QUEENSLAND FLOODS COMMISSION OF INQUIRY

Requirement to Provide Written Statement to Commission of Inquiry

Graeme Scheu, Mayor,
Goondiwindi Regional Council

In accordance with section 5(1)(d) of the *Commissions of Inquiry Act 1950* (Qld), I Graeme Scheu, Mayor, Goondiwindi Regional Council, provide the following statement of information as directed by letter dated 22nd August, 2011.

1. ***The effect that levee banks in New South Wales have on the Goondiwindi Regional Council area.***

   I am not qualified to provide detailed engineering advice as to the effect of levee banks. Technological details would be available in the various hydrological models that have been prepared by both Council and various government departments from both States. Most of the information relating to New South Wales levee banks would be held by the New South Wales Department of Environment and Climate Change as they are responsible for the regulation and monitoring of floodplain development in that State.

2. ***The effect that levee banks in the Goondiwindi Regional Council area have on New South Wales.***

   I am not qualified to provide detailed engineering advice as to the effect of levee banks upon New South Wales. Some information may be included in the various hydrological models prepared for Councils. Copies of these documents are attached to this statement and marked Appendix "2". Information of this nature is also likely to be held by the New South Wales Department of Environment and Climate Change as they undertake the regulation and monitoring role for floodplain development in that State. However, from the perspective of a lay person having lived and worked in the area for many years I have observed that the New South Wales floodplain is much larger and open than the Queensland floodplain which dissipates additional flows more readily.

3. ***Further comment regarding suggestion that there should be co-ordination in land use planning across the Queensland/New South Wales border.***

   Where a development application is made in one (1) State that requires notification of adjoining owners or public notification, it is Council's view that some mechanism must be established to require that the notification (and opportunity to submit comment) includes owners adjoining the land in the other State but for the existence of the water course. This is particularly important for the development of levee banks because of their designed purpose to displace water but would also exist for other development that may produce odour, noise or other nuisances. During the period of peak levee bank development in the 1980's and 1990's, this co-operation did exist between interstate parties on a voluntary basis. However, it relies upon the good

[redacted]...
Deponent

[redacted]....
Solicitor / Justice of the Peace / ~~Commissioner for Declarations~~

nature of the parties and does not provide jurisdiction for formal submission relating to the impact of any such development.

4. ***For those areas of Goondiwindi town not protected by levee***

   a. ***Specific planning decisions to mitigate the effect of flooding***

   b. ***Specific planning controls to mitigate the effect of flooding***

   c. ***Whether there are plans to extend the town levee to protect these or other areas.***

The area known as Brigalow Estate is the only urban area not protected by the town levee as it consists of large semi-rural residential parcels. The area is identified on the attached map marked appendix "1".

a. Council has limited the minimum lot size in this area to two (2) hectares to ensure that it is not able to be densely populated due to its flood exposure. Council also provides previous flood levels to local surveyors to enable residents to obtain such levels prior to planning the construction of housing.

b. There are no plans to extend the town levee to include this area as:-

   i. The area lies in a creek floodplain with many anabranches and breakouts that may not support the construction of an effective levee system;

   ii. The area is a large very sparsely populated area such that the construction of a levee would be very expensive for the benefit derived;

   iii. There are many residential parcels both developed and ready for sale and still to be developed within the levee protected area to provide for the future growth of the town.

5. ***Why the Goondiwindi Regional Council monitors the building of private levee banks***

The existing Council are continuing the service established by the former Waggamba Shire Council in monitoring the construction of private levee banks. It is my understanding that the former Waggamba Shire Council believed that the control of levee banks was the responsibility of the State due to their legislated role in regulating water harvesting, storage and diversion. The Waggamba Shire Council also believed that the State was better placed to exercise jurisdiction over impacts that may extend beyond Council boundaries. I understand that the former Waggamba Shire Council felt that the disadvantage afforded to local residents through the State not undertaking regulation and monitoring of levee banks was so great as to justify the Council establishing a head of power to carry out those actions. The current Council believes that the impact upon others of levee development like any other development must be considered before such development occurs. Despite its efforts to fill the void, the current Council also believes that levee bank regulation is best managed by the State as is the practice in New South Wales.

[redacted]....
Deponent

[redacted]
~~Solicitor / Justice of the Peace / Commissioner for Declarations~~

6. ***Whether a proposed local law to regulate private levee banks is to be enacted to cover the whole of the Goondiwindi Regional Council.***

Council has recently resolved to prepare a local law controlling levee bank development across the region. However, in practice the construction of such levees is generally limited to the floodplain area of the former Waggamba Shire Council. Limits on water availability and other impacts upon the agricultural industry have effectively seen the cessation of the development of further levees as the area is generally regarded as being fully developed. It is intended that this local law will be rescinded once the Council adopts its new planning scheme.

7. ***Whether Council is considering any amendments to the planning scheme to regulate private levee banks.***

Council is in the process of preparing its new planning scheme and it is currently planned to roll the monitoring and regulation of levee bank development into the definition of operational works so that such development is managed through planning processes. I am familiar with the various advantages and disadvantages of regulating levee bank development through the planning scheme rather than a local law and I believe that the decision to regulate this form of development in a planning scheme relies upon many factors relevant to the specific circumstances, including the resources available to undertake the role of regulator. I recommend that the Commission either seek specific advice or recommend in its report that the State seek such advice in forming any opinion as to the most preferable method of regulating levee banks and other flood plain development. I do however again reiterate Council's position that to ensure consistency of outcomes the monitoring and regulation of levee banks would be best managed by the State through the instruments available to it.

8. ***What is the rationale behind the implementation of the Goondiwindi Regional Council Urban Levee Bank Policy?***

The policy is a strategic policy of Council that does not have any head of power and is intended to provide guidance to landowners in the urban area where the town levee traverses their property. The objectives of the policy are to:-

i. Provide Council and property owners with clear guidelines on their rights, obligations and restrictions on the use of land upon which levee banks and easements are situated.

ii. Ensure access to levee banks for maintenance and emergency works.

iii. Ensure the levees remain structurally adequate.

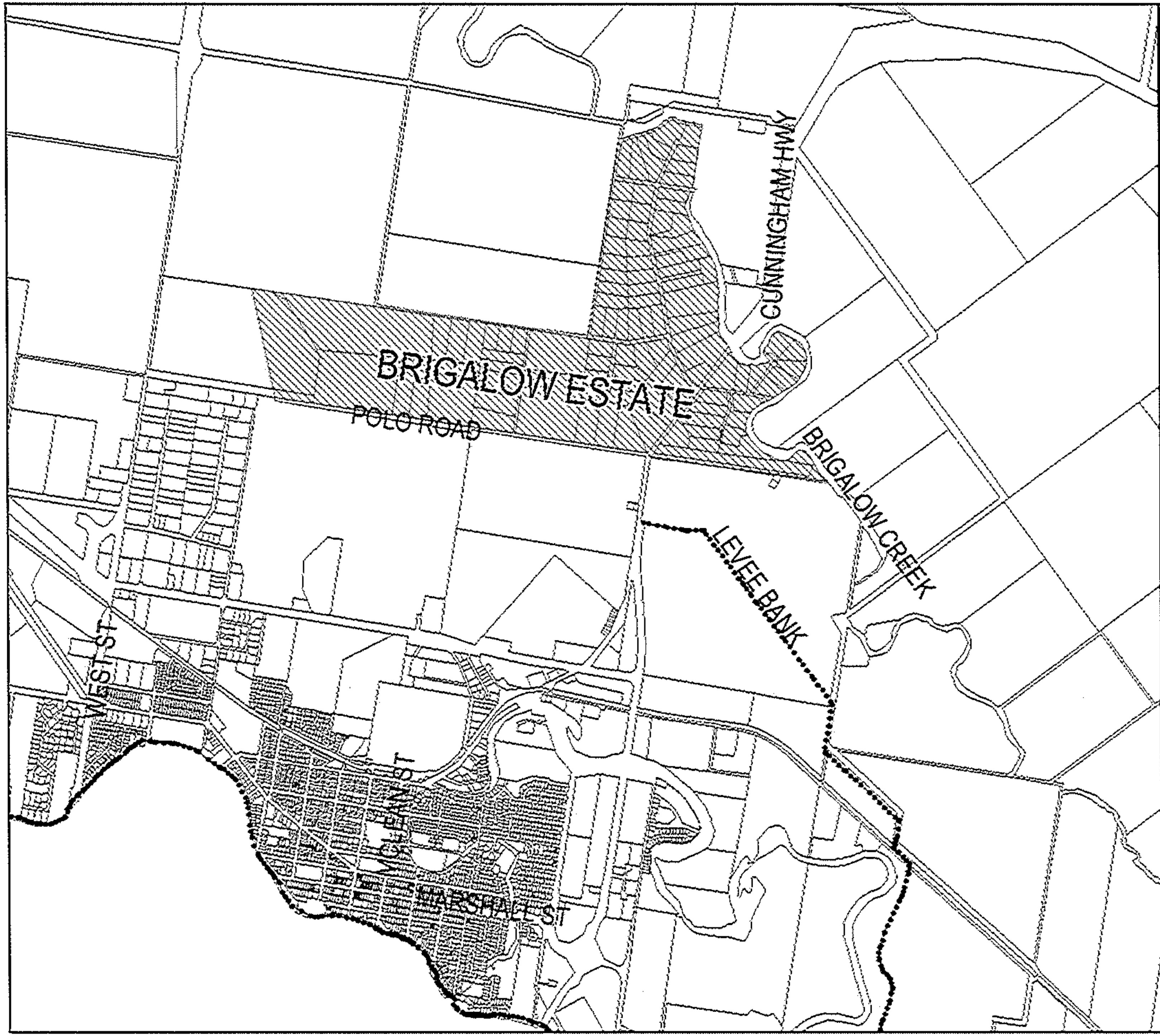
Sworn by Graeme Scheu at Goondiwindi this 12th day of September 2011 in the presence of: [redacted]

.... [redacted] .... [redacted] ....

Deponent [redacted] Solicitor / Justice of the Peace / Comm. Dec. [redacted]

JUSTICE OF THE PEACE (QUALIFIED) Reg.No.: 71207 DEPT. OF JUSTICE & ATTORNEY-GENERAL

Appendix 1



GOONDIWINDI

GOONDIWINDI REGIONAL COUNCIL

APPENDIX 2

BRIGALOW ESTATE AREA

0 500 1,000
metres

ASSESSMENT OF FLOODING IMPACTS OF A PROPOSED RESIDENTIAL DEVELOPMENT

'RIGA', GOONDIWINDI

Report Prepared For

A.J. & N. F. Wallis

Report #J7897/R1
January, 2002

L A W S O N   A N D   T R E L O A R   P T Y   L T D

AUSTRALIA

ASSESSMENT OF FLOODING IMPACTS OF A PROPOSED RESIDENTIAL DEVELOPMENT

'RIGA', GOONDIWINDI

Report Prepared For

A.J. & N. F. Wallis

Report #J7897/R1
January, 2002

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QUALITY ASSURED SUPPLIER
QLD GOVERNMENT

A.C.N. 001 882 873
ABN: 55 001 882 873

REPORT STATUS

Version	Date	Status	Prepared by:	Reviewed by:	Approved by:
1	4/1/02	FINAL	SBK	CLC	JMcA
			[redacted]	[redacted]	[redacted]

It is the responsibility of the reader to verify the currency of the version number of this report. All subsequent releases will be made directly to the Client.

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1. PURPOSE OF THE REPORT

This report has been prepared by Lawson & Treloar Pty Ltd (L&T) to provide advice on predicted flood impacts resulting from works associated with a proposed residential development on Kildonan Road, Goondiwindi. The property ('Riga') is described as Lot [redacted] on [redacted] and [redacted] on [redacted]

The proposed works consist of construction of a levee system to protect the proposed residential development.

Flooding impacts have been assessed for a February 1976 magnitude flood in the Macintyre River system.

The property owner, A.J. Wallis, intends to apply to the Queensland Department of Natural Resources and Mines (NR&M) for approval of the proposed works. Figure 1 shows the extent of the proposed works in relation to adjacent properties and the existing Goondiwindi town levee.

Results from this investigation will assist NR&M in determining the extent of allowable levee bank development on the property.

2. APPROACH

2.1 Previous Studies

2.1.1 The Border Rivers Floodplain Study

In 1998, detailed hydrologic and hydraulic modelling of the entire Border Rivers system was completed to downstream of Mungindi, as part of the Border Rivers Floodplain Hydraulic Analysis (BRFHA). This work was undertaken using the following approach:

- derive design flood hydrographs for all significant creeks and rivers feeding into the Border Rivers system for the 1996 and 1976 flood events;
- set-up a detailed MIKE 11 quasi-two-dimensional numerical hydraulic model of the entire Border Rivers floodplain, from east of Boggabilla to west of Mungindi, including the Weir River;
- ensure consistency between model predictions and recorded flood levels for the 1996 and 1976 floods; and
- review results and prepare guidelines for floodplain development for Waggamba Shire Council.

2.1.2 Macintyre River 2D Study

Waggamba Shire Council commissioned L&T in 1999 to perform a detailed analysis of the Macintyre River from Boggabilla to Dingo Creek using a two-dimensional numerical flow model. This investigation was performed using the following approach:

- utilise the established BRFHA MIKE 11 hydraulic model to obtain general flows in the vicinity of the study area;
- set-up a full two-dimensional hydraulic model using DHI's MIKE 21 modelling system;
- calibrate the two-dimensional model using known 1996 historical event flood levels and verify using known 1976 historical flood levels;

2.2 The Current Study

This investigation has been undertaken by constructing a fine scale two-dimensional model within the bounds of the larger two-dimensional model previously developed by Lawson and Treloar (J7484/R1, 2001) for the Boggabilla to Dingo Creek analysis. The approach adopted for this project has been as follows:

- set-up a detailed full two-dimensional model using the DELFT-FLS modelling system covering the Macintyre River from 2.5km upstream of the development site to 2.5 km downstream of the development site, using photogrammetric survey obtained for the BRFHA and available spot level survey over the subject site;

- obtain Manning's roughness values from the established Boggabilla to Dingo Creek MIKE 21 model;

- obtain boundary flow and height data from the established Boggabilla to Dingo Creek MIKE21 model for the 1976 magnitude flood event;

- run the DELFT-FLS model for the existing situation, taking account of all existing levees in the area;

- incorporate the proposed works into the DELFT-FLS model and re-run; and

- assess predicted impacts and advise whether or not acceptable impacts will be achieved.

3. ADOPTED GUIDELINES FOR ASSESSMENT OF DEVELOPMENT PROPOSALS

For this investigation, the guidelines used are those arising out of the BRFHA Study adopted by the Steering Committee for the Study (L&T, 1998). These can be summarised as follows:

- floodways must possess adequate hydraulic capacity and continuity to enable the orderly passage of floodwater through the floodplain;
- any system of floodways should conform as closely as is reasonable to the natural drainage pattern after taking into account the existing floodplain development;
- the exit of floodwater from floodways should be at rates and depths similar to those which would have been experienced under natural conditions and should discharge as close as practicable to the location of natural floodways;
- sufficient pondage must be retained on the floodplain so that the flood peak is not unduly accelerated to downstream areas or its height increased;
- velocities of flood flow in the floodways should be minimised and be of an order which would not cause erosion under various land uses;
- there should be no detrimental impact on any individual landholder or community infrastructure;
- there is no significant redistribution of floodwater; and
- a peak water level increase of 200mm on any adjacent property boundary is the maximum allowable. Where development is proposed adjacent to fully developed sites, the regulatory authority has the discretion to relax this guideline provided they are satisfied that no adverse effect will occur on adjacent properties.

4. RESULTS

Peak flood levels have been tabulated below in Table 1 for the 1976 magnitude event. Reporting locations are shown in Figure 1.

Table 1 – Peak Water Surface Levels and Impacts for a 1976 Magnitude Event

Reporting Location	Existing Case Peak WSL (m AHD)	Developed Case Peak WSL (m AHD)	Difference (m)
R1	218.47	218.47	0.00
R2	218.63	218.62	-0.01
R3	218.77	218.76	-0.01
R4	218.88	218.86	-0.02
R5	219.03	219.00	-0.03
R6	219.17	219.17	0.00
R7	219.32	219.42	0.10
R8	219.26	219.52	0.26
R9	219.38	219.54	0.16
R10	219.54	219.65	0.11
R11	219.55	219.67	0.12
R12	219.75	219.84	0.09
R13	218.46	218.46	0.00
R14	218.49	218.50	0.01
R15	219.02	218.99	-0.03
R16	218.75	218.79	0.04
R17	218.60	218.63	0.03
R18	218.66	218.71	0.05
R19	219.14	219.24	0.10
R20	219.56	219.66	0.10

Figures 2 and 3 show the predicted peak flood levels and associated velocity vectors for the existing and post-development situations respectively.

Figure 4 shows the predicted impacts of the proposed development as a difference diagram, subtracting existing situation peak levels from post-development levels.

5. DISCUSSION ON RESULTS

Impacts immediately upstream of the development are in excess of 200mm (reporting point R8), which reduces the freeboard of the adjacent town levee locally to approximately 50mm. Goondiwindi Town Council has indicated that these impacts will be acceptable if town levee works are included to maintain a 500mm freeboard to the top of the levee.

On the NSW side of the Macintyre River and over the Newell Highway, the proposed works increase peak water surface levels by up to 100mm. This may impact on the flood immunity of sections of the Newell Highway.

Predicted flood velocities around the proposed site earthworks are less than 1 m/s, which is below scouring velocity. It is therefore anticipated that earthworks batters will require only vegetated cover.

To allow low flows into the site, in order to maintain the site's internal watercourse, a gate is proposed. This gate will be shut at high flood stages to prevent inundation of the site.

Other factors that may need to be considered in the assessment of the levee works that are not addressed in this report include:

- stream stability & erosion;
- environmental considerations; and
- other local flooding & drainage issues.

6. REFERENCES

Delft Hydraulics, 2001, Delft-FLS Version 2.55 User Manual

Lawson and Treloar, 1998, 'Border Rivers Floodplain Hydraulic Analysis Detailed Hydraulic Report' for Waggamba Shire Council

Lawson & Treloar, 2001, 'Macintyre River – Boggabilla to Dingo Creek Flooding Analysis' for Waggamba Shire Council

7. QUALIFICATIONS

This report has been prepared for M.F.G. Shaw & Associates Pty Ltd acting on behalf of A.J. & N.F. Wallis, to provide details on the theoretical pre- and post-development flooding characteristics of a proposed levee associated with a residential development.

Our analysis and overall approach has been specifically catered for the particular requirements of M.F.G. Shaw & Associates and their Client and may not be applicable beyond this scope. For this reason, any other third parties are not authorised to utilise this report without further input and advice from Lawson and Treloar.

The report is based on the following studies and information prepared by others:

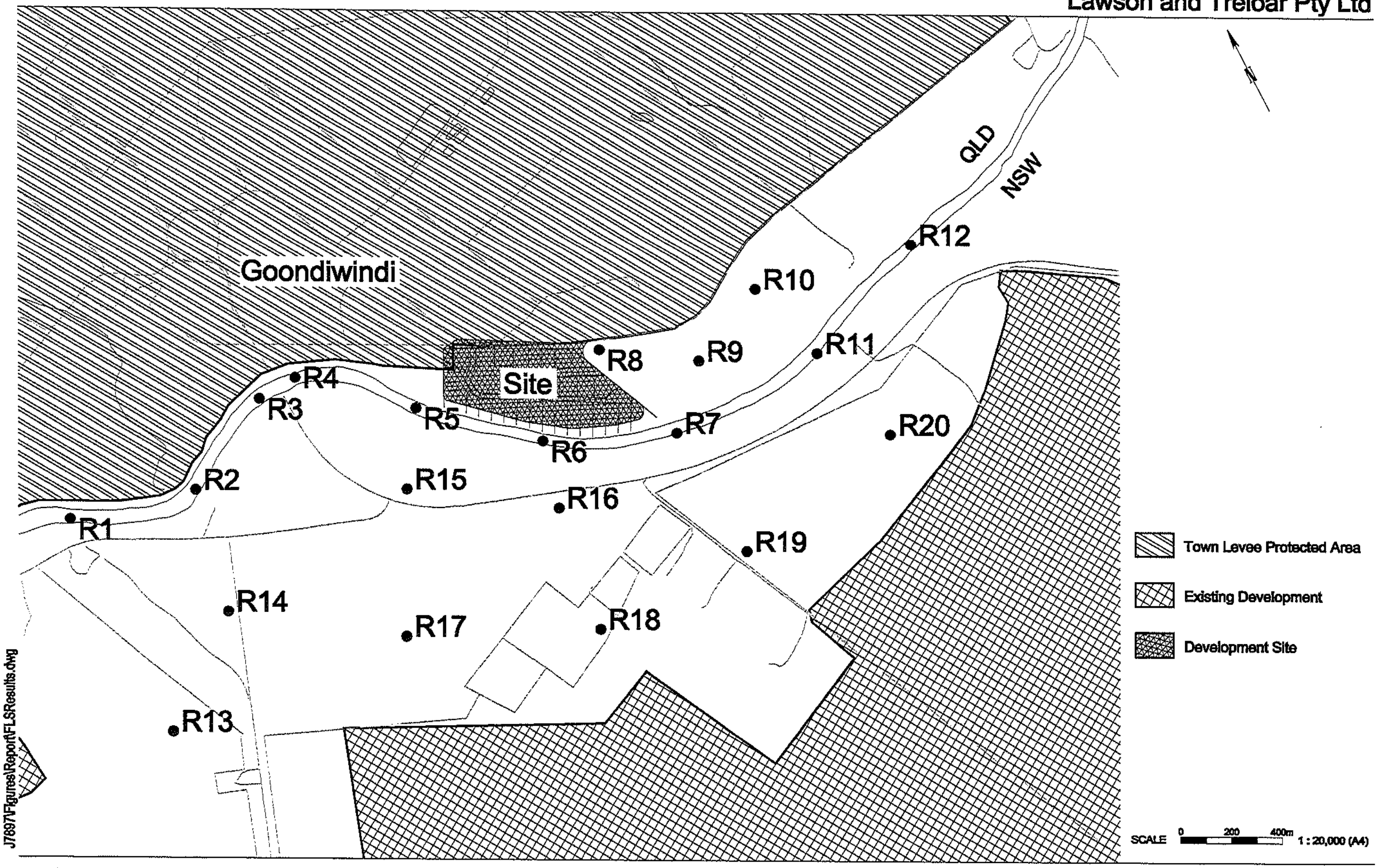
- Lawson and Treloar (L&T) has relied on survey data provided by:
  - Waggamba Shire Council as part of the BRFHA Study;
  - M.F.G. Shaw & Associates

The accuracy of the survey limits the accuracy of predictions.

- L&T has relied on peak flood flow and level information prepared as part of the Boggabilla to Dingo Creek Study

In particular, assessments have been based on the updated 1976 design flood. This is a theoretical flood in this area of the floodplain, which has been derived from a previous numerical model study.

