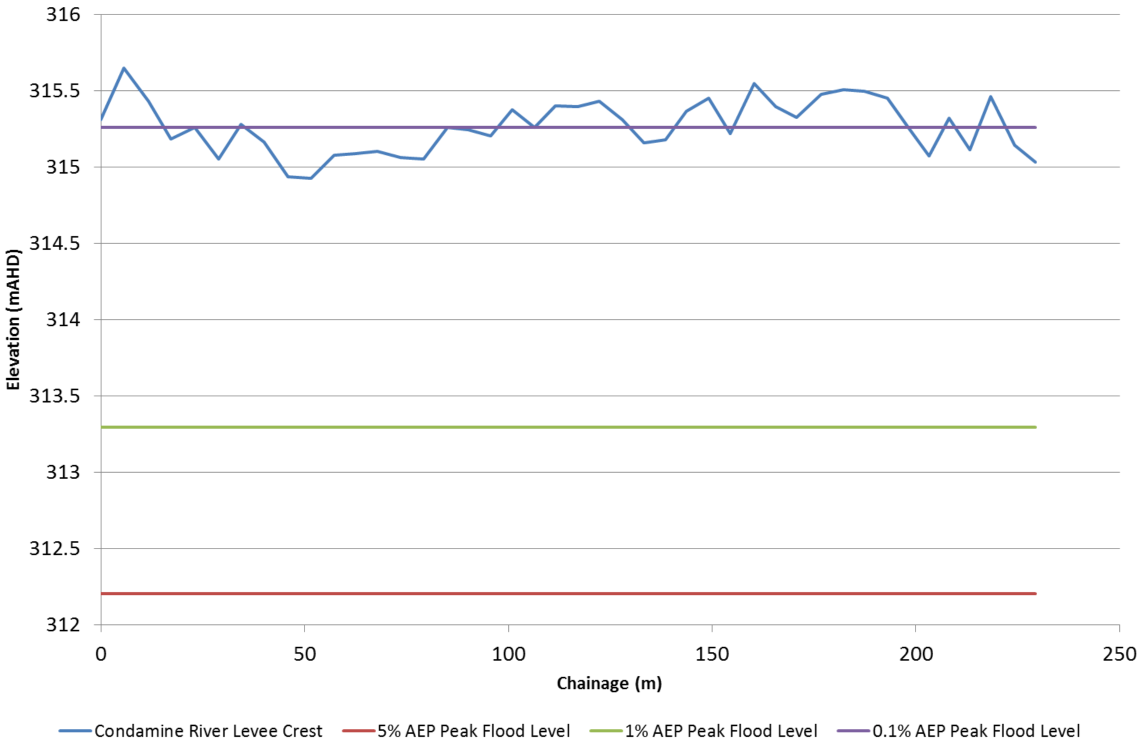

Figure 7.4 - Peak flood water surface elevation at the Condamine River levee

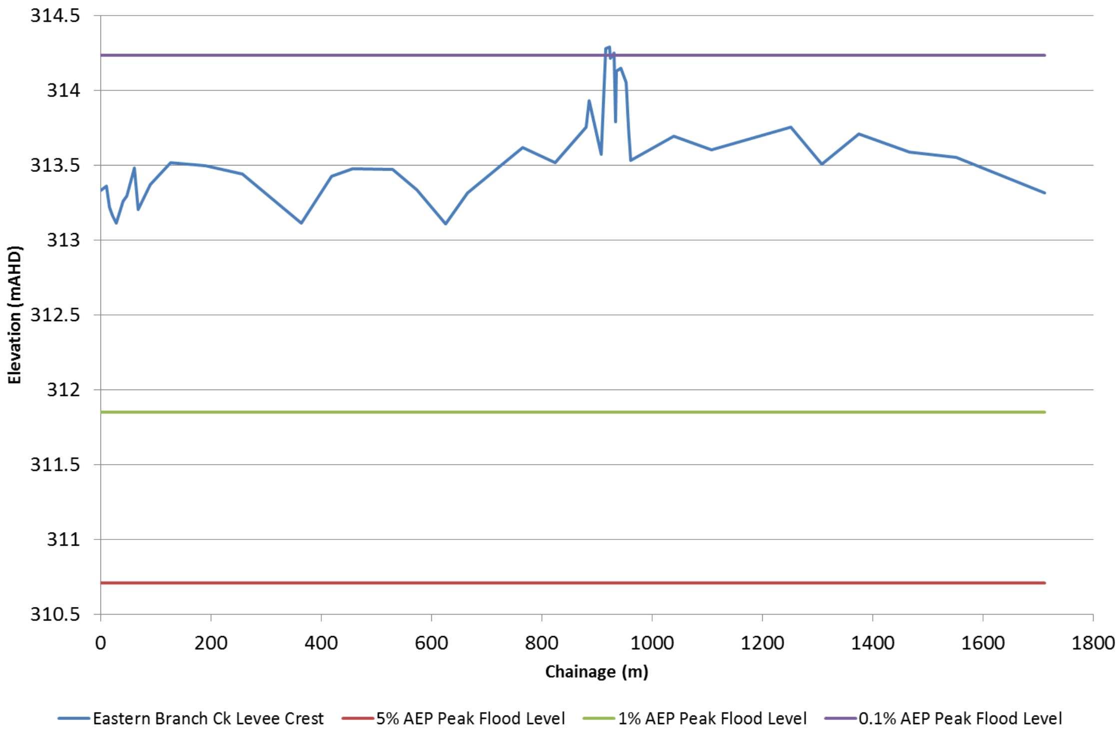

Figure 7.5 - Peak flood water surface elevation at the Eastern Branch Creek levee

7.4 DESIGN FLOOD VELOCITIES

Predicted flood velocities are shown for the three design events in Figure 7.6 to Figure 7.8. The following is of note:

- For the 5% AEP event, peak velocities adjacent to the existing levees are less than 0.5 m/s with the exception of the levee adjacent to the Eastern Branch Creek diversion where peak velocities reach 0.7 m/s.
- For the 1% AEP event, peak velocities:
  - are less than 0.3 m/s adjacent to the Condamine River levee;
  - are less than 1.0 m/s at the base of the OPAC;
  - are less than 0.8 m/s adjacent to the Eastern Branch Creek levee; and
  - are less than 1.2 m/s adjacent to the Eastern Branch Creek diversion.
- For the 0.1% AEP event, peak velocities:
  - exceed 1.5 m/s as they overtop the Condamine River levee;
  - are less than 1.85 m/s at the base of the OPAC;
  - exceed 1.5 m/s as they overtop the Eastern Branch Creek levee; and
  - are less than 1.25 m/s adjacent to the Eastern Branch Creek diversion.

The results suggest that the Condamine River levee is generally in a backwater area of the river with low velocities until it is overtopped. Peak velocities at the base of the northeastern corner of the OPAC are significant and therefore have a high erosion potential. Some scour protection is recommended at this location to protect the integrity of the OPAC levee and embankment. Peak velocities adjacent to the Eastern Branch Creek levee are generally low with the exception of the Eastern Branch Creek diversion. Erosion protection measures are already in place along the Eastern Branch Creek levee.

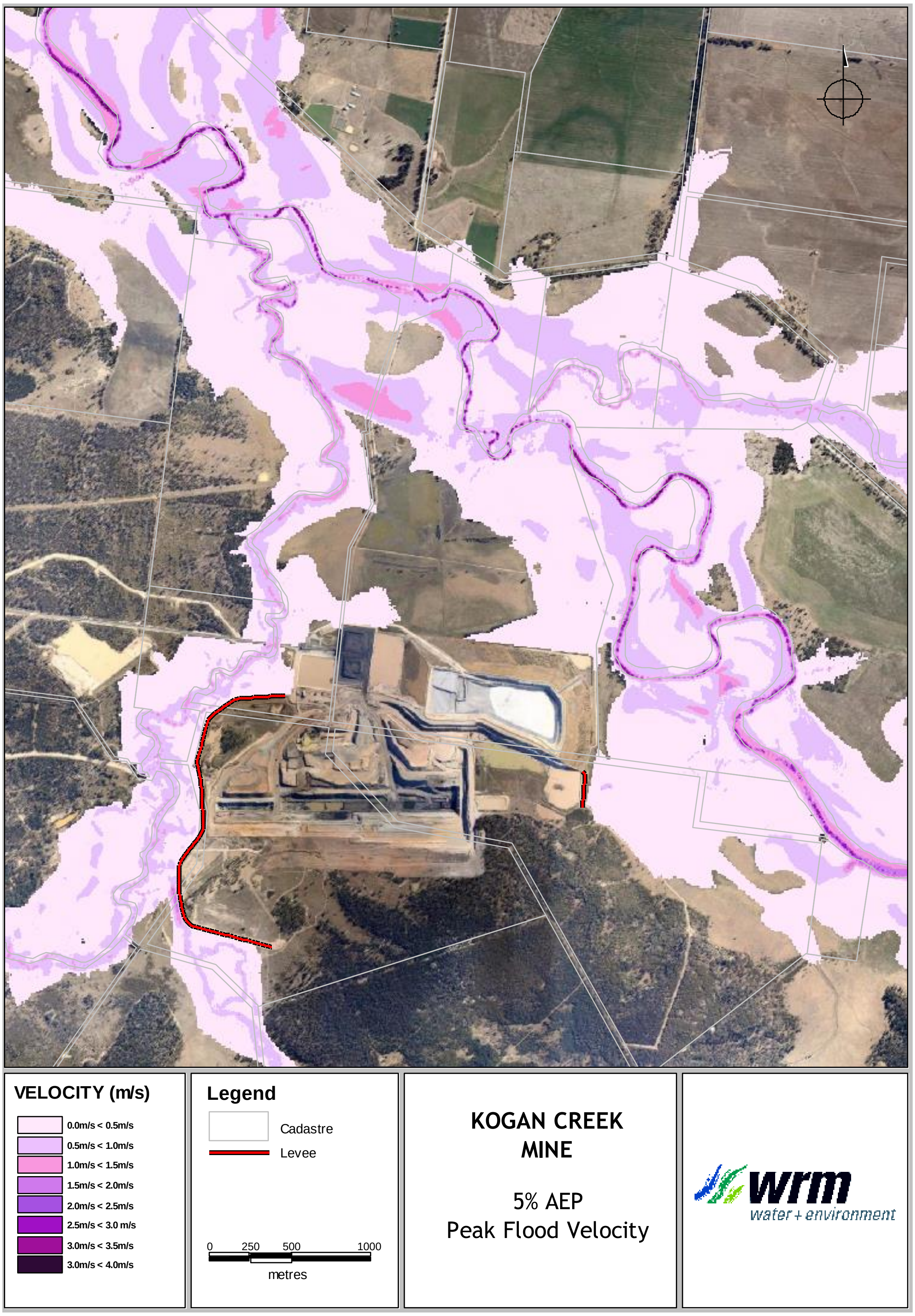

Figure 7.6 - Condamine River peak flood velocities, 5% AEP event

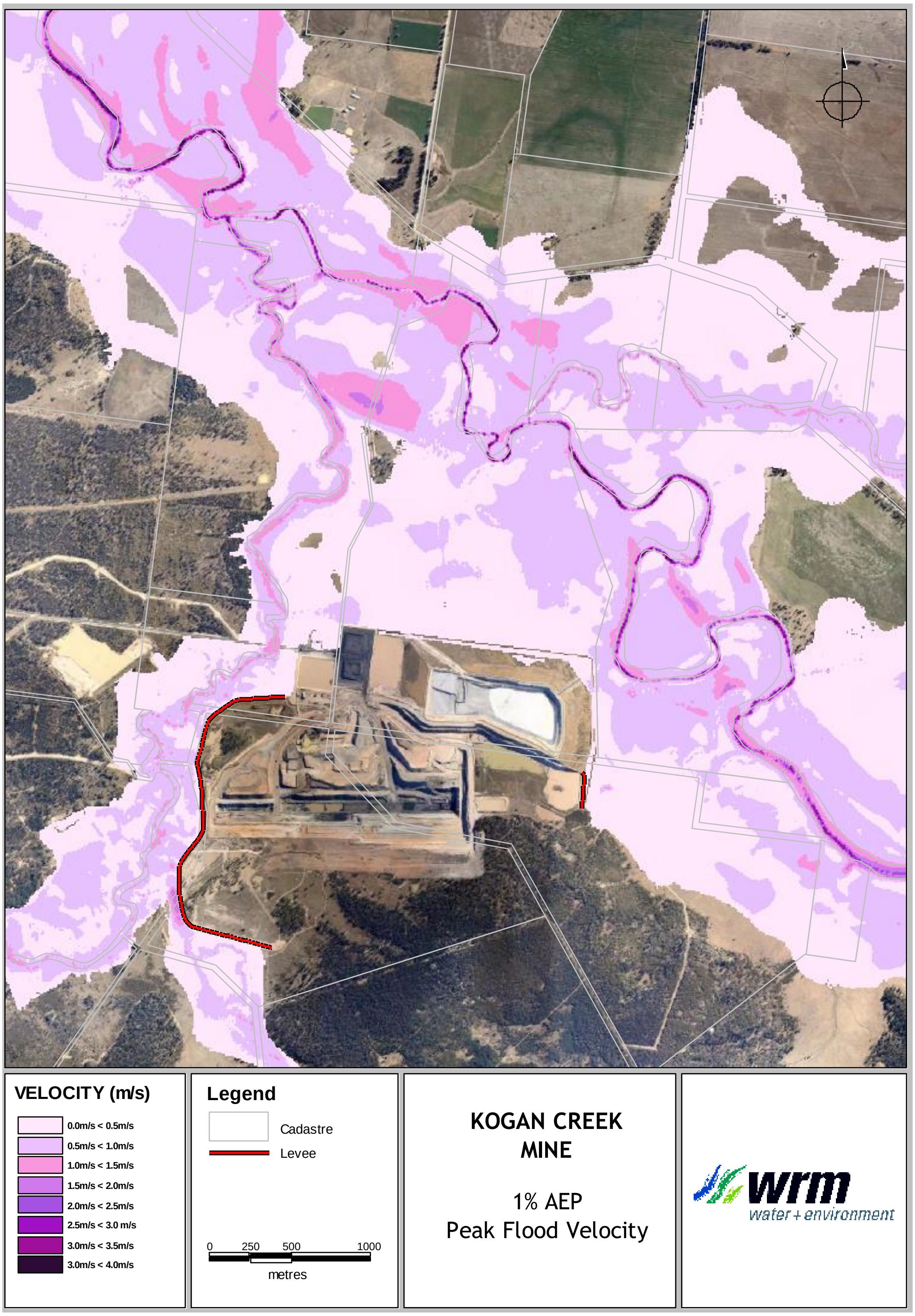

Figure 7.7 – Condamine River peak flood velocities, 1% AEP event

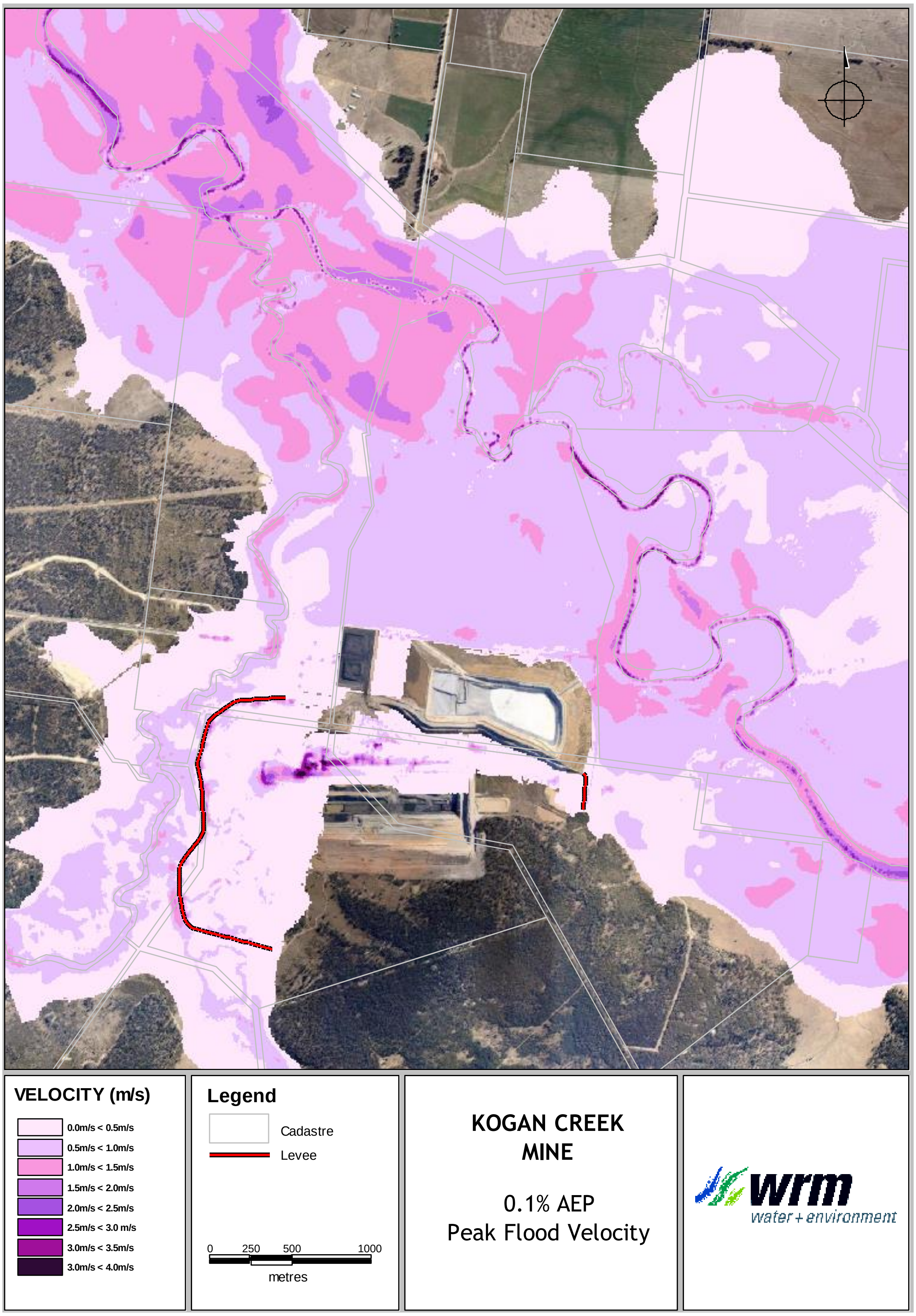

Figure 7.8 – Condamine River peak flood velocities, 0.1% AEP event

8 Proposed Levee upgrade

8.1 OVERVIEW

The flood modelling demonstrates that the Kogan mine is prone to flooding for the 0.1% AEP event and the levees that prevent the open pit from inundation would be regulated structures under the EPAct.

It is proposed to upgrade the levees to provide flood immunity to the open cut pit for the 0.1% AEP event to satisfy the regulatory requirements of levees constructed as part of an ERA. The locations of the new and old levees are shown in Figure 1.2. The following works are proposed to satisfy the regulatory requirements and to provide immunity for future mining areas:

- The Condamine levee will be raised;
- The EBC levee will be raised;
- The old EBC levee will not be raised but will be maintained at its current height;
- The haul road will be upgraded to replace the old EBC levee (haul road levee); and
- The EBC levee will be extended further to the south to protect future mining areas.

8.2 CONSEQUENCE ASSESSMENT

Table 8.1 shows the consequence category assessment for each of the existing and proposed levees. It is likely that the consequence of environmental harm would be significant if the levees preventing egress to the open pit were breached or overtopped and are therefore required to be regulated under the EPAct. Once the haul road has been upgraded to act as a levee, the old EBC levee will no longer be required. Note that the OPAC, ROM pad, ROM pond and conveyor sit outside the flood protection levees. The OPAC and ROM pad are on elevated ground above the 0.1% AEP flood and therefore do not require a levee. The consequence category of the ROM pond has been assessed elsewhere and does not form part of this study.

Table 8.1 – Levee consequence category assessment

Levee	Purpose	Consequence category	Regulated
Condamine Levee	Preventing egress to open cut pit	Significant	Yes
EBC levee	Preventing egress to open cut pit	Significant	Yes
Haul road levee	Preventing egress to open cut pit	Significant	Yes
EBC levee extension	Preventing egress to open cut pit	Significant	Yes
Old EBC levee	None	Low	No

8.3 PROPOSED LEVEE UPGRADE

The proposed levee system was designed to provide a freeboard of at least 0.3 m to account for the differences in model calibration and the error bands of the ground level survey (reported to be ±0.15 m). The minimum crest levels of the levees are as follows:

- Condamine levee – 315.56 mAHD; and
- Eastern Branch Creek levee and haul road – 314.54 mAHD.

8.4 FLOOD IMPACT ASSESSMENT

Figure 8.1 and Figure 8.2 show the 0.1% AEP flood level and flood velocity impacts respectively due to raising the flood protection levees. The impacts have been determined by subtracting the existing conditions flood levels/velocities from the proposed conditions levels/velocities. Note that there would be no impact on peak levels or velocities for the 5% and 1% AEP events as the levees are not overtopped. Therefore the impact assessment has been undertaken on the 0.1% AEP event only.

The results show that peak 0.1% AEP flood levels and velocities are generally not impacted by the proposed levee raise. There is minor increase in peak velocities to the western side of the proposed levee and haul road but the peak velocities at these locations are mostly less than 1 m/s. Overall, the raising of the levees will not impact the Condamine River, Kogan Creek or Eastern Branch Creek.