FIGURES



Walls Development, Goondiwindi

Figure 1 - Reporting Point Locations

Lawson and Treloar Pty Ltd

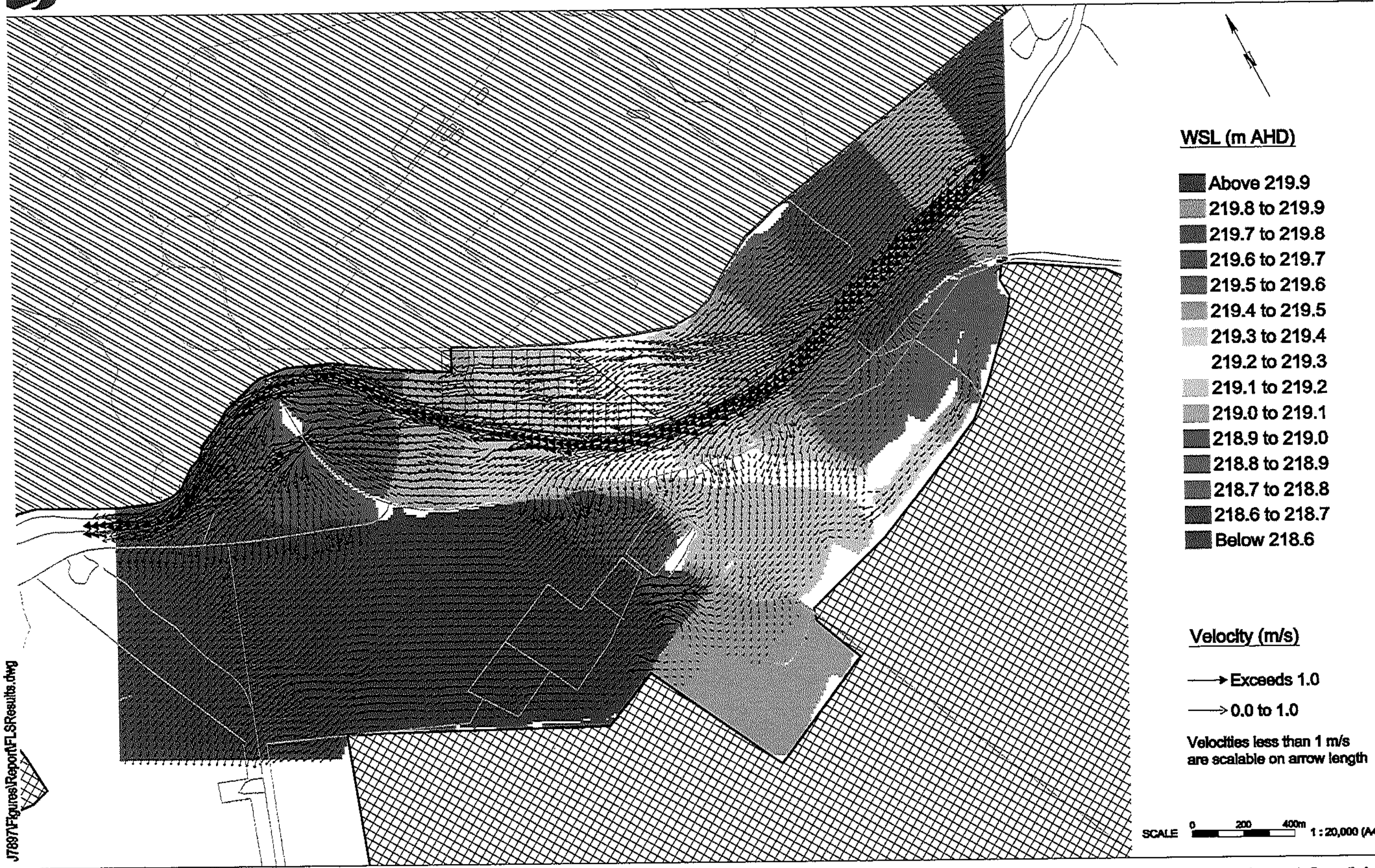


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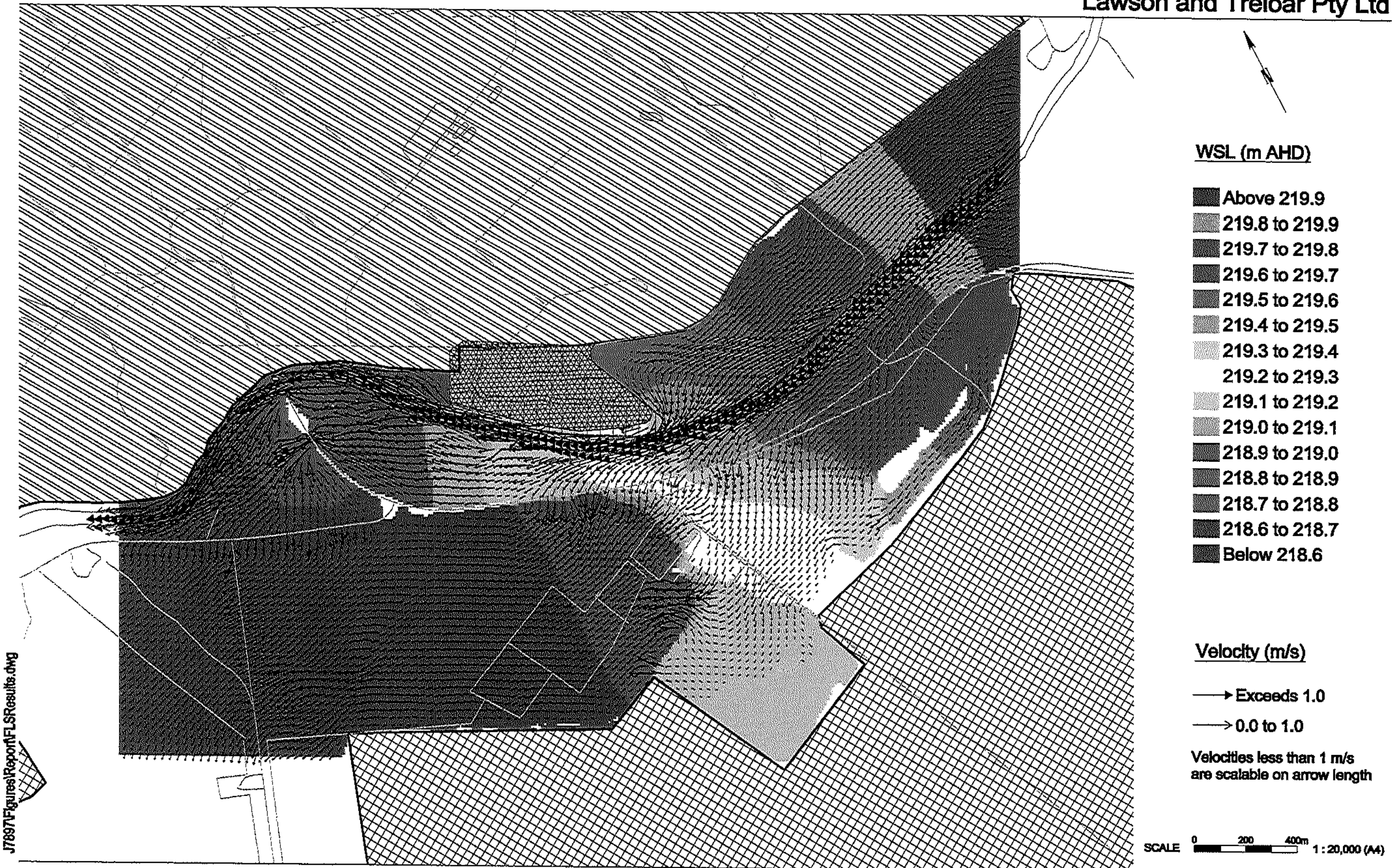
Figure 2 - Peak WSL and Velocities (Existing)

Lawson and Treloar Pty Ltd



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Wallis Development, Goondiwindi

Figure 3 - Peak WSL and Velocities (Developed)

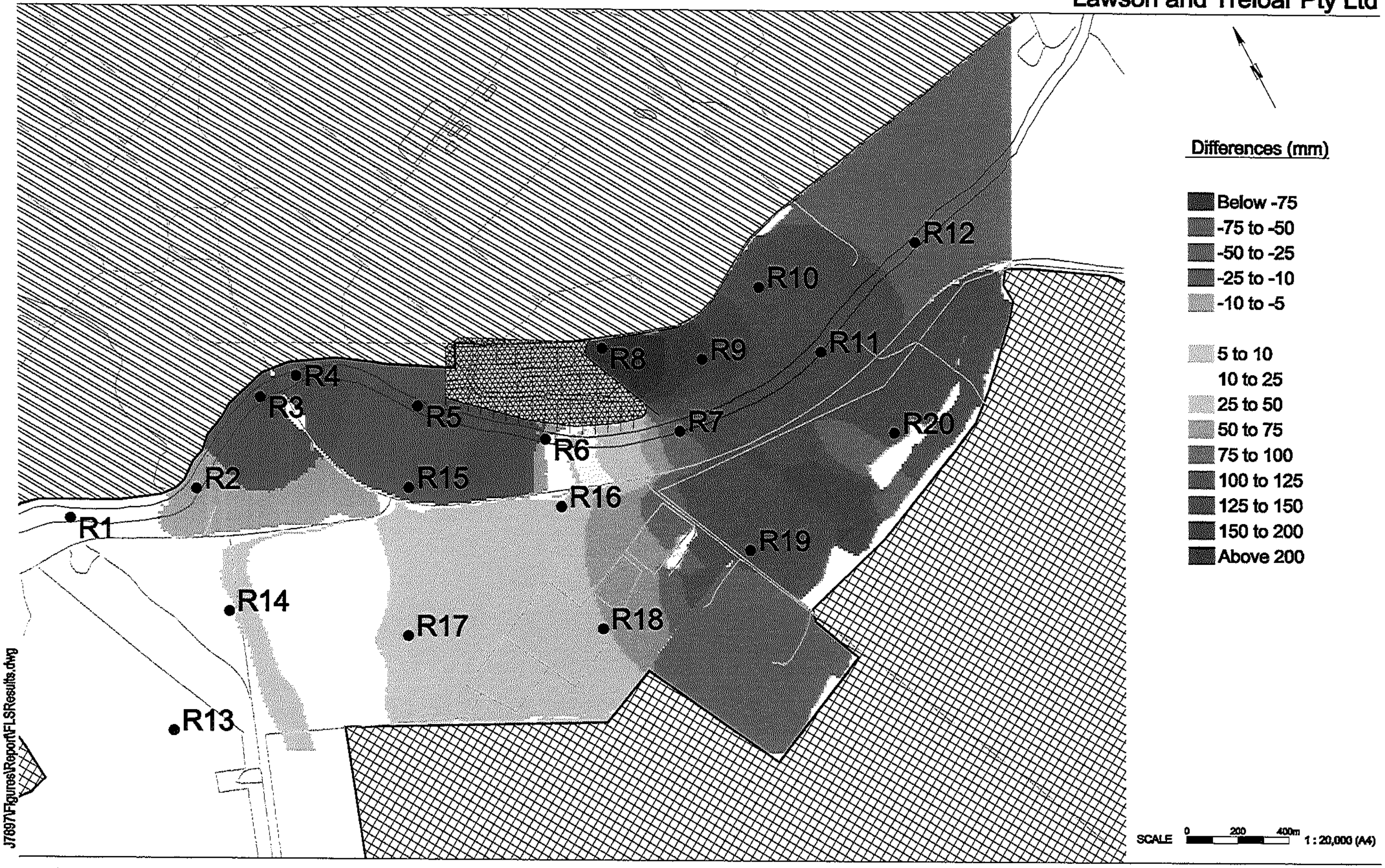

Figure 4 - Peak WSL Differences (Proposed over Existing)

BUREAU OF METEOROLOGY BRISBANE

MACINTYRE RIVER

REVIEW OF
FLOOD FORECASTING MODEL

Hydrology Section
Bureau of Meteorology
Queensland
November 1996

MACINTYRE RIVER

REVIEW OF FLOOD FORECASTING MODEL

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MACINTYRE RIVER

REVIEW OF
FLOOD FORECASTING MODEL

1. INTRODUCTION

During the January floods of 1996, the operational URBS model was used for the first time on major floods in the system. Several shortcomings and inaccuracies were identified during this period and, as a result, the model has been recalibrated with additional data and additional events.

The short comings in the existing model were identified as:

* Explicitly modelling Coolmunda Dam
* Over estimation of inflow volumes;
* Over estimation of some peak flows, especially in the Dumaresq River;
* Absence of the February 1976 flood, one of the largest on record, in the calibration set, and;
* Impact of inflows from Beebo Ck, Oaky Ck and Campbells Ck.

Floods in the Macintyre River may be the result of flow in any of the three major river systems upstream, Macintyre Brook, Dumaresq River or Macintyre River or by a combination of flows in all three systems. The basin configuration is shown in Figure 1.

Prior to this review, input into the flood forecasting model was in the form of observed hydrographs at 6 locations; Terraine and Barongarook in the Macintyre Brook system, Haystack and Roseneath in the Dumaresq system and Ashford and Wallangra in the Macintyre River system. These stations only account for 45% of the total catchment area to Goondiwindi.

At this stage, the model does not take into account rain falling on the catchment below the 6 upstream inflow stations and this may account for a significant increase in flood flows and volumes, especially if heavy rain falls in the lower reaches of the system as occurred in January 1996. Some improvement could be expected by including flows from Oaky, Beebo and Campbells Creeks.

TABLE 2
RIVER HEIGHT RECORDS

AWRC	Station	Feb 1976	Mar 1982	May 1983	Jul 1984	Apr 1988	Apr 1990	Jan 1991	Feb 1991	Feb 1992	Jan 1996(1)	Jan 1996(2)	Jan 1996(3)
416404	Terraine	x	x	x	x	x	x	x	x	x	x	x	x
416010	Barongarook	x	x	x	x	x	x	x	x	x	-	-	-
416409	Coolmunda HW	x	x	x	x	x	-	-	-	x	x	x	x
416416	Coolmunda TW	pk	pk	-	-	x	-	-	-	-	x	x	x
416904	Inglewood	x	pk	pk	pk	x	pk	-	-	pk	x	x	x
416407	Woodspring	x	-	pk	-	x	-	pk	-	-	x	x	x
416402	Inglewood Weir	-	x	x	x	x		x	x	x	x	x	x
416415	Booba Sands	-	-	-	-	x	x	x	x	x	x	x	x
416011	Roseneath	x	x	x	x	x	x	-	x	p	x	x	x
416008	Haystack	-	x	x	x	x	x	x	x	p	x	x	x
416007	Bonshaw Weir	x	x	x	x	x	-	-	x	-	x	x	x
416901	Texas	pk	pk	pk	pk	-	-	-	-	pk	x	x	x
416049	Mauro	-	-	-	-	pk	x	x	x	x	x	x	x
416915	New Bengalla	x	x	x	x	-	x	x	x	x	x	x	-
416006	Ashford	x	x	-	x	x	x	-	-	x	x	x	x
416010	Wallangra	x	x	x	x	x	x	x	x	x	x	x	x
416902	Yetman	x	pk	pk	pk	pk	-	pk	pk	pk	pk	pk	pk
416012	Holdfast	p	x	x	x	x	x	-	x	x	x	x	x
416917	New Kildonan	-	-	-	-	-	x	x	x	x	-	-	p
416002	Boggabilla	pk	pk	pk	pk	pk	-	-	pk	pk	-	-	-
416201	Goondiwindi	x	x	x	x	x	x	x	x	x	p	x	x

x : Continuous record for whole event
pk: Peak height only

p : Partial record
- : No record

4. DISCUSSION

Based on data from the recent events and the February 1976 and April 1988 floods, the average travel times and reach length factors were re-derived for each reach incorporating the latest data sets. The adopted reach length factors are shown in Figure 3.

The effect of Coolmunda Dam was incorporated by inclusion of the stage-storage-discharge data for the reservoir, as shown in Table 4. The discharge curve was determined from tailwater readings and comparison with upstream and downstream flows at rated stations. It assumes normal automatic operation of the Coolmunda gates. If this automatic operation is over ridden, headwater levels will not correctly reflect the Coolmunda outflow.

TABLE 4
COOLMUNDA DAM
STAGE-STORAGE-DISCHARGE TABLE

Dam (AHD)	Level (m)	Storage (Ml)	Volume to Spill (Ml)	Discharge (m^3/s)	
301.00	-13.07	0	75200	0	
302.00	-12.07	800	74400	0	
304.00	-11.07	1400	73800	0	
304.32	-10.07	1660	73540	0	Spillway Crest
305.00	-9.07	2200	73000	0	
306.00	-8.07	3700	71500	0	
307.00	-7.07	6000	69200	0	
308.00	-6.07	10000	65200	0	
309.00	-5.07	16000	59200	0	
310.00	-4.07	24000	51200	0	
311.00	-3.07	33000	42200	0	
312.00	-2.07	44000	31200	0	
313.00	-1.07	57000	18200	0	
314.00	-0.07	74000	1200	0	
314.07	0.00	75200	0	0	FSL
314.10	0.03	76440	0	25	
314.20	0.13	77680	0	100	
314.30	0.23	79090	0	200	
314.40	0.33	80500	0	500	
314.50	0.43	82150	0	1300	
314.60	0.53	83800	0	2133	
314.80	0.73	87500	0	3353	
315.00	0.93	91000	0	4454	

The recession constants used in the estimation of inflow hydrographs were adjusted to more accurately reflect observed recessions.

By 36 hours prior to the peak, the amplitude error improves considerably and the model appears to have reached the limit of its amplitude accuracy +/- 0.5 metres.

However, the phase error still remains considerable, +/- 9 hours, even twelve hours prior to the observed peak and users should consider modifying alpha during an event to improve the timing error. Indications are that a 10% change in alpha will result in a 3-6 hour change in timing of the peak at Goondiwindi.

In practice during flood events, the forecasts produced by the model are refined by manual analysis, especially during the later stages of the flood.

6. SUMMARY & RECOMMENDATIONS

The Border Rivers URBS model has been considerably improved by the inclusion of more floods in the calibration data set, the explicit modelling of Coolmunda Dam and the inclusion of Oaky Creek, Beebo Creek and Campbells Creek.

Since the review was completed, the station at Mauro has been moved to Glenarbon and the station on Campbells Creek has been closed.

The model should give reasonable estimates of the height at Goondiwindi, typically within 0.5 metres gauge height, but the user should be wary of the timing of the prediction. Some sensitivity analysis on the impact of changes to alpha should be conducted, especially in the minor to moderate floods, as well as refinement of the predictions using manual empirical techniques.

To improve the model, it is recommended that it be converted into a rainfall runoff model but there is probably insufficient real time rainfall available at the current time to be useful. As an interim measure, the model should be run with matching at the most reliable downstream stations.

March 1982

Station	Date of Peak	Time	Peak Height (m)	Peak Flow (m3/s)
Inglewood	12 March 1982	0000	5.25	140
Woodspring				
Inglewood Weir	13 March 1982	0145	5.58	180
Booba Sands				
Riverton	11 March 1982	0900	4.85	
Roseneath	11 March 1982	1230	4.07	560
Haystack	11 March 1982	0200	4.60	310
Bonshaw Weir	11 March 1982	0750	6.07	940
Texas	11 March 1982	1100	7.30	910
Mauro				
New Bengalla	12 March 1982	2030	9.35	820
Ashford	11 March 1982	0910	4.52	540
Wallangra	11 March 1982	1230	5.60	590
Yetman	11 March 1982		8.90	980
Holdfast	12 March 1982	0045	7.62	1040
New Kildonan				
Boggabilla	13 March 1982	0200	11.15	1670
Goondiwindi	13 March 1982	0600	10.00	

May 1983

Station	Date of Peak	Time	Peak Height (m)	Peak Flow (m3/s)
Inglewood	3 May 1983	1400	9.65	740
Woodspring	3 May 1983		7.47	
Inglewood Weir	3 May 1983	1515	9.77	860
Booba Sands				
Riverton	3 May 1983	1800	5.80	
Roseneath	3 May 1983	1600	4.78	700
Haystack	2 May 1983	1700	2.50	170
Bonshaw Weir	4 May 1983	0550	5.38	700
Texas	4 May 1983	0900	6.75	690
Mauro				
New Bengalla	5 May 1983	0300	9.80	1230
Ashford				
Wallangra	3 May, 1983	0900	6.25	690
Yetman	4 May 1983	0600	10.57	
Holdfast	4 May 1983	0300	8.76	1540
New Kildonan				
Boggabilla	5 May 1983	0800	11.87	2490
Goondiwindi	5 May 1983	0600	10.40	

9	2300			1550	1400	660
10	3000			2250	2150	1280
11	4000			3200	3300	2200
12						3000

(c) Macintyre River

Gauge Height (m)	416006 Ashford	416010 Wallangra	416902 Yetman	416012 Holdfast	416917 New Kildonan
0	0	0	0	0	0
1	12	3	25	26	20
2	82	41	100	101	60
3	212	126	150	210	120
4	428	265	225	300	200
5	650	469	320	420	300
6	880	700	460	600	380
7	1280	1040	640	840	460
8	1630	1450	870	1180	580
9	2200	1910	1050	1800	780
10	2900	2500	1300	5500	1150
11			1800		1400
12			2700		2100
13			5500		8000

April 1990

Station	Date of Peak	Time	Peak Height (m)	Peak Flow (m3/s)
Inglewood	21 April 1990	1130	8.80	510
Woodspring				
Inglewood Weir	21 April 1990	0750	8.68	500
Booba Sands	22 April 1990	0300	7.81	400
Riverton	21 April 1990	2100	4.30	
Roseneath	22 April 1990	0900	2.70	270
Haystack	21 April 1990	0600	2.80	100
Bonshaw Weir				
Texas				
Mauro	22 April 1990	0640	5.16	280
New Bengalla	23 April 1990	0000	8.02	480
Ashford	22 April 1990	0300	3.91	400
Wallangra	22 April 1990	0300	3.30	170
Yetman				
Holdfast	22 April 1990	2100	4.50	360
New Kildonan	23 April 1990	1500	8.20	810
Boggabilla				810
Goondiwindi	24 April 1990	0300	7.90	

January 1991

Station	Date of Peak	Time	Peak Height (m)	Peak Flow (m3/s)
Inglewood				
Woodspring	27 January 1991	2300	4.30	
Inglewood Weir	28 January 1991	1700	3.40	49
Booba Sands	29 January 1991	1200	2.96	55
Riverton				
Roseneath	28 January 1991	1145	1.70	100
Haystack	27 January 1991	0845	1.50	15
Bonshaw Weir				
Texas				
Mauro	28 January 1991	1800	3.13	110
New Bengalla	29 January 1991	0600	3.70	160
Ashford				
Wallangra	28 January 1991	0600	5.50	530
Yetman	28 January 1991	1800	6.60	
Holdfast				
New Kildonan	29 January 1991	1800	6.80	450
Boggabilla				
Goondiwindi	29 January 1991	2300	7.20	

January(1) 1996

Station	Date of Peak	Time	Peak Height (m)	Peak Flow (m3/s)
Inglewood	3 January 1996	1820	8.00	760
Woodspring	4 January 1996	0400	6.30	120
Inglewood Weir	3 January 1996	2030	9.66	810
Booba Sands	4 January 1996	1130	8.52	600
Riverton	4 January 1996	0000	7.00	
Roseneath	4 January 1996	0230	5.96	1020
Haystack	3 January 1996	1400	5.37	490
Bonshaw Weir	4 January 1996	1130	6.06	970
Texas	4 January 1996	1500	7.20	960
Mauro	5 January 1996	0730	7.70	940
New Bengalla	5 January 1996	1130	9.69	1250
Ashford	6 January 1996	2030	3.03	210
Wallangra	6 January 1996	1130	3.06	130
Yetman				
Holdfast	7 January 1996	0600	3.79	280
New Kildonan				
Boggabilla				1190
Goondiwindi	6 January 1996	0900	8.60	

January(2) 1996

Station	Date of Peak	Time	Peak Height (m)	Peak Flow (m3/s)
Inglewood	9 January 1996	2030	8.10	360
Woodspring	10 January 1996	2100	6.50	130
Inglewood Weir	9 January 1996	2330	8.17	500
Booba Sands	10 January 1996	1730	8.45	580
Riverton	10 January 1996	1200	6.10	
Roseneath	10 January 1996	1130	5.11	800
Haystack	9 January 1996	1700	4.51	330
Bonshaw Weir	10 January 1996	2045	5.94	840
Texas	11 January 1996	0500	7.10	820
Mauro	11 January 1996	1730	7.64	810
New Bengalla	11 January 1996	1730	9.82	1310
Ashford	11 January 1996	0000	3.45	370
Wallangra	9 January 1996	1730	3.37	170
Yetman				
Holdfast	10 January 1996	1445	5.55	520
New Kildonan				
Boggabilla				1670
Goondiwindi	12 January 1996	0230	9.99	