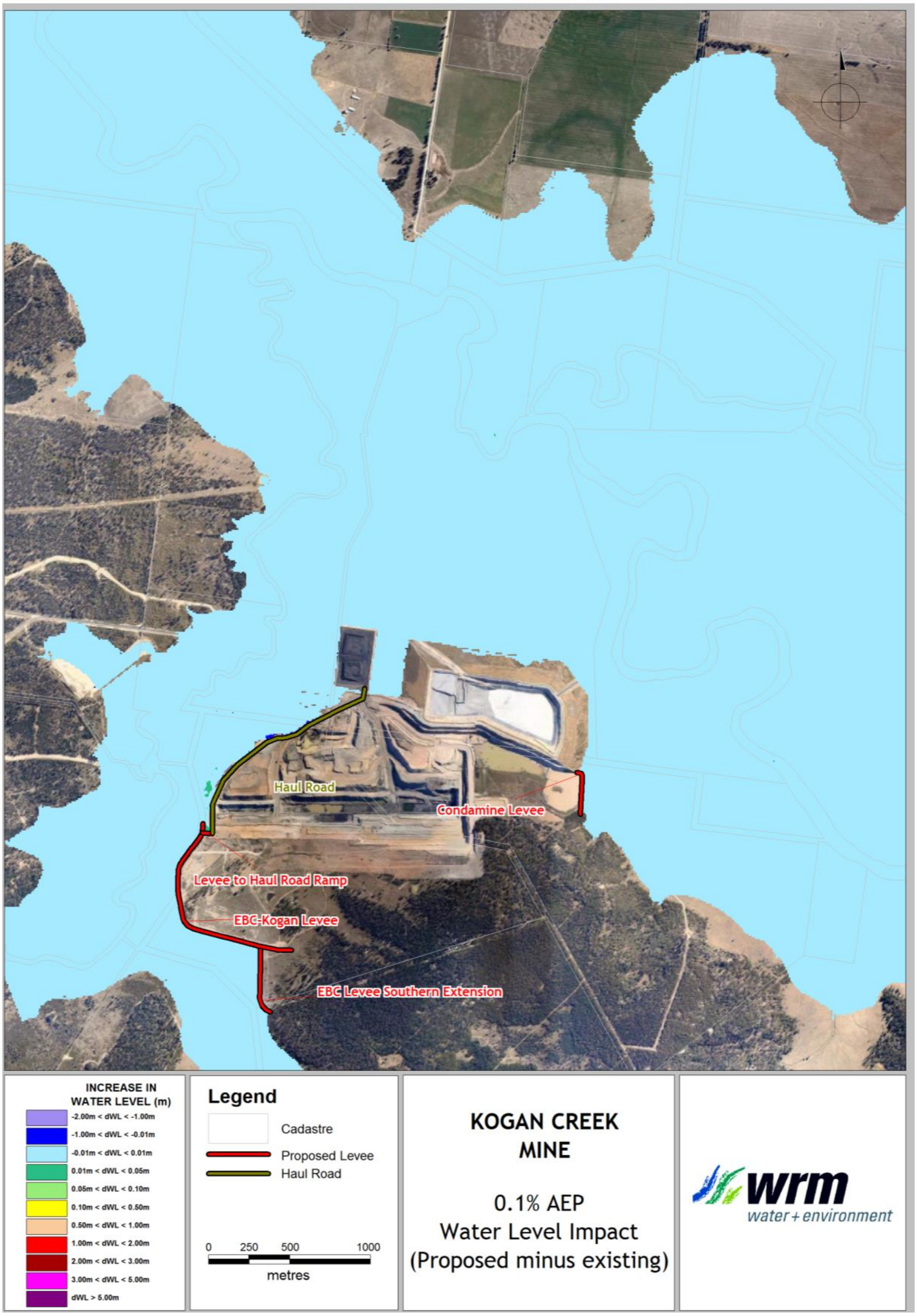

Figure 8.1 – Flood level impact, 0.1% AEP event

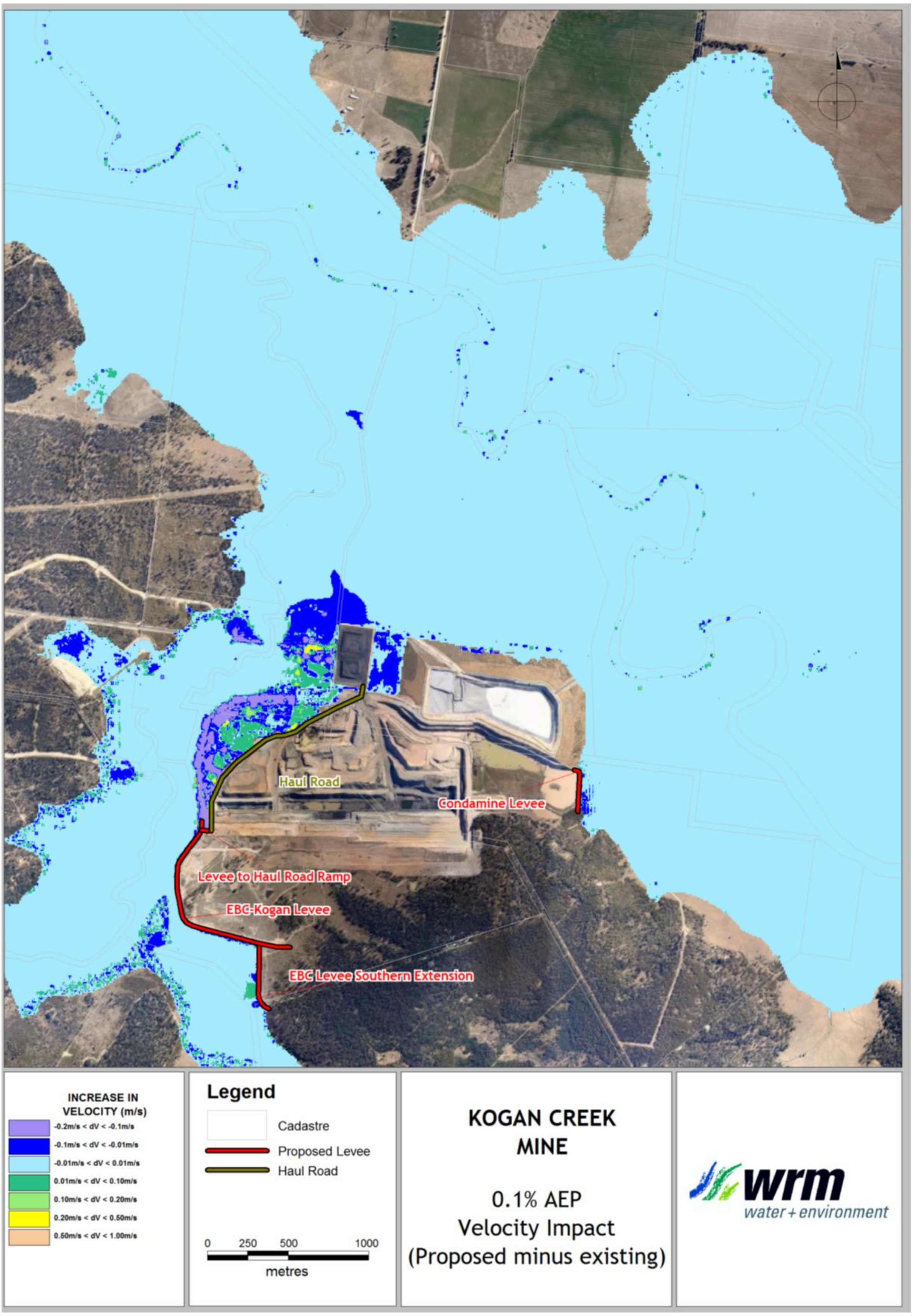

Figure 8.2 – Peak velocity impact, 0.1% AEP event

9 Summary

The Kogan Creek Mine is protected by flooding from the Condamine River and the Kogan Creek system by earthen levees. A flood study of the Condamine River and Kogan Creek has been undertaken to determine the flood immunity of the existing levees and recommend revised crest levels to satisfy regulatory requirements. An URBS rainfall runoff routing model was developed of the Condamine River and Kogan Creek systems to estimate design discharges and a fully two-dimensional hydraulic model was developed of the floodplain to determine design flood levels. The study estimated peak discharges and flood levels for the 5%, 1% and 0.1% AEP flood levels. The results of the study are as follows:

- Design discharges for the three events were estimated to be 2,047 m^3/s, 3,914 m^3/s and 10,395 m^3/s. The 5% and 1% AEP discharges are similar to the previous estimates. The 0.1% AEP discharge has not previously been estimated as the previous levees were based on the 0.2% AEP event.
- The December 2010 flood, which almost breached the Kogan Creek levees, had an estimated AEP of between 1% and 0.5%.
- The existing Kogan Creek levees would not be overtopped for the 5% and 1% AEP events.
- Both levees would be overtopped by the 0.1% AEP event. The Eastern Branch Creek levee is overtopped to an average depth of 0.73m, while the Condamine River levee is overtopped to an average depth of 0.16m.

It is proposed to modify the existing levees by raising both of the levees and replacing a section of the EBC level by upgrading the haul road. The Eastern Branch Creek will also be extended to the south to allow for future mining.

The Condamine Levee, EBC levee, EBC levee extension and haul road levee would be regulated structures under the EPACT and are required to provide flood immunity for the 0.1% AEP event. It is also proposed to include a 0.3 m freeboard to account for the differences in model calibration and the error bands of the ground level survey.

The recommended minimum crest level settled is 315.56 mAHD for the Condamine levee and 314.54 mAHD for the Eastern Branch Creek levees and the haul road.

Hydraulic modelling of the proposed levee upgrade found that peak 0.1% AEP flood levels and flood velocities are generally not impacted by the levee raise and as such the raising of the levees will not impact the Condamine River, Kogan Creek or Eastern Branch Creek.

10 References

BOM (2005)	*Guidebook for the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method*, prepared by the Hydrometeorological Advisory Service, Australian Government, BOM, September 2005.
Carroll (2012)	*URBS A Rainfall Runoff Routing Model for Flood Forecasting & Design*, D.G. Carroll, Version 5.00, December 2012.
Carroll (2014)	URBS Rainfall Runoff Routing Model software, D.G. Carroll, Version 5.85, 2014.
Catchment Simulation Solutions Pty Ltd (2013)	CatchmentSim software, Catchment Simulation Solutions Pty Ltd, Version 3, 2013.
DEHP (2016)	*Manual for assessing consequence categories and hydraulic performances of structures*, Department of Environment and Heritage Protection State of Queensland, March 2013
Engineers Australia (2012)	*Australian Rainfall and Runoff – Revision Projects Project 5 Regional Flood Methods Stage 2 report*. Engineers Australia, Barton, ACT, 1998.
Hargraves (c2004)	*Final Report, Extreme Rainfall Estimation Project, CRCFORGE and (CRC) ARF Techniques, Queensland and Border Locations, Development and Application*, Report prepared by Gary Hargraves, Water Assessment Group, Water Assessment and Planning, Resource Sciences Centre, undated, circa 2004.
Malone (2000)	*Using URBS for Real Time Flood Modelling*, T. Malone in Water 99 Joint Congress, Institution of Engineers, July 1999.
Pilgrim (1998)	*Australian Rainfall and Runoff – A Guide to Flood Estimation*, Revised Edition, Institution of Engineers Australia, 1998.
Water Studies (2003)	*Kogan Creek Power Station Development Flood Study and Eastern Branch Creek Diversion*, report prepared for Montgomery Watson Harza by Water Studies August 2003
WBM (2014b)	*TUFLOW FLIKE Portal*, http://www.tuflow.com/flike.aspx?UseFLike, Accessed August, 2014.
WMB (2010)	TUFLOW User Manual, GIS Based 2D/1D Hydrodynamic Modelling, Build 2013-12-AC, BMT WBM 2010
WMB(2014a)	TUFLOW 2013-12 Release Notes, Build 2013-12-AC, BMT WBM 2014
WRM (2011)	*Review of the December 2010 and January 2011 Condamine River Flood at Kogan Creek Mine*, WRM Water & Environment Pty Ltd,, 2011
WRM (2012)	*Kogan Creek Mine Flood Levee Assessment and Emergency Plan*, Report prepared for MWH Australia Pty Ltd by WRM Water & Environment Pty Ltd, August 2012.

Appendix A Catchment areas and main stream lengths

Contents

A1.1 WARWICK MODEL

Table A.1 - Catchment areas and main stream lengths - Warwick Model

ID	Area (km^2)	Main Stream Length (km)	ID	Area (km^2)	Main Stream Length (km)	ID	Area (km^2)	Main Stream Length (km)	ID	Area (km^2)	Main Stream Length (km)
1	20.3	4.6	21	20.3	7.2	41	10.2	4.0	61	0.1	0.4
2	21.0	4.9	22	24.5	12.3	42	13.7	5.9	62	36.3	7.5
3	8.2	3.3	23	20.3	11.6	43	10.1	3.6	63	13.5	8.7
4	1.7	1.1	24	23.7	9.8	44	30.4	13.1	64	3.8	1.5
5	35.1	7.8	25	14.7	6.8	45	17.4	5.8	65	19.2	10.5
6	0.1	0.1	26	10.1	6.7	46	5.2	3.0	66	12.4	4.8
7	4.2	2.7	27	6.9	5.1	47	22.2	6.5	67	12.4	5.5
8	12.2	3.7	28	20.7	5.4	48	44.0	10.2	68	20.2	3.1
9	0.1	0.1	29	18.3	6.3	49	14.9	3.7	69	28.2	10.8
10	1.9	0.7	30	19.3	8.4	50	10.2	4.8	70	47.8	14.8
11	0.4	0.5	31	17.2	5.8	51	9.0	4.5	71	16.7	7.2
12	25.1	11.2	32	6.1	4.9	52	7.9	6.9	72	16.6	4.3
13	40.9	11.7	33	12.8	0.0	53	15.4	6.4	73	18.5	4.1
14	25.7	8.7	34	18.3	3.5	54	14.6	4.8	74	17.9	5.7
15	43.1	12.3	35	7.2	3.4	55	14.5	5.2	75	3.7	1.7
16	28.4	5.7	36	17.6	10.2	56	29.5	6.8	76	2.8	2.6
17	33.2	8.2	37	20.8	7.2	57	19.9	6.7	77	5.6	3.8
18	33.0	4.2	38	6.5	3.3	58	26.5	10.1	78	19.6	8.0
19	34.4	6.1	39	1.9	1.4	59	23.0	6.6	79	5.6	4.3
20	39.4	8.5	40	23.5	8.3	60	20.7	6.1			

A1.2 TUMMAVILLE MODEL

Table A.2 – Catchment areas and main stream lengths – Tummaville Model

ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)
1	45.2	10.7	34	12.5	5.6	67	19.1	6.4	100	17.4	5.7
2	0.4	0.6	35	7.4	3.9	68	11.0	5.1	101	13.7	5.5
3	3.6	2.3	36	8.8	5.9	69	4.3	2.0	102	38.5	12.5
4	1.1	0.3	37	49.4	13.1	70	18.3	9.0	103	24.7	7.8
5	0.1	0.4	38	15.2	5.7	71	5.4	3.1	104	25.2	11.0
6	31.4	8.9	39	10.9	7.2	72	50.4	12.4	105	28.7	8.9
7	51.8	10.4	40	17.2	4.9	73	24.0	7.1	106	28.9	10.8
8	41.7	8.4	41	24.3	8.3	74	24.7	9.1	107	43.0	12.0
9	4.1	4.3	42	24.6	6.6	75	21.8	6.1	108	13.0	9.1
10	43.3	8.1	43	16.9	5.4	76	14.3	6.8	109	34.0	8.6
11	46.7	0.0	44	5.7	2.6	77	44.8	10.3	110	32.7	10.7
12	23.4	5.1	45	13.7	6.5	78	32.8	6.4	111	19.4	6.7
13	14.8	2.8	46	14.2	6.9	79	26.6	10.1	112	34.4	11.9
14	6.0	5.8	47	32.4	12.4	80	33.0	5.9	113	54.1	8.5
15	66.4	10.4	48	1.7	1.9	81	5.3	2.1	114	37.5	12.5
16	26.7	6.7	49	29.2	11.1	82	14.8	7.8	115	65.1	8.8
17	6.0	3.7	50	19.8	8.2	83	31.4	8.5	116	37.3	6.7
18	16.6	7.5	51	27.7	9.8	84	17.7	5.4	117	34.0	7.3
19	19.3	7.9	52	2.0	1.6	85	24.0	4.0	118	7.5	2.9
20	29.4	6.6	53	28.8	11.6	86	11.4	4.2	119	50.6	13.0
21	14.8	5.6	54	27.6	6.3	87	13.9	7.7	120	49.1	9.7
22	51.8	16.2	55	31.5	10.4	88	10.8	6.7	121	28.2	11.4
23	29.5	12.2	56	27.0	7.9	89	13.2	3.2	122	24.8	6.8
24	28.9	8.8	57	37.6	11.0	90	3.2	2.5	123	20.5	8.0
25	29.4	11.4	58	34.7	10.6	91	19.1	6.9	124	54.8	12.0
26	8.5	5.3	59	19.8	7.5	92	1.4	2.9	125	38.5	11.0
27	9.7	6.6	60	21.2	8.0	93	15.3	8.5	126	73.9	13.0
28	26.9	8.7	61	27.2	9.1	94	15.6	6.5	127	19.5	5.4
29	25.0	7.5	62	42.2	12.4	95	14.2	5.1	128	14.8	4.7
30	17.6	7.0	63	17.0	7.3	96	8.1	5.4	129	31.2	12.1
31	19.2	7.0	64	22.6	8.8	97	48.1	7.2	130	45.3	6.5
32	36.4	7.6	65	25.4	6.3	98	18.0	3.4	131	27.6	13.1
33	13.2	4.9	66	11.9	5.0	99	36.2	8.3	132	13.9	9.3

ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)
133	46.1	8.0	166	42.0	4.8	199	7.1	3.2
134	1.4	3.1	167	22.7	9.0	200	2.9	2.7
135	47.3	14.2	168	34.0	12.2	201	14.3	6.9
136	1.1	3.1	169	7.6	4.2	202	1.9	3.0
137	26.2	7.7	170	44.7	14.5			
138	5.4	5.4	171	13.0	6.1			
139	6.8	4.0	172	14.0	4.2			
140	1.9	3.8	173	17.5	9.8			
141	39.2	7.6	174	37.1	11.9			
142	26.6	6.7	175	50.1	10.2			
143	33.1	8.2	176	27.8	0.1			
144	36.4	13.7	177	22.9	5.5			
145	33.6	7.6	178	16.7	10.2			
146	14.3	7.8	179	16.7	5.5			
147	62.9	8.4	180	1.2	3.0			
148	50.6	12.3	181	45.0	5.3			
149	28.2	7.6	182	39.9	5.7			
150	30.8	5.0	183	24.7	8.4			
151	24.1	10.7	184	28.0	7.8			
152	16.3	10.0	185	29.6	5.2			
153	17.7	6.4	186	20.8	3.7			
154	1.1	1.3	187	29.4	6.9			
155	37.0	6.3	188	31.6	10.6			
156	6.5	5.2	189	6.0	4.9			
157	35.9	12.0	190	3.5	2.4			
158	8.3	6.3	191	49.7	13.1			
159	76.9	12.2	192	46.4	7.1			
160	11.3	5.4	193	10.7	3.0			
161	17.0	7.2	194	3.5	4.2			
162	26.2	9.0	195	39.4	11.5			
163	10.2	4.5	196	3.2	2.6			
164	8.8	5.9	197	19.4	4.1			
165	39.7	10.9	198	3.8	4.3			

A1.3 EAST RIDGES MODEL

Table A.3 – Catchment areas and main stream lengths – East Ridges Model

ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)
1	14.9	4.6	34	36.6	11.7	67	65.0	8.0	100	9.7	4.4
2	3.0	1.2	35	44.5	13.3	68	80.8	11.2	101	19.1	9.0
3	21.7	6.1	36	57.6	6.0	69	18.9	5.1	102	6.9	3.4
4	20.1	5.1	37	22.6	8.1	70	23.6	10.4	103	11.5	5.9
5	5.3	2.7	38	59.6	12.3	71	26.7	8.8	104	23.6	6.0
6	3.8	1.0	39	48.0	12.3	72	20.8	8.6	105	11.5	4.4
7	1.1	0.7	40	71.7	14.1	73	18.3	4.9	106	10.3	4.0
8	0.0	0.1	41	28.0	7.4	74	30.4	11.2	107	11.5	5.2
9	11.7	7.0	42	77.8	12.2	75	62.8	11.9	108	14.7	6.6
10	14.8	5.1	43	53.1	8.2	76	50.2	10.4	109	21.4	8.0
11	113.6	17.7	44	44.5	13.5	77	24.1	6.3	110	11.8	5.2
12	50.6	16.6	45	30.4	12.2	78	44.6	11.0	111	43.6	6.8
13	58.2	15.6	46	55.0	12.1	79	19.9	6.1	112	36.9	7.2
14	56.4	15.3	47	11.3	6.2	80	28.8	9.3	113	33.0	6.8
15	53.4	13.6	48	8.7	8.4	81	17.4	9.5	114	21.1	6.6
16	77.9	18.0	49	30.3	13.0	82	30.9	8.7	115	17.6	3.9
17	22.0	9.6	50	1.0	1.3	83	42.0	7.2	116	10.1	7.3
18	26.9	11.9	51	31.0	10.7	84	24.1	9.7	117	8.5	5.0
19	13.2	3.1	52	12.5	5.1	85	14.3	8.5	118	24.0	7.6
20	14.9	6.5	53	2.4	3.1	86	0.5	0.4	119	5.6	4.7
21	22.8	7.8	54	29.3	9.4	87	24.5	9.7	120	2.2	2.1
22	1.4	1.6	55	43.8	7.9	88	7.8	5.9	121	7.1	5.2
23	10.6	2.7	56	14.0	5.3	89	15.5	6.6	122	9.0	3.2
24	15.0	4.9	57	2.2	2.3	90	8.4	3.5	123	6.2	4.3
25	6.8	3.2	58	35.1	7.7	91	29.0	7.6	124	10.2	6.3
26	93.8	15.3	59	25.6	9.2	92	6.8	3.8	125	25.4	10.9
27	37.3	6.6	60	11.8	6.9	93	11.1	5.8	126	25.6	5.1
28	39.6	8.5	61	11.1	6.0	94	14.7	5.6	127	29.7	6.8
29	36.7	14.1	62	52.1	10.9	95	14.2	5.2	128	13.2	7.0
30	32.7	8.8	63	52.3	12.6	96	29.7	7.9	129	16.9	5.1
31	4.4	2.9	64	30.5	9.9	97	17.4	6.9	130	17.0	5.7
32	1.5	1.1	65	41.3	11.6	98	12.5	3.9	131	23.0	7.1
33	13.3	4.1	66	18.8	5.2	99	16.7	3.8	132	20.6	6.4

ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)
133	9.9	6.1	166	5.1	2.1	199	24.7	13.4	232	8.7	3.4
134	23.5	5.9	167	6.4	4.4	200	12.9	4.0	233	41.4	13.0
135	12.8	6.0	168	7.2	5.3	201	20.1	6.7			
136	23.8	8.2	169	7.6	4.7	202	16.1	8.6			
137	12.9	6.5	170	4.2	3.4	203	12.3	6.0			
138	6.3	2.9	171	12.4	5.0	204	2.9	4.9			
139	12.5	7.7	172	7.5	4.4	205	12.3	6.0			
140	12.2	7.2	173	4.0	4.0	206	28.3	3.8			
141	16.0	5.0	174	14.3	4.6	207	45.0	7.2			
142	15.4	7.4	175	5.6	4.2	208	8.4	5.9			
143	10.1	6.1	176	6.7	2.7	209	18.2	4.4			
144	20.6	6.5	177	3.2	3.5	210	11.1	3.1			
145	33.1	6.6	178	3.6	2.4	211	12.6	2.9			
146	26.0	5.0	179	2.9	1.9	212	4.2	2.3			
147	9.1	4.9	180	2.5	3.1	213	6.7	3.5			
148	14.5	5.8	181	2.2	1.7	214	10.7	7.1			
149	18.8	3.9	182	4.6	3.8	215	10.1	3.3			
150	10.2	4.9	183	14.6	8.0	216	5.6	4.5			
151	14.7	5.7	184	16.4	4.3	217	9.7	3.8			
152	6.0	3.6	185	11.5	4.4	218	18.2	5.3			
153	9.3	4.8	186	9.2	5.0	219	6.1	3.2			
154	1.4	1.1	187	11.8	4.6	220	10.1	2.3			
155	6.7	5.1	188	14.6	6.7	221	18.3	5.6			
156	8.7	6.6	189	23.9	7.8	222	10.1	3.8			
157	9.5	3.7	190	37.8	9.8	223	7.8	6.0			
158	5.4	3.2	191	28.1	8.4	224	6.4	4.5			
159	7.9	5.8	192	30.5	5.0	225	6.1	4.7			
160	12.1	5.6	193	29.8	8.2	226	4.4	2.2			
161	2.3	1.3	194	29.0	6.3	227	34.8	8.6			
162	9.9	5.6	195	28.7	6.7	228	10.8	6.0			
163	6.0	3.2	196	50.5	8.0	229	14.6	6.2			
164	8.5	4.3	197	17.9	6.1	230	1.6	2.4			
165	6.5	4.6	198	6.5	4.3	231	16.5	8.6			

A1.4 LOUDOUN MODEL

Table A.4 - Catchment areas and main stream lengths - Loudoun Model

ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)
1	66.9	16.1	34	55.1	16.1	67	14.8	5.1	100	8.7	3.4
2	39.7	11.6	35	31.8	8.0	68	23.7	7.1	101	9.6	6.9
3	67.8	14.2	36	59.4	14.4	69	52.5	15.2	102	9.4	7.3
4	27.1	8.7	37	16.2	9.2	70	35.3	9.0	103	17.9	9.8
5	81.4	10.9	38	31.3	10.1	71	6.4	3.9	104	25.6	8.5
6	18.8	8.6	39	6.2	5.3	72	16.4	3.0	105	16.1	7.6
7	34.6	9.0	40	44.8	7.6	73	4.2	3.5	106	40.9	8.6
8	67.5	12.1	41	8.1	6.3	74	16.0	7.9	107	27.1	5.0
9	26.0	11.9	42	20.6	4.5	75	32.7	8.0	108	31.5	6.5
10	38.1	6.7	43	68.8	16.3	76	16.9	7.6	109	20.9	8.8
11	20.1	10.6	44	42.9	9.8	77	30.5	7.5	110	32.0	7.2
12	32.3	6.9	45	40.3	7.4	78	27.1	9.7	111	21.3	5.4
13	30.5	11.6	46	1.1	3.1	79	10.6	7.7	112	7.9	4.1
14	0.3	0.5	47	11.9	5.1	80	0.0	0.2	113	21.1	10.6
15	57.8	14.6	48	1.2	3.5	81	45.2	13.9	114	19.8	10.5
16	24.0	7.3	49	55.1	12.8	82	14.1	6.6	115	25.3	10.8
17	76.8	16.6	50	39.6	10.2	83	4.0	3.4	116	60.8	8.7
18	46.4	17.3	51	20.3	3.8	84	24.9	8.2	117	30.8	6.6
19	66.7	17.7	52	25.2	11.6	85	2.4	2.0	118	54.9	11.2
20	11.0	4.9	53	2.2	3.8	86	30.8	9.7	119	27.1	13.5
21	49.6	13.6	54	3.9	2.9	87	24.4	8.7	120	14.6	10.2
22	24.9	9.6	55	11.7	7.0	88	19.4	9.2	121	16.1	10.5
23	26.9	7.2	56	2.1	2.5	89	36.0	5.3	122	15.3	4.9
24	17.9	6.4	57	39.1	11.7	90	29.4	13.2	123	8.6	6.1
25	18.4	8.5	58	33.4	10.5	91	25.6	8.1			
26	19.5	5.0	59	11.5	10.3	92	37.4	11.5			
27	12.3	6.8	60	20.2	6.3	93	9.0	7.8			
28	41.0	6.5	61	16.5	7.3	94	11.5	5.2			
29	19.1	6.4	62	39.2	12.9	95	21.7	6.5			
30	37.0	9.8	63	27.6	12.5	96	19.5	9.4			
31	12.4	4.2	64	42.8	10.2	97	29.6	8.2			
32	47.8	8.2	65	0.7	1.0	98	28.7	9.2			
33	57.4	14.6	66	48.6	8.5	99	30.4	10.9			

A1.5 CHINCHILLA WEIR MODEL

Table A.5 – Catchment areas and main stream lengths – Chinchilla Weir Model

ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)
1	35.0	11.1	34	29.9	11.1	67	2.3	1.7	100	35.7	14.4
2	8.6	7.1	35	14.2	5.8	68	14.2	5.4	101	11.5	5.2
3	45.7	10.5	36	44.7	13.5	69	2.6	2.8	102	7.0	3.7
4	41.9	13.8	37	59.6	15.6	70	7.2	2.8	103	7.1	2.8
5	20.3	8.7	38	4.8	3.5	71	8.6	3.3	104	16.8	9.8
6	11.9	2.8	39	19.7	8.3	72	2.6	2.9	105	19.7	7.5
7	5.0	5.0	40	5.8	3.8	73	4.9	4.3	106	6.7	2.3
8	23.6	7.8	41	1.8	1.2	74	10.5	7.0	107	3.5	3.7
9	30.2	6.9	42	28.2	13.5	75	4.3	4.2	108	4.9	3.0
10	21.6	10.9	43	14.3	6.2	76	10.5	3.1	109	5.3	2.2
11	26.7	9.8	44	5.9	1.9	77	2.2	3.6	110	20.9	9.7
12	9.9	3.2	45	12.3	5.1	78	22.6	5.5	111	29.1	8.7
13	26.1	6.7	46	39.0	9.3	79	38.6	9.5	112	0.5	0.7
14	21.8	5.2	47	4.4	2.0	80	3.3	3.0	113	1.9	3.2
15	2.8	4.3	48	19.6	9.3	81	3.8	3.2	114	5.0	3.0
16	42.3	13.3	49	24.1	6.4	82	10.0	2.9	115	3.8	3.7
17	12.1	4.0	50	2.2	1.6	83	0.2	0.5	116	8.3	5.2
18	0.2	0.5	51	11.4	9.5	84	14.4	6.7	117	3.8	2.5
19	28.4	10.7	52	4.2	4.9	85	0.7	1.4	118	18.2	8.8
20	28.8	8.8	53	8.9	2.4	86	5.0	2.8	119	44.2	9.9
21	20.4	10.7	54	5.5	3.0	87	16.7	7.4	120	24.7	8.9
22	45.8	12.9	55	6.1	4.6	88	4.6	3.8	121	18.5	6.7
23	17.6	7.1	56	18.5	8.8	89	2.1	1.4	122	4.0	2.6
24	34.6	10.6	57	22.6	8.5	90	13.7	7.5	123	3.1	2.4
25	8.1	6.1	58	21.9	7.6	91	23.7	5.0	124	34.6	12.7
26	28.6	13.4	59	8.6	4.3	92	5.5	4.1	125	53.9	17.9
27	4.9	4.7	60	10.1	3.9	93	29.1	7.3	126	1.6	1.8
28	30.7	12.4	61	2.8	3.5	94	21.9	7.6	127	10.6	5.3
29	26.1	8.9	62	5.0	2.1	95	7.0	5.1	128	12.1	3.4
30	16.8	9.4	63	12.2	6.1	96	8.6	3.2	129	8.4	2.2
31	31.8	8.3	64	51.6	11.6	97	31.3	9.0	130	9.2	3.5
32	4.9	4.8	65	19.1	5.4	98	0.0	0.1	131	6.6	3.6
33	35.6	8.8	66	16.0	5.8	99	32.1	12.2	132	11.5	4.7

ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)	ID	Area (km2)	Main Stream Length (km)
133	1.0	1.6	166	44.2	8.7	199	39.7	11.0	232	8.2	6.2
134	28.0	15.0	167	8.0	5.9	200	16.9	6.9	233	16.4	7.9
135	6.6	5.9	168	5.4	2.2	201	21.3	7.2	234	10.7	6.9
136	9.6	7.9	169	9.5	7.8	202	6.6	7.0	235	13.1	7.7
137	4.6	4.1	170	3.2	3.3	203	10.2	4.0	236	9.8	7.4
138	4.3	3.3	171	9.9	6.6	204	9.0	4.1	237	17.9	5.8
139	12.2	3.5	172	41.6	9.6	205	20.6	6.1	238	4.6	5.4
140	6.0	4.1	173	15.4	7.4	206	28.0	5.6	239	3.8	3.5
141	19.8	6.5	174	1.9	3.1	207	34.6	9.5	240	5.6	4.6
142	18.5	5.9	175	30.3	9.4	208	6.8	4.5	241	8.4	7.2
143	12.6	5.3	176	64.9	11.3	209	8.0	5.5			
144	8.9	2.7	177	49.9	12.0	210	33.3	9.6			
145	5.7	3.2	178	14.7	5.5	211	14.5	6.2			
146	9.8	4.0	179	35.1	7.7	212	19.1	8.0			
147	4.1	3.4	180	42.9	8.3	213	26.2	10.0			
148	5.2	2.8	181	26.5	5.1	214	14.5	6.9			
149	4.1	2.9	182	46.2	13.3	215	16.5	8.6			
150	25.1	6.2	183	27.0	13.8	216	12.8	6.9			
151	5.7	4.4	184	14.2	6.9	217	34.2	12.3			
152	9.7	5.6	185	18.9	7.3	218	20.6	9.0			
153	16.2	4.7	186	48.2	11.5	219	29.9	10.7			
154	49.2	9.3	187	24.3	10.4	220	30.4	13.8			
155	18.8	4.8	188	19.7	6.9	221	8.4	5.7			
156	13.2	8.7	189	19.9	6.9	222	16.6	6.3			
157	14.4	9.3	190	22.0	9.6	223	40.9	12.2			
158	17.9	6.6	191	50.7	13.7	224	22.6	9.7			
159	29.2	6.5	192	50.1	13.1	225	16.4	7.2			
160	12.0	6.2	193	15.8	6.5	226	28.0	9.1			
161	31.1	8.6	194	29.5	8.7	227	34.4	10.6			
162	2.8	1.8	195	21.1	6.0	228	73.8	11.6			
163	4.4	4.0	196	99.6	20.8	229	5.7	4.2			
164	26.1	5.9	197	30.2	8.6	230	8.7	5.9			
165	22.3	5.5	198	30.6	6.6	231	10.7	6.7			

Appendix B Calibration Results

Contents

B2 May 1996

B2.1 WARWICK MODEL

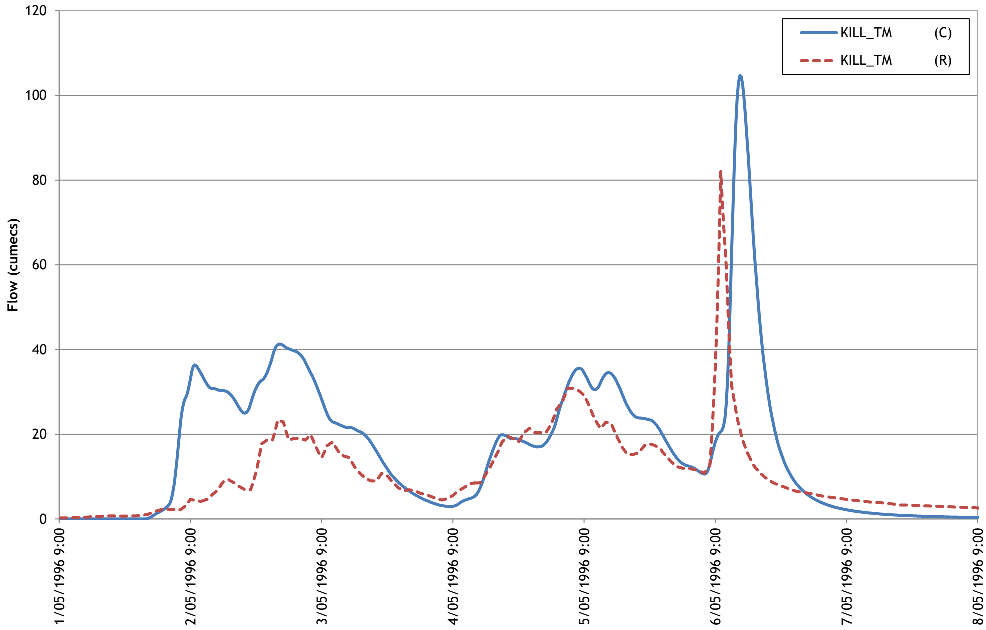

Figure B.1 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Spring Creek at Killarney TM, May 1996

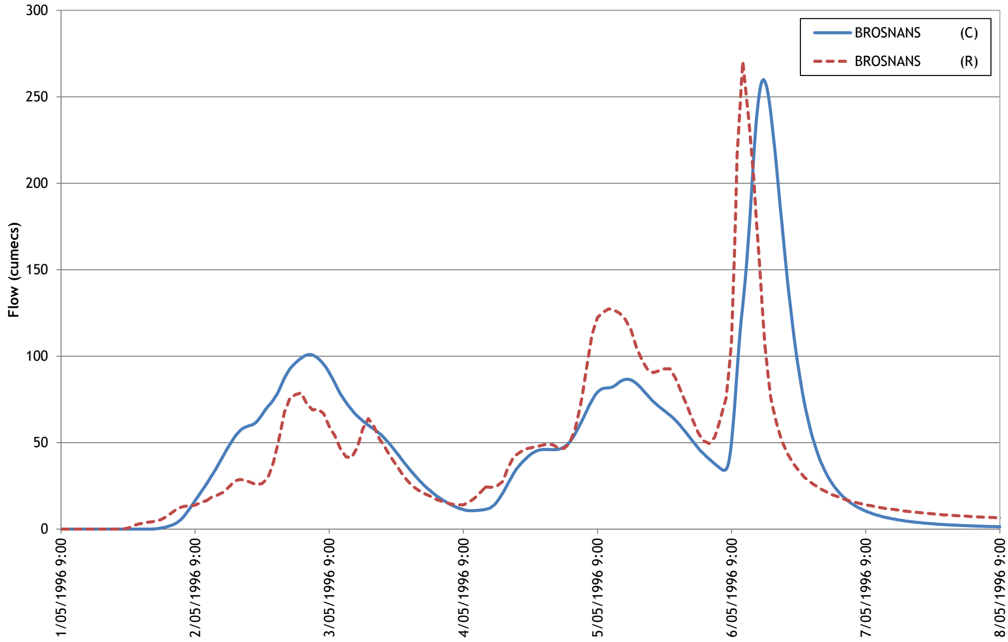

Figure B.2 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Brosnans Barn TM, May 1996

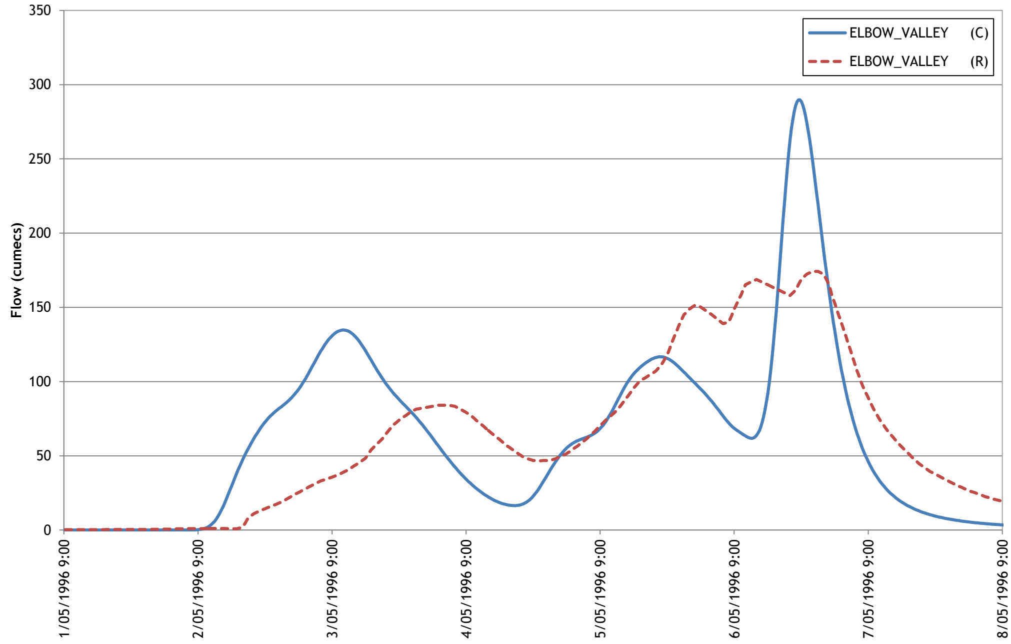

Figure B.3 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Elbow Valley, May 1996

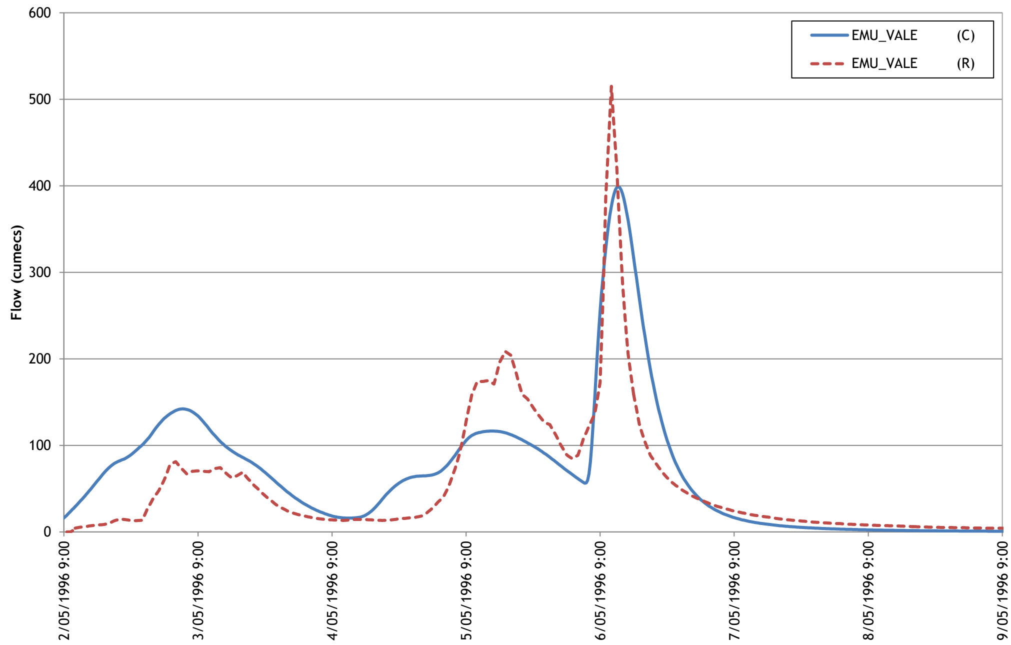

Figure B.4 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Emu Creek at Emu Vale, May 1996

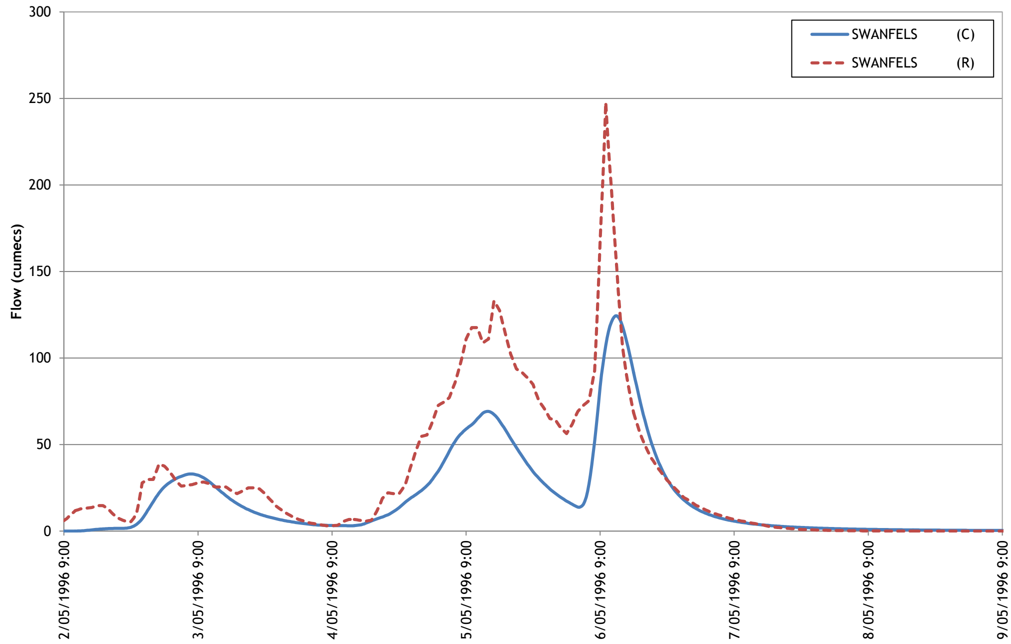

Figure B.5 – Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Swan Creek at Swanfels, May 1996

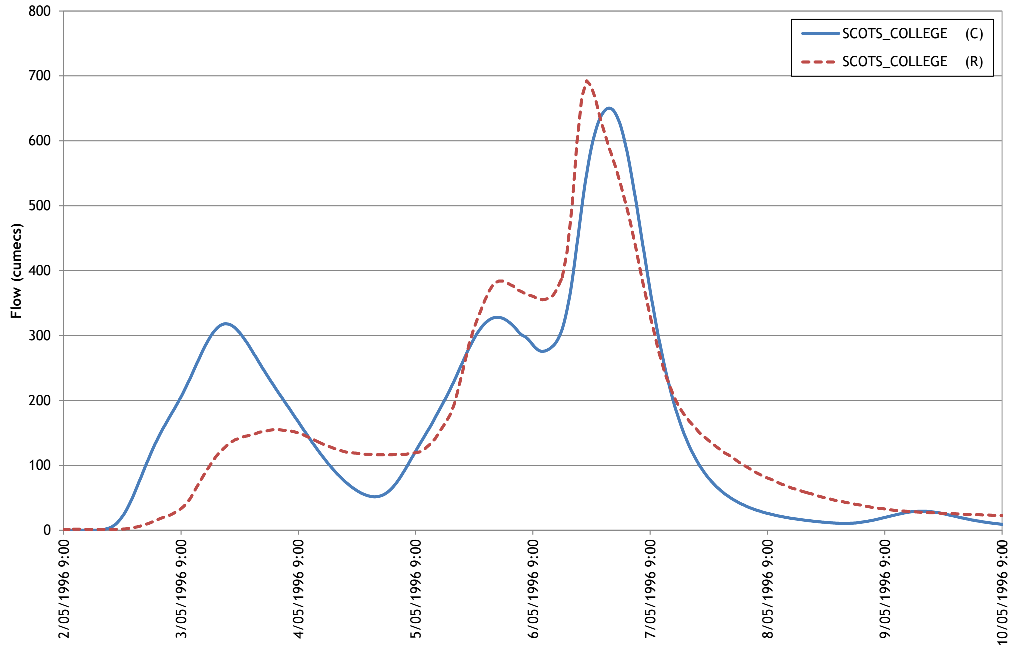

Figure B.6 – Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Scots College, May 1996

B2.2 TUMMAVILLE MODEL

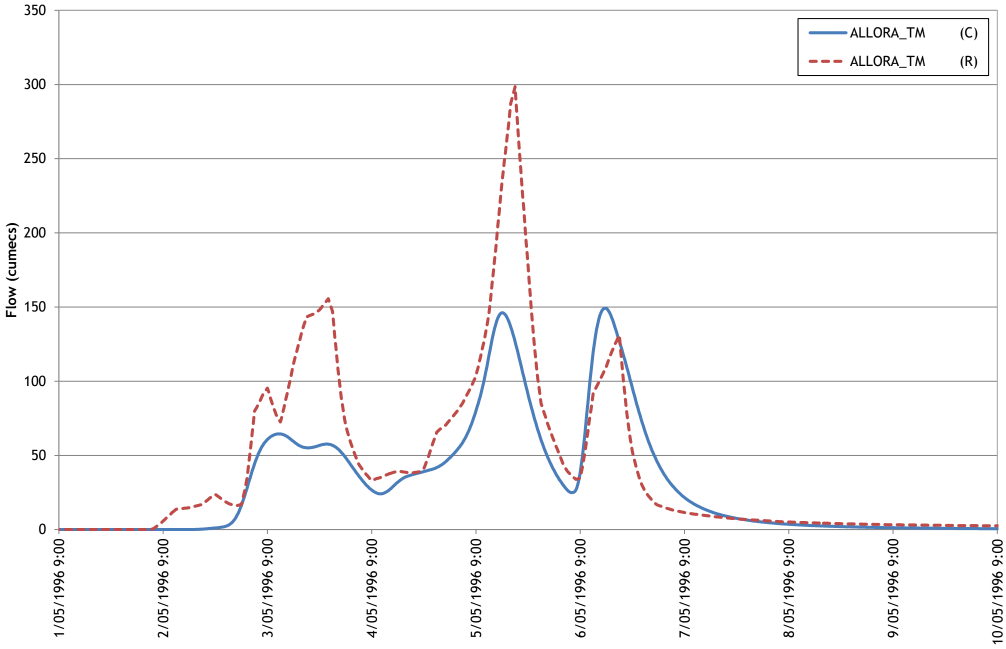

Figure B.7 – Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Dalrymple Creek at Allora TM, May 1996