BUREAU OF METEOROLO
Queensland Regional Offi

MAP 416.2

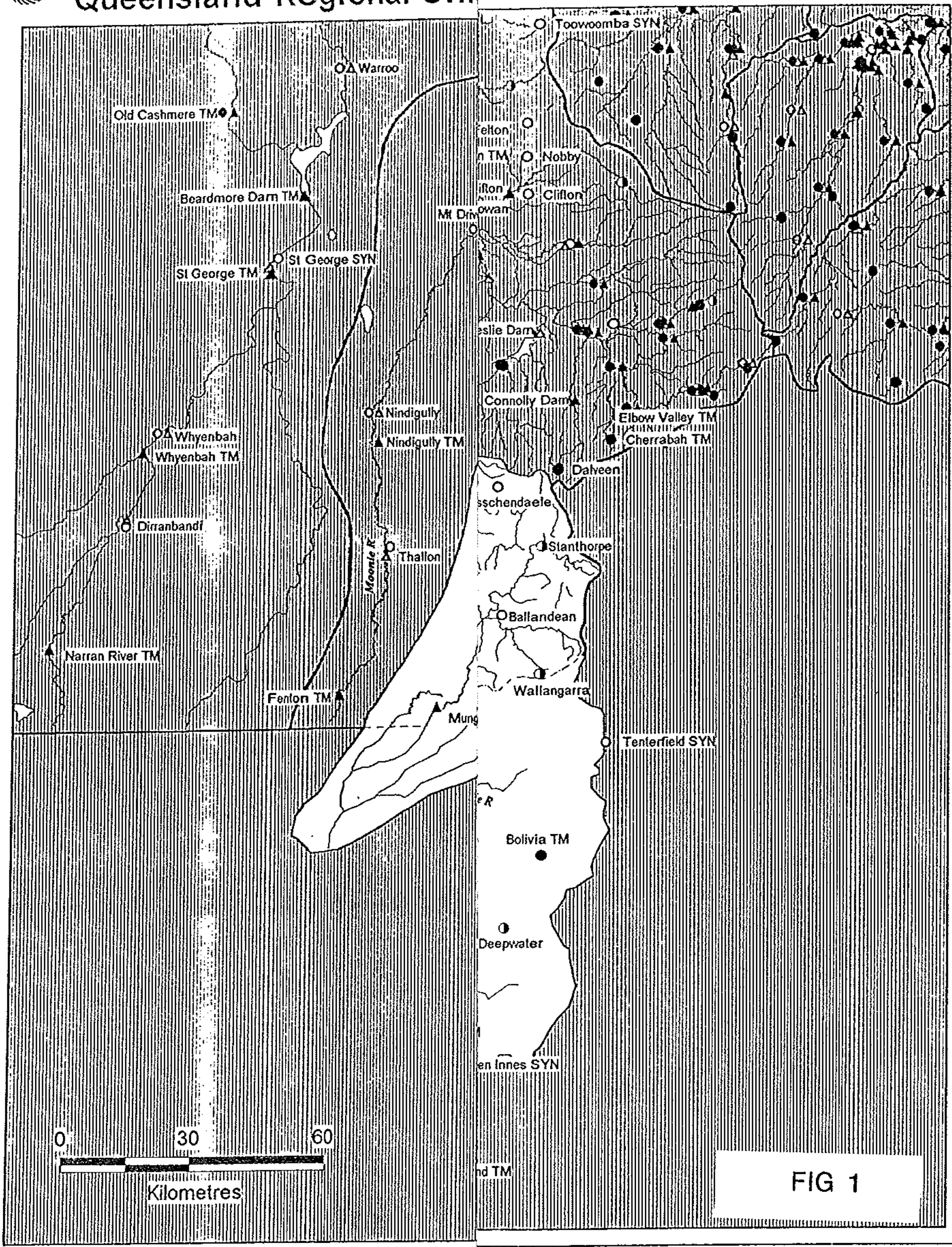


FIG 1

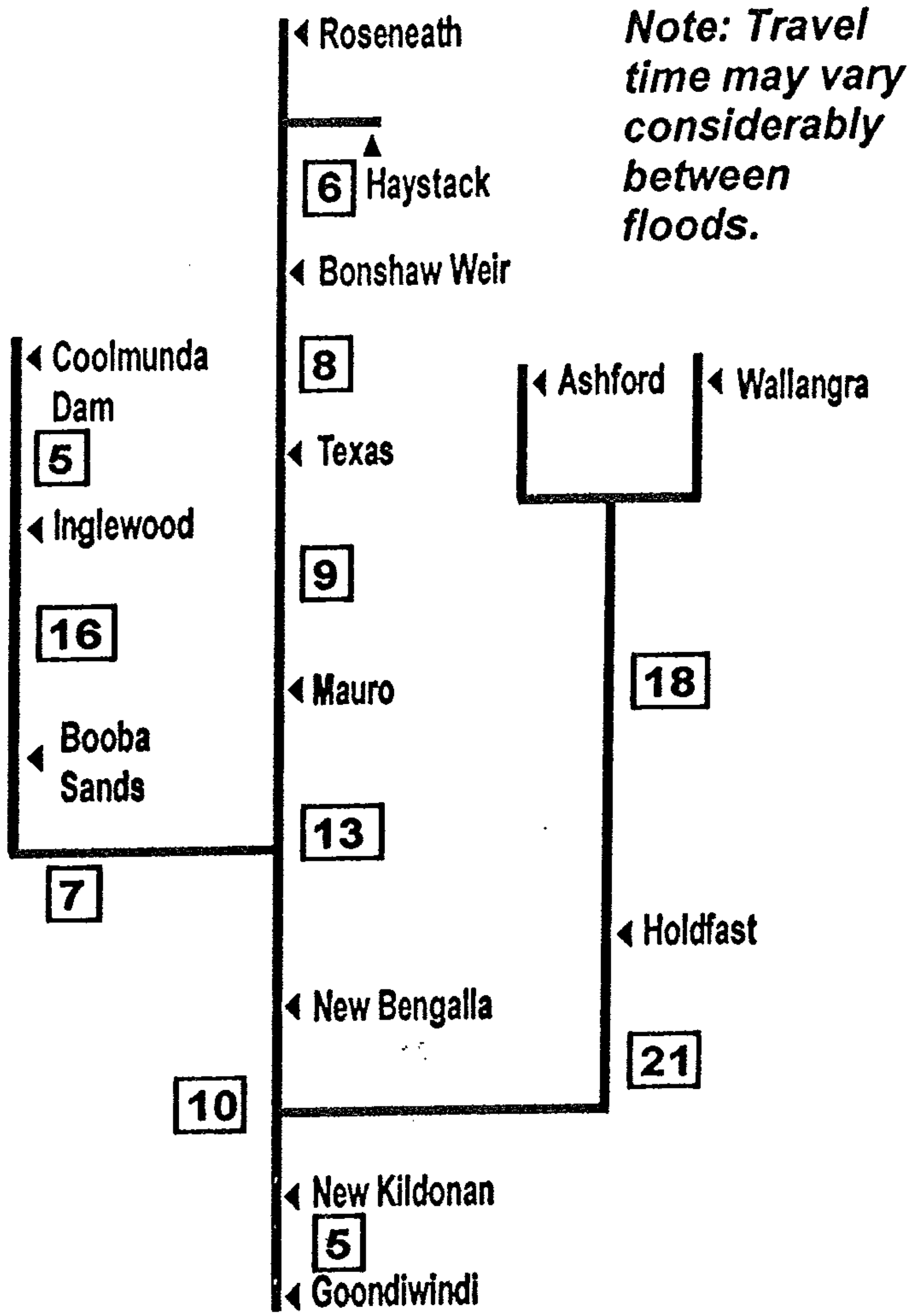
- ◑ Manual Heavy Rainfall Station
- ● Daily Reporting Rainfall Station
- △ Manual River Station
- ● Telemetry Rainfall Station
- ▲ Telemetry River Station

Rainfall Period ....

Ending at ....

Revised : Nov 1996

Macintyre River Schematic



21 Approximate travel time to downstream station in hours

Bureau of Meteorology

FIG 2

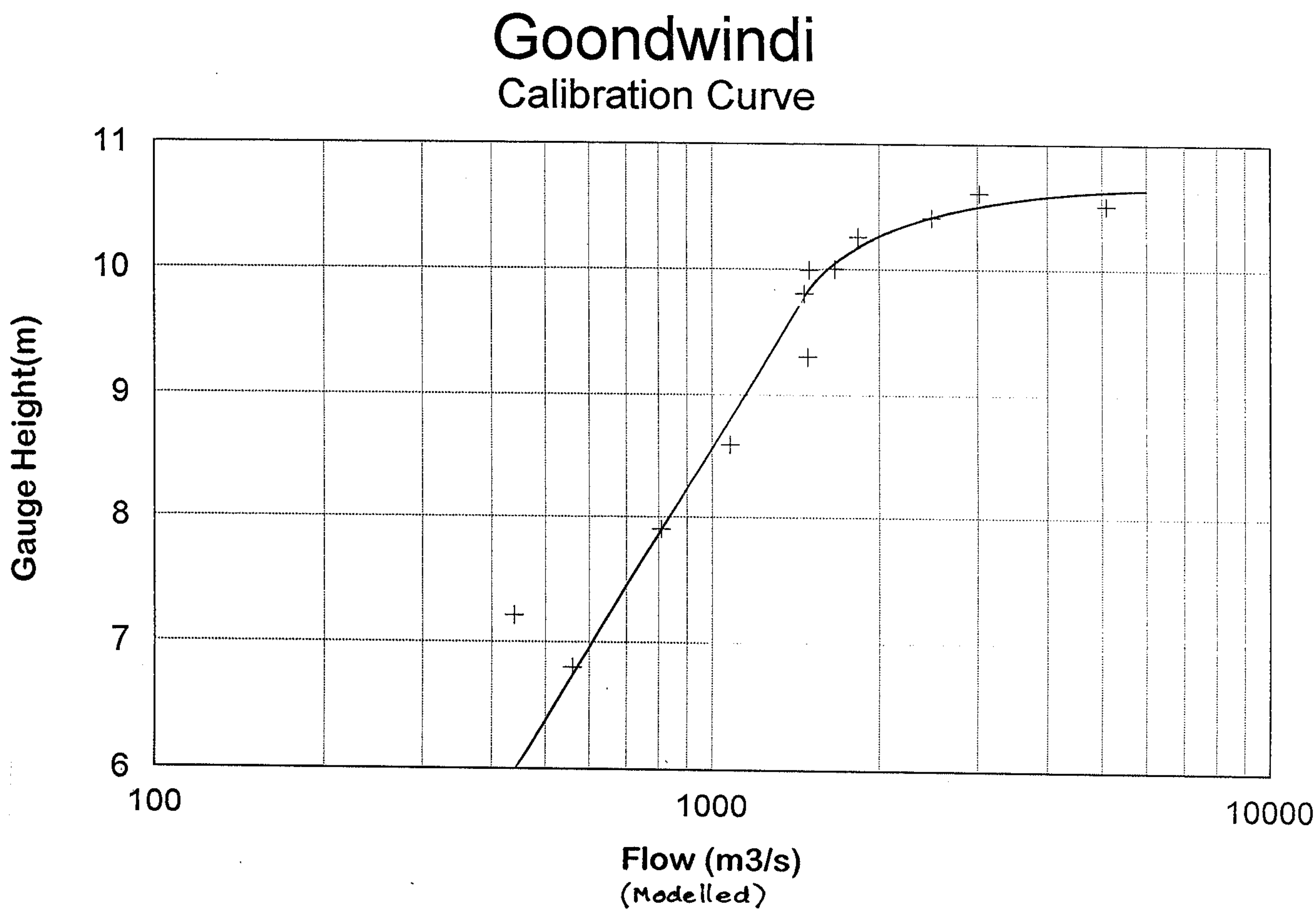
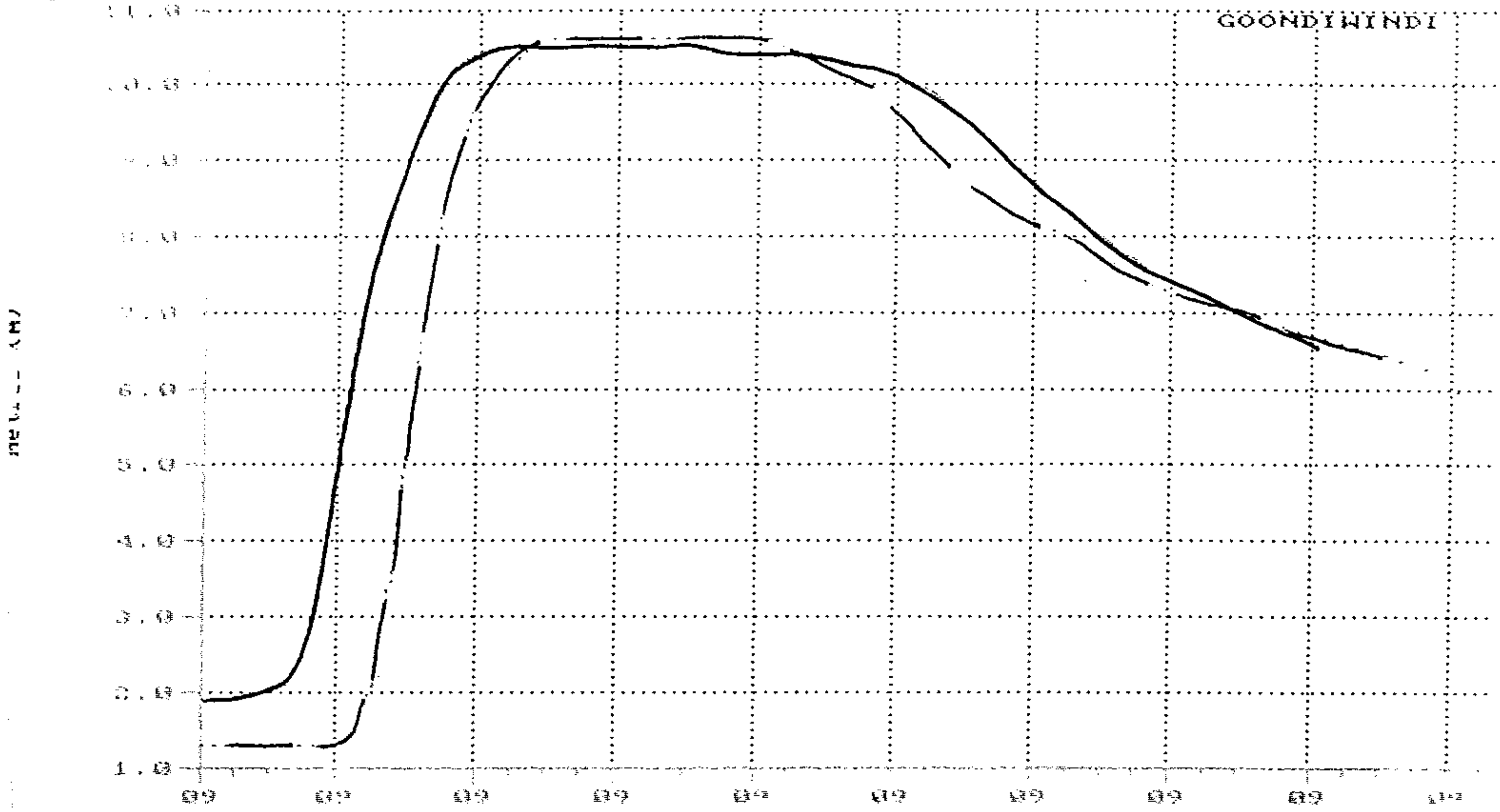

Goondwindi
Calibration Curve
Gauge Height(m)
11
10
9
8
7
6
100
1000
10000
Flow (m3/s)
(Modelled)

FIG 3

ACINTYRE RIVER TO GOONDIWINDI
EBRUARY 1976 (no forecast rainfall)
alpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00



Time starting Mon Feb 10 09:00:00 1986 (hours)
NOTE :- Solid line is Observed & Dotted line is Modelled

FIG 4

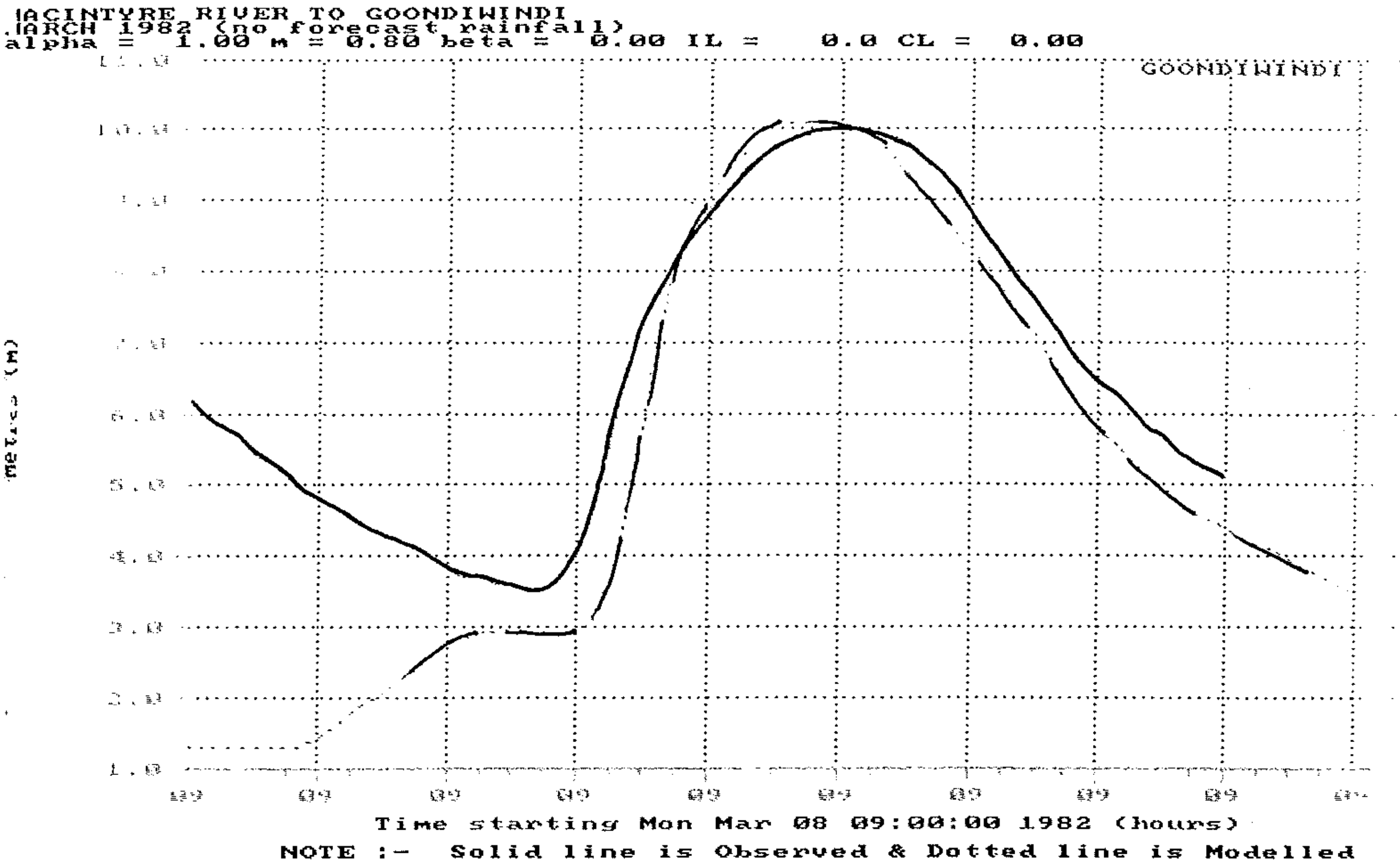

MACINTYRE RIVER TO GOONDIWINDI
MARCH 1982 (no forecast rainfall)
alpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00
GOONDIWINDI
metres (m)
10.0
6.0
5.0
4.0
3.0
1.0
09
Time starting Mon Mar 08 09:00:00 1982 (hours)
NOTE :- Solid line is Observed & Dotted line is Modelled

FIG 5

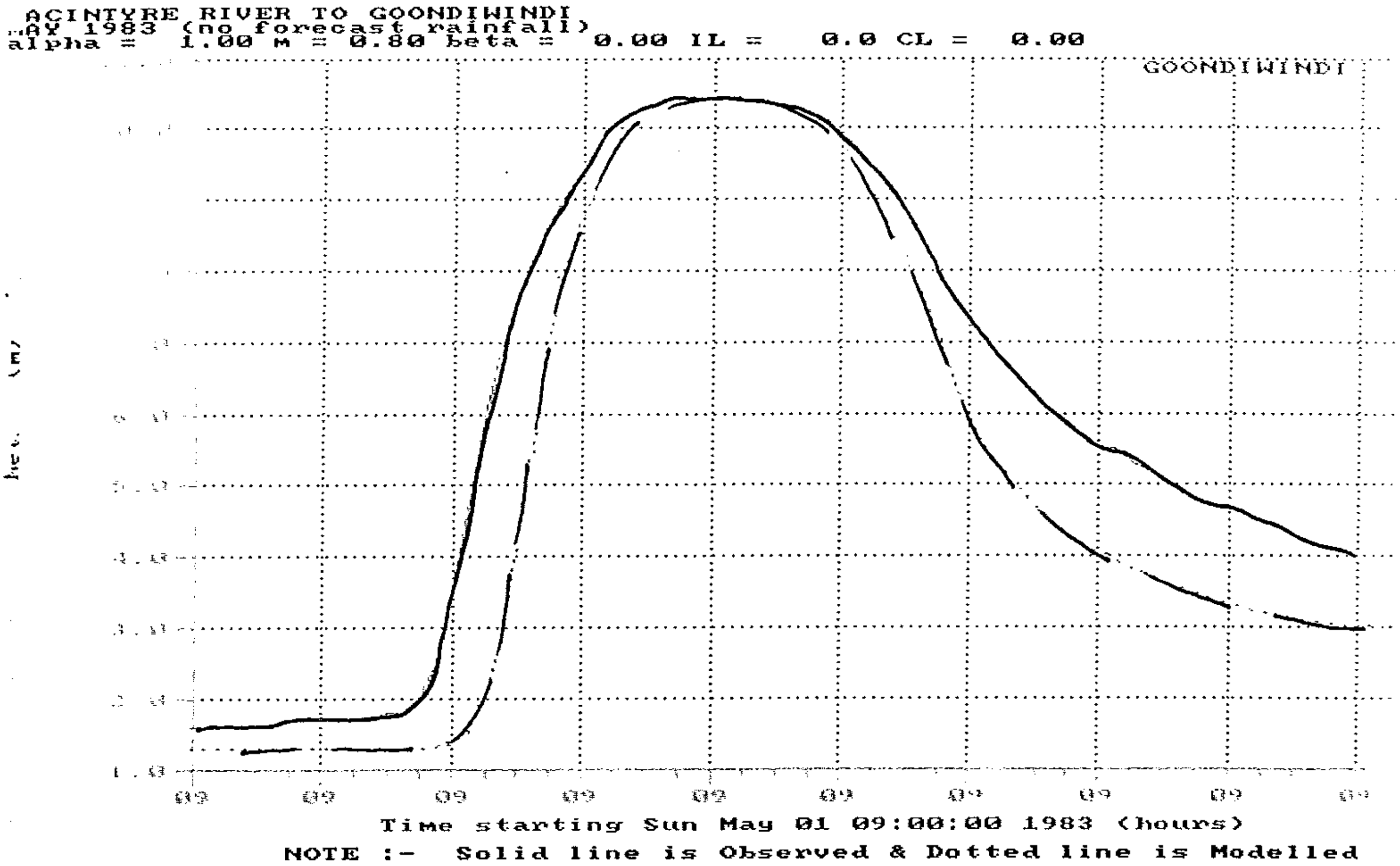
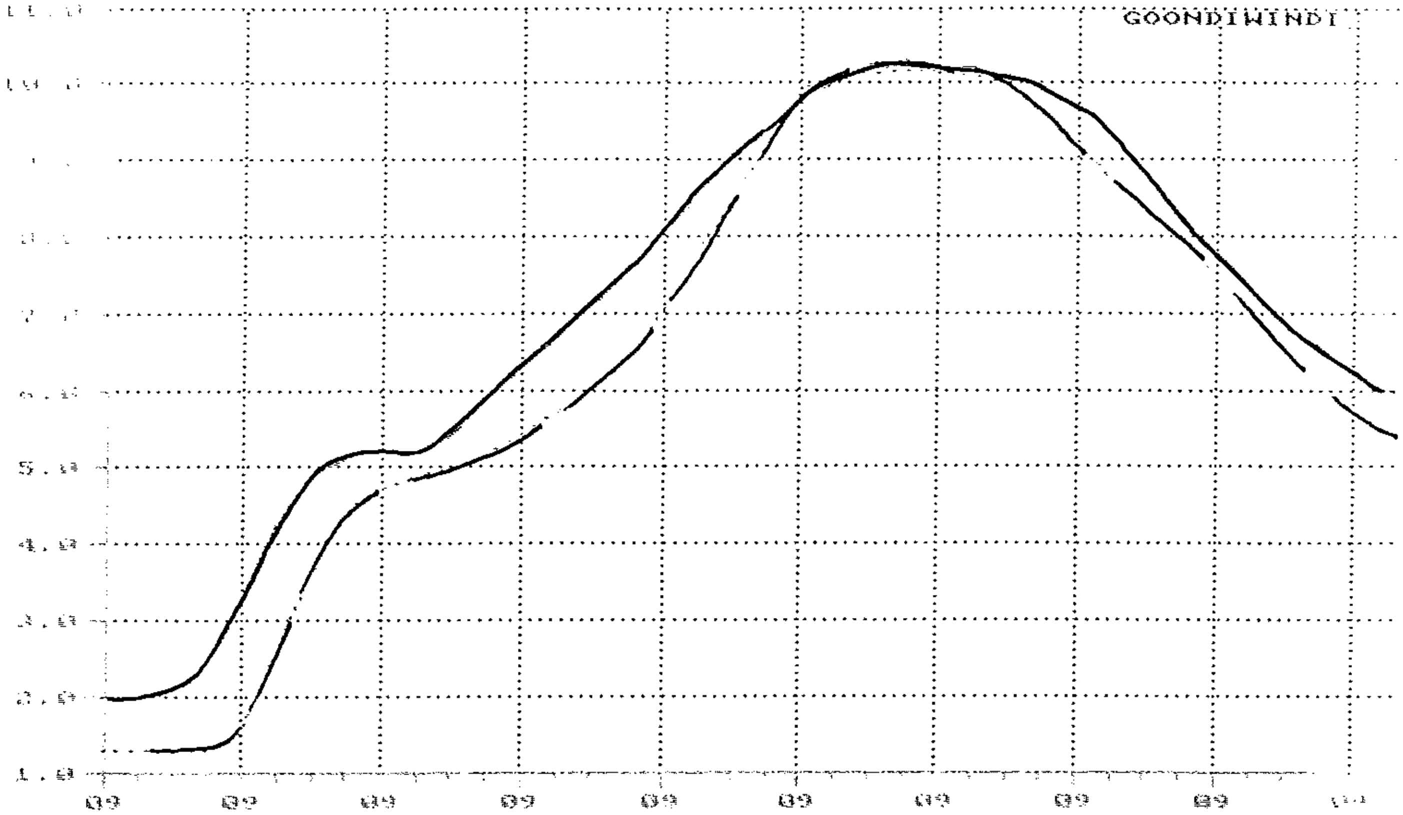

ACINTYRE RIVER TO GOONDIWINDI
MAY 1983 (no forecast rainfall)
alpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00
GOONDIWINDI
09 09 09 09 09 09 09 09 09 09
Time starting Sun May 01 09:00:00 1983 (hours)
NOTE :- Solid line is Observed & Dotted line is Modelled