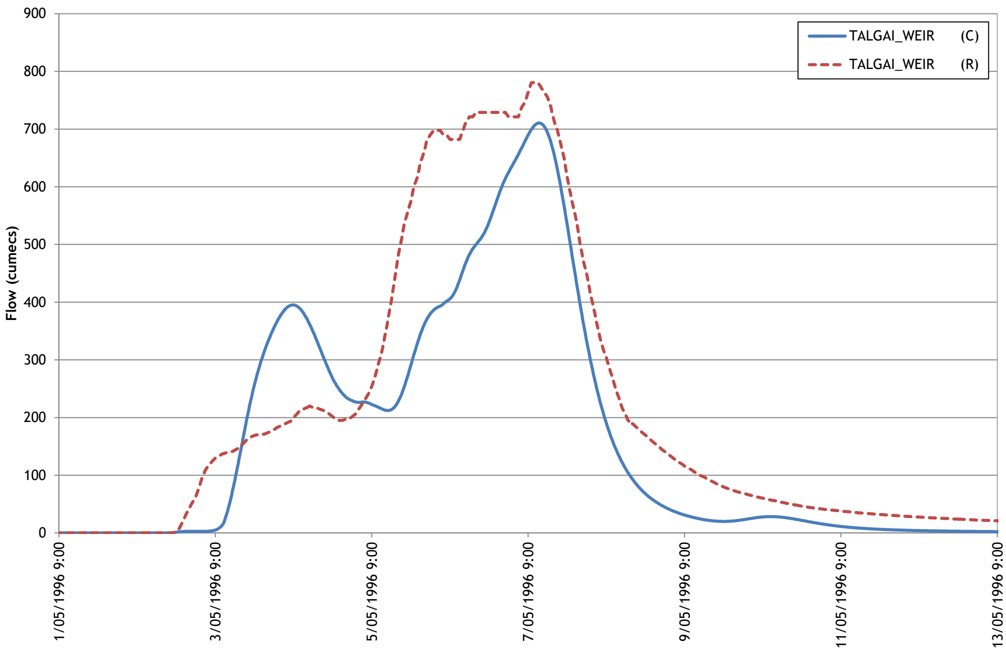

Figure B.8 – Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Talgai Weir, May 1996

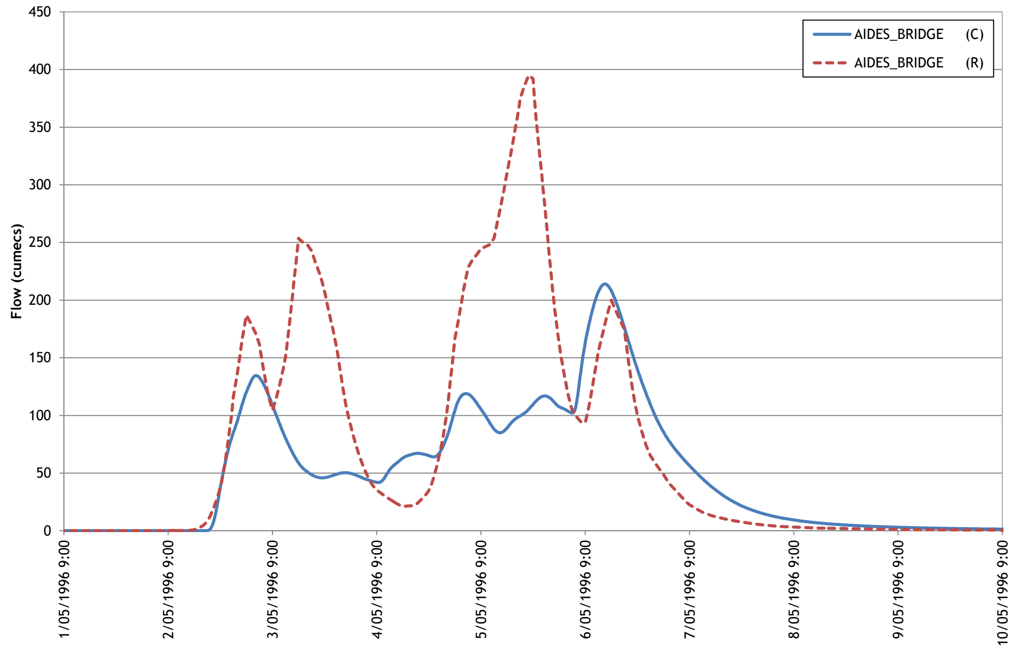

Figure B.9 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Kings Creek at Aides Bridge, May 1996

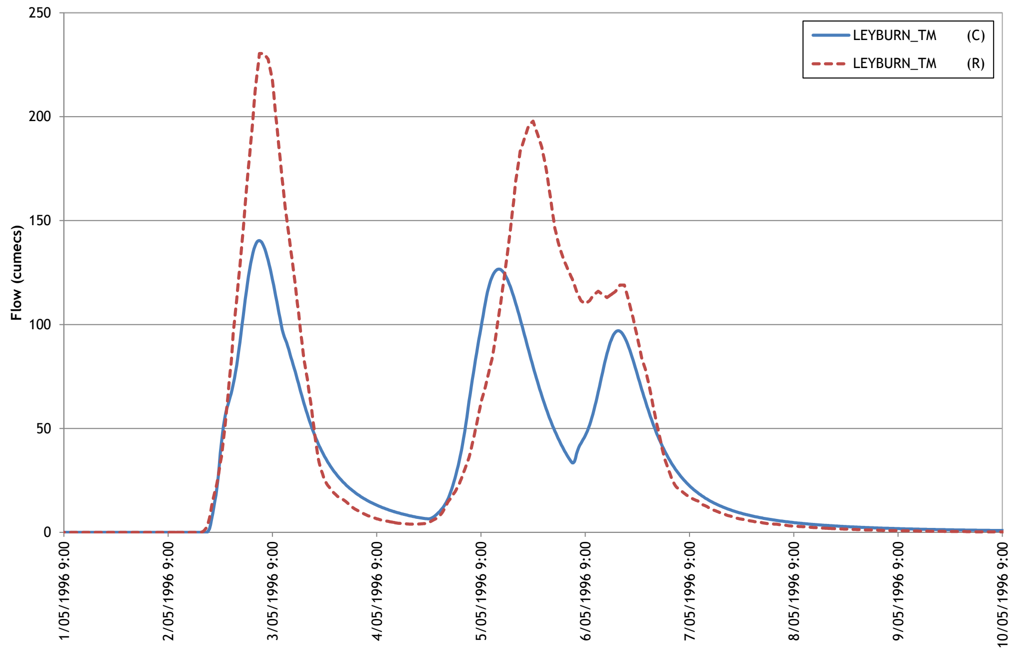

Figure B.10 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Canal Creek at Leyburn TM, May 1996

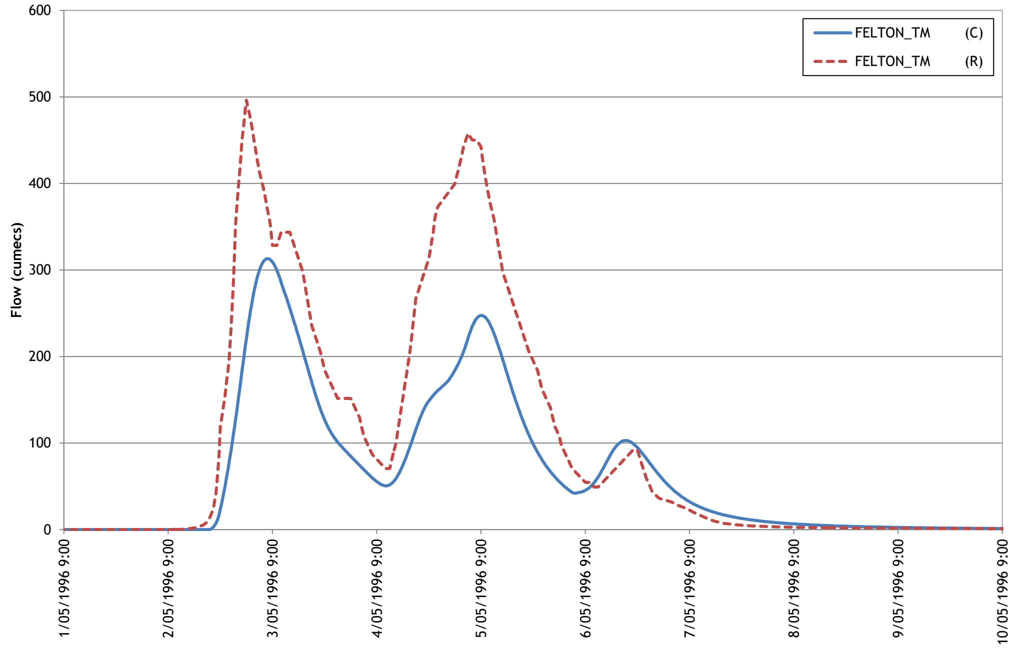

Figure B.11 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Hodgson Creek at Felton TM, May 1996

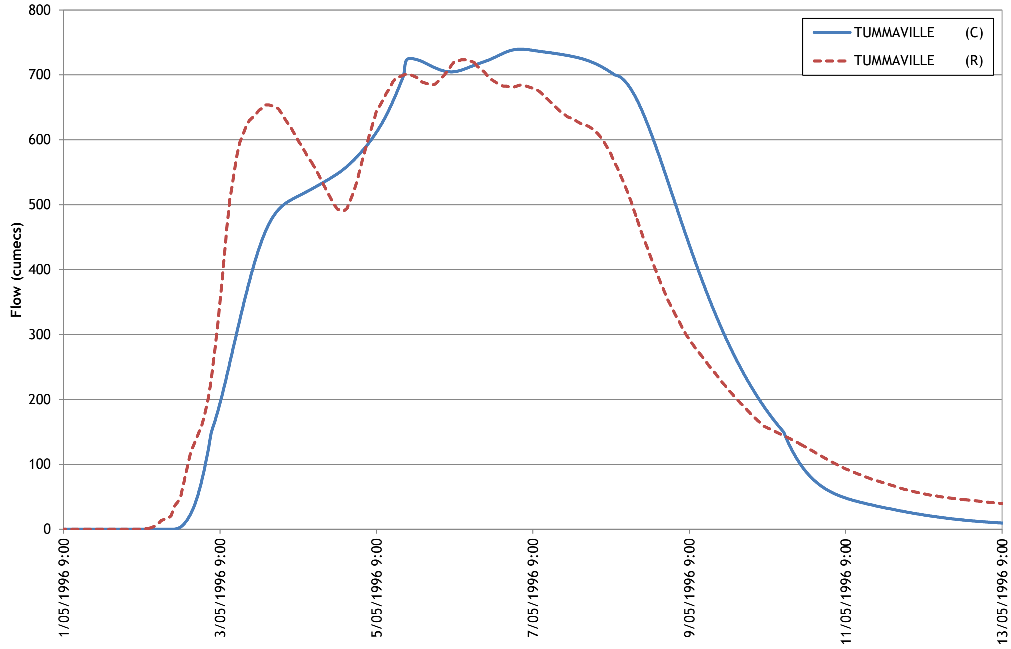

Figure B.12 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Tummaville, May 1996

B2.3 EAST RIDGES MODEL

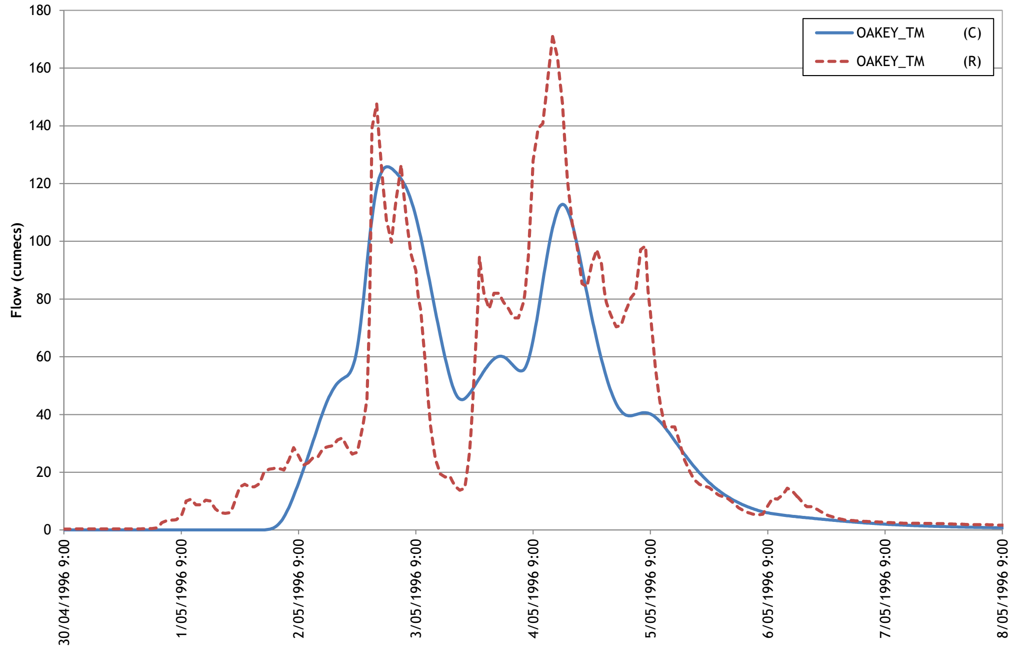

Figure B.13 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Gowrie Creek at Oakey TM, May 1996

B2.4 LOUDOUN MODEL

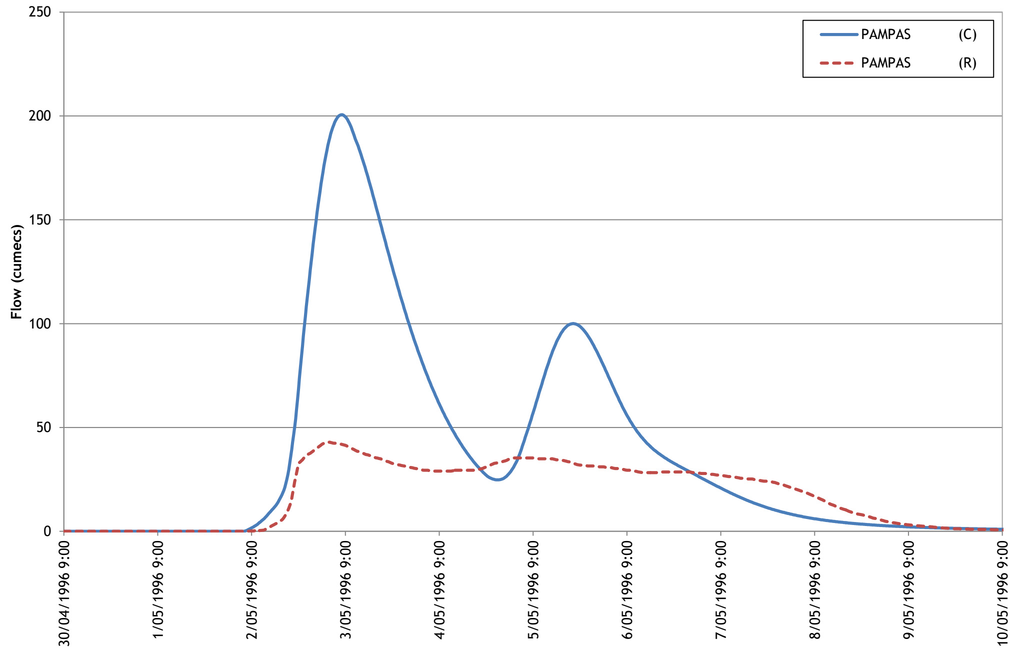

Figure B.14 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River North Branch at Pampas, May 1996

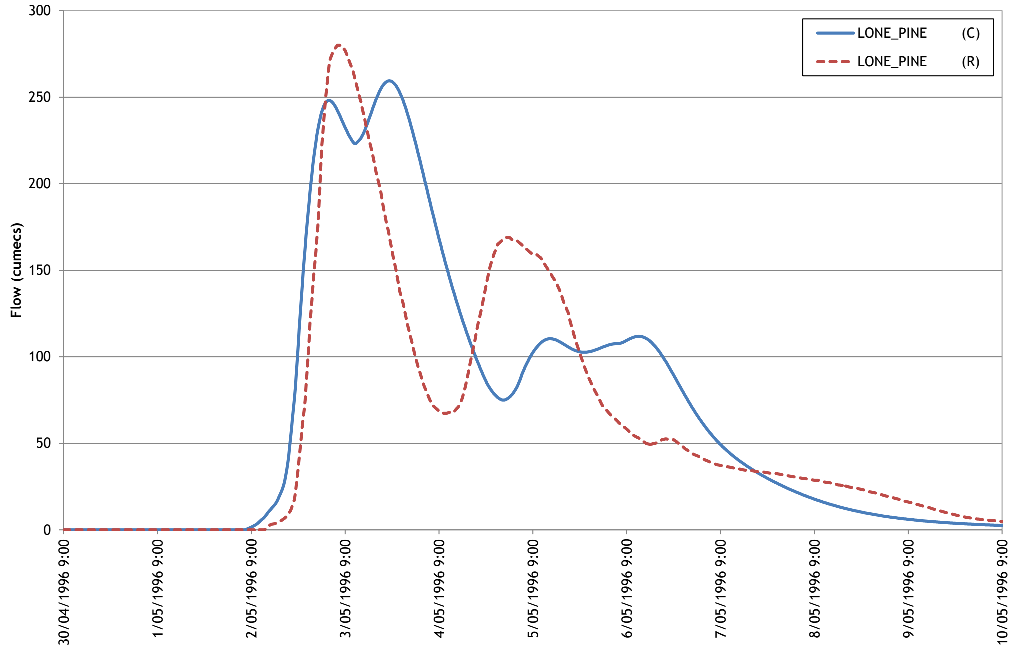

Figure B.15 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River North Branch at Lone Pine, May 1996

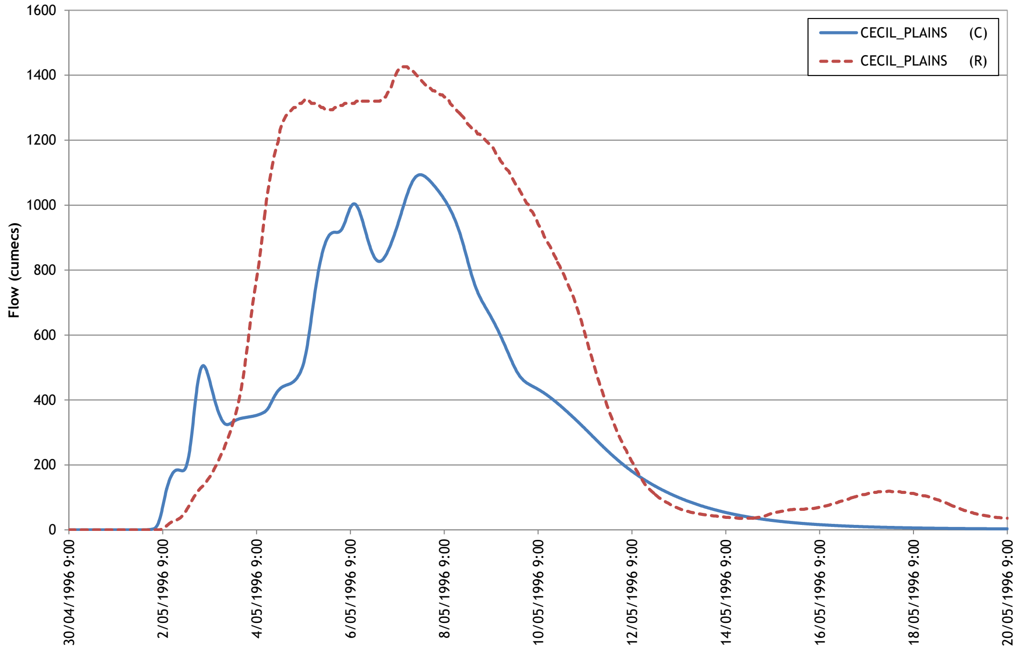

Figure B.16 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Cecil Plains TM, May 1996

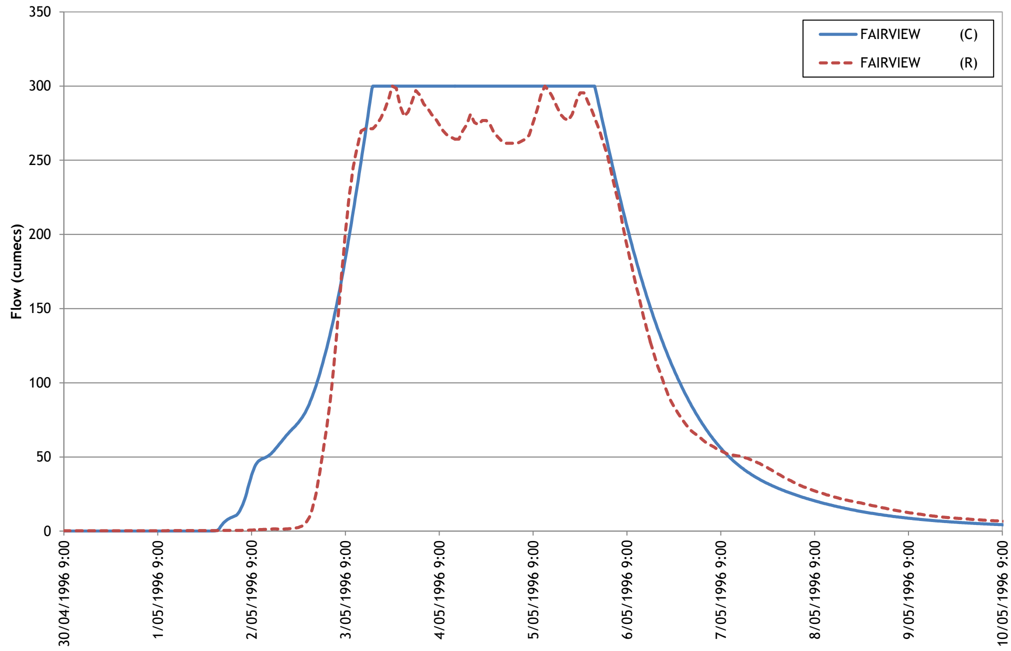

Figure B.17 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Oakey Creek at Fairview TM, May 1996

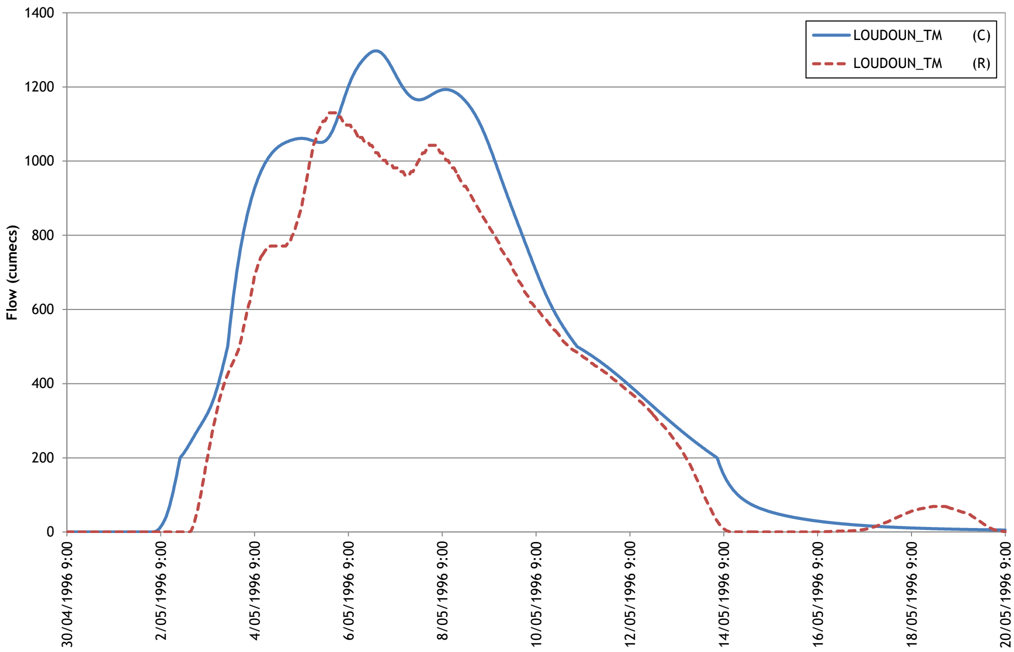

Figure B.18 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Loudoun TM, May 1996

B2.5 CHINCHILLA WEIR MODEL

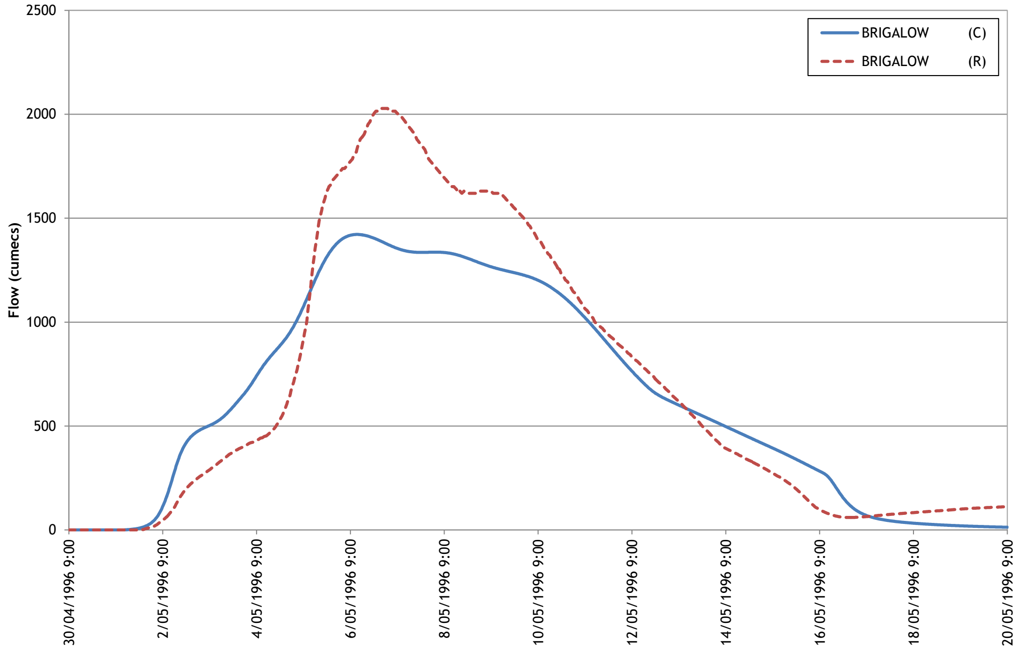

Figure B.19 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Brigalow Bridge TM, May 1996

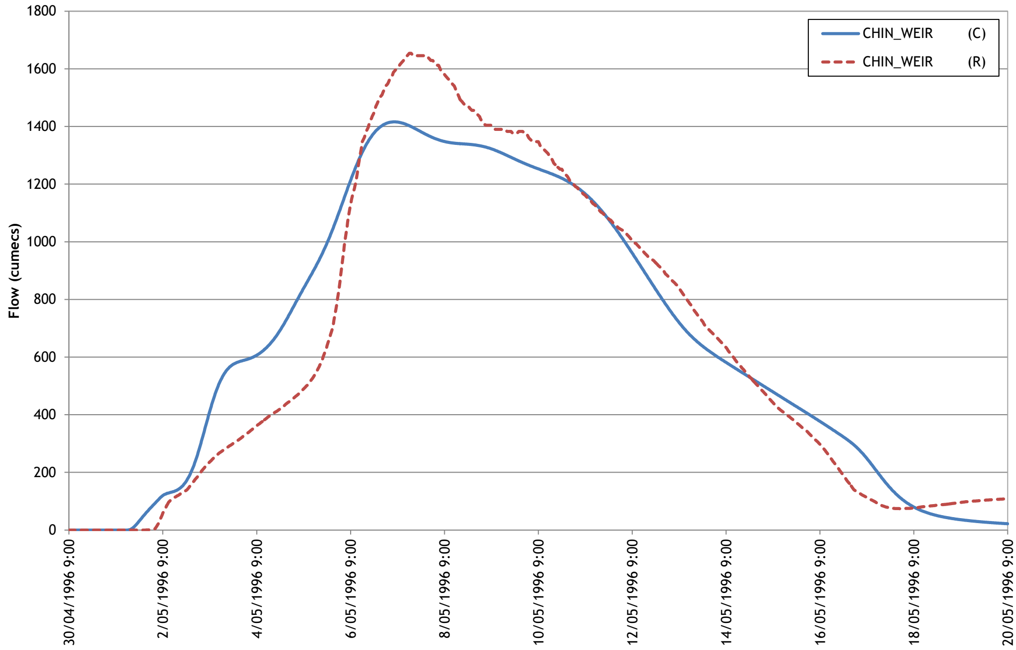

Figure B.20 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Chinchilla Weir TM, May 1996

B3 December 2010

B3.1 WARWICK MODEL

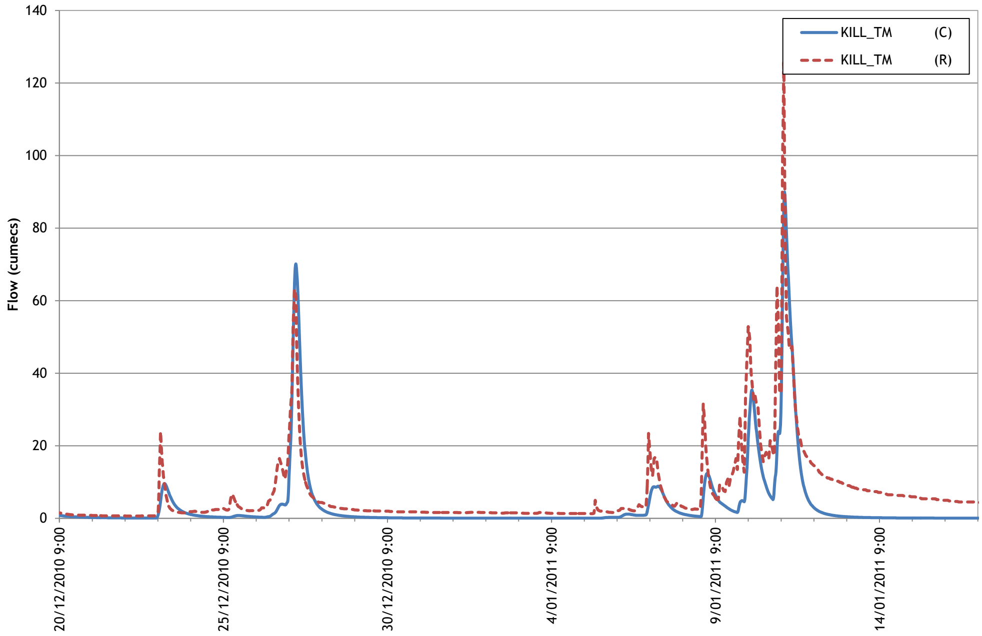

Figure B.21 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Spring Creek at Killarney TM, Dec 2010

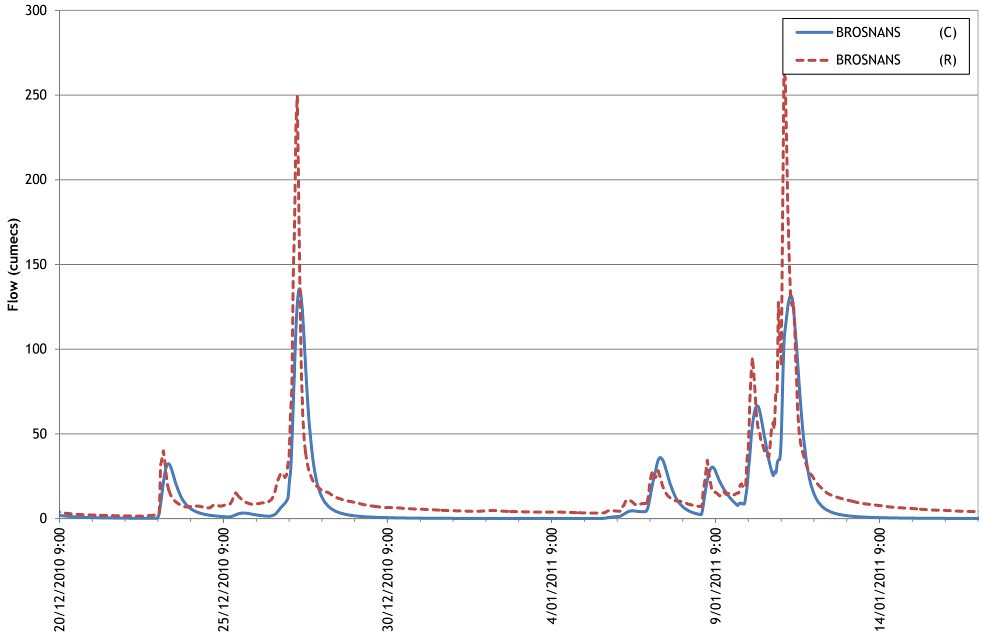

Figure B.22 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Brosnans Barn TM, Dec 2010

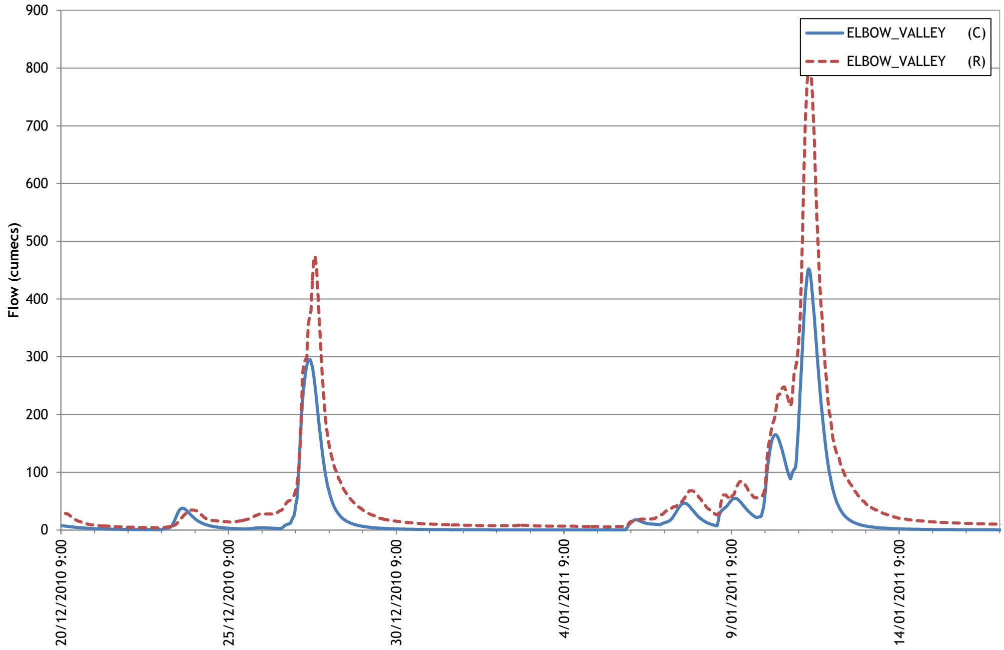

Figure B.23 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Elbow Valley, Dec 2010

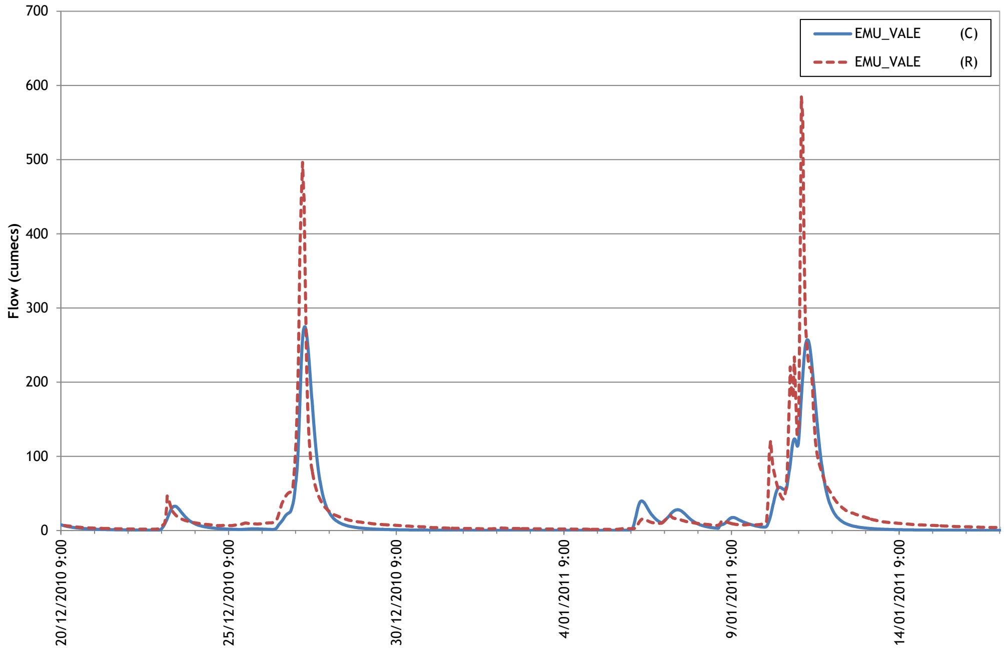

Figure B.24 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Emu Creek at Emu Vale, Dec 2010

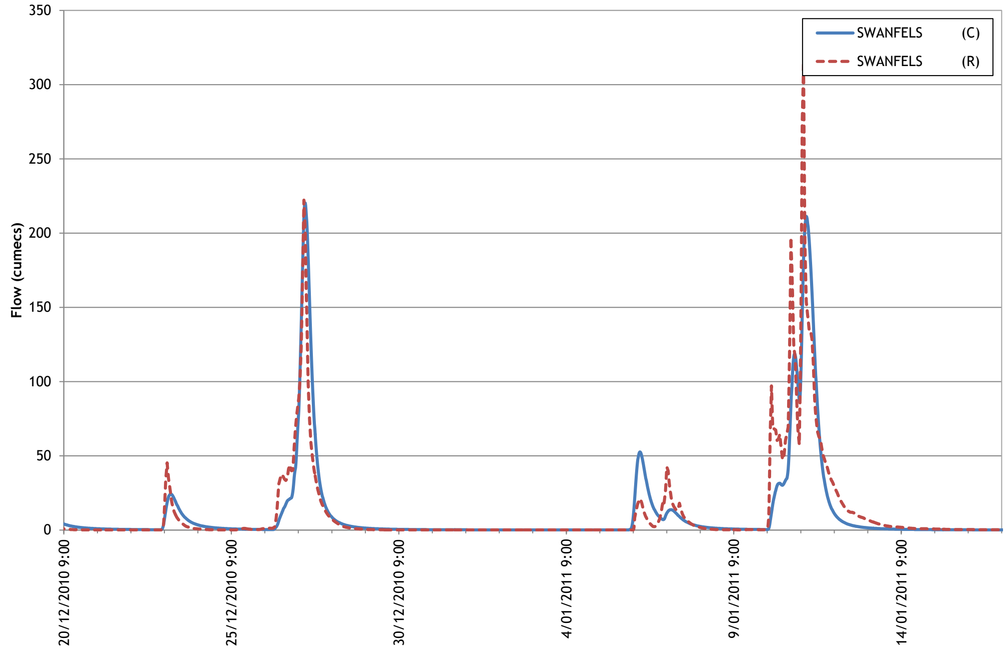

Figure B.25 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Swan Creek at Swanfels, Dec 2010

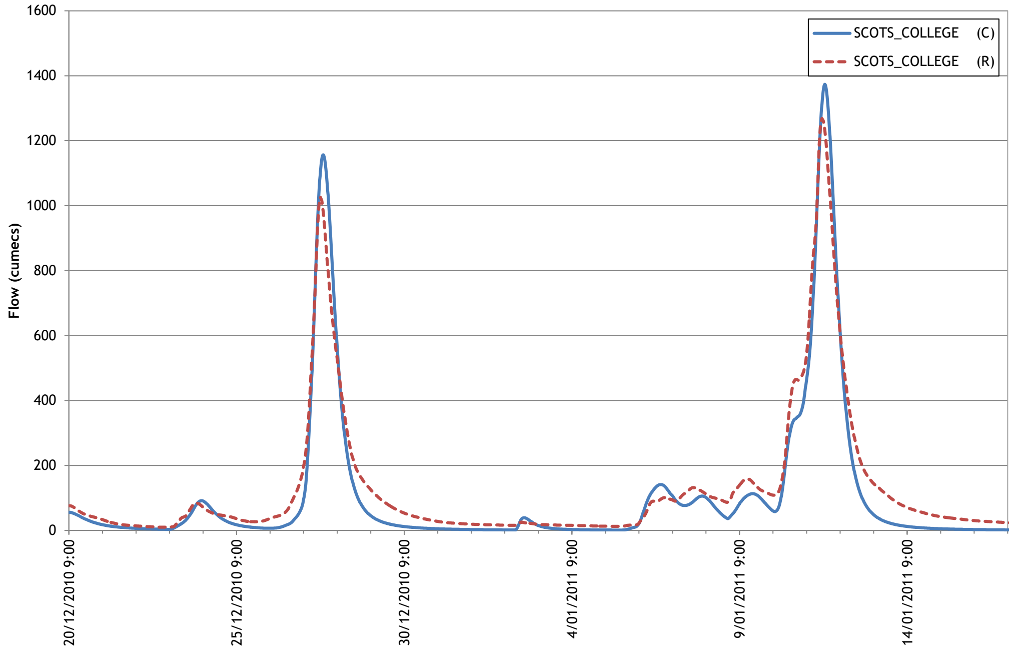

Figure B.26 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Scots College, Dec 2010

B3.2 TUMMAVILLE MODEL

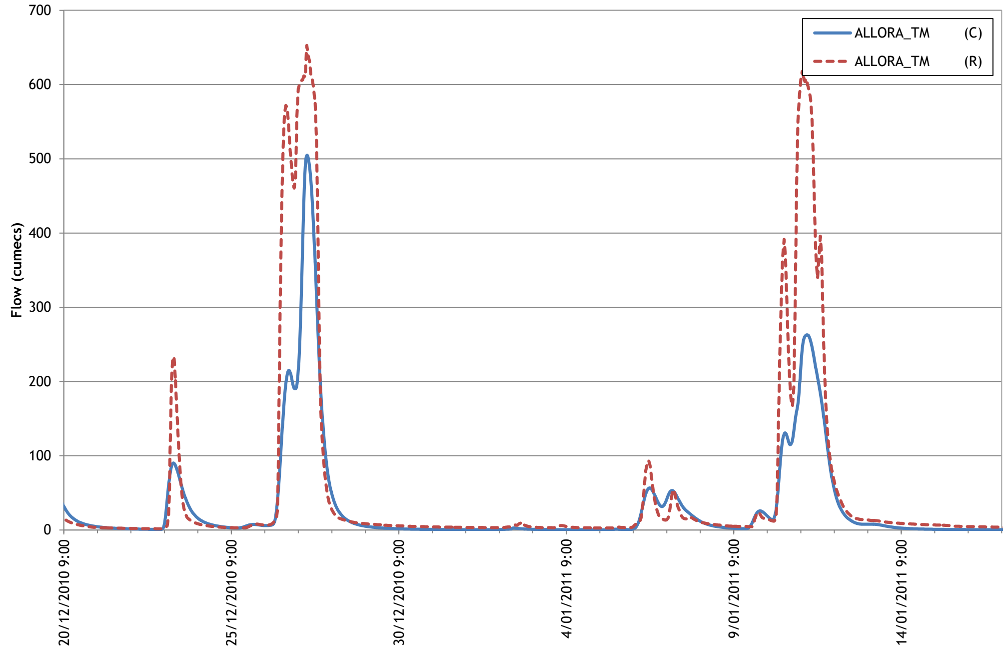

Figure B.27 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Dalrymple Creek at Allora TM, Dec 2010

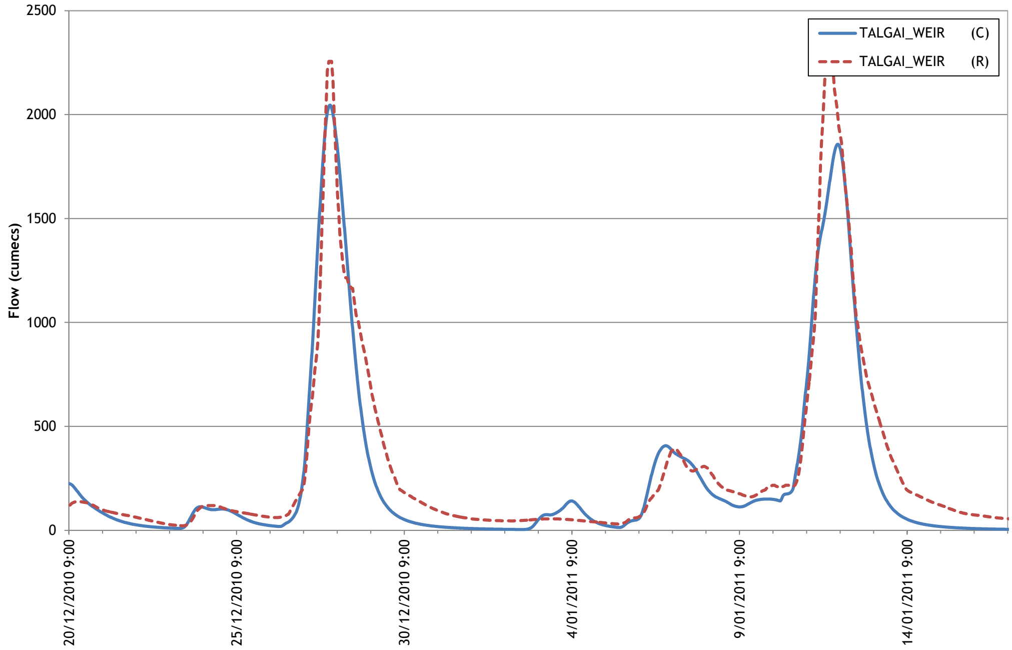

Figure B.28 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Talgai Weir, Dec 2010

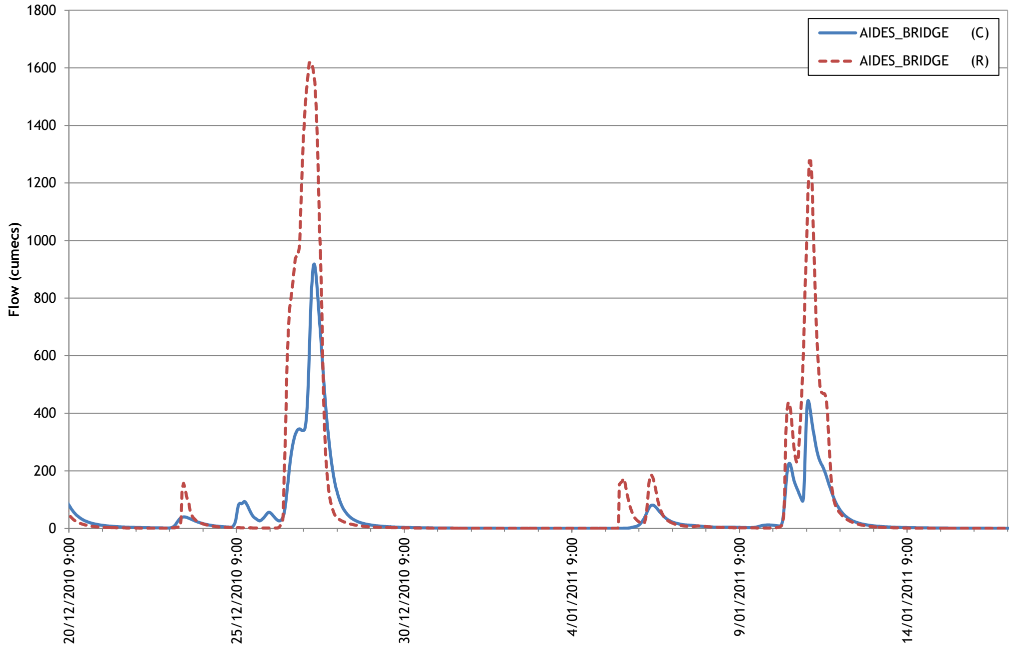

Figure B.29 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Kings Creek at Aides Bridge, Dec 2010