FIG 6

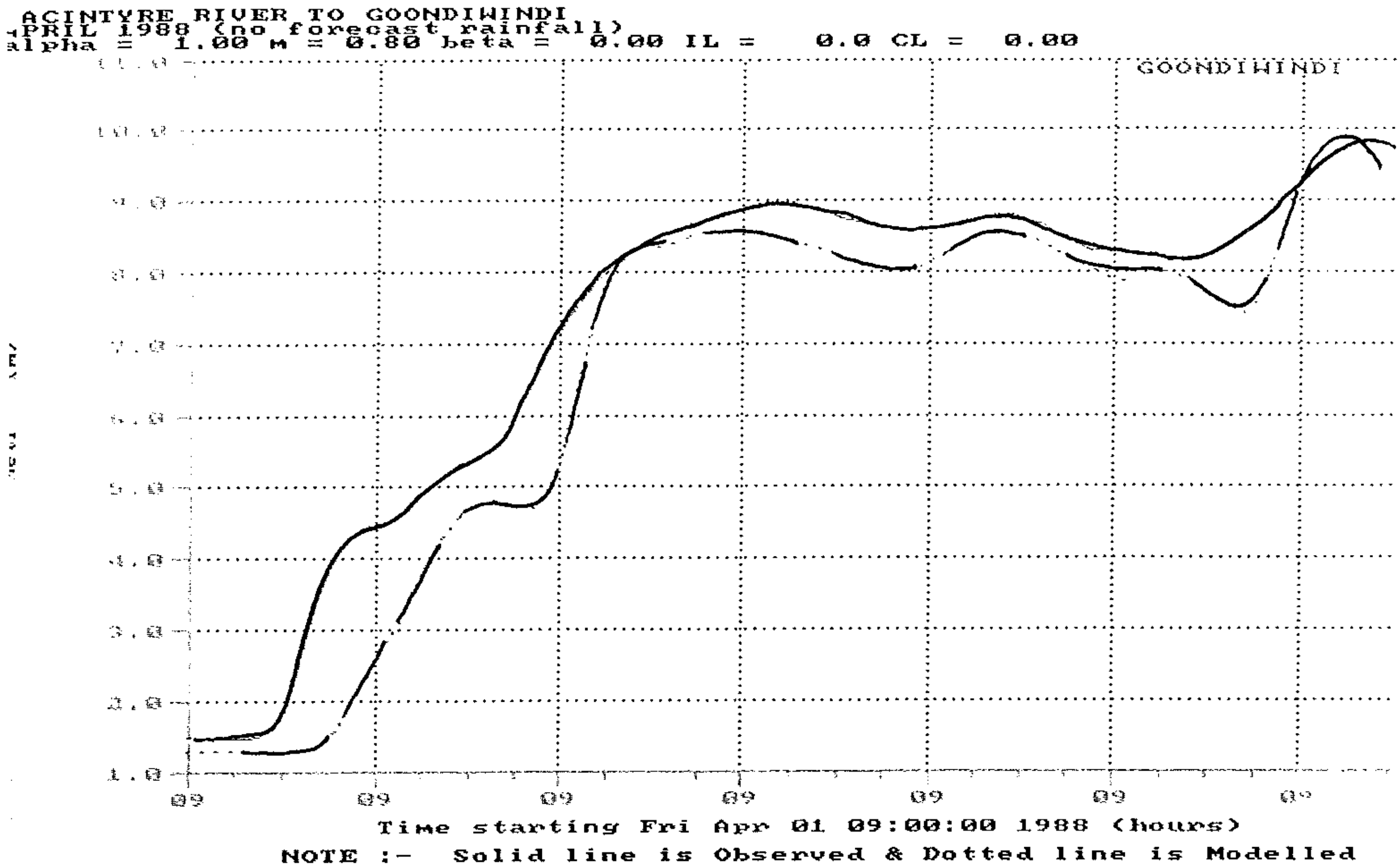
ACINTYRE RIVER TO GOONDIWINDI
ULY 1984 (no forecast rainfall)
lpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00



Time starting Tue Jul 24 09:00:00 1984 (hours)

NOTE :- Solid line is Observed & Dotted line is Modelled

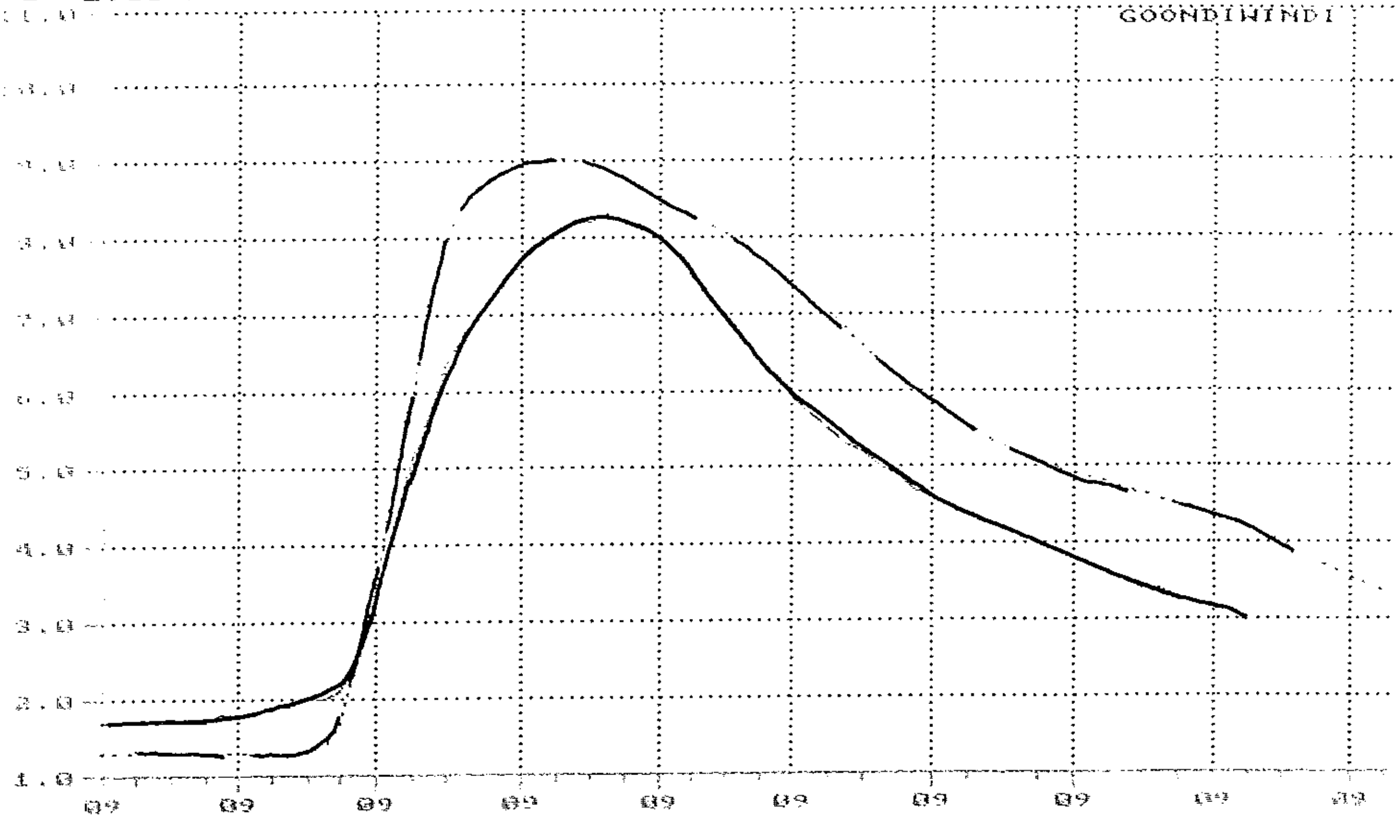
FIG 7



ACINTYRE RIVER TO GOONDIWINDI
APRIL 1988 (no forecast rainfall)
alpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00
GOONDIWINDI
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
09
09
09
09
09
09
Time starting Fri Apr 01 09:00:00 1988 (hours)
NOTE :- Solid line is Observed & Dotted line is Modelled

FIG 8

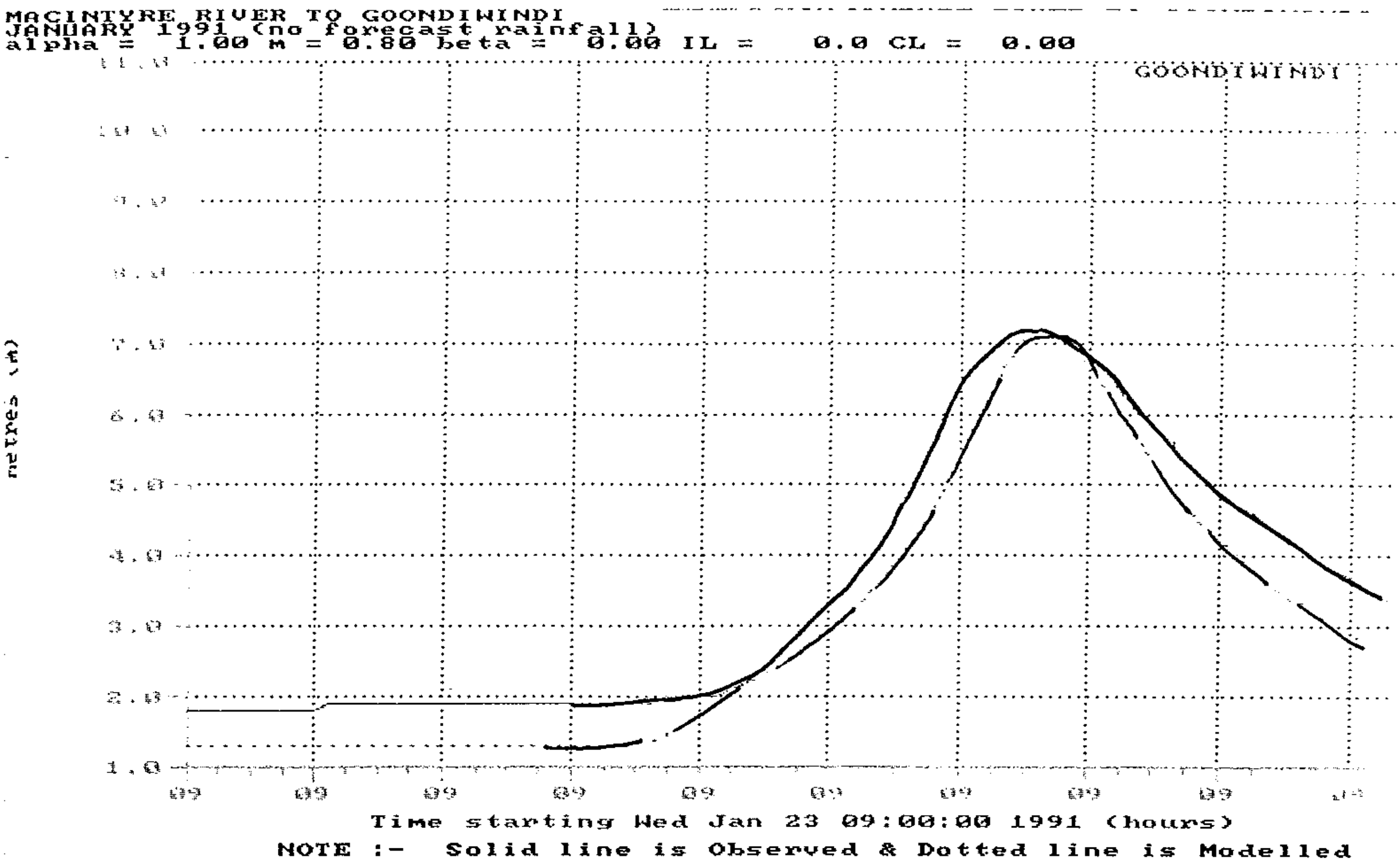
ACINTYRE RIVER TO GOONDIWINDI
PRIL 1990 (no forecast rainfall)
lpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00



Time starting Fri Apr 20 09:00:00 1990 (hours)

NOTE :- Solid line is Observed & Dotted line is Modelled

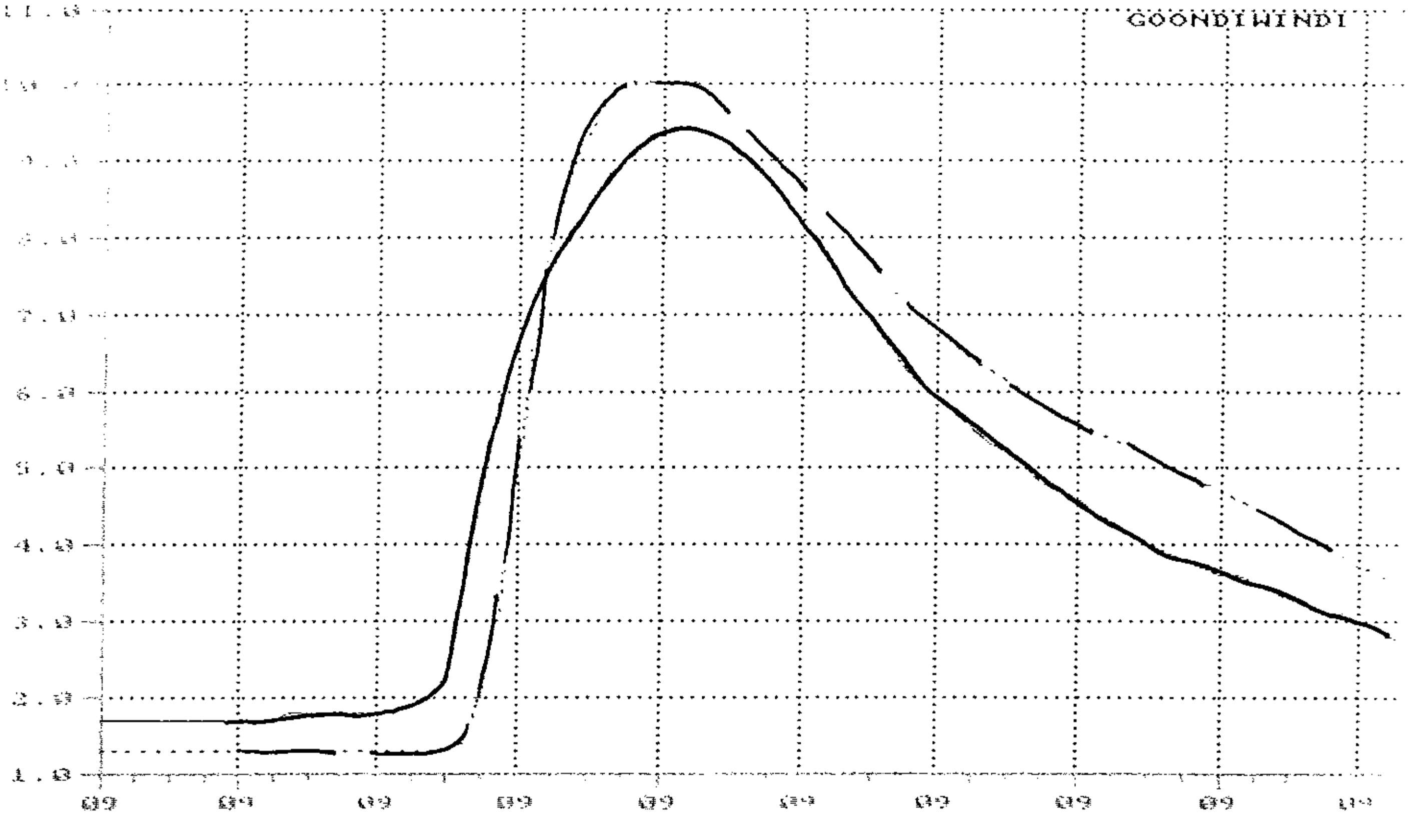
FIG 9



MACINTYRE RIVER TO GOONDIWINDI
JANUARY 1991 (no forecast rainfall)
alpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00
GOONDIWINDI
metres (m)
Time starting Wed Jan 23 09:00:00 1991 (hours)
NOTE :- Solid line is Observed & Dotted line is Modelled

FIG 10

ACINTYRE RIVER TO GOONDIWINDI
EBRUARY 1991 (no forecast rainfall)
lpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00



Time starting Wed Feb 06 09:00:00 1991 (hours)

NOTE :- Solid line is Observed & Dotted line is Modelled

FIG 11

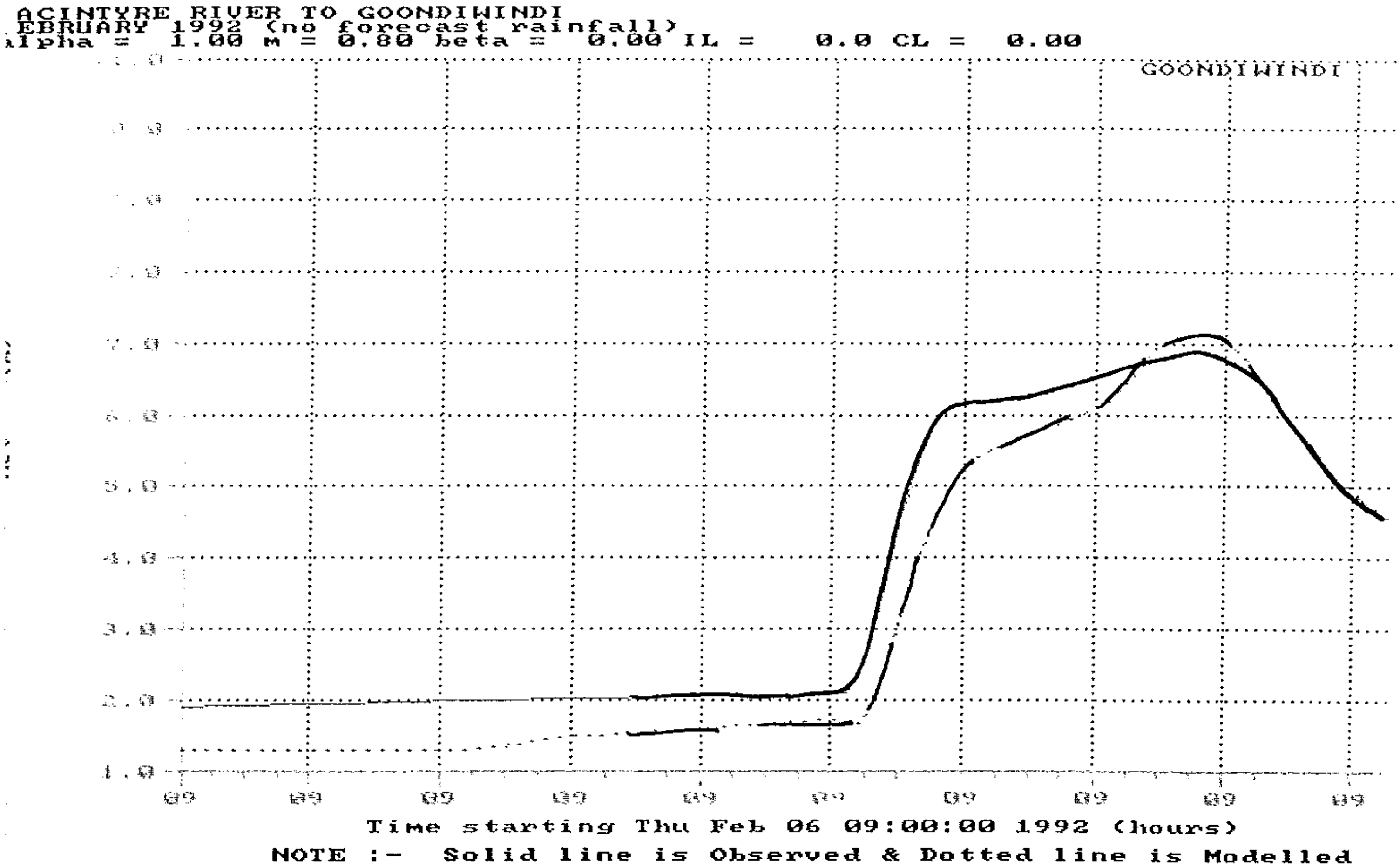
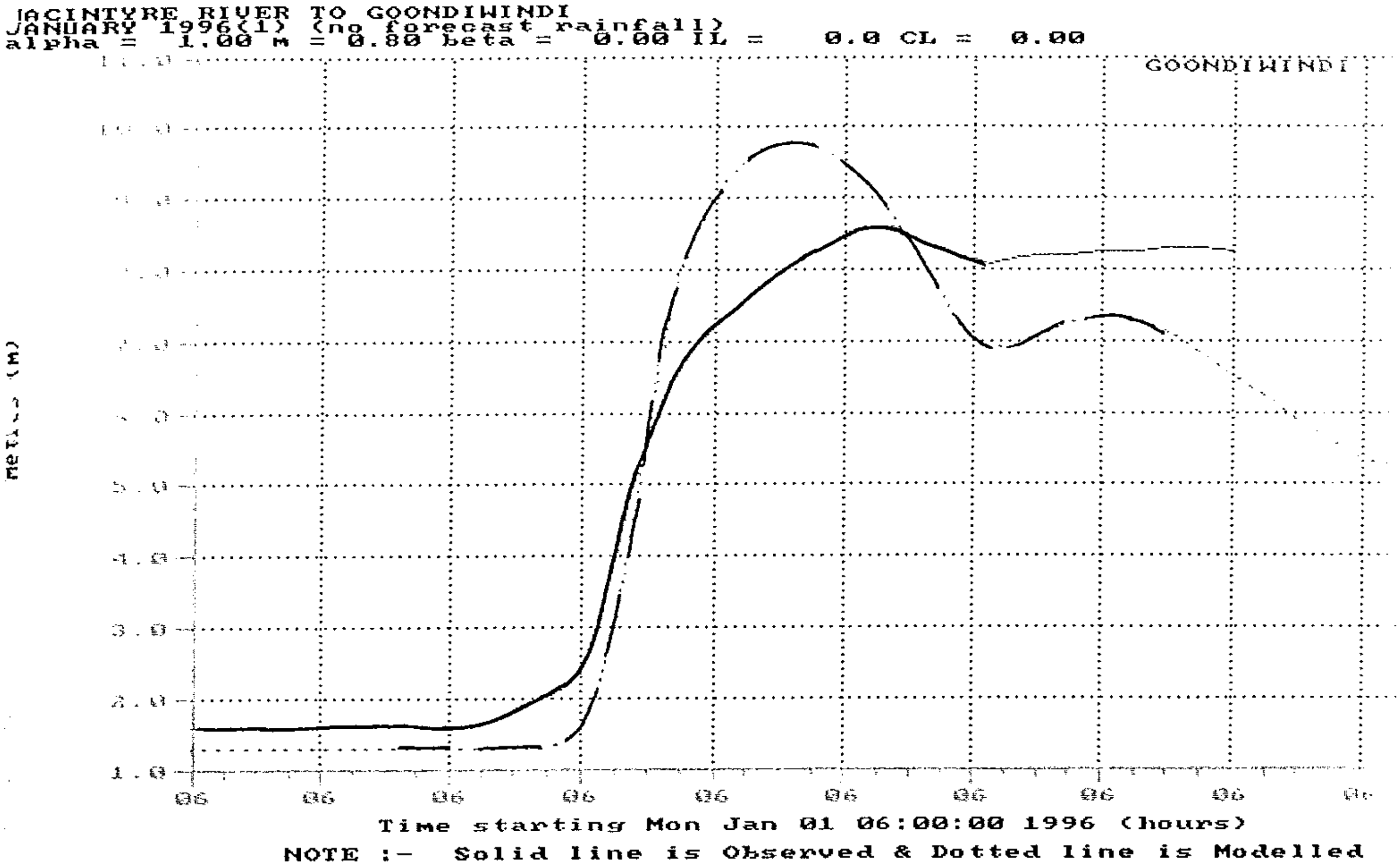

ACINTYRE RIVER TO GOONDIWINDI
EBRUARY 1992 (no forecast rainfall)
lpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00
GOONDIWINDI
7.0
6.0
5.0
4.0
3.0
2.0
1.0
09
Time starting Thu Feb 06 09:00:00 1992 (hours)
NOTE :- Solid line is Observed & Dotted line is Modelled