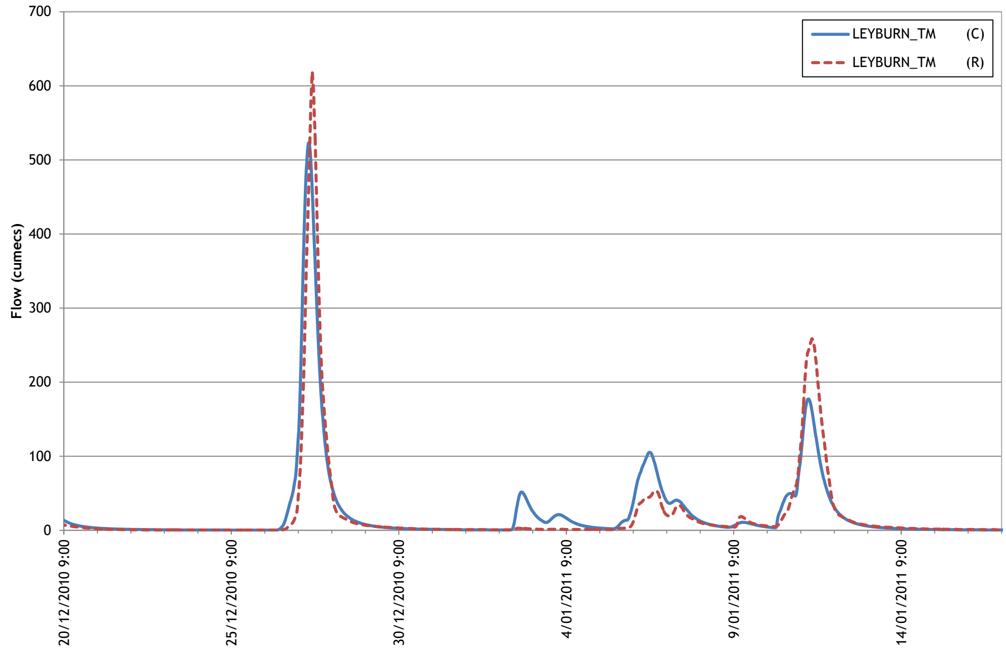

Figure B.30 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Canal Creek at Leyburn TM, Dec 2010

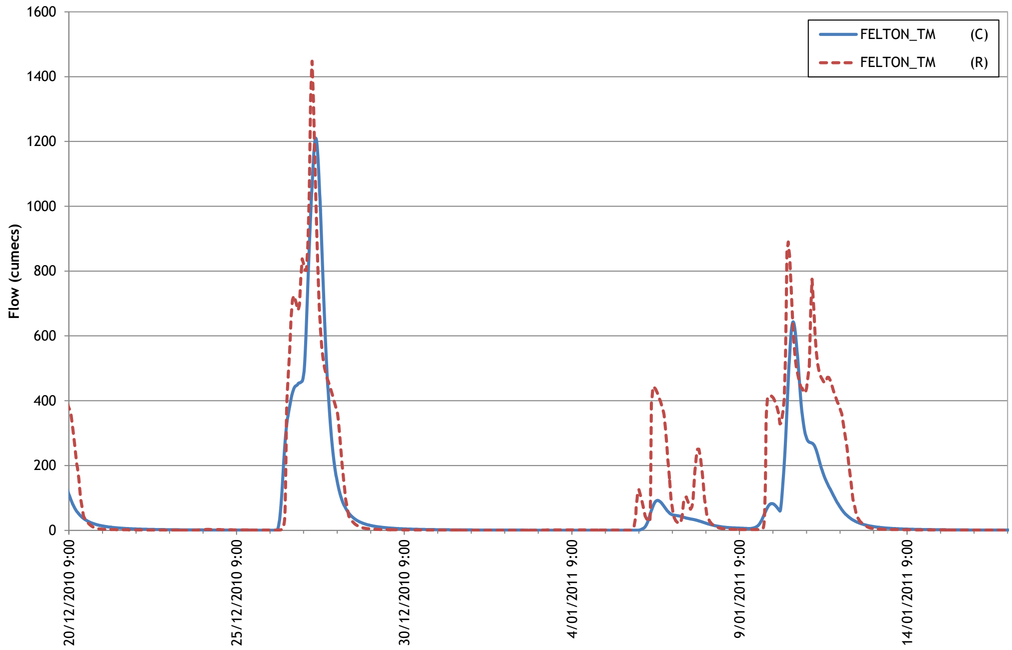

Figure B.31 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Hodgson Creek at Felton TM, Dec 2010

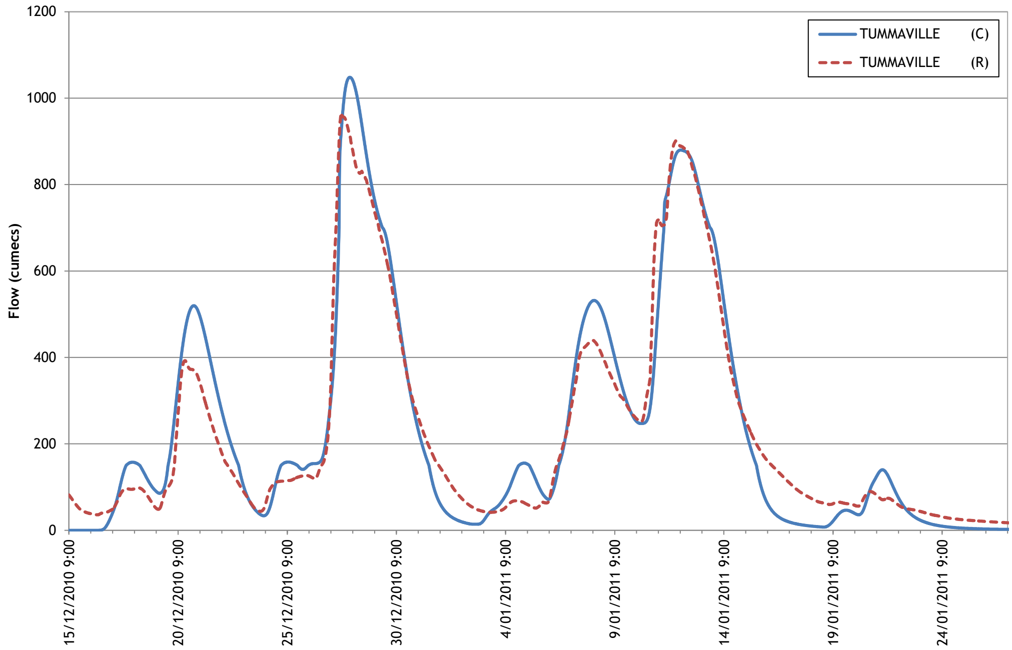

Figure B.32 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Tummaville, Dec 2010

B3.3 EAST RIDGES MODEL

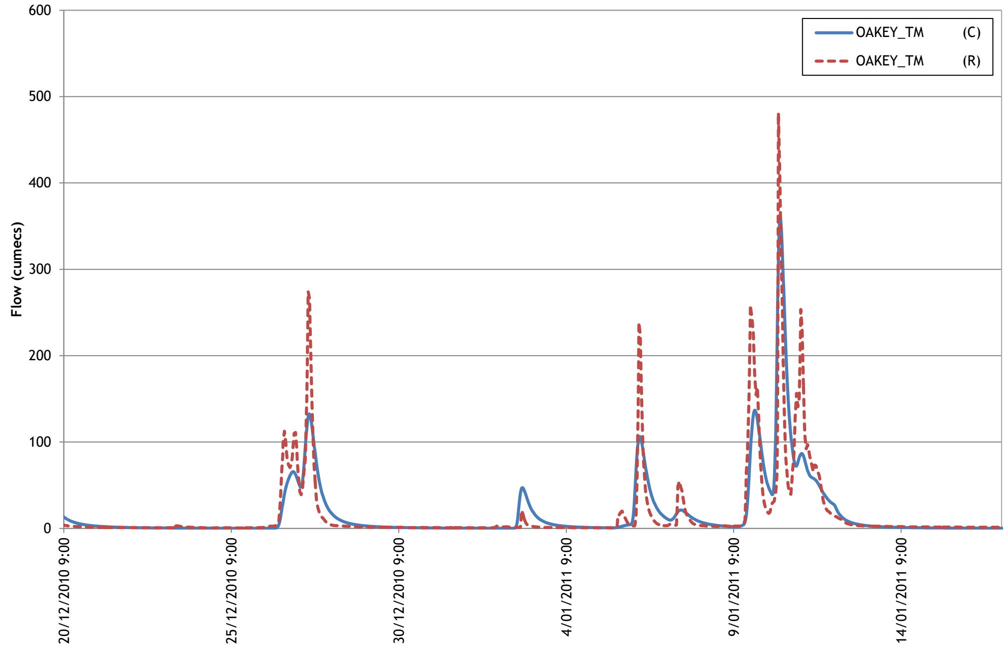

Figure B.33 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Gowrie Creek at Oakey TM, Dec 2010

B3.4 LOUDOUN MODEL

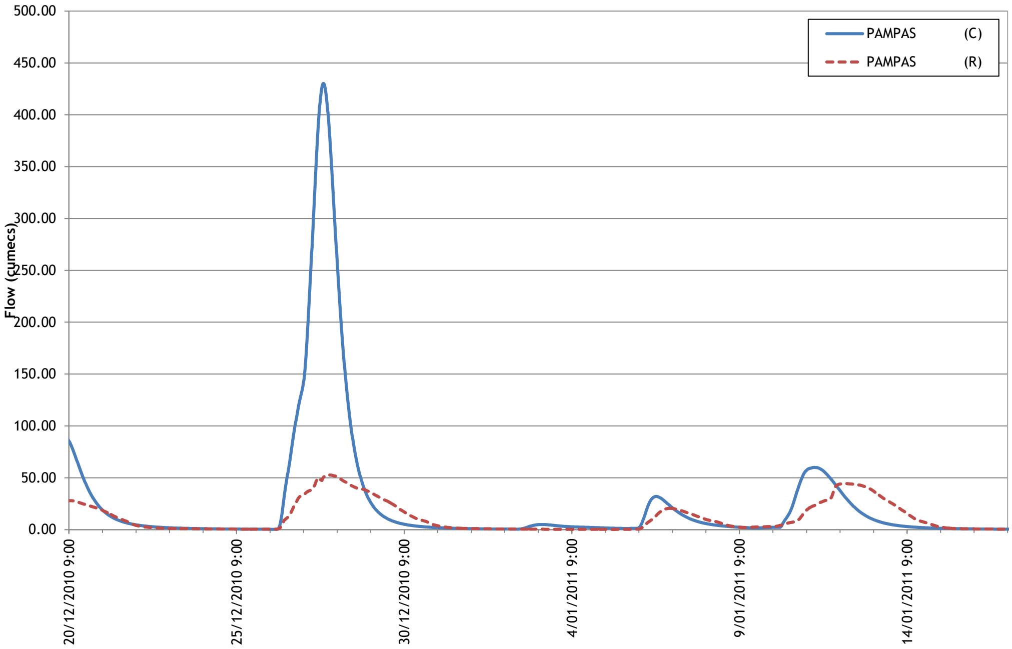

Figure B.34 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River North Branch at Pampas, Dec 2010

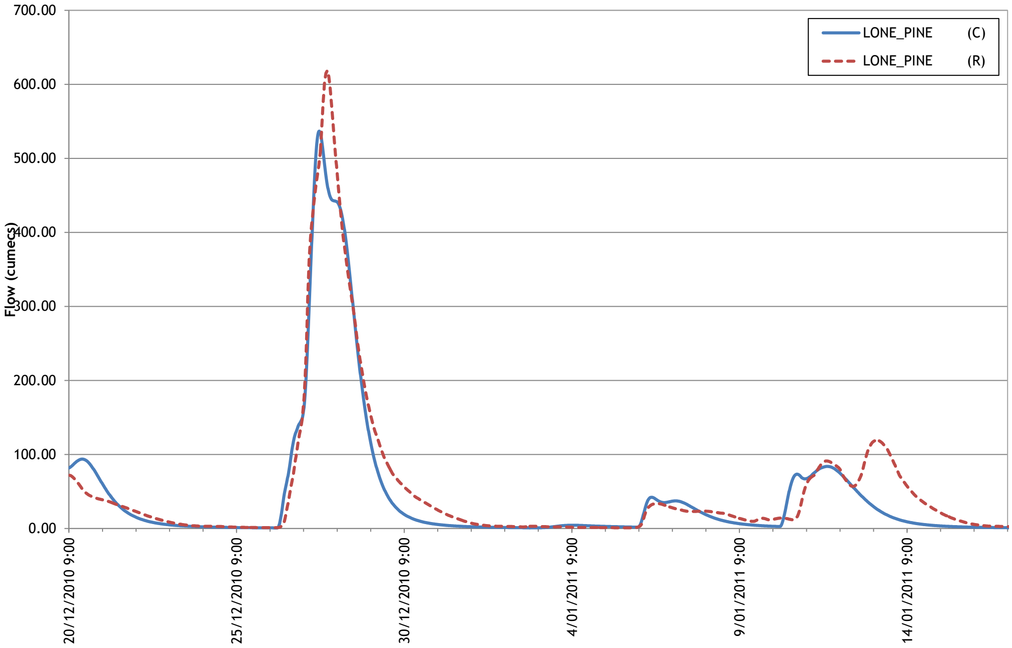

Figure B.35 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River North Branch at Lone Pine, Dec 2010

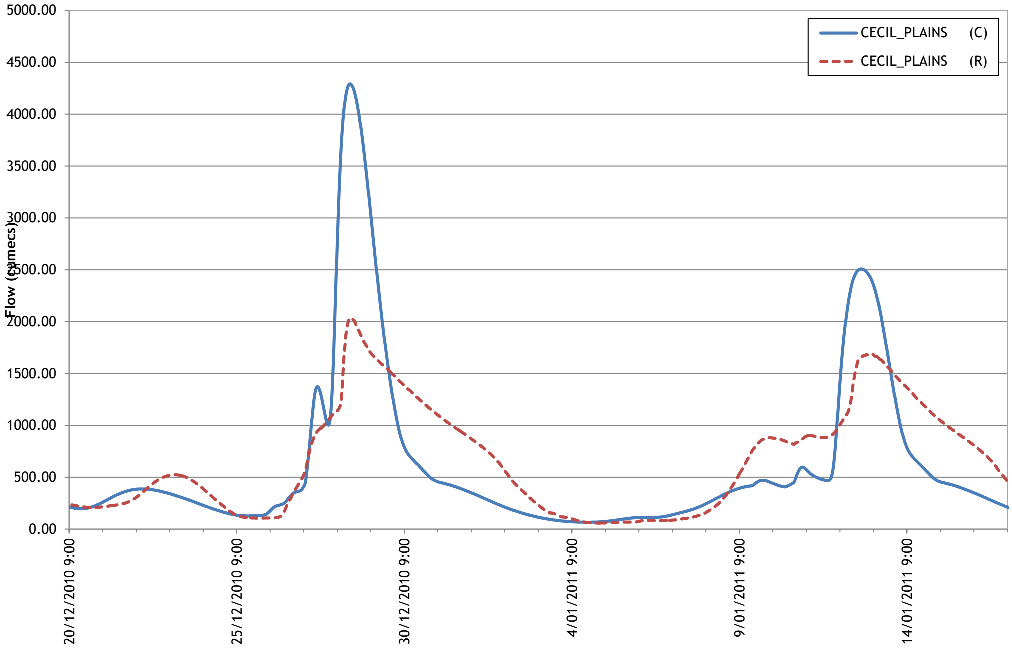

Figure B.36 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Cecil Plains TM, Dec 2010

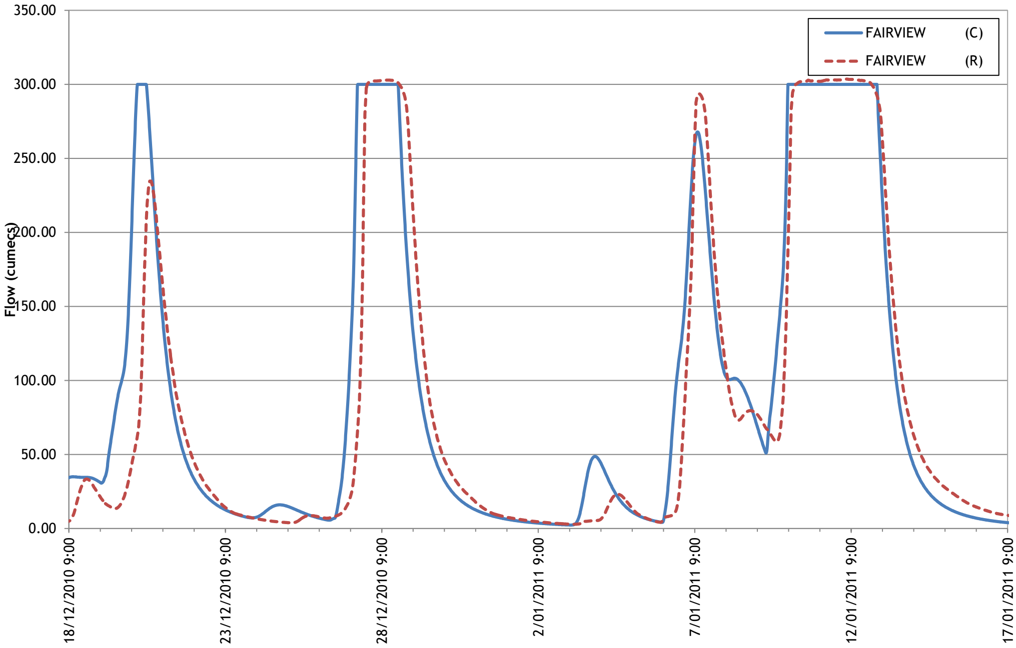

Figure B.37 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Oakey Creek at Fairview TM, Dec 2010

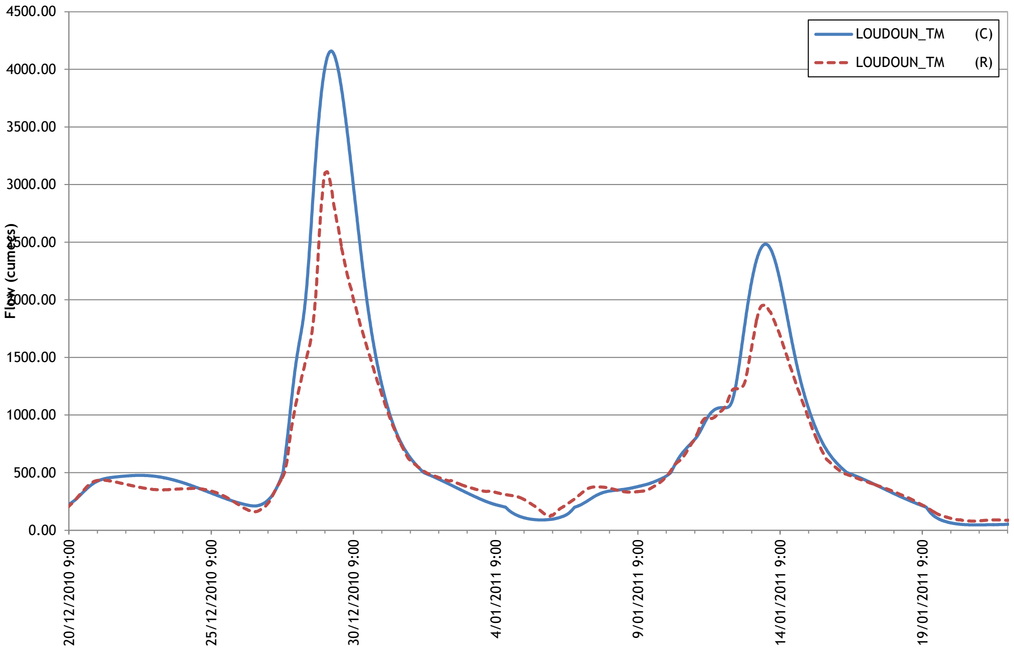

Figure B.38 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Loudoun TM, Dec 2010

B3.5 CHINCHILLA WEIR MODEL

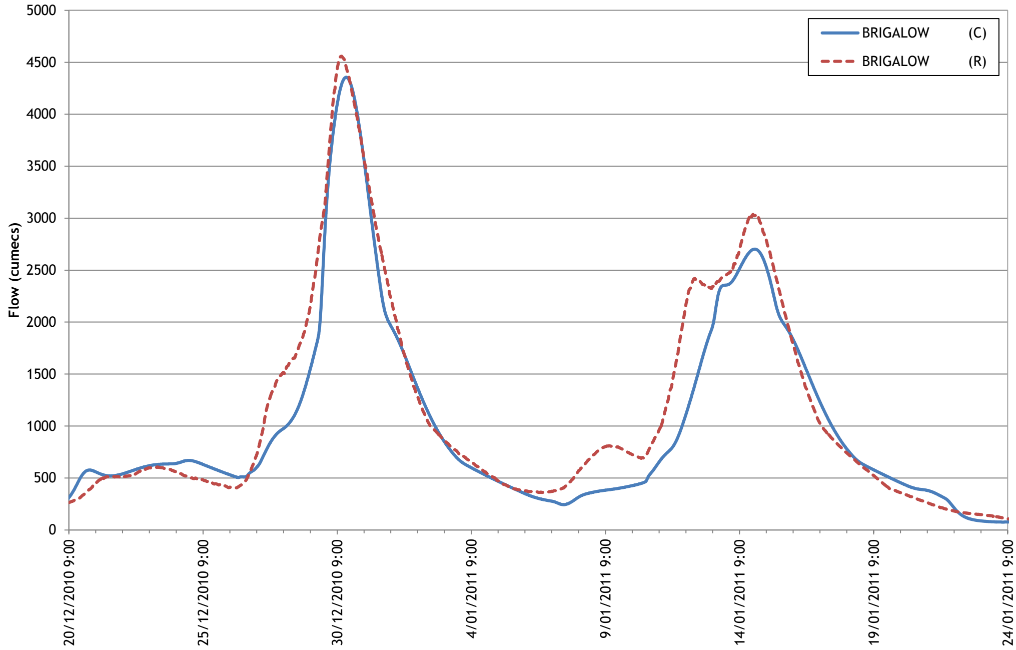

Figure B.39 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Brigalow Bridge TM, Dec 2010

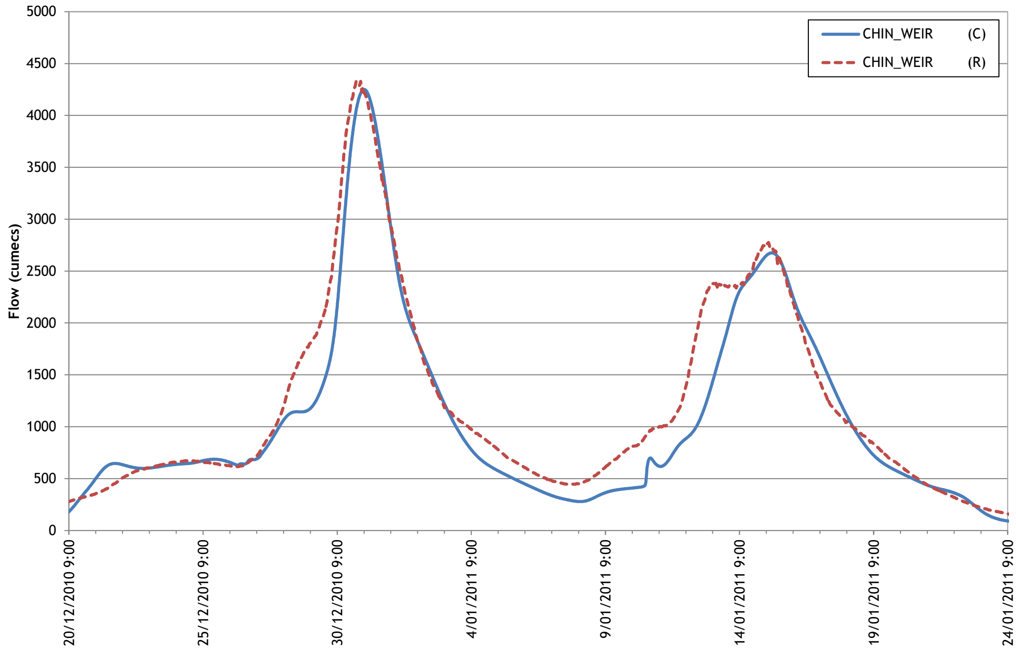

Figure B.40 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Chinchilla Weir TM, Dec 2010