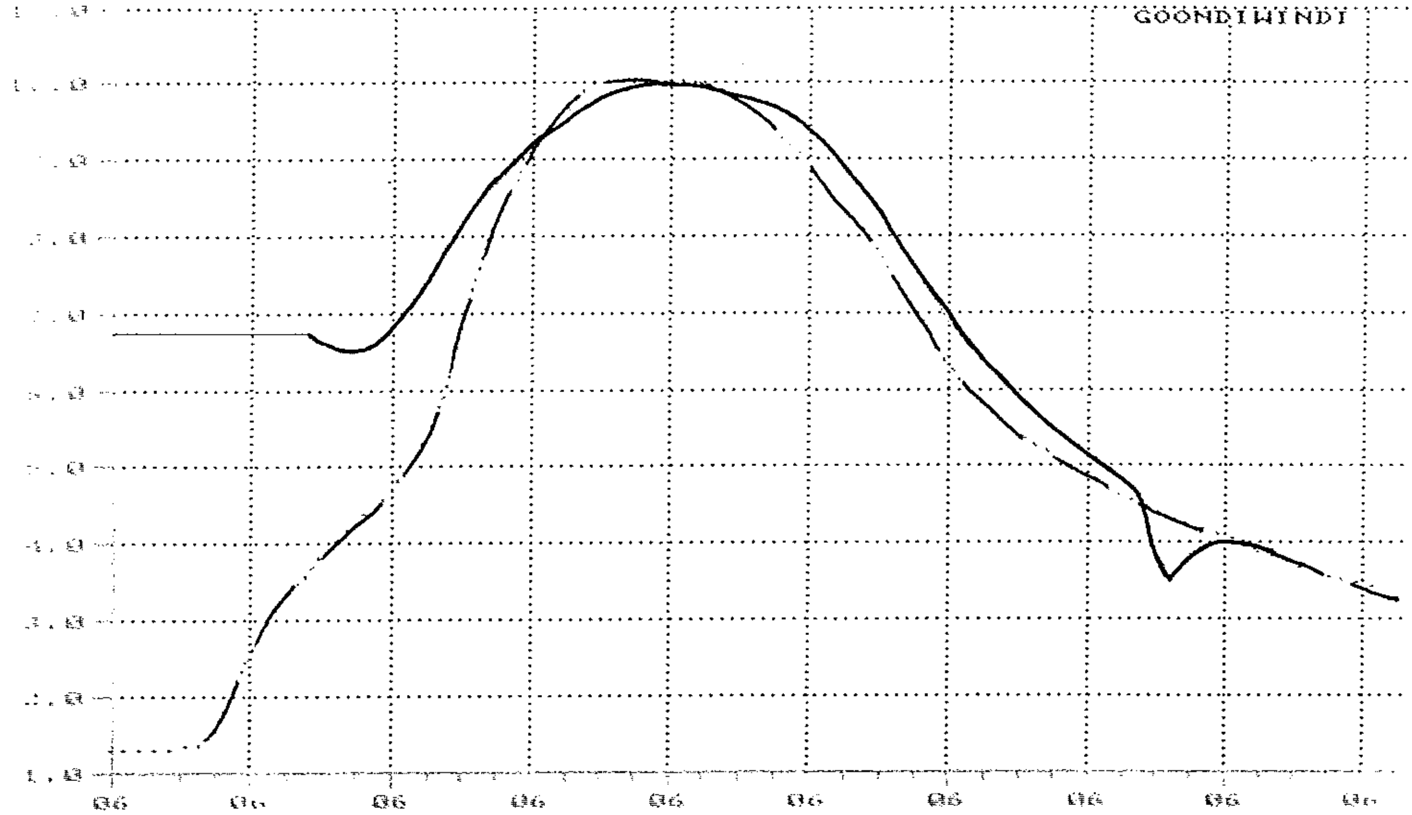
FIG 12



MACINTYRE RIVER TO GOONDIWINDI
JANUARY 1996(1) (no forecast rainfall)
alpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00
GOONDIWINDI
5.0
4.0
3.0
2.0
1.0
06
Time starting Mon Jan 01 06:00:00 1996 (hours)
NOTE :- Solid line is Observed & Dotted line is Modelled

FIG 13

ACINTYRE RIVER TO GOONDIWINDI
ANUARY 1996(2) (no forecast rainfall)
lpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00



Time starting Mon Jan 08 06:00:00 1996 (hours)

NOTE :- Solid line is Observed & Dotted line is Modelled

FIG 14

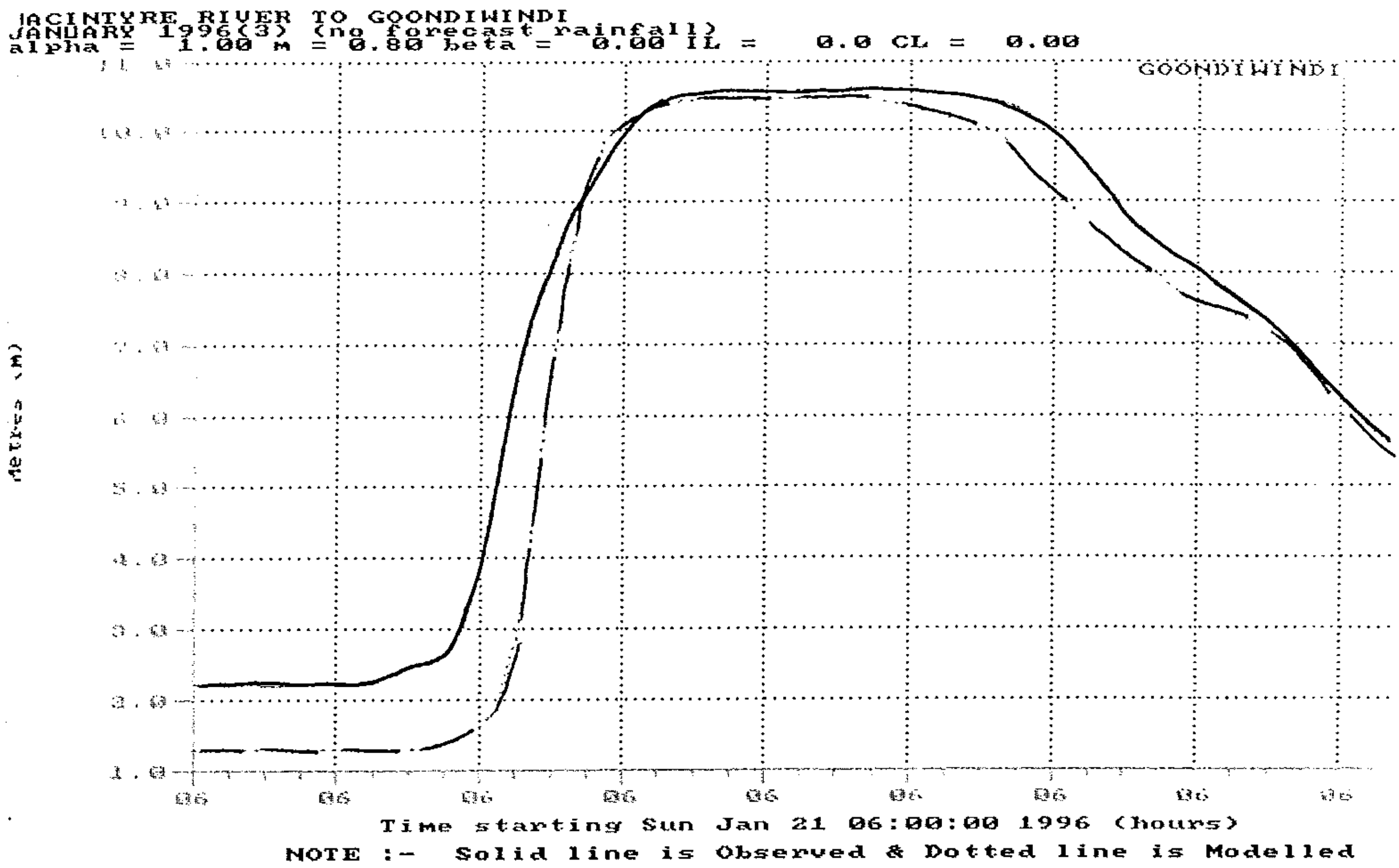
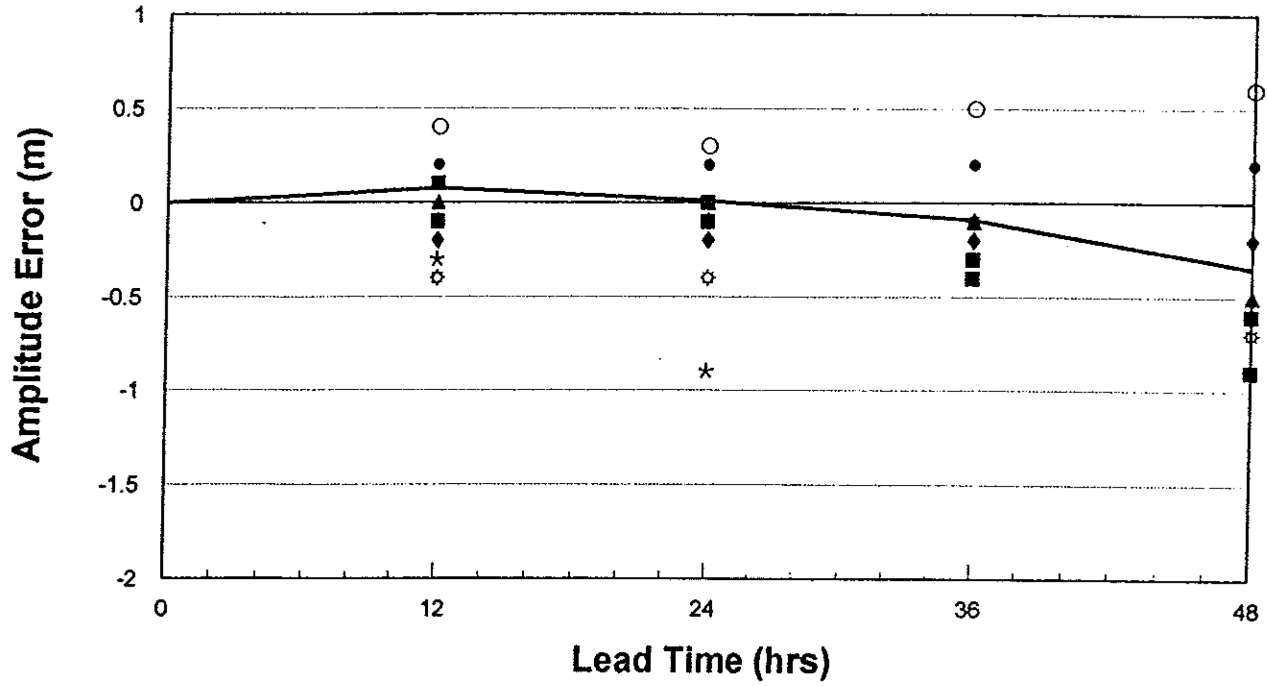
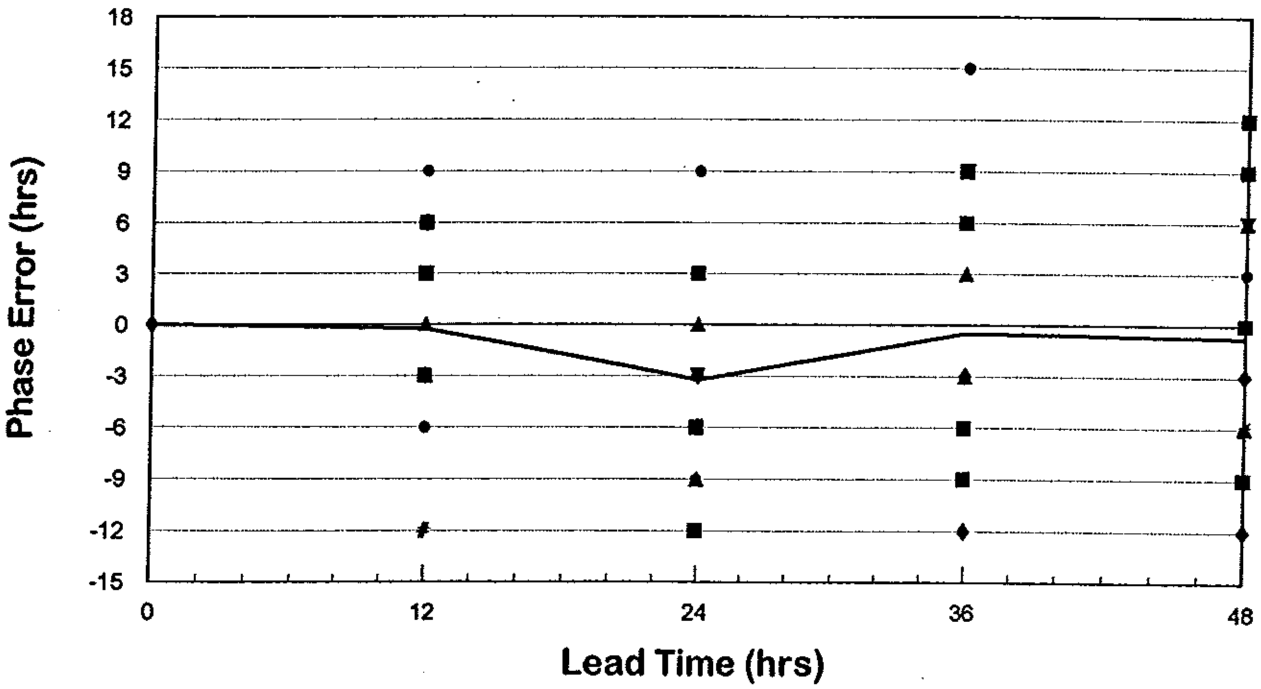

JACINTYRE RIVER TO GOONDIWINDI
JANUARY 1996(3) (no forecast rainfall)
alpha = 1.00 m = 0.80 beta = 0.00 IL = 0.0 CL = 0.00
GOONDIWINDI
Metres (m)
5.0
4.0
3.0
2.0
1.0
06
Time starting Sun Jan 21 06:00:00 1996 (hours)
NOTE :- Solid line is Observed & Dotted line is Modelled

FIG 15

Goondiwindi URBS Model

Average Forecast Accuracy





Matched at all available TMs upstream of Kildonan

FIG 16

Cardno
Lawson Treloar

GOONDIWINDI ENVIRONS

FLOODING INVESTIGATION

March 2007
Job No. LJ8651/R1_V3

Waggamba Shire Council

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APPENDICES

1. INTRODUCTION

This study has been prepared for Waggamba Shire Council (WSC) by Cardno Lawson Treloar (CLT) to assess the extent of flooding in the Goondiwindi Environs and the associated levels of hazard resulting from flooding for existing and future residential development, and to assist in floodplain risk management planning for the future growth of the township of Goondiwindi.

The study forms part of a package of investigations being undertaken under the National Disaster Risk Management Studies Programme run by the Australian Government Department of Transport and Regional Services, with funding from the Australian and State Governments, and the local authorities of Waggamba Shire Council (WSC) and Goondiwindi Town Council.

The overall study comprises the undertaking of airborne laser survey, numerical flood modelling, flood mapping and flood mitigation assessment. The study area encompasses land within a 12 km radius of Goondiwindi, referred to as the Goondiwindi Environs.

The Airborne Laser Survey has been undertaken under a separate component of the study by AAM-Hatch, and the resultant survey has been a major input to this flood investigation study.

This flood report is one of the first steps in floodplain risk management planning and provides the necessary background information to identify the level of risk, possible mitigation options and possible evacuation routes. These outputs will help WSC to plan future development and form a basis for disaster and rescue plans for WSC, Goondiwindi Shire Council and the Department of Emergency Services.

2. EXISTING LEVEES AND FUTURE DEVELOPMENT

The Goondiwindi Environs cover the township of Goondiwindi and its near surroundings. It is situated in Queensland, adjacent to the New South Wales border, approximately 400 km south west of Brisbane. The Goondiwindi Environs is bounded by the Macintyre River to the south, Callandoon Creek to the west and Piggy Piggy Creek and the Weir River to the east and north.

The township is on the northern bank of the Macintyre River, which flows in a westerly direction past the township and drains a catchment of approximately 6,900 sq.km. The Macintyre River catchment is part of the "Border Rivers" drainage basin which also includes the Weir and the Dumaresq Rivers. This system eventually drains into the Barwon River before joining the Murray Darling System.

2.1 Levee System

The township has experienced flooding in the past, predominantly from the Macintyre River, and hence has had a levee protection system in place for some time. During the 1976 flood, the levee was overtopped by about 100mm at Kildonan Road and floodwaters were lapping the crest of the levee system at other localised sections. Subsequent to the 1976 flood the levee system was raised. Further levee raising and construction also occurred based on recommendations included in flooding investigations carried out by the Department of Local Government in 1985 and by Lawson and Treloar in 1998 and from information gathered following the 1996 flood.

Previous assessments have indicated that the township levee is currently at a sufficient height to exclude an AEP 1%, or 1 in 100 year flood (Lawson and Treloar, 1998). Levee banks have 500 mm freeboard to a 1976 size flood event, which is one of the largest floods on record at Goondiwindi.

2.2 Future Residential Development

There is currently considerable development pressure for urban land within the Goondiwindi Environs area. Waggamba Shire Council has provided a study area for possible future residential development, as shown on Figure 1.1. The study area comprises the direct northerly surroundings of the township of Goondiwindi. Some of these areas are outside the direct protection of the existing levee system or the natural banks. Hence, part of the study area could be potentially flood prone land.

3. PREVIOUS INVESTIGATIONS AND GUIDING PRINCIPLES

3.1 Previous Investigations

Waggamba Shire Council (WSC) has, for over 20 years, been actively involved in floodplain management in the Border Rivers, through powers vested under the Local Government Act. Council's aim has always been to support sustainable development in an equitable manner, without creating adverse impacts on other landholders and stakeholders in the floodplain, or on the environment.

WSC was the first local government authority in Queensland to initiate full floodplain management, which commenced in 1985 with identification of key floodways throughout the Shire using historical events and in particular, the 1984 floods. Sinclair Knight Merz, using broadbrush and qualitative techniques, undertook this analysis with the result contained in 'Border Rivers Flood Plain Management Study' (1987). The primary objective of this study was the determination of a set of development guidelines for the Border Rivers floodplain region contained within Waggamba Shire.

In early 1990 WSC took the initiative to apply one of the first fully scientifically based floodplain studies in Queensland. Connell Wagner was commissioned to carry out an Hydraulic Analysis of Proposed Levee Banks in the Callandoon Creek Area of the Border Rivers Floodplain. This study was conducted using state of the art RUBICON hydraulic modelling software.

The RUBICON model was used successfully for several years to manage floodplain development and to effectively preserve floodways, until in 1997, pressures for development beyond the Callandoon Creek area meant that the RUBICON model extent was insufficient and extension was required.

In 1997, WSC applied for and received funding under the National Land Care Program to extend the hydraulic model to cover the Border Rivers floodplain from upstream of Boggabilla to downstream of Mungindi. An extensive photogrammetric survey of the Borders Rivers floodplain was carried out over the hydraulic model extents.

This survey, along with supplementary main channel survey was used by Lawson and Treloar (L&T) to build a new, more detailed and more extensive flood model, based on the quasi two-dimensional MIKE 11 modelling system, from the Danish Hydraulic Institute (DHI). This hydraulic model, at the time, was at the leading edge of technology, in terms of size. The model was completed and adopted for development assessment in late 1998.

This model was also utilised to obtain floodplain flow distributions. However, with improvements in technology and because of the availability of a full floodplain terrain model (based on the photogrammetric survey) by early 1999 and property specific ground survey, all development application assessments were being carried out by Council using full two-dimensional local area models, as a sub-part of the full floodplain model. Flows for the local two dimensional sub-models were obtained from the full floodplain MIKE11 model (Danish Hydraulic Institute (DHI), 2001).

In addition the 1998 flood showed an unexpected high water level at the Goondiwindi Gauge. L&T was commissioned by WSC to investigate possible causes of the increased flood levels at the Goondiwindi Gauge as well as causes of erosion at the entrance of Callandoon Creek. For this investigation L&T build a full two dimensional MIKE 21 (Danish Hydraulic Institute (DHI), 2003) Macintyre River (Boggabilla to Dingo Creek) model.

The MIKE 21 model showed that the 1998 MIKE 11 model had over-estimated the amount of flow breaking out of the Macintyre River upstream of Goondiwindi and flowing north around Goondiwindi. Subsequently, L&T updated the MIKE 11 model to make it more consistent with flows predicted by the more detailed MIKE 21 model investigation.

In 2002 a hydraulic impact assessment was undertaken by CLT on behalf of WSC and Goondiwindi Town Council for several town levee failure scenarios. The outcomes of this study were the basis for the Goondiwindi Township Disaster Risk Management report. This report considered the risk to the existing township and environs areas of a failure of the town levee bank system, but did not deal specifically with major river flooding constraints beyond the existing leveed portion of the town.

3.2 WSC Guidelines for Floodplain Management

Any new development or levee works needs to comply with Waggamba Shire council local law no. 26 (levee banks) 2002.

Performance Objectives described in the local law include:

P1 – Floodways possess adequate hydraulic capacity and continuity to enable the orderly passage of flood water through the floodplain.

P2 – Floodway systems conform as closely, as is reasonable, to the natural drainage pattern.

P3 – Flood peak levels and timing are not unduly affected by the proposal.

P4 – Velocities of flow will be minimised and will be of an order that will not cause erosion under various land uses including cultivation.

P5 – There will not be any detrimental impact on any individual landholder or community infrastructure as a result of the proposal.

P6 – The risk of a proposed Levee Bank failing and causing hazards to people or property must be acceptable to the community

Recommended Measures that are relevant for this study are as follows

M1 A continuous network of core floodways is to be retained, including all river, creek and waterway main channels.

M2.1 The exit of flood water from floodways should be at rates and depths similar to those which would have been experienced under natural conditions and should discharge as close as practicable to the location of natural floodways.

M3.1 Sufficient pondage will be retained on the floodplain so that the flood peak is not significantly accelerated (ie. no significant change in flow time from Boggabilla to Mungindi) to downstream areas or its height increased.

M4.1 Velocities of flood flow in floodways will not be greater than 1m/s within all land the subject of a Permit application.

M5.1 The increase in maximum peak water level measured at the property boundaries for the land the subject of a Permit application compared to existing and pre-floodplain development (no levees) peak water levels is to be an absolute maximum of 200mm under a range of floods.

3.3 Floodplain Risk Management Guiding Principles

In relation to risk management, urban communities in South East Queensland have specified a requirement for 100 year flood immunity and additional freeboard for habitable floor levels. This is also established by the Standing Committee in Agricultural and Resource Management Report No. 72, 2000, entitled 'Floodplain Management in Australia Best Practice Principles and Guidelines'. Risk management is also considered by Department of Emergency Services in their 'Disaster Risk Management' publication by Zamecka and Buchanan (1999). The New South Wales Government Floodplain Management Manual (2001) is also a useful reference, stating current best practice in relation to flood management.

In relation to emergency services, evacuation emergency planning under more severe events beyond the 100 year flood event needs to be considered. In New South Wales, it is a requirement that assessment be made of the 0.5% AEP flood event up to the probable maximum flood in this regard. Hence, a requirement of this study is to consider such severe and extreme events.

4. AIM OF THE STUDY

The primary study aim has been to prepare a detailed flood study, which in turns relies upon a detailed two-dimensional hydraulic model along the Macintyre River, encompassing the existing township and its protection levee system, and future potential growth areas within 12 kilometres of the town centre.

This model has been calibrated against historical flooding events of 1976 and 1996 and used to assess flood extents for a number of design events. The model results have been used to assess hazard levels for existing and future development associated with the flooding events. Subsequently, mitigation options have been investigated to reduce the hazards levels.

The desired key outcomes for this investigation are:

- Development of a new flood model of the entire Goondiwindi Environs, encompassing the existing township and its protection levee system, and future potential growth areas within 12 kilometres of the town centre;
- Assessment of flood inundation extents, depths and durations of key historic events (1976 and 1996) and an assessment of the appropriate event for determination of habitable floors;
- Provision of flood maps for selected design events;
- Identification of hazards and risks associated with the modelled floods;
- Consideration of two key mitigation options;
- Provision of a database of flood information including depths and risk, to assist Council in their planning activities for the future; and
- Assistance with emergency / evacuation planning.

5. STUDY APPROACH

CLT has carried out this investigation using a full two dimensional flow modelling analysis and the following general methodology:

- Interrogate existing models for flood inflow hydrograph and downstream tailwater conditions to provide boundary conditions for the new Goondiwindi Environs (GE) flood model.
- Establish a new flood model of the GE area using:
  - New Airborne Laser Survey undertaken by AAMHatch;
  - Updated 1999 Heilbronn photogrammetric survey of the Border Rivers Floodplain;
  - Ground survey of the Goondiwindi Town Levee (July 2006); and
  - Below water (bathymetric) sections of the river.
- Calibrate the GE model to the 1976 and 1996 historic events.
- Undertake a flood frequency analysis of Goondiwindi and Boggabilla gauge information.
- Simulate the following design events:
  - 'Half of 1976' floods (a currently used design floods);
  - AEP 5%, 2% and 1% design events using Boggabilla gauge data;
  - AEP 0.2% and 0.5% design event by extrapolating the Boggabilla gauge results; and
  - An approximate Probable Maximum Flood (PMF), assumed to be twice the magnitude of the 1976 flood.
- Prepare flood maps for three key design flood events over the GE Area.
- Assess mitigation requirements (e.g. levee extensions and raising) including impacts, of two selected mitigation options.
- Identify flood hazards.
- Review previous detailed Goondiwindi levee failure risk assessment carried out by CLT.
- Identify key evacuation routes, stage/times and appropriate refuge locations to assist in emergency planning and management.

6. HYDROLOGY

6.1 Historical Flood Data at Boggabilla and Goondiwindi Gauges

As part of this study historical flood information was sought to gain an understanding of previous flood history and flood patterns as well as for model calibration purposes.

The major flooding events in February 1976 and January 1996 were used for calibration of the model.

Flood level and flow information associated with the Boggabilla and the Goondiwindi stream gauges, with station numbers 416002 and 416201A respectively, had previously been obtained as part of the Border River Floodplain Hydraulic Analysis.

The locations of the Boggabilla and Goondiwindi gauges are shown on Figure 1.1. The Goondiwindi gauge is located at the bridge over the Macintyre River located at the junction of Macintyre Street and McLean Street.

The Boggabilla gauge is situated approximately one kilometre downstream of the township of Boggabilla. The Boggabilla gauge has been chosen as the upstream boundary of the 2D model. The historical flood data of the Boggabilla Gauge has therefore been critical in calibrating the model and assessing design flows. It should be noted that the Gauge at Boggabilla has undergone three significant changes since it was established in 1895. The first changes were in gauge zero in 1924 and 1937. The Boggabilla Weir, completed in 1991, rendered this gauge ineffective due to ponding behind the weir. Hence, a new gauge was established in October 1991 downstream of this weir.

6.2 Historic Events of 1976 and 1996

Flood flows associated with the 1976 and 1996 Macintyre River events have been obtained from the rated stream gauging station at Boggabilla (Station Number 416002).

The rated flows indicated the following:

- 1976 event – 3241m3/s
- 1996 event – 3308m3/s

As the rated flows did not relate to the recorded flood levels, a joint calibration using the 2D hydraulic model was undertaken to obtain a more accurate flow rating. This calibration provided the following peak flow at the stream gauge for the corresponding peak gauge levels.

Table 6-1 Boggabilla Peak Discharges – Historic Events

Flood	Recorded Water Level (mAHD)	Peak Discharge (m^3/s)
1976	221.27	2760 – ✓
1996	220.99	2280

6.3 Design Events

The Boggabilla stream gauge has 101 years of height and rated flow records. A flood frequency analysis based on peak annual floods and using a Log Pearson III distribution was undertaken with the 1976 and 1996 flood events amended in accordance with the rating provided by the hydraulic model.

The distribution is shown in Appendix A and design event flows are presented below.

Table 6-2 Boggabilla Peak Discharges – Design Events

ARI (years)	AEP (%)	Peak Discharge (m^3/s)
2	50	576
5	20	1157
10	10	1582
20	5	1996
50	2	2526
100	1	2912
200	0.5	3284
500	0.2	3754

6.4 Probable Maximum Flood (PMF)

A PMF of 5520 m^3/s, twice the 1976 flood magnitude, has been assumed based on previous studies by the NSW Department of Infrastructure, Planning and Natural Resources (DIPNR).

Note:
In assessing design floods detailed above, it is important to recognise the highly complex nature of flooding at Goondiwindi, which can be caused by flooding in four separate stream systems, each of which can independently cause flooding. Hence, all studies of flooding to date by both NSW and QLD authorities have recognised that it is impractical to consider all individual and combination events. For this reason the investigations have been limited to specific historic events and local gauge derived design events. Similarly, the application of a Probable Maximum Precipitation (PMP) approach is considered equally impractical; hence DIPNR's approach to the PMF.

7. HYDRAULIC MODELLING

7.1 Modelling Software

The hydraulic analysis was performed with the aid of the computer program SOBEK, version 2.09.004 SOBEK is a hydrodynamic package developed by Delft Hydraulics in the Netherlands.

The model can simulate steady and unsteady hydrodynamic flow in two directions on a rectilinear grid. It is based on a robust finite difference scheme able to compute both subcritical and supercritical flow regimes.

The SOBEK model is suited for simulation of dynamic hydraulic behaviour of overland flow over initially dry land. Based on this and its supercritical solving ability the SOBEK modelling system was considered the most appropriate investigative tool.

7.2 Model Construction

7.2.1 Model Topography

Three topographic maps have been used in the analysis. The first topographic map has been used for calibration of the 1976 event. It has the original Macintyre River alignment without the Boggabilla Weir (Refer Figure 2.1). The second map has been used for calibration of the 1996 flood event. It incorporates the Boggabilla Weir and the new associated river alignment (Refer Figure 2.2). The last map reflects the new aerial laser survey topography for Goondiwindi and its surroundings. This case has been used for the design events (Refer Figure 2.3).

The model topography has been discretised into 20m square grid elements.
The extent of the hydraulic model is shown on Figure 1.1.

7.2.2 Levee systems

In each of the topographic maps the following three levee systems were incorporated.

Goondiwindi Levee System
The height of the Goondiwindi Township Levee was incorporated into the model using the 2006 ground survey data.

New South Wales Levee systems
The location of levee systems in New South Wales are based on existing and approved levees as described in the Guidelines for Macintyre River and Whalan Creek Flood Plain Development Boggabilla to Mungundi (Water Resources Commision – NSW – 1981).

In the SOBEK model it is assumed that no overtopping of the levee systems in New South Wales occurs during extreme events up to the PMF event. However, in reality some of the levees in New South Wales may overtop during extreme events and minor overtopping may occur during the AEP1% event. More detailed ground survey of the top of the levee banks will be required to determine this.

With the NSW levee heights adopted in the SOBEK model as described above, a conservative approach has been applied for the extreme events. Even allowing for this assumption, for flood events up to the AEP 1% event the impact of the levee heights on peak water levels will be limited.

NSW Local Levee System opposite Goondiwindi Township

One particular area of interest is a local levee system located opposite Goondiwindi Township, on the New South Wales side of the Macintyre River, approximately in line with Marshall Street. This levee forms part of a local water distribution network and managed to block the 1976 and 1996 Macintyre River floods. In the SOBEK model the height of this local levee system is set at a conservative (high) level of RL 218.5mAHD. For a scenario where this local levee system is removed, it is estimated that peak water levels can be reduced by 0.03 to 0.05 metres for the PMF event. Such removal would have very little effect on flooding of the Goondiwindi Township and the proposed works.

7.2.3 Boundary Conditions

Inflow boundaries for the historic events of 1976 and 1996 were determined as described in Section 6.2. Design event discharges have been estimated using a flood frequency analysis (Refer to Table 6.2).

Tailwater conditions in the SOBEK model were controlled by a discharge/water level (Q/H) relationship at the downstream boundary of the model based on normal depth conditions.

Downstream model boundaries were set at a distance which will have a negligible influence on peak water levels in the areas of interest, such as the study area for possible future development and the existing levee system of the Goondiwindi Township.

7.2.4 Roughness

The spatial variation of roughness was incorporated into the model by assigning each grid element an individual Manning's 'n' roughness value.

Model roughness (Manning's n) values were chosen based on generally accepted roughness values for different landuses. The roughness values used are shown below in Table 7.1. A general Mannings 'n' value of 0.05 was adopted, mostly for the grassed / grazing floodplain areas.

Table 7-1 Typical Roughness Values Adopted

Land Use	Manning's 'n' Value
Flood Plain Trees	0.05 – 0.08
Flood Plain Cleared Land	0.05
Macintyre River	0.03
Creeks	0.04 - 0.08
Local Ponds	0.025
Built up area (buildings)	0.20
Roads	0.02

7.3 Model Calibration

Calibration was undertaken using 2 historic flood events, the major event in 1976 and 1996, as discussed in Section 6. Models have been calibrated to recorded peak flood levels.

Tables 7.2 and 7.3 compare available historic data and calibrated model results for the 1996 and 1976 events respectively. The 1996 and 1976 models have been calibrated to the recorded water levels at the Boggabilla and the Goondiwindi Gauges. Also two flood marks were found at the Millers residency for the 1996 event during the 2006 levee survey.

These flood marks are located on the downstream section of the model, along the Macintyre River (Refer to Figure 1.1 for the location of these additional flood marks).

Table 7-2 Calibration Summary 1996 event

Location	Gauge zero (m AHD)	Recorded Depth (m)	Recorded Level (m AHD)	Modelled Level (m AHD)	Difference (m)
Gauge Boggabilla	208.48	12.513	220.99	221.01	+ 0.02
Gauge Goondiwindi	207.56	10.615	218.18	218.19	+ 0.01
Millers Flood Mark			215.73 215.75	215.70	- 0.03 - 0.05

For the 1976 event additional information was found in the report "Investigation of Flooding at Goondiwindi" prepared by the Engineering & Technical Services Division for Goondiwindi Town Council in December 1985. A recorded water level at the most upstream location of the Goondiwindi Town Levee has been used specifically for the calibration of the 1976 model (refer Figure 1.1 for location of 1976 Flood Mark).

Table 7-3 Calibration Summary 1976 event

Location	Gauge zero (m AHD)	Recorded Depth (m)	Recorded Level (m AHD)	Modelled Level (m AHD)	Difference (m)
Gauge Boggabilla	208.48	12.8	221.27	221.27	+ 0.00
Gauge Goondiwindi	207.56	10.5	218.06	218.17	+ 0.11
Upstream of Goondiwindi Levee	--	--	219.88	219.88	+ 0.00

It should be noted that the hydraulic model incorporates current (as of 2006) topography including farming levees. Some of these levees, especially in the floodplain area south of Goondiwindi, may not have existed in 1976, impacting on flow distribution within the floodplain. It is therefore considered the 1976 calibration result is reasonable taking into account this uncertainty.

7.4 Design Events

Design event hydraulic modelling was run using the calibrated SOBEK model in conjunction with the calculated design discharges as discussed in section 6.3.

7.5 Model Results and Figures

For the historic events of 1996 and 1976 and for the design events the following model results are included in the Figure section at the end of this report:

- Peak water levels combined with flow patterns;
- Peak water depth combined with flow patterns;
- Hazard maps (as described in following Section 7.6)

Table 7.4 shows the flows and predicted water and gauge levels at the Goondiwindi and the Boggabilla gauge (1996 location) for the two historic events of 1976 and 1996 and for the design events.

Table 7-4 Predicted Water Levels and Flows in Sobek

Event	Boggabilla Gauge			Goondiwindi Gauge		
	Flows	Water Levels	Gauge Levels	Flows	Water Levels	Gauge Levels
AEP	(m^3/s)	(m. AHD)	(m. AHD)	(m^3/s)	(m. AHD)	(m. AHD)
5%	1996	220.91	12.43	1310	218.16	10.60
1996*	2280	221.02	12.54	1380	218.19	10.63
2%	2526	221.09	12.61	1430	218.21	10.65
1976**	2760	221.15 ***	12.67	1430	218.17	10.61
1%	2912	221.2	12.72	1500	218.24	10.68
0.5%	3284	221.3	12.82	1561	218.27	10.71
0.2%	3754	221.41	12.93	1636	218.30	10.74
PMF	5520	221.78	13.30	1857	218.41	10.85

* Based on 1996 Topography
** Based on 1976 Topography
*** Predicted water level at existing Boggabilla Gauge location.

7.6 Hazard maps

Provisional Hydraulic Hazard Categories – as defined in the Figure G2 (Appendix G) of NSW Floodplain Management Manual (2001), have been calculated through and around the township for the historic events of 1976 and 1996 and for each design event.

The Provisional Hazard Categories include definitions of:

- 'High' Hazard,
- 'Moderate' Hazard, and
- 'Low' Hazard.

Areas of high hazard indicate possible danger to personal safety as wading and evacuation by trucks becomes difficult. There will also be the potential for structural damage to buildings. Areas of low hazard indicate that able bodied adults should be able to wade without difficulty and evacuation by trucks should be possible. In areas defined as the transition zone the degree of hydraulic hazard is dependent on its landuse (NSW Floodplain Management Manual).

Definitions of these categories can also be found in the glossary in section 15.

It should be noted that these definitions are appropriate for able-bodied adults only. In the case where children, elderly or disabled persons are affected by floodwaters the hazard categorisation of 'Low' is likely to be upgraded to 'High'.

8. FLOOD RISKS TO BE MANAGED

In development of a floodplain risk management plan, three specific flood risks need to be addressed:

Existing Risk
The control of flood damage and personal danger to the existing community and properties at risk (Refer to section 8.1).

Future Risk
The control of flood damage and personal danger in areas yet to be developed (Refer to section 8.2).

Continuing Risk
The control of flood damage and personal danger associated with management measures being overwhelmed by a larger flood than the flood used to design management measures, and / or those areas outside the "protected" area.

To address the risks a floodplain management plan should aim to achieve an appropriate mix of measures. There are four groups of management measures:

- Structural flood mitigation measures (refer to section 9);
- Land use controls (property modification measures);
- Development and building controls (property modification measures);
- Flood emergency management measures (refer to section 10).

8.1 Existing Risk

The township is protected by a levee system. The results of this study show that no severe flooding of the existing township occurs for events up to a 0.2% AEP event, provided that (minor) overtopping of the levee system doesn't lead to erosion or a breach of this levee system.

Severe overtopping of the levee system does occur during a PMF event, in particular on the north eastern levee banks along Brigalow Creek and on the south eastern levee banks along the Macintyre River. Locations where overtopping occurs during the 1% and the 0.2% AEP Event are marked in Figure 1.3.

Areas of high risk within the township during this PMF event are:

- The area around Jabiru Drive/Jacaranda Drive/George Street, partially surrounded by Serpentine Lagoon.
- Koloma Home for the Aged.
- Between Albert and Moffatt Streets.

Refer to Figure 1.2 for these locations.

8.2 Future Risk

Figure 1.1 shows the study area for possible future development. The results of this flood study show that the northern and eastern side of the study area is inundated to depths of 1.0 to 2.0 metres in the floodplain, and locally up to 5.5 metres in Brigalow Creek.

Similarly, the majority of this part of the study area is in the high hazard category for all events.

Safe locations in the study area are located:

- East of the airport and south of Crooked Creek;
- Around Brennan Road.

Refer to Figure 1.3 for these safe future development areas.

9. IMPLEMENTATION OF STRUCTURAL MEASURES

In this investigation the following structural flood modification options were examined:

- Extension of the levee system around the airport, to allow for transport by air even during severe flooding, when access by roads may be blocked.
- Raising the levees to prevent the township from being flooded in a 1% AEP event; and
- Raising the levees to prevent the township from being flooded in a 0.2% AEP event.

9.1 Proposed New Levee Height

Figure 1.4 shows the proposed new levee height based on the 1% AEP Peak Flood Levels and a proposed freeboard of 300mm in relation to the existing levee heights, surveyed in July 2006. Figure 1.4 also shows the 0.2% AEP Peak Flood Level with no freeboard.

The 0.2% flood levels are in general lower than the new proposed levee height, except for some locations on the eastern banks along Brigalow Creek.

9.2 Impacts of Structural Measures

The purpose of the proposed measures is to provide a higher level of safety for the inhabitants within the levee protected area.

The proposed measures will still need to comply with WSC guidelines for floodplain management as described in section 3.2. As can be seen on Figure 14.4 the increase in peak water level in the floodplain is well within the stated 200 mm range for a 1% AEP event.

The highest increase in peak water levels for the 1% AEP event occurs near the proposed extension of the levee system around the airport, with peak water levels rising up to 140 mm on adjacent properties east of the Cunningham Highway.

Raising the levee system along Brigalow Creek results in impacts of up to 40 mm. Raising the levee system along the Macintyre River shows no adverse impacts for the 1% AEP event.

10. FLOOD PLANNING LEVELS

An important aspect of a floodplain risk management study is the selection by Council of flood planning levels (FPLs) to be used for risk management purposes in the floodplain risk management plan.

The flood planning levels used for planning control purposes is derived from a combination of the adopted flood level plus freeboard, as explained below.

Adopted Flood Level
Flood Planning Levels used to be based on the biggest recorded flood, which for the Goondiwindi Environs was the 1976 flooding event. The Flood Study indicates that this 1976 flood was an event with an AEP less than 1% (refer to Section 6).

At this time, the 1% AEP Flood has become the most common basis for FPL's used in Australia, particularly for residential development in urban areas. It is proposed to adopt the 1% AEP Flood as the new basis for future flood planning levels for the Goondiwindi Environs. The choice of the 1% AEP will result in a requirement for higher habitable floor and road levels, than for the 1976 flood.

Freeboard
The purpose of freeboard is to cater for uncertainties in the estimation of flood levels across the floodplain, localised hydraulic behaviour, impacts that are related to a specific event, embankment or levee settlement, and other effects such as climate change. In effect, freeboard acts as a factor of safety, however, it should never be relied on to provide protection against floods larger than the flood used to derive the FPL. Any added protection is a bonus, not a guarantee.

Local guidelines used by Councils in South East Queensland required a freeboard of 300 to 500 mm.

The Queensland Urban Drainage Manual (Neville and Jones, 1995) and Australian Rainfall and Runoff (the Institution of Engineers, 1998) recommend 300mm freeboard.

For the Goondiwindi Environs 300mm freeboard corresponds to a large amount of additional flow through the relatively large floodplain. Hence, it is considered appropriate from a hydraulic perspective to adopt a freeboard of 300mm.

10.1 Habitable Floor Levels Future Development

It is recommended that habitable floor levels for future development be set at the 1% AEP Flood Level with an additional freeboard of 300mm.

10.2 Habitable Floor Levels and Road Levels Brennan Road

To set future habitable floor and road levels for the Brennan Road area two flooding scenarios have been investigated using the 2D SOBEK model.

External Flooding from Macintyre River
This scenario assumes that the Brennan Road area is inundated due to a failure / a breach of the levee system during a 1% AEP flood in the Macintyre River. Peak water levels over the main part of the Brennan Road area are at 214.86m AHD (Refer to figure 11.1).

Local Rainfall Flooding

Since the Brennan Road area has no natural point of discharge, there is potential for excessive pondage in the Brennan Road area during extreme rainfall events. This scenario has been tested with the SOBEK 2D model.

The size of the catchment area that contributes is assessed at approximately 180 ha. The extent of the catchment area is shown in Figure 12.1.

The probable maximum precipitation (PMP) has been determined for a range of storm durations. A 12 hour PMP storm has been found to be critical. This event has 0.66 m. of rainfall, enough to pond the Brennan Road area, which then starts draining in a northerly direction to a local tributary of Callandoon Creek.

Peak water levels over the main part of the flooded Brennan Road area are at 215.23m AHD (Refer to figure 12.1).

From the results detailed above, the extreme local rainfall burst produces higher peak flood levels. However, when freeboard considerations are taken into account, there is little difference between the required levels for extreme local rainfall bursts (with no freeboard) and for Macintyre River 1% AEP flooding events (with freeboard):

1% AEP External Flood + 300 mm. freeboard	= 215.16 m AHD
PMP peak flood level	= 215.23 m AHD

Hence, a minimum habitable floor level of RL 215.2m AHD is recommended for this area.

11. FLOOD EMERGENCY RESPONSE AND EVACUATION

Flood emergency management consists of:

- Flood warning;
- Mobilisation of emergency services, and
- Evacuation (if required).

This section describes flood emergency management strategies for severe flooding events with occurrence of:

- Overtopping of the levees, and
- Levee failures.

Levee Failure scenarios are based on the previously reported Levee Failure Study ("Goondiwindi Township Disaster Risk Management Report", J7803/R2, February 2003, Cardno Lawson Treloar). All figures from this report can be found in the reference section of this report.

11.1 Flood Warning

The Bureau of Meteorology manage an ALERT flood warning system for the Border Rivers, including flooding at Goondiwindi.

Given the large catchment of the Macintyre River, warning times are generally more than a day; however, once water levels reach within a metre of overtopping levees, increased frequency of monitoring and review of evacuation requirements should occur.

11.1.1 1% AEP Event Warning Times in the Flood Plain

With the SOBEK 2D model it is assessed how long it takes for a 1% AEP design flood to fill the floodplain. Appendix B shows flow rates and water levels at the Boggabilla and Goondiwindi Gauges for this 1% AEP Flood Event.

Based on the rising limb of the 1976 flooding event, it is assumed that a 1% AEP Flood can rise from a relative small flow (25 m^3/s) to its peak discharge of 2912 m^3/s in a time of 48 hours. Within those 48 hours, the entire floodplain of the Goondiwindi Environs is flooded. Refer to Appendix B1 for the exact shape of this 1% AEP flood at the Boggabilla Gauge.

The 1% AEP flood shows the following flooding process:

- When water levels in the Macintyre River rise above RL 217.25m AHD at the Goondiwindi Gauge, a break out of the Macintyre to the floodplain south of Goondiwindi is likely to occur. Within 12 hours after a flood reaching this gauge height, this part of the floodplain could be completely inundated.
- When water levels in the Macintyre River rise above RL 220m AHD at the Boggabilla Gauge, a break out of the Macintyre River to the north is getting more likely to occur and evacuation of inhabitants within the flood plain east and north of Goondiwindi will be required. Within 24 hours after a flood reaching this gauge height, this part of the floodplain could be completely inundated.

Figure 8.4 shows the inundation of the floodplain in time steps of 4 to 8 hours from the moment the 1% AEP flood commences at Boggabilla. Priorities should be based on flooding times, as shown in Figure 8.4.

11.1.2 PMF Event Warning Times in the Township

Figure 5.4 shows what areas are inundated in the township in time steps of 6 to 12 hours during a PMF event after the first overtopping of the levees occurs. Most of the township is inundated within 12 to 18 hours after the first overtopping of the levee system occurs during the PMF flood.

11.1.3 Levee Failure Warning Times in the Township

In terms of warning times in the event of a levee bank failure, Figure 6 in the reference section of this report, shows broad indicative zones of 1, 3 and 6 hour times to flood.

11.2 Emergency Services Mobilisation

Mobilisation for assistance from the SES can occur through residents contacting the SES or through the Queensland Police activating the response where emergency services are mobilised in accordance with the findings of this Report.

In case of a levee failure, or overtopping of the levees during a severe flooding event (PMP), the following three services are surrounded with depths of around 0.5 metres:

- The Fire Brigade Station on the corner of Herbert and Bowen Streets;
- The Ambulance Station on the corner of Marshall and Frideswide Streets;
- The Police Station on the corner of Herbert and Brisbane Streets.

It is therefore important to ensure that all three emergency services receive priority notification to ensure vehicles can exit the site prior to inundation.

The police station is immediately adjacent to higher, flood-free land.

11.3 Evacuation

Details of evacuation are listed here in terms of:

- Priorities;
- Routes; and
- Centres.

The need to evacuate will be identified by the SES who issues evacuation warning messages. These messages will normally take the following form (SES, 1995):

- Time of issue and title of Authorising Officer,
- Description of the area to which the warning applies and the flood threat to that area, and
- Information on:

- Location of and route to evacuation centre,
- Time by which evacuation should occur, and
- Arrangements for those without their own transport.

SES volunteers should ensure that:

- Residents raise furniture above the likely flood level;
- Residents secure buildings and vehicles. It is advisable to remove all vehicles from properties unless secured against movement during floods;
- Where practical, floatable objects are suitably secured to prevent debris or environmental impacts;
- Where practical and safe, that electrical hazards are minimised by turning off and disconnecting all appliances and equipment;
- All evacuees register at the closest/most convenient evacuation centre, and
- No individuals remaining within properties are unaware of the need to evacuate and the method of evacuation.

11.3.1 Evacuation Priorities In The Floodplain

Areas that are not protected by the existing or the proposed extended levee system require habitable floor levels up to PMF peak water levels for all new development, rather than evacuation.

For existing properties Council will need to undertake extensive floor level survey, before the actual need for evacuation can be assessed. It is not practical to raise existing road levels in flood prone areas. Hence for safe evacuation it is required to start evacuation procedures at the early stages of flooding.

The Brennan Road area doesn't need direct evacuation, provided the levee banks don't breach or fail, since this area is not inundated during the PMP event

11.3.2 Evacuation Priorities In The Township

The cause of flooding influences the maximum available time to evacuate and is therefore of direct relevance to the priority order to evacuate.

When the levees of the township overtop during a PMF sized flood, the list of evacuation of residents should be based on Figure 5.4, with time zones indicating the priority of evacuation.

However, should a levee breach or fail, than the proposed order of evacuation priority is as follows.

- Residences within 50 metres of the levee breach — Priority 1
- Kaloma Home for the Aged — Priority 2
- Hospital* — Priority 3
- 1 Hour time to flood zone ** — Priority 4
- 3 Hour time to flood zone ** — Priority 5

- 6 Hour time to flood zone ** Priority 6

* If at Risk of Flooding, due to levee failure
** Refer to Figure 6 in the Reference Section of this report.

It should be noted that the pattern of levee failure may change the order in which flooding occurs. Clearly, any houses in the immediate vicinity of a levee breach must be evacuated, because of the potential for high hazard should flood height reach the breach height. Monitoring of river levels relative to breach height is critical.

The list of evacuation priorities is based on the age, health and likely number of people within a particular area, as well as the concentration of people within a small area (such as a school or retirement village).

Unless additional structural measures are put in place to protect the Kaloma Home for the Aged, because of its low level and proximity to the main drainage path from the township, evacuation immediately after a levee breach will need to be a priority.

11.3.3 Evacuation Routes

Figure 7 in the reference section shows critical evacuation routes, possible evacuation refuge centres and zones feeding each centre.

Local refuges are suggested at the Golf Club, the Community Centre and around River Gums Drive. As long as the levees don't breach or fail, these local refuges are safe (dry) locations. In case of (multiple) levee breach failures, the airport could potentially be the only sizable area actually free from flooding.