B4 January 2013

B4.1 WARWICK MODEL

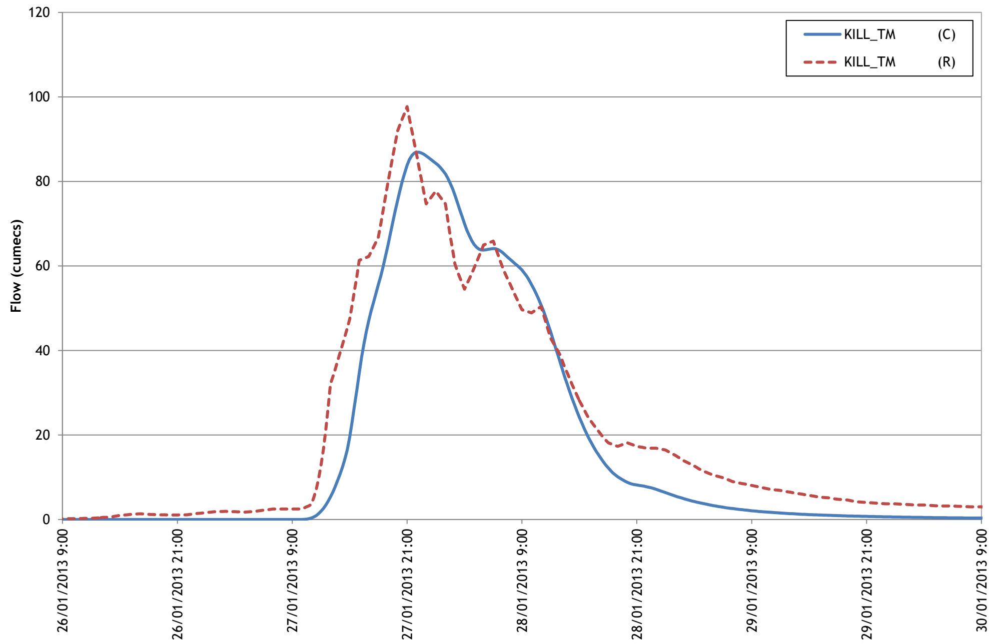

Figure B.41 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Spring Creek at Killarney TM, Jan 2013

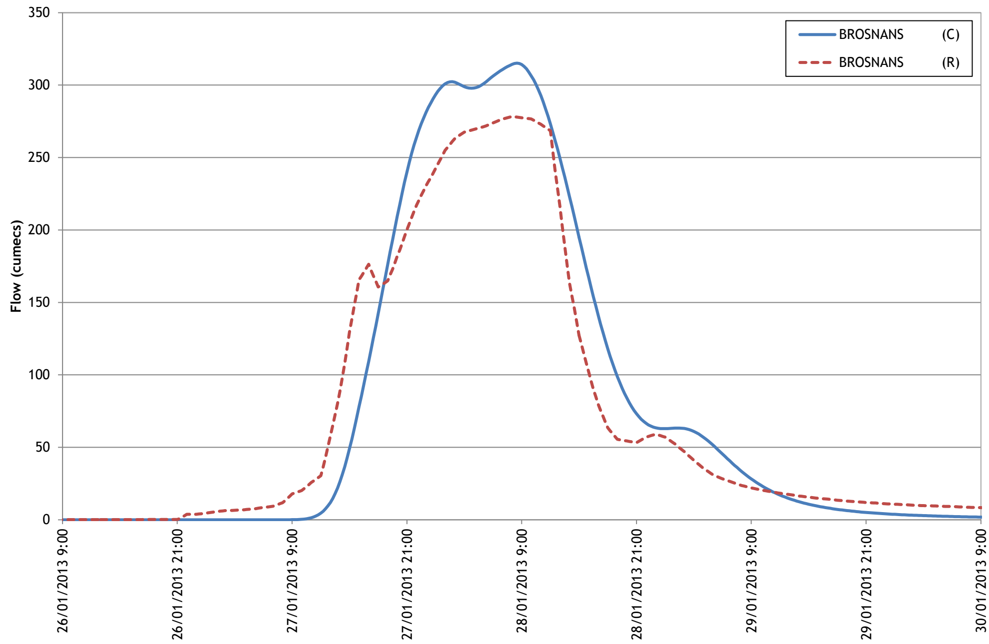

Figure B.42 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Brosnans Barn TM, Jan 2013

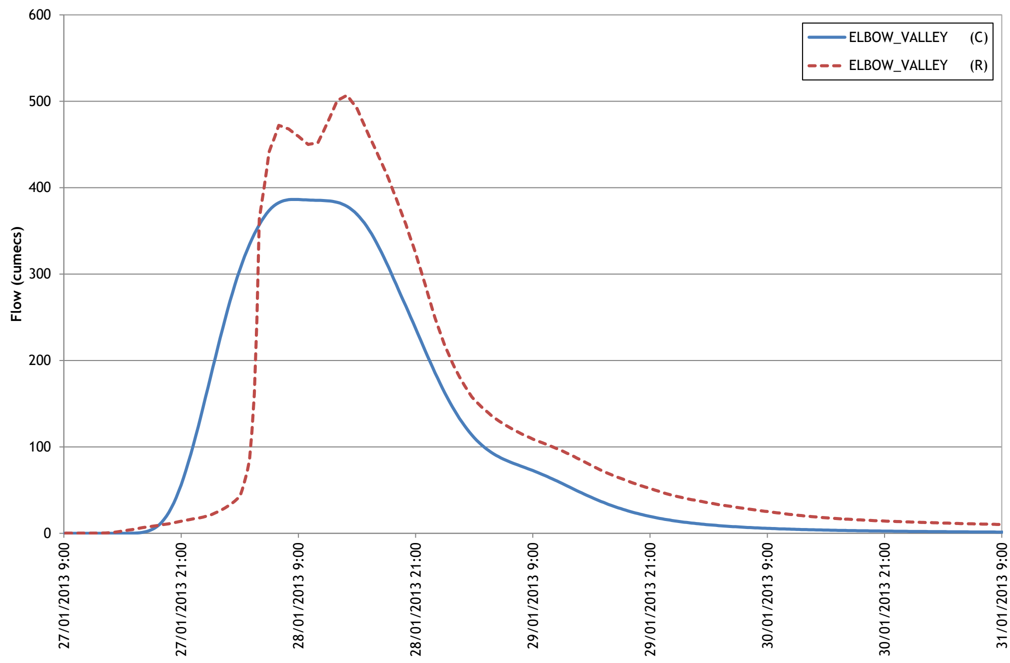

Figure B.43 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Elbow Valley, Jan 2013

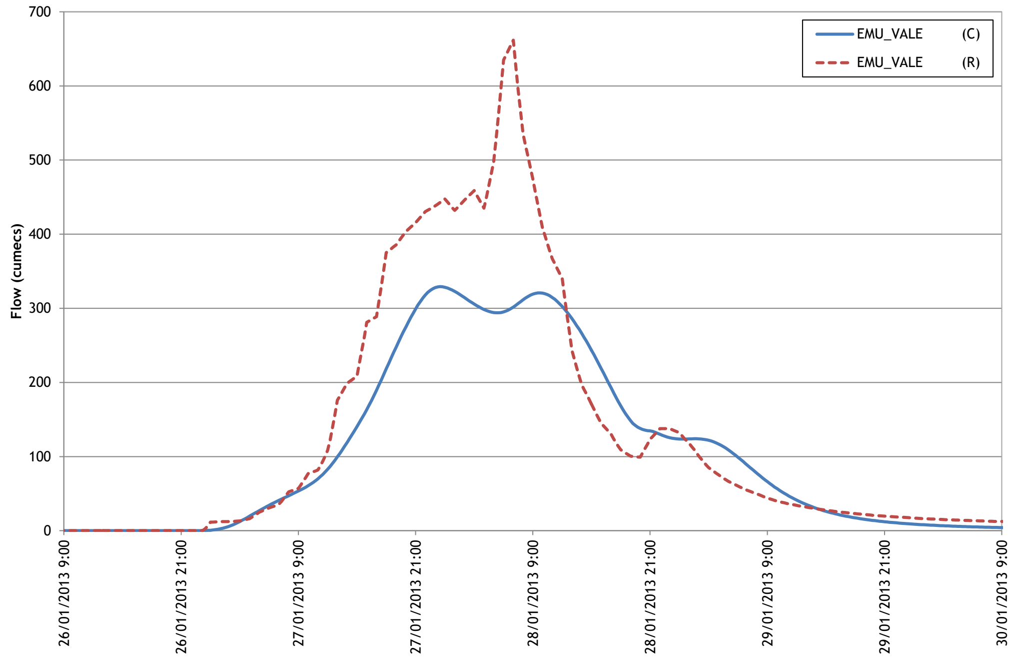

Figure B.44 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Emu Creek at Emu Vale, Jan 2013.

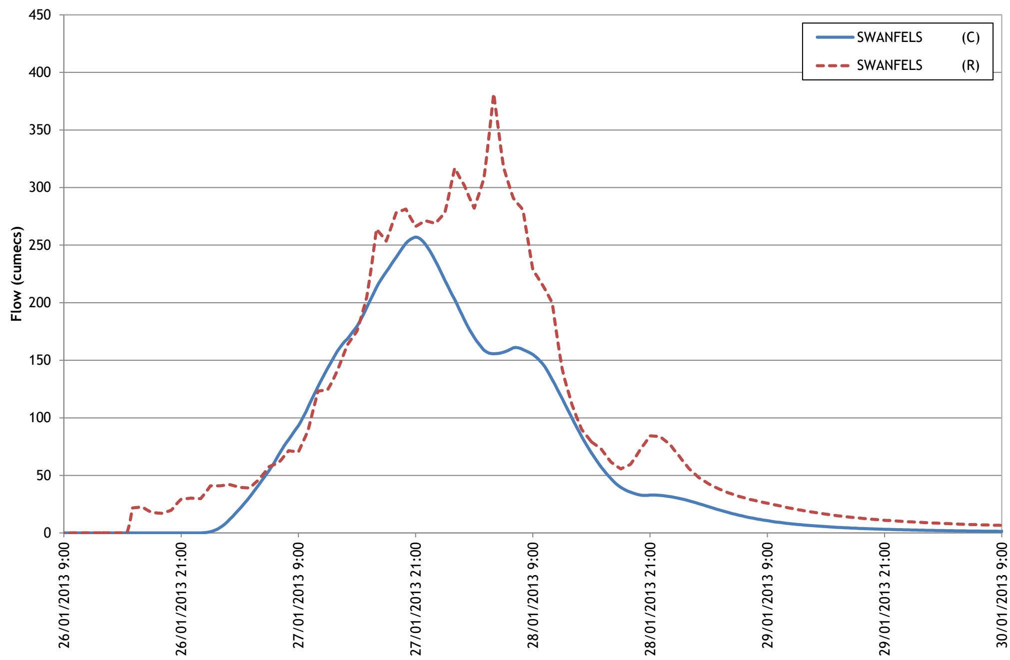

Figure B.45 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Swan Creek at Swanfels, Jan 2013

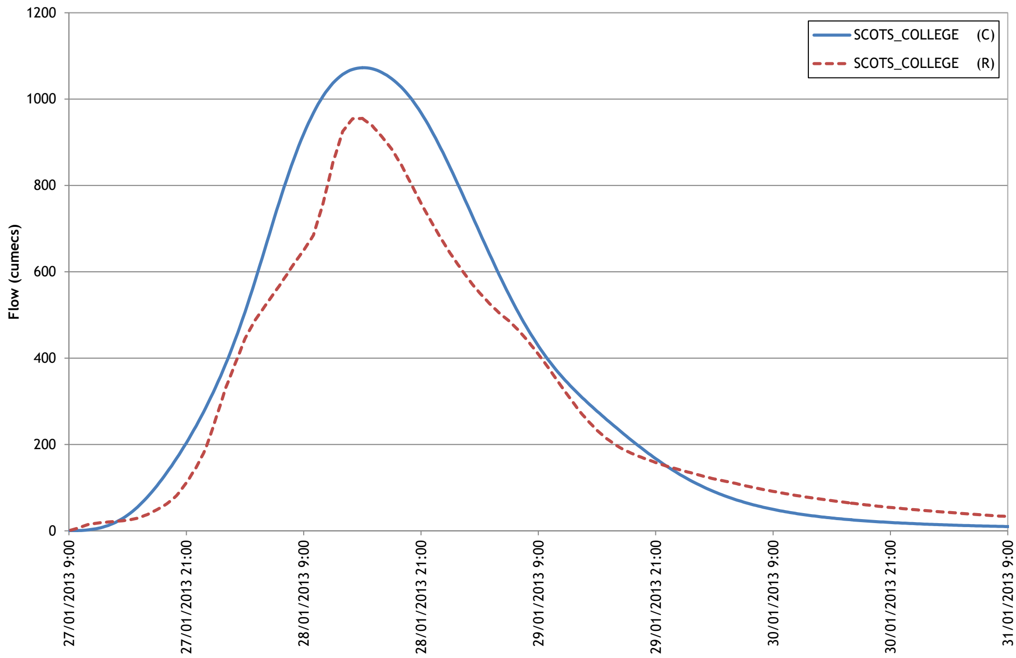

Figure B.46 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Scots College, Jan 2013

B4.2 TUMMAVILLE MODEL

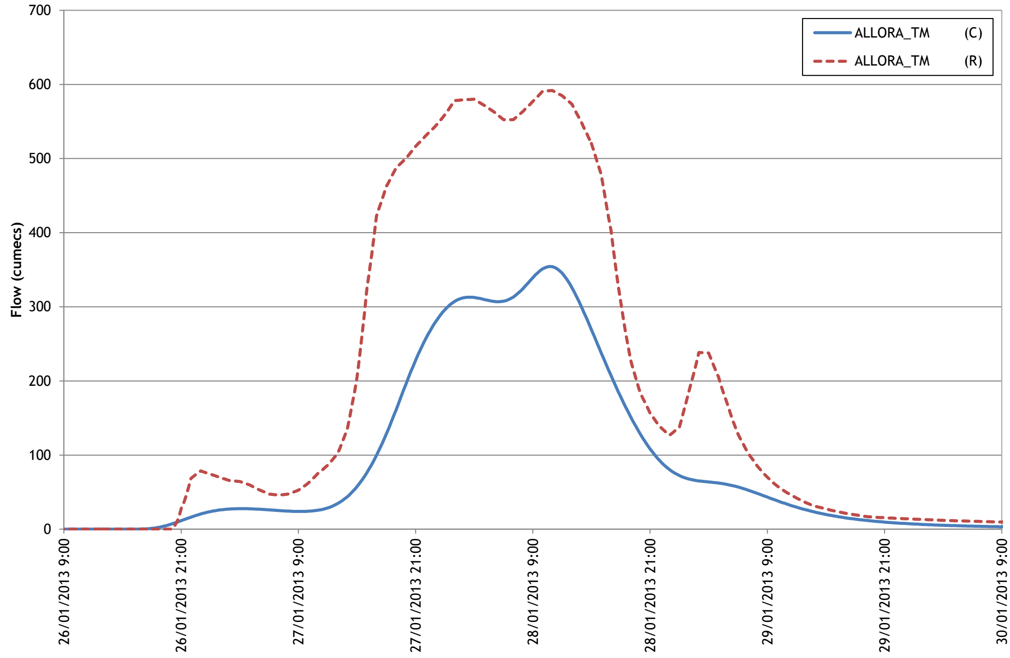

Figure B.47 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Dalrymple Creek at Allora TM, Jan 2013

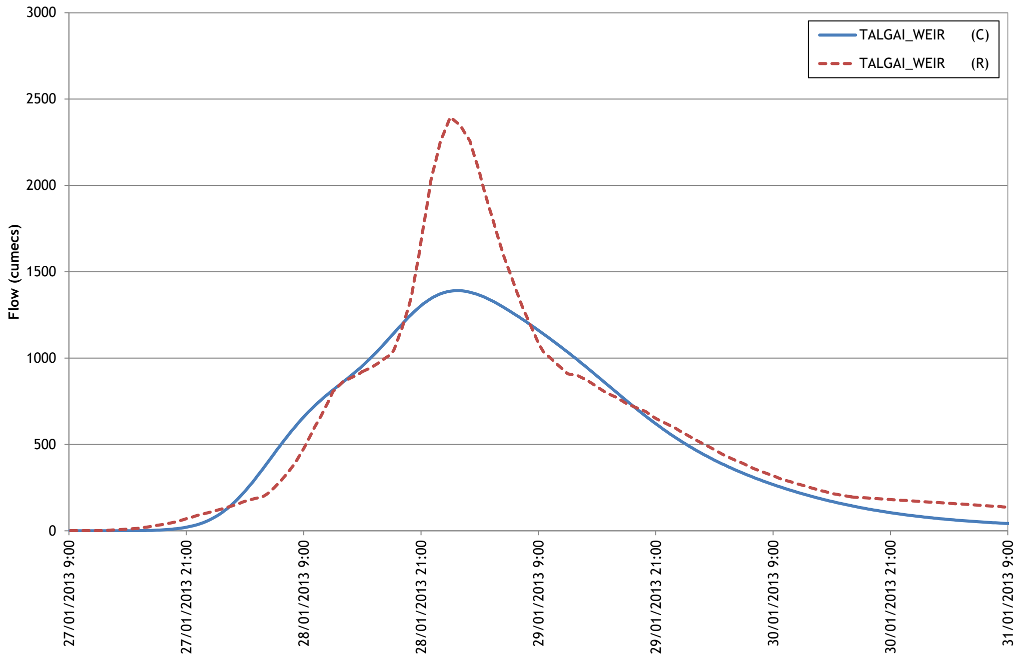

Figure B.48 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Talgai Weir, Jan 2013

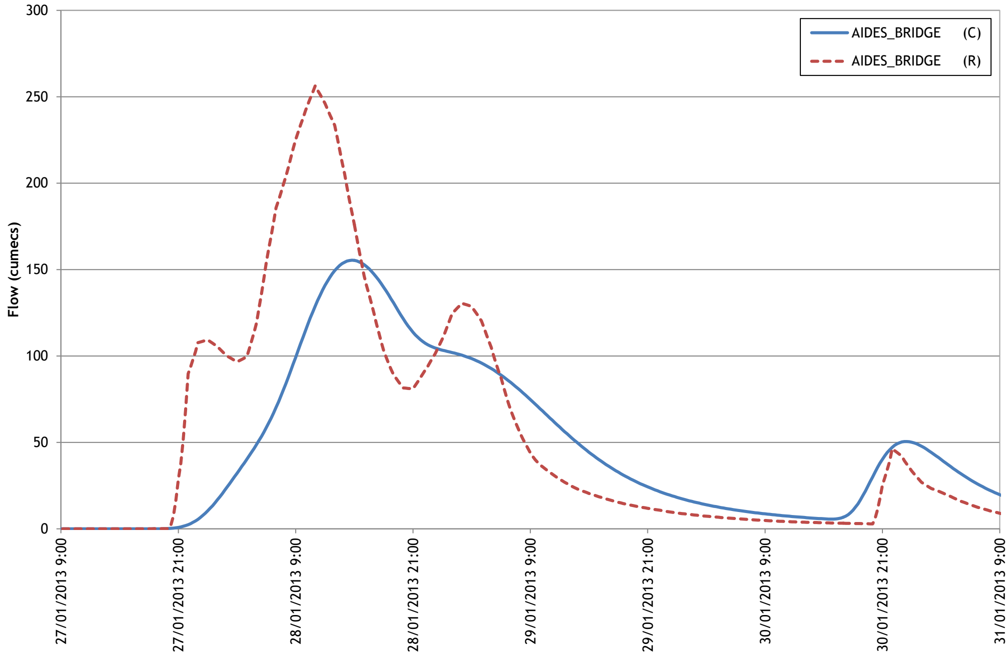

Figure B.49 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Kings Creek at Aides Bridge, Jan 2013

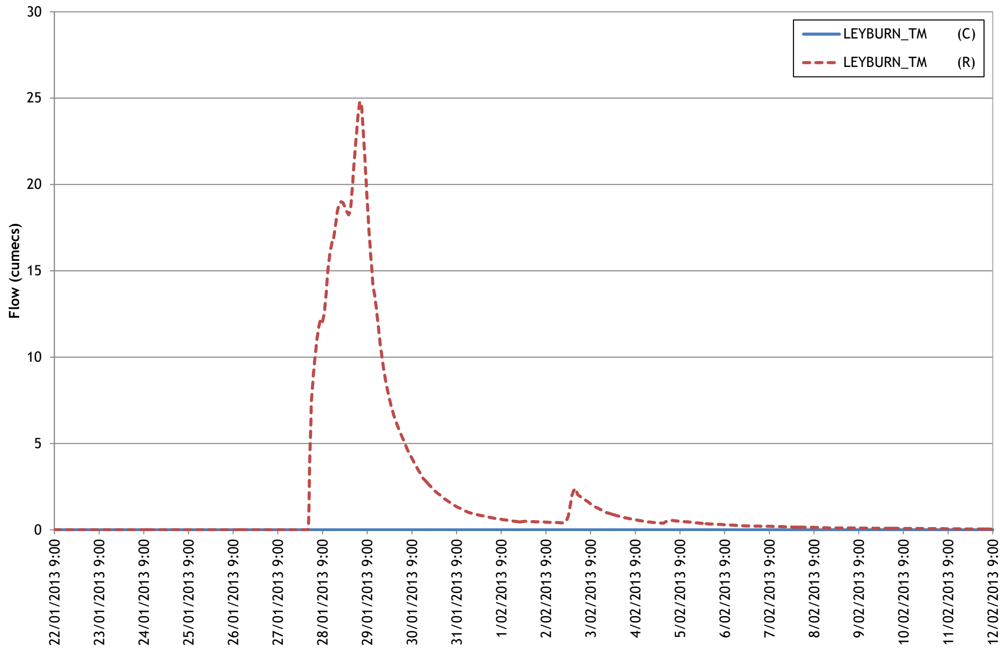

Figure B.50 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Canal Creek at Leyburn TM, Jan 2013

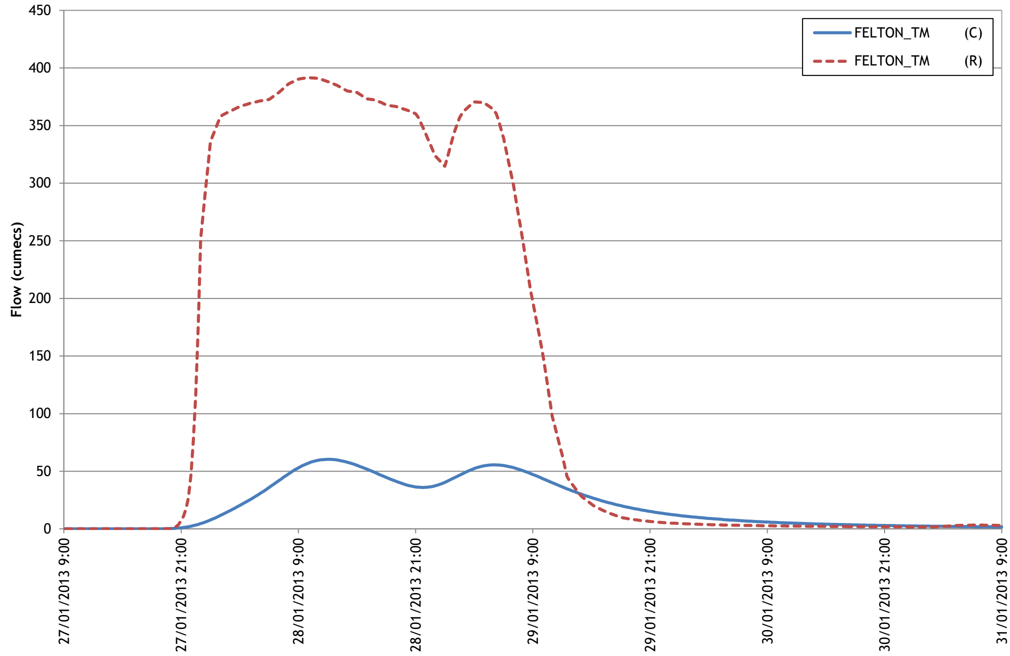

Figure B.51 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Hodgson Creek at Felton TM, Jan 2013