11.3.4 Evacuation Centres

Possible locations of evacuation centres have been identified as part of the Levee Failure Study ("Goondiwindi Township Disaster Risk Management Report", J7803/R2, February 2003, Cardno Lawson Treloar) to assist with the identification process, and are shown in Figure 7 in the reference section of this report. This figure also shows feeder zones for each centre.

Some locations that would otherwise be suitable for evacuation actually lie within the floodplain. Likely areas of refuge within the floodplain or located where access may be compromised include:

- Goondiwindi Community Centre,
- Goondiwindi Golf Club, and
- High ground around River Gums Drive.

A review of the suitability of these facilities should be undertaken by the Disaster Management Committee.

11.4 Post Flood Recovery

Following a flood, a number of activities will ensue:

- Once flood waters recede, the SES are to advise residents when they may return to their properties.
- Council and other relevant authorities will need to arrange for restoration or clean up of public assets.

Following a flood it is important to collate as much data as possible close to the event. For example, data to be collected include:

- Photographs/video of flooding;
- Rainfall;
- Weather patterns;
- Flood levels;
- Flood velocities;
- Number of persons evacuated and location of evacuation;
- Insurance claims and damage cost estimates (separated into private residences, businesses and public utilities);
- Effectiveness of evacuation plan, and
- Effectiveness of flood warning systems.

12. CONCLUSIONS

This study has been prepared for Waggamba Shire Council (WSC) by Cardno Lawson Treloar (CLT) to assess the extent of flooding in the Goondiwindi Environs and the associated levels of hazard resulting from flooding for existing and future residential development, and to assist in floodplain risk management planning for the future growth of the township of Goondiwindi.

The overall study comprises the undertaking of airborne laser survey, numerical flood modelling, flood mapping and flood mitigation assessment. The study area encompasses land within a 12 km radius of Goondiwindi, referred to as the Goondiwindi Environs.

This flood report is one of the first steps in floodplain risk management planning and provides the necessary background information to identify the level of risk, possible mitigation options and possible evacuation routes. These outputs will help WSC to plan future development and form a basis for disaster and rescue plans for WSC, Goondiwindi Shire Council and the Department of Emergency Services.

The hydraulic model that was built for the hydraulic flooding investigation was based on accurate survey data and has been calibrated and validated against the recorded water levels for the historic flooding events of 1996 and 1976 recorded, in particular for the Boggabilla and the Goondiwindi Gauge.

The Flood Study indicates that the largest flood on record in the Goondiwindi Environs, the 1976 flood, was a flood event with an AEP less than 1%. As the flood model has been calibrated to this event and the smaller 1996 event, it is considered results for design events up to the 1% AEP are within acceptable confidence limits.

A flood frequency analysis was used to estimate design flooding events ranging from 5% to 0.2% AEP event, which have consequently been investigated with the new SOBEK 2D model.

The model results have been used to assess peak water levels, peak water depths and hazard levels for each design event. Mitigation scenarios have been investigated, consisting of raising levees and extending the existing levee system around the airport. The hydraulic impacts of these mitigation options have been assessed and comply with the allowable maximum 200mm raise of peak water levels for a 1% AEP event.

New levee heights and future flood planning levels are proposed based on the 1% AEP event flood levels and an additional recommended 300mm freeboard.

Safe future development areas in the study area are located east of the airport, south of Crooked Creek and around Brennan Road.

Flood emergency management strategies have been described based on the model results, and have been compared to the previously undertaken Levee Failure Study ("Goondiwindi Township Disaster Risk Management Report", J7803/R2, February 2003, Cardno Lawson Treloar).

Future studies and work by Council will utilise the findings of this investigation to refine future planning for growth in the Goondiwindi Environs, and to refine emergency flood management procedures for the town and surrounding area.

13. REFERENCES

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14. LIMITATIONS AND QUALIFICATIONS

This report has been prepared by CLT specifically for WSC and specifically to provide advice on the flooding characteristics of the Macintyre River at the Goondiwindi Environs.

Our analysis and overall approach has been specifically catered for the particular requirements of WSC, and may not be applicable beyond this scope. For this reason any other third parties are not authorised to utilise this report without further input and advice from CLT.

CLT has relied on the following studies and information prepared by others:

- 3D terrain information and survey provided by AAMHatch.
- 3D ground survey data of the existing levee system (July 2006) provided by SMK Consultants Pty Ltd.
- Limited historic flood levels and flows at the Department of Infrastructure, Planning & Natural Resources (DIPNR) Boggabilla stream gauge and at the Department of Natural Resources and Mines (DNRM) Goondiwindi stream gauge.
- Photogrammetry carried out for the Border Rivers Floodplain Hydraulic Analysis (BRFHA) Study.

The accuracy of the report is dependent on the accuracy of this information.

Future observed flood levels may vary from the predicted levels in this report depending on the characteristics of the catchments, rainfall, channels and floodplain.

In particular caution is required in use of events larger than the 1976 flood, since no historic data exists for such events. The nominal PMF event used in this study is based on the NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) approach. This approach has been applied to previous studies, but is not based on PMP analysis.

15. GLOSSARY OF TERMS*

Annual Exceedence Probability (AEP)
Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be relatively large.

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

Cadastre, cadastral base
Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.

Catchment
The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.

Design flood
A significant event to be considered in the design process; various works within the floodplain may have different design events. e.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.

Development
The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.

Discharge
The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.

Flash flooding
Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.

Flood
Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.

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

Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. The maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning levels (FPL)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severity's. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodways	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.

Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Moderate hazard	A transition zone between low and high hazard. The dregree of hazard is dependant on site conditions and the nature of the proposed development.
Peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probable Maximum Precipitation (PMP)	The greatest depth of precipitation for a given duration meteorologically possible for a given size storm at a particular location at a particular time of year.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedence Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

FIGURES

Cardno Lawson Treloar

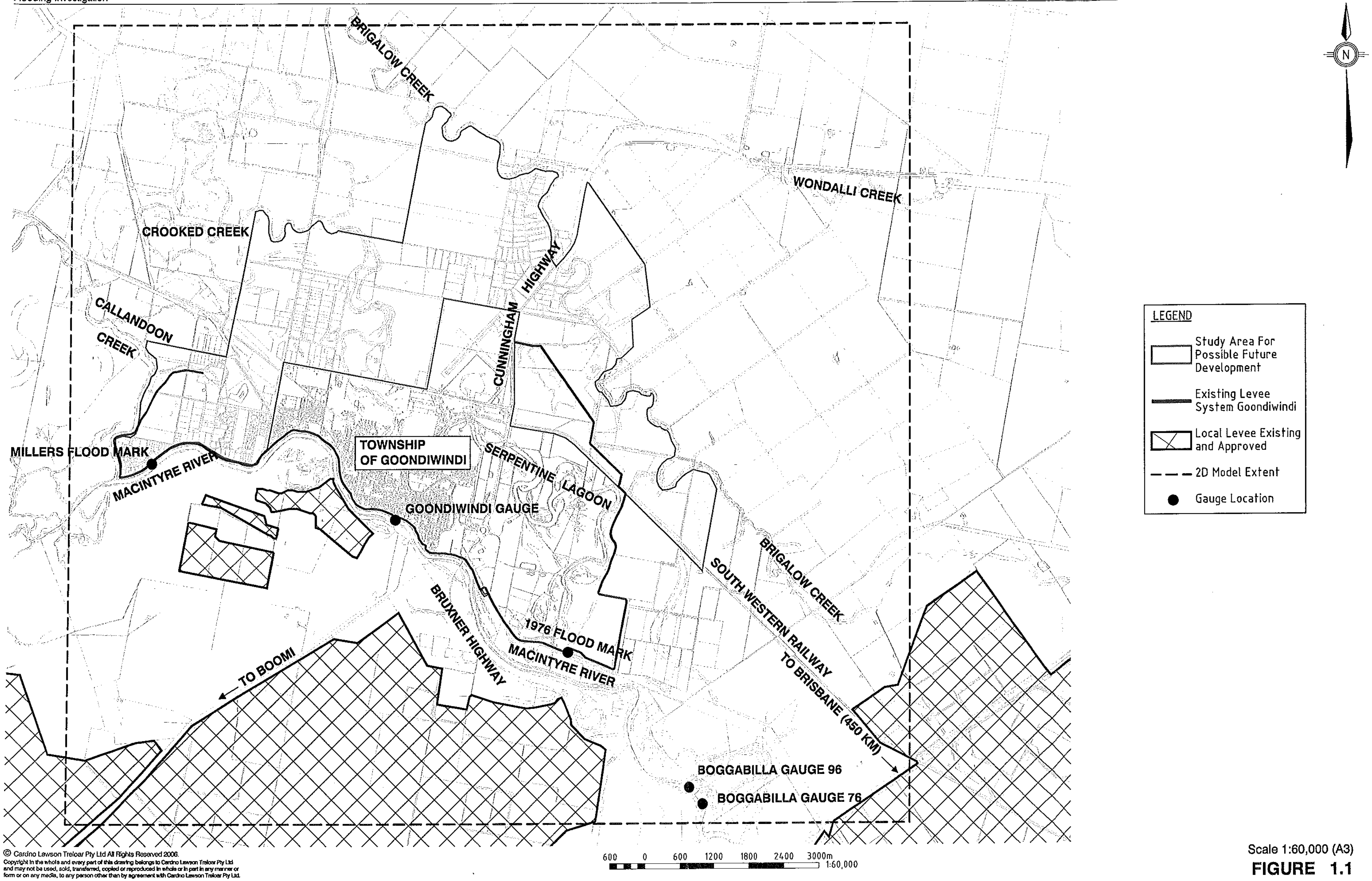

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FIGURE 1.1

STUDY AREA POTENTIAL FUTURE RESIDENTIAL DEVELOPMENT AND MODEL EXTENT

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 3:26pm

Rev: Orig. Date: March 2007

Waggamba Shire Council

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Cardno Lawson Treloar

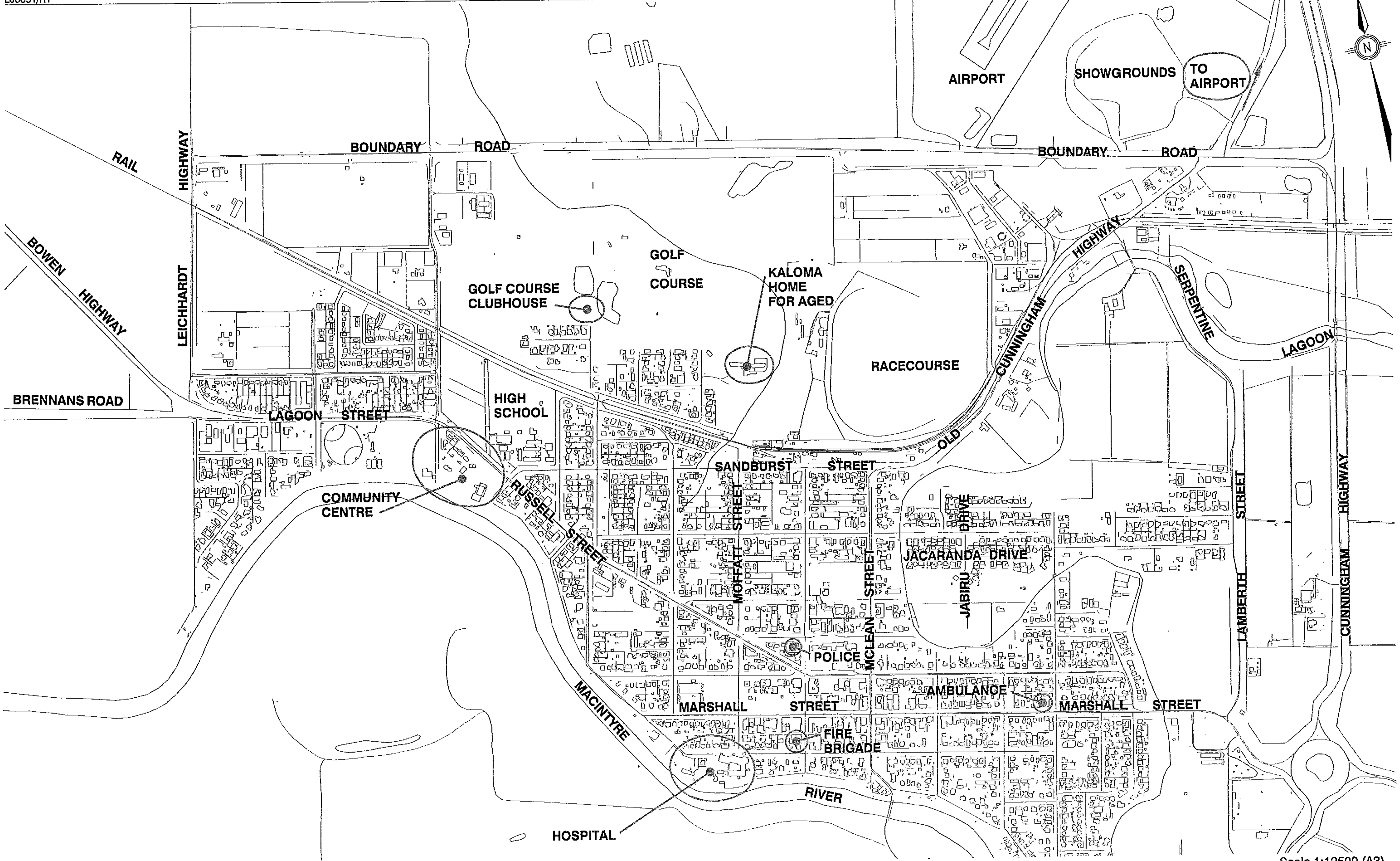

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FIGURE 1.2

EXISTING RESIDENTIAL AREA AND REPORTING REFERENCE POINTS

Rev: Orig. Date: March 2007

Project No.: LJ8651

PRINT DATE: 29 March, 2007 - 3:27pm

Waggamba Shire Council

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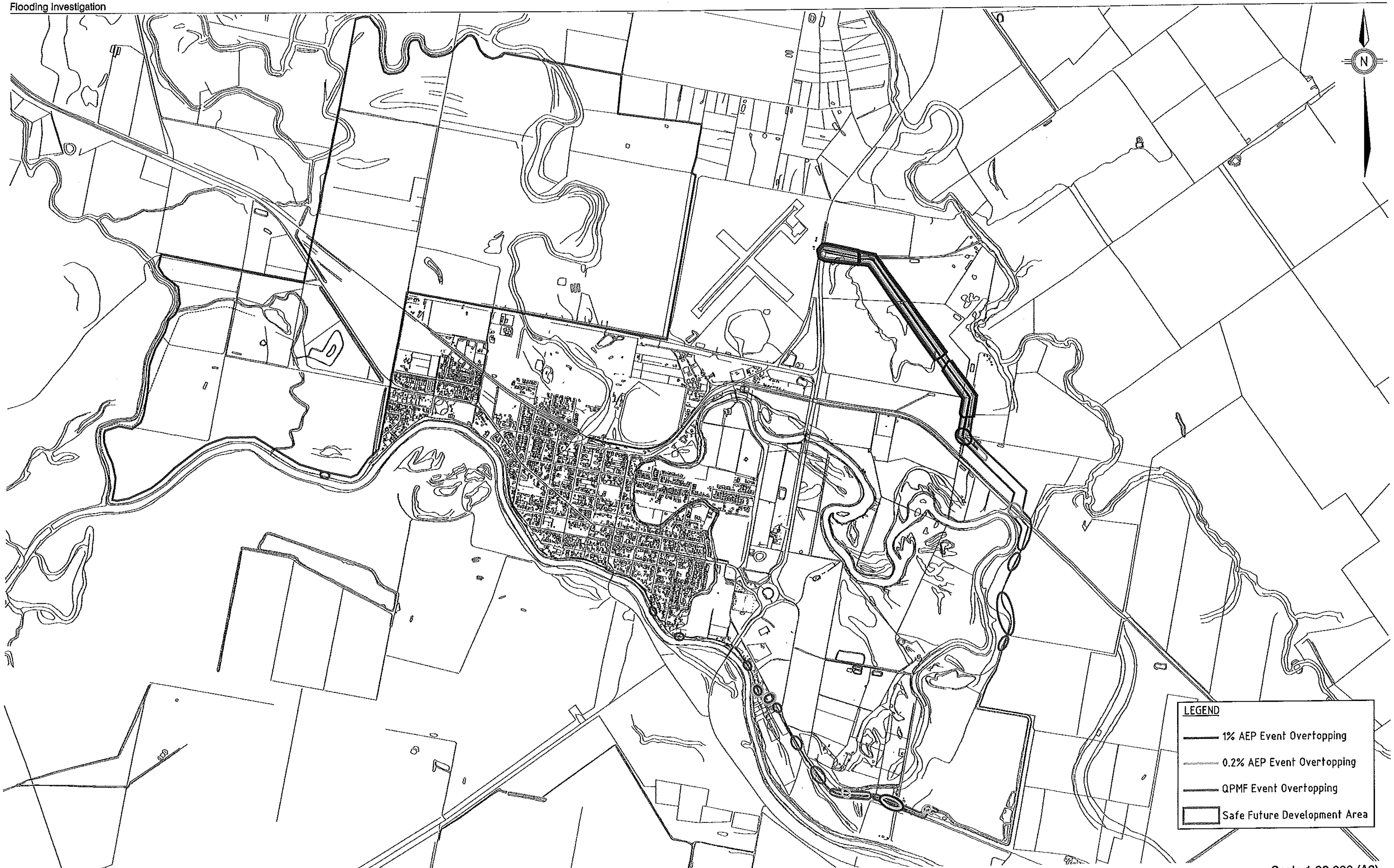

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FIGURE 1.3

OVERTOPPING OF LEVEE SYSTEM AND SAFE FUTURE DEVELOPMENT AREAS

Project No.: J8651/R1

PRNT DATE: 29 March, 2007 - 3:37pm

Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 1.3 Overtopping.dwg

Cardno
Lawson Treloar

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Scale 1:30,000 (A3)

FIGURE 1.4

0.2% AEP PEAK WATER LEVELS AND PROPOSED AND EXISTING LEVEE HEIGHTS

Rev: Orig. Date: March 2007

Project No.: J8651/R1

PRINT DATE: 29 March, 2007 - 3:37pm

Waggamba Shire Council

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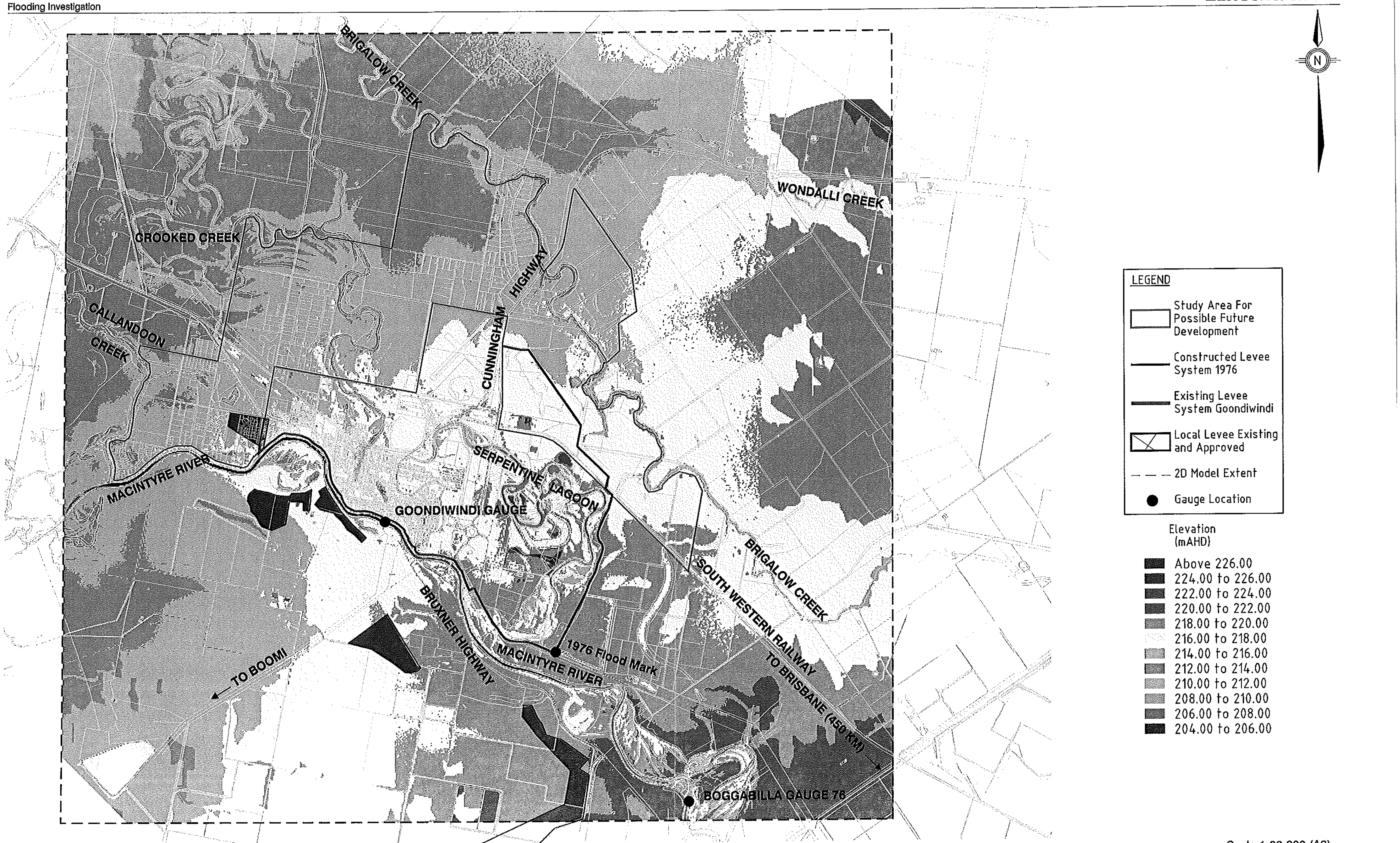

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FIGURE 2.1

1976 FLOODING EVENT - TOPOGRAPHIC MAP AND LEVEE LOCATIONS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

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PRNT DATE: 29 March, 2007 - 3:41pm

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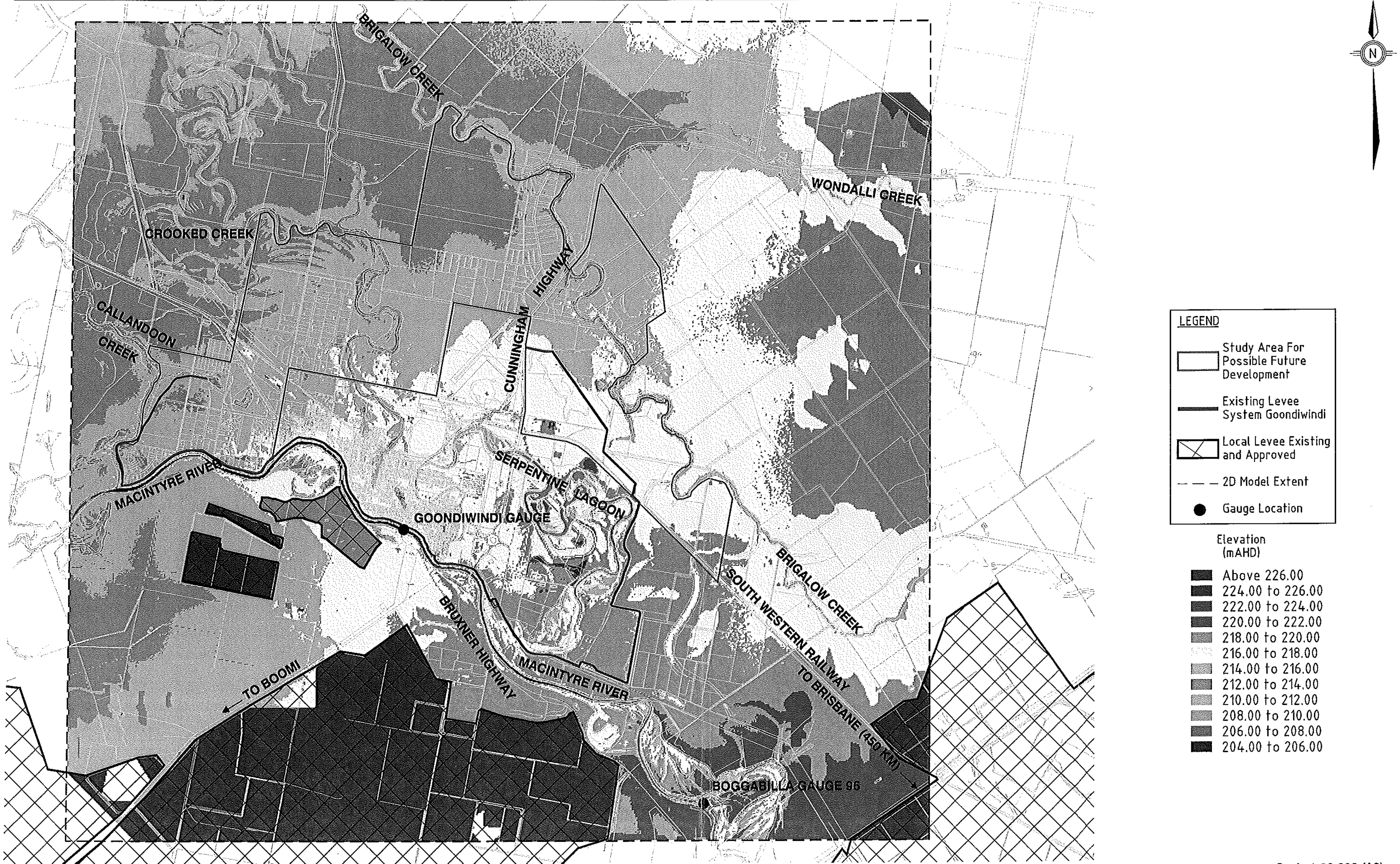