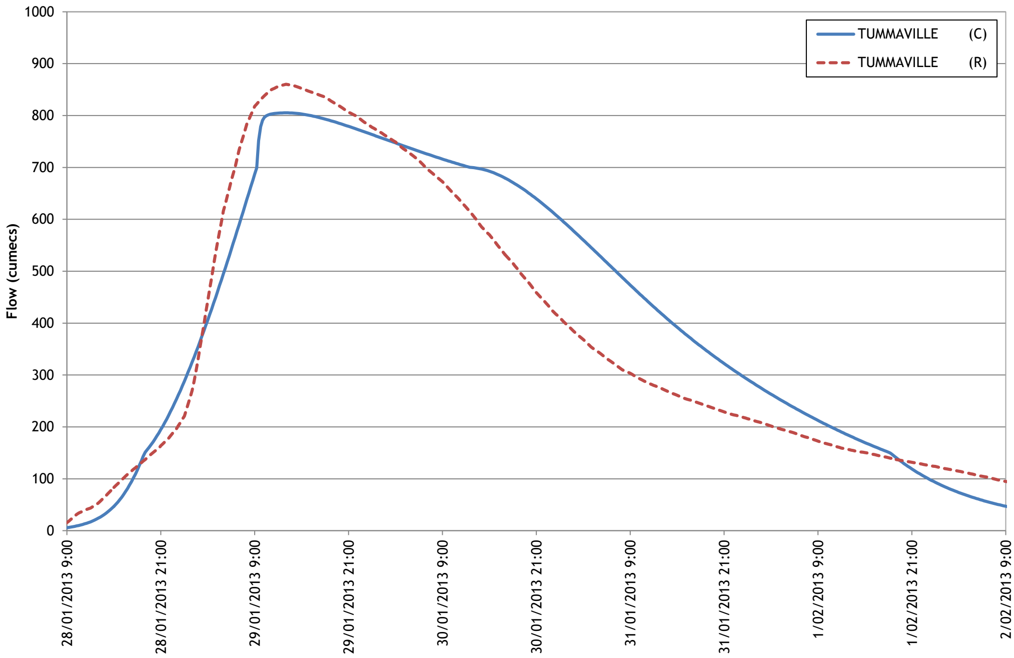

Figure B.52 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Tummaville, Jan 2013

B4.3 EAST RIDGES MODEL

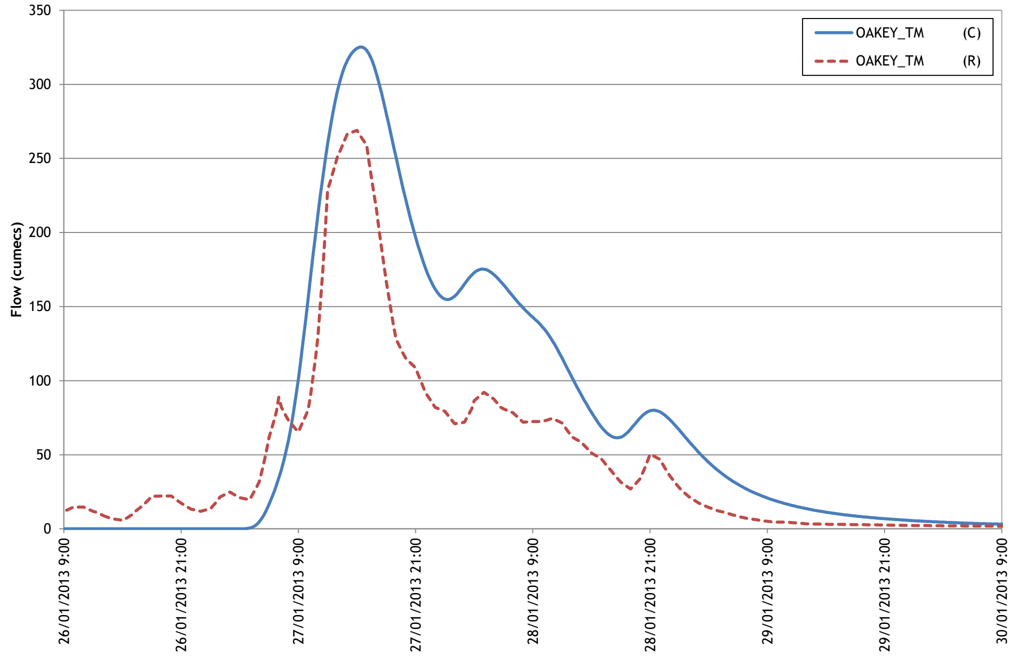

Figure B.53 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Gowrie Creek at Oakey TM, Jan 2013

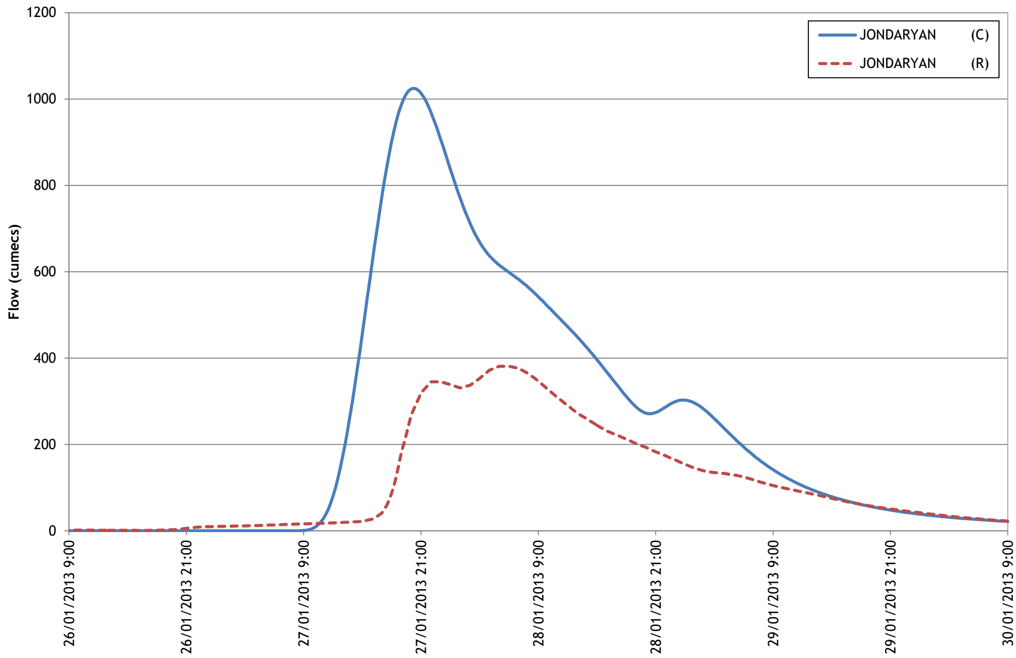

Figure B.54 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Oakey Creek at Jondaryan TM, Jan 2013

B4.4 LOUDOUN MODEL

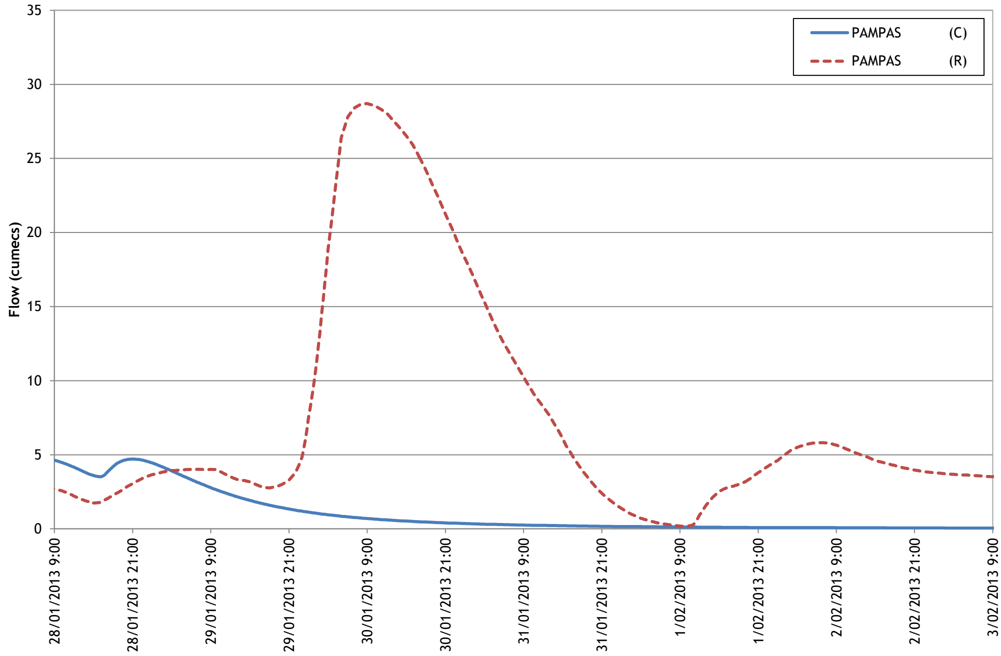

Figure B.55 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River North Branch at Pampas, Jan 2013

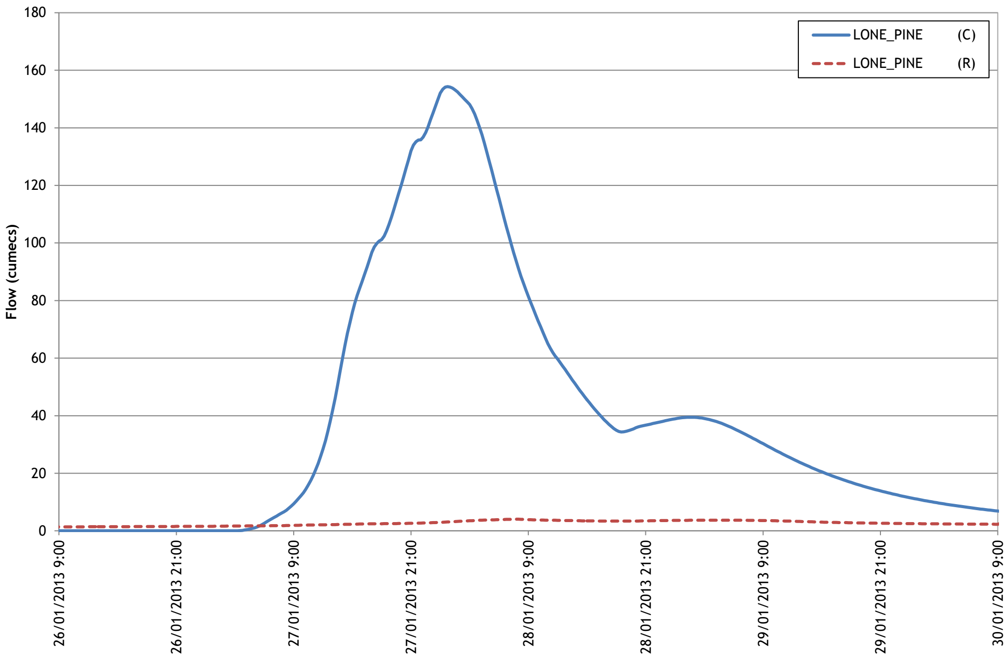

Figure B.56 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River North Branch at Lone Pine, Jan 2013

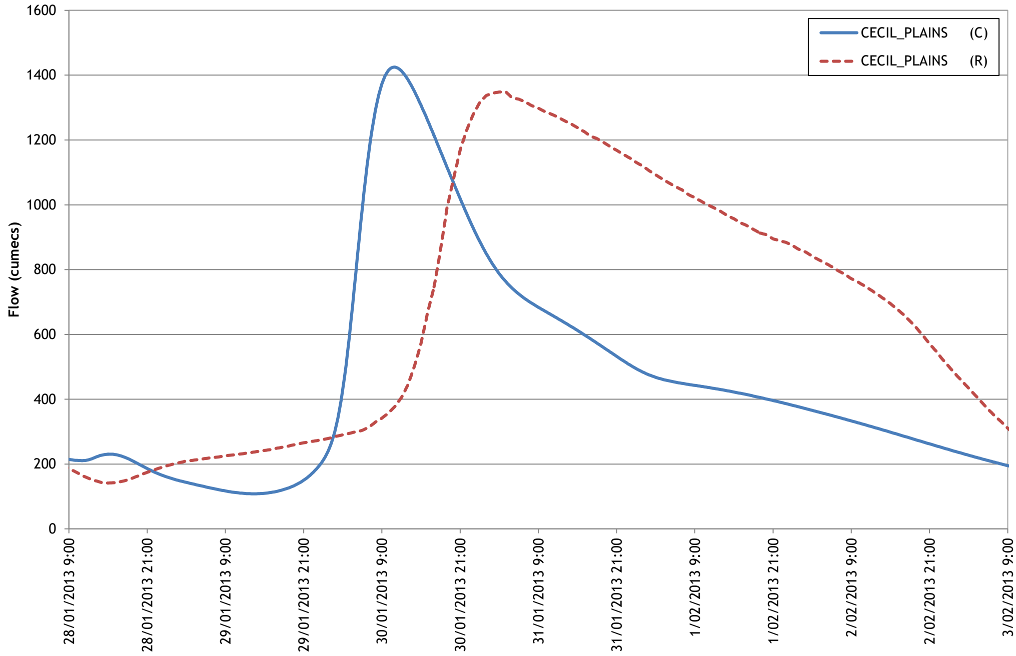

Figure B.57 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Cecil Plains TM, Jan 2013

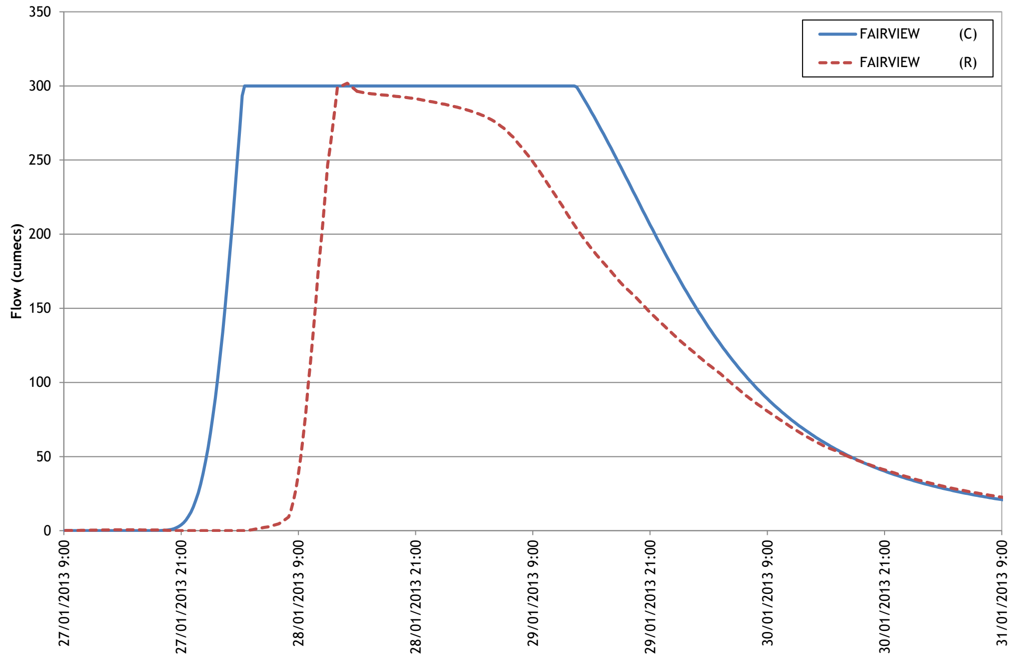

Figure B.58 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Oakey Creek at Fairview TM, Jan 2013

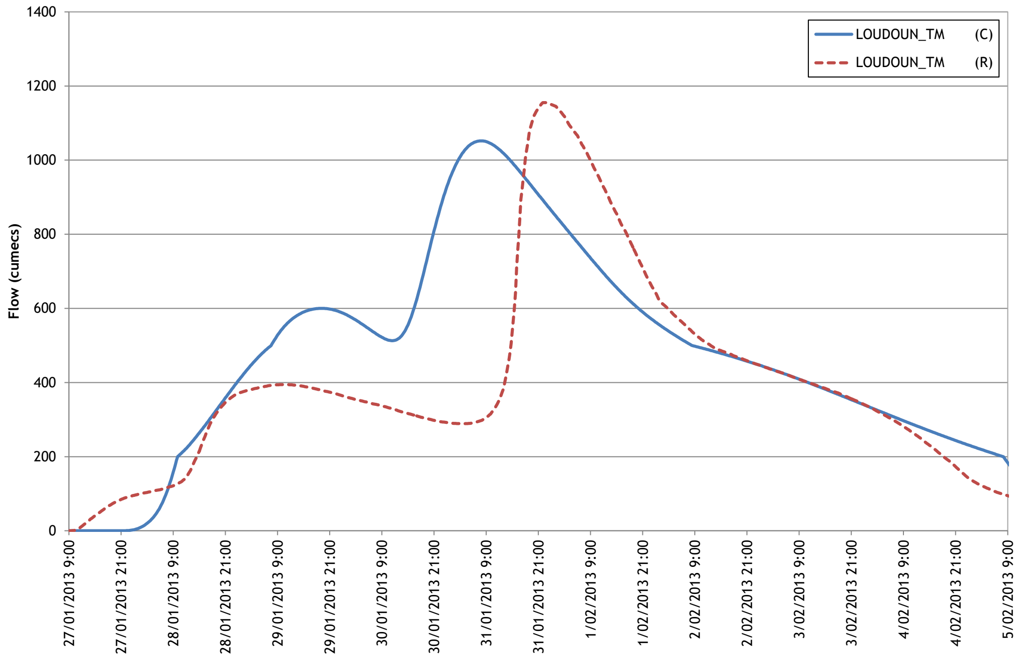

Figure B.59 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Loudoun TM, Jan 2013

B4.5 CHINCHILLA WEIR MODEL

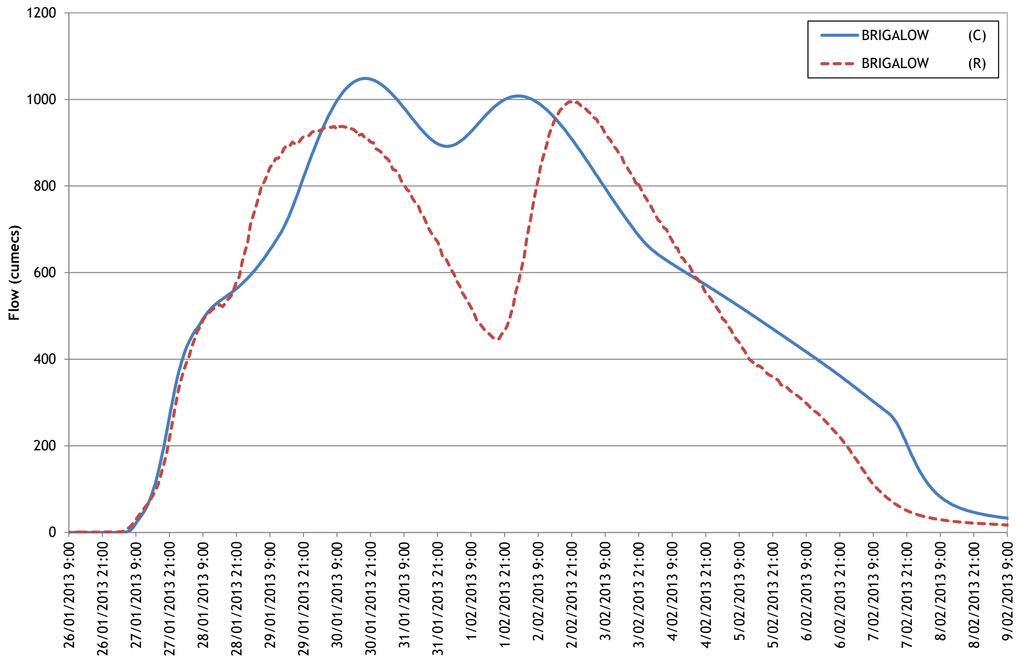

Figure B.60 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Brigalow Bridge TM, Jan 2013

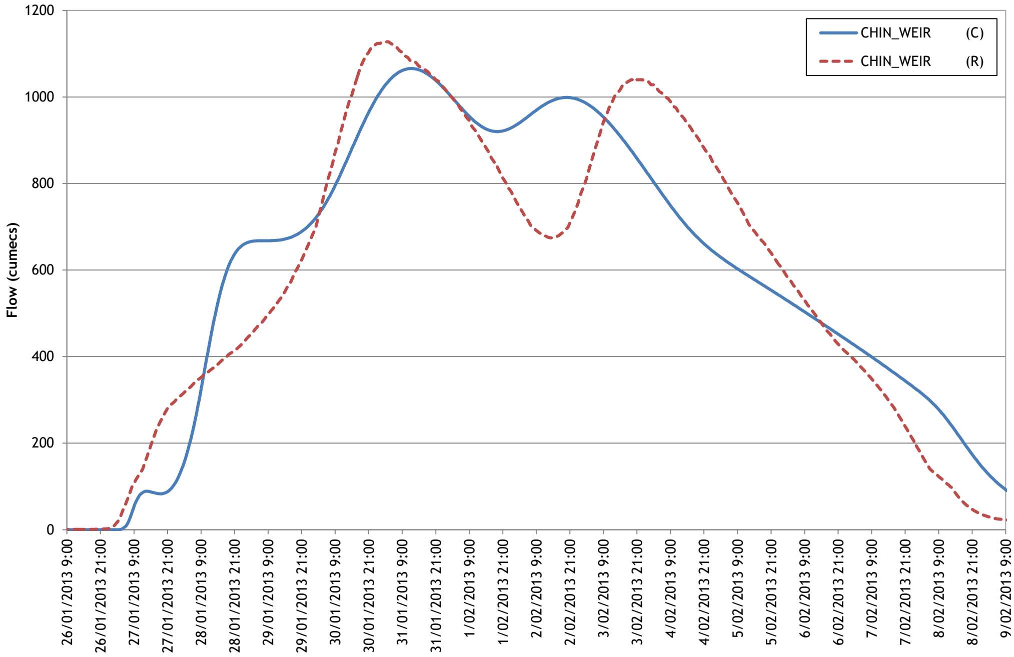

Figure B.61 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Condamine River at Chinchilla Weir TM, Jan 2013

Appendix C Chinchilla Weir peak annual discharge

Table C.1 – Flood Frequency Analysis Raw Data, Chinchilla Weir Gauge Annual Maximum Discharge

Year	Peak Annual Discharge (m^3/s)	Year	Peak Annual Discharge (m^3/s)	Year	Peak Annual Discharge (m^3/s)
1921	409	1953	151.9	1985	51.2
1922	1932.2	1954	628.3	1986	32.1
1923	11.9	1955	378	1987	36.3
1924	215.1	1956	1782.2	1988	2855.5
1925	40.1	1957	478.6	1989	258.2
1926	160.3	1958	459.7	1990	173.6
1927	1103	1959	446.3	1991	370.5
1928	712.1	1960	313	1992	101.9
1929	294.3	1961	149.6	1993	6.1
1930	109.9	1962	256.6	1994	270.2
1931	399.2	1963	345.2	1995	49.7
1932	115.8	1964	330.3	1996	1817.8
1933	196.7	1965	214.8	1997	115.3
1934	412.4	1966	321.9	1998	316.3
1935	345.5	1967	290.6	1999	486.2
1936	23.7	1968	268.4	2000	98.2
1937	266.6	1969	55.6	2001	110.7
1938	131.9	1970	36.9	2002	58.7
1939	315.3	1971	1277.8	2003	1.9
1940	313.4	1972	470.2	2004	255.1
1941	376.4	1973	1322.4	2005	3.3
1942	1856.1	1974	1168	2006	83.9
1943	777.1	1975	112.2	2007	1.2
1944	235.1	1976	1786.4	2008	386.6
1945	194.3	1977	282.2	2009	217.6
1946	398.2	1978	252.2	2010	395.8
1947	355.6	1979	68.5	2011	4498.7
1948	343.3	1980	152.9	2012	125.6
1949	30	1981	1545.7	2013	1129.1
1950	1274.4	1982	229.5		
1951	446.8	1983	2252.1		
1952	101.7	1984	1420.2		