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FIGURE 2.2

1996 FLOODING EVENT - TOPOGRAPHIC MAP AND LEVEE LOCATIONS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 4:02pm

Waggamba Shire Council
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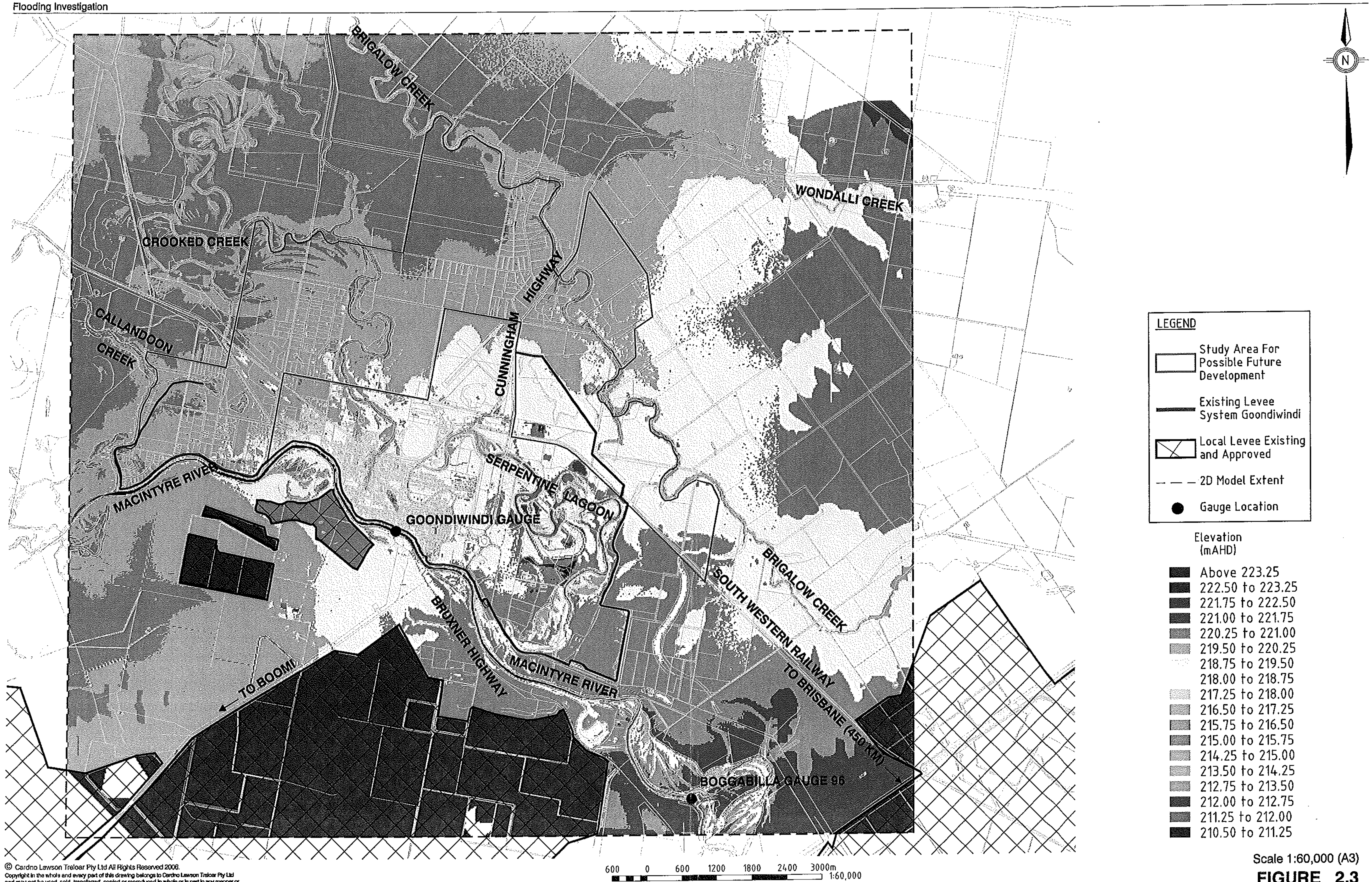

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FIGURE 2.3

DESIGN FLOODING EVENT - TOPOGRAPHIC MAP AND LEVEE LOCATIONS

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 3:56pm

Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\Rev3\Figure 5 2006 PMF.dwg
XREF's J7803FigureBase; Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Cardno Lawson Treloar

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Local Rainfall Catchment Brennans Road

Elevation (mAHD)

- Above 226.00
- 224.00 to 226.00
- 222.00 to 224.00
- 220.00 to 222.00
- 218.00 to 220.00
- 216.00 to 218.00
- 214.00 to 216.00
- 212.00 to 214.00
- 210.00 to 212.00
- 208.00 to 210.00
- 206.00 to 208.00
- 204.00 to 206.00

Scale 1:20,000 (A3)

FIGURE 2.4

LOCAL PMP FLOODING BRENNANS ROAD - TOPOGRAPHIC MAP AND LEVEE LOCATIONS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

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PRNT DATE: 29 March, 2007 - 3:47pm

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Scale 1:60,000 (A3)

FIGURE 3.1

1976 FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 3:45pm

Rev: Orig. Date: March 2007

Waggamba Shire Council

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Cardno Lawson Treloar

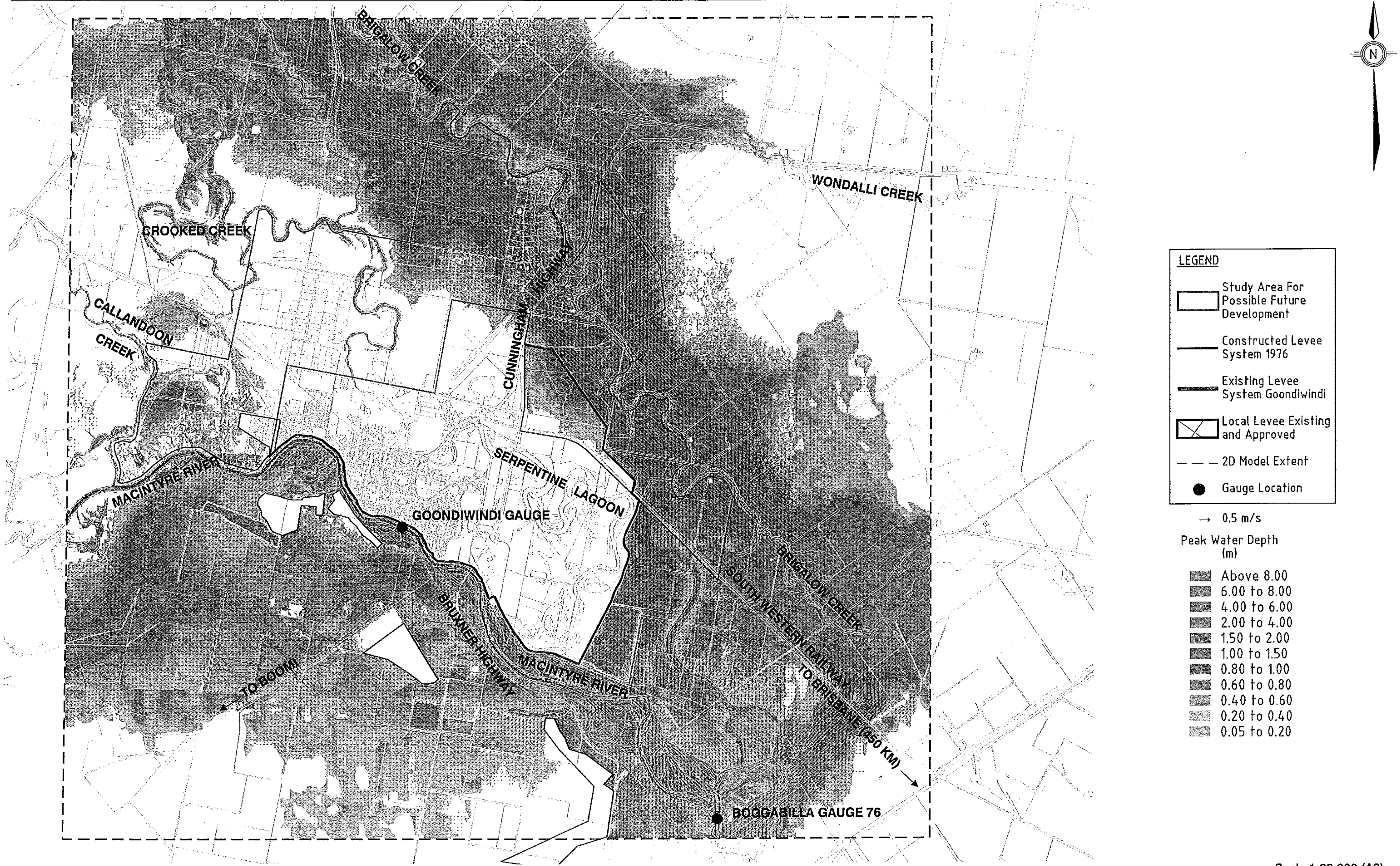

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FIGURE 3.2

1976 FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

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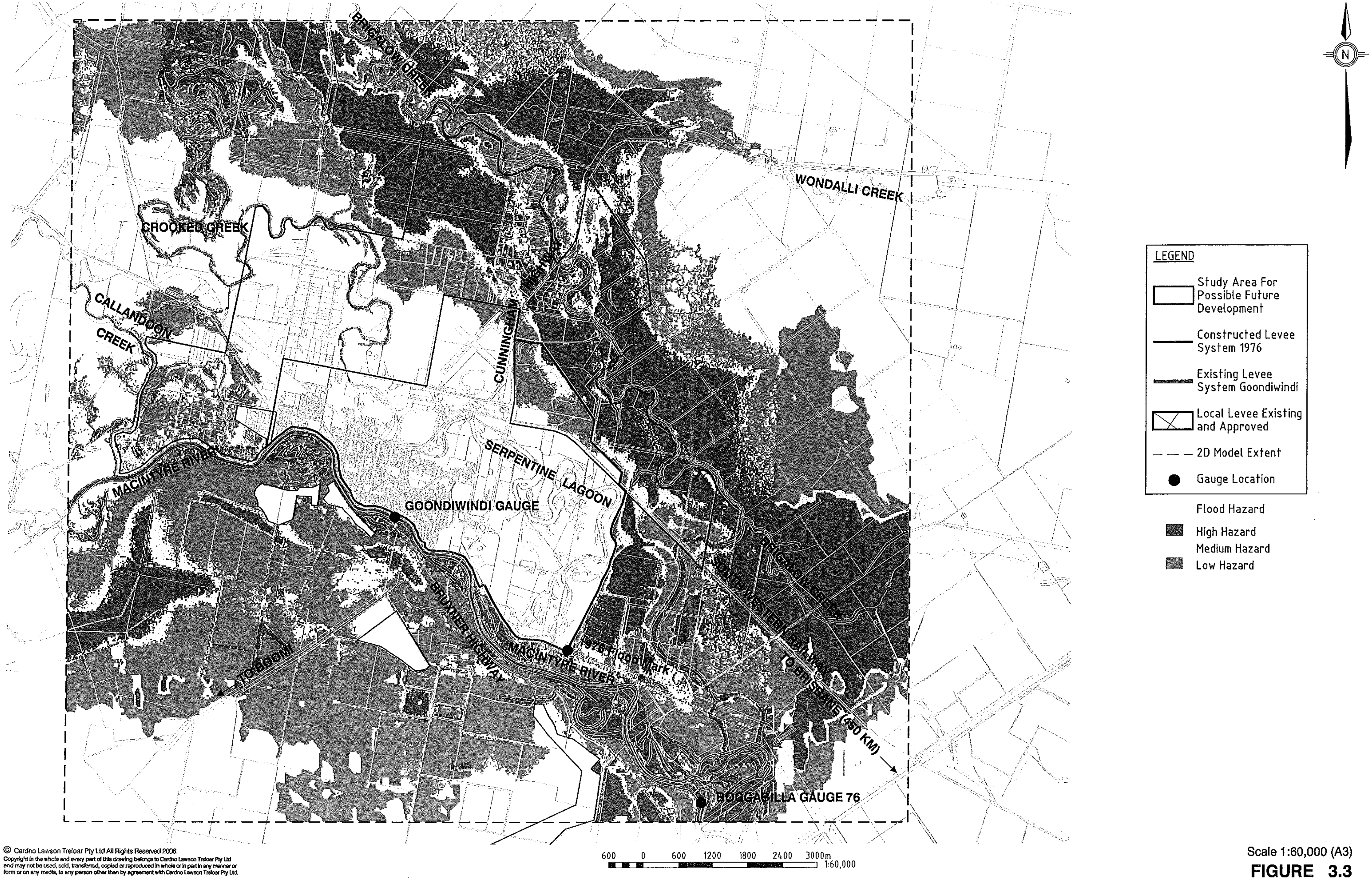

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FIGURE 3.3

1976 FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

PRNT DATE: 29 March, 2007 - 3:55pm

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Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 4.1

1996 FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 3:57pm

Waggamba Shire Council

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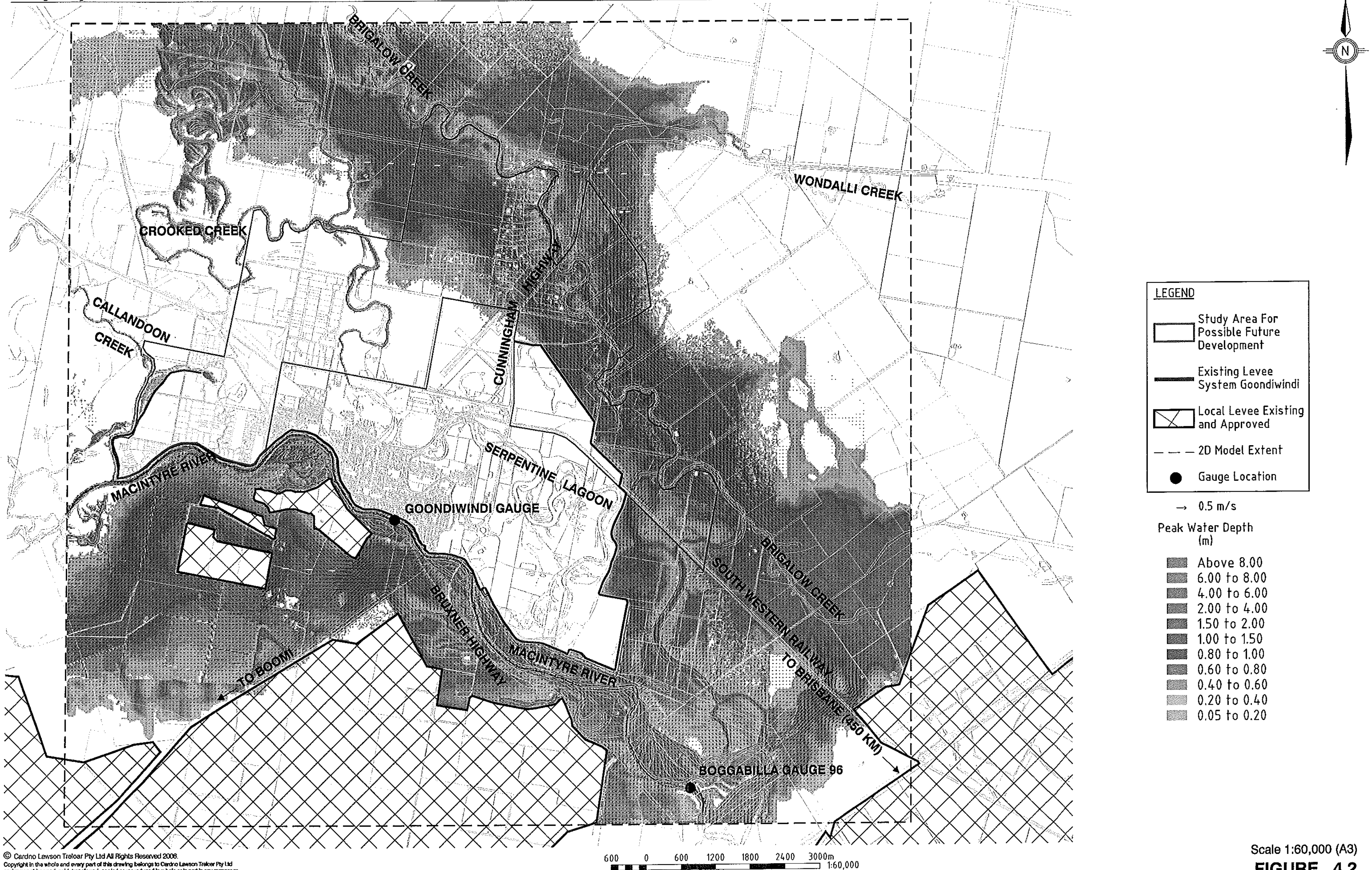

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FIGURE 4.2

1996 FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

PRINT DATE: 29 March, 2007 – 3:58pm

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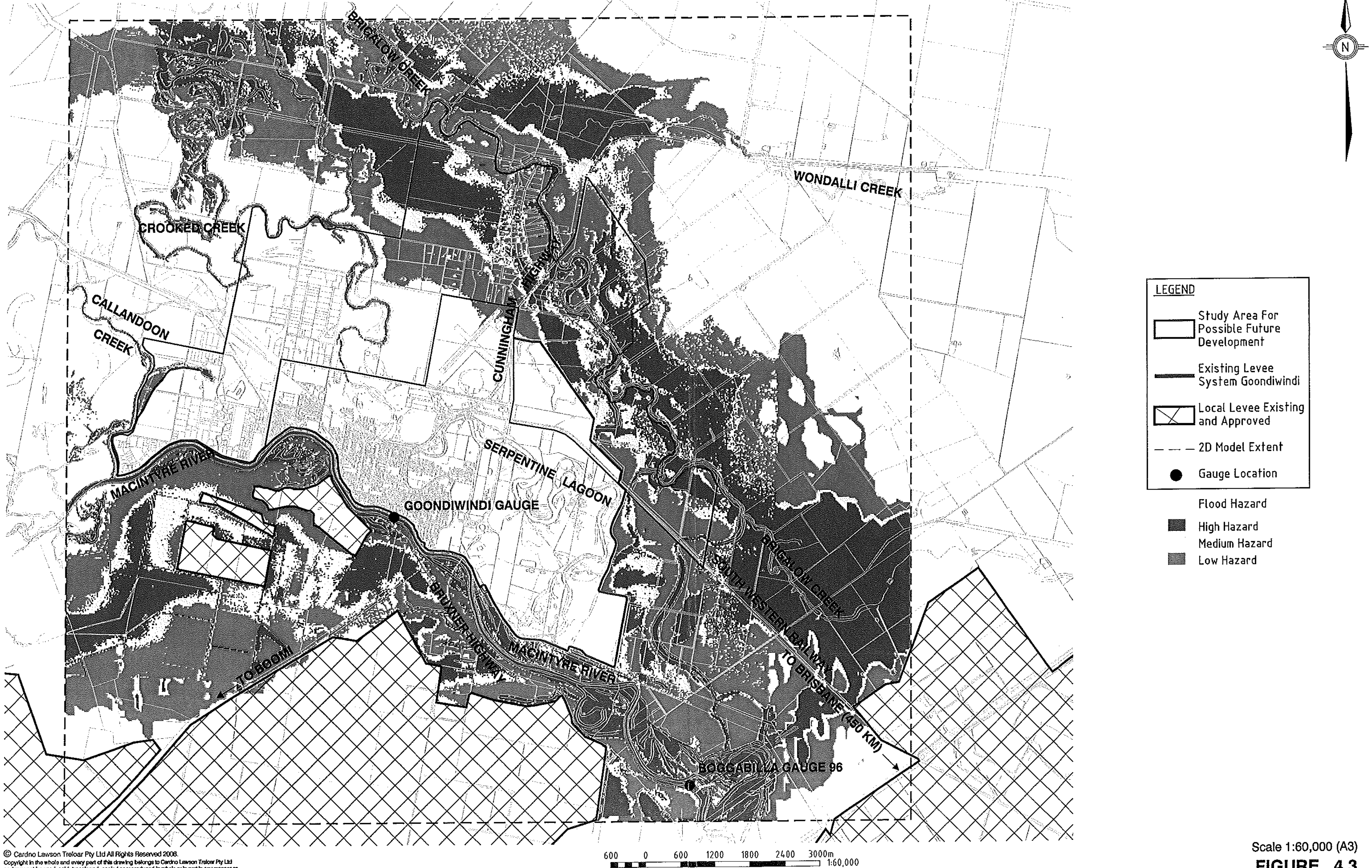

Rev: Orig. Date: March 2007

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FIGURE 4.3

1996 FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 3:55pm

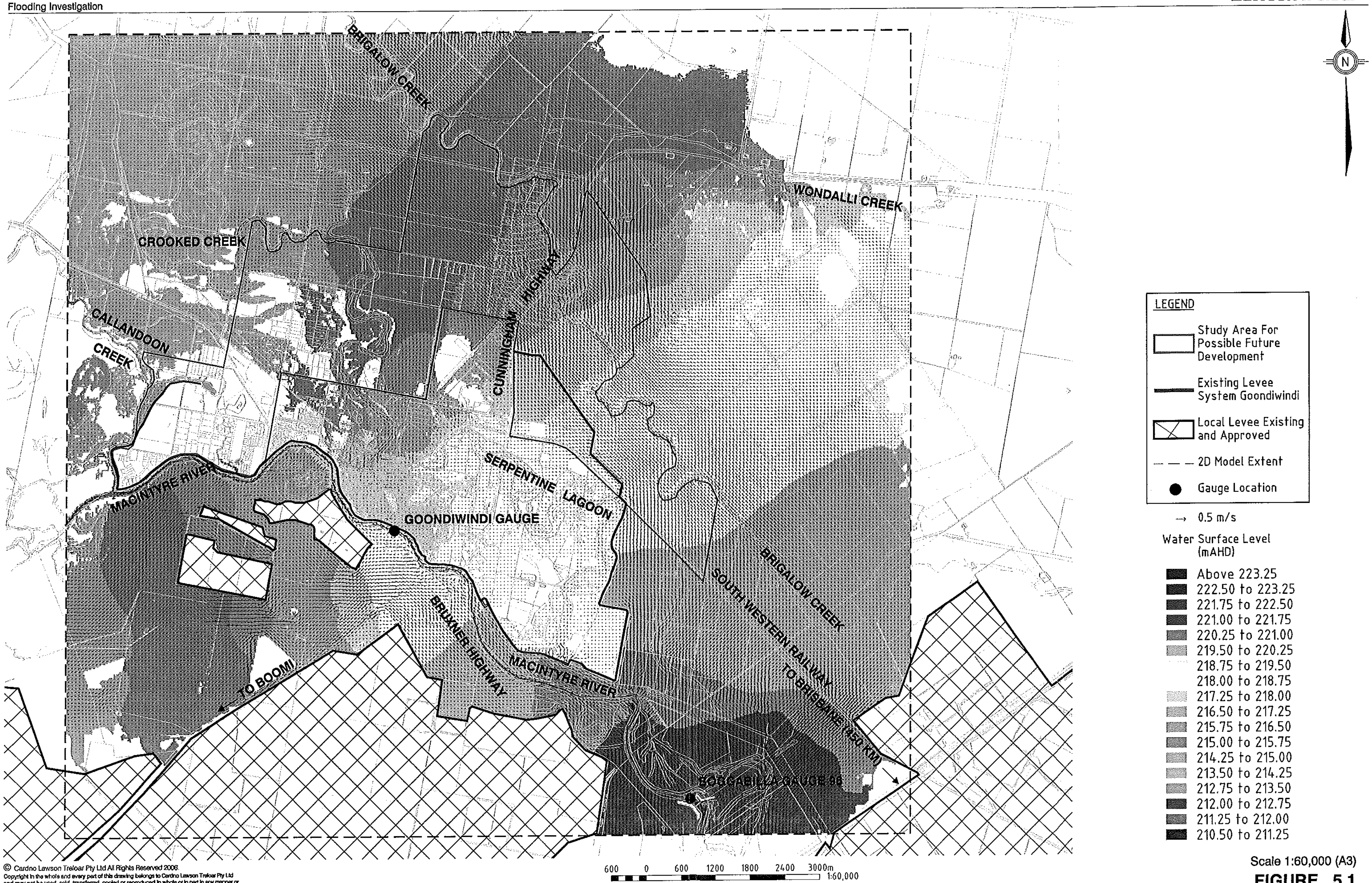

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FIGURE 5.1

2*1976 (ASSUMED PMF) FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

PRNT DATE: 29 March, 2007 - 4:03pm

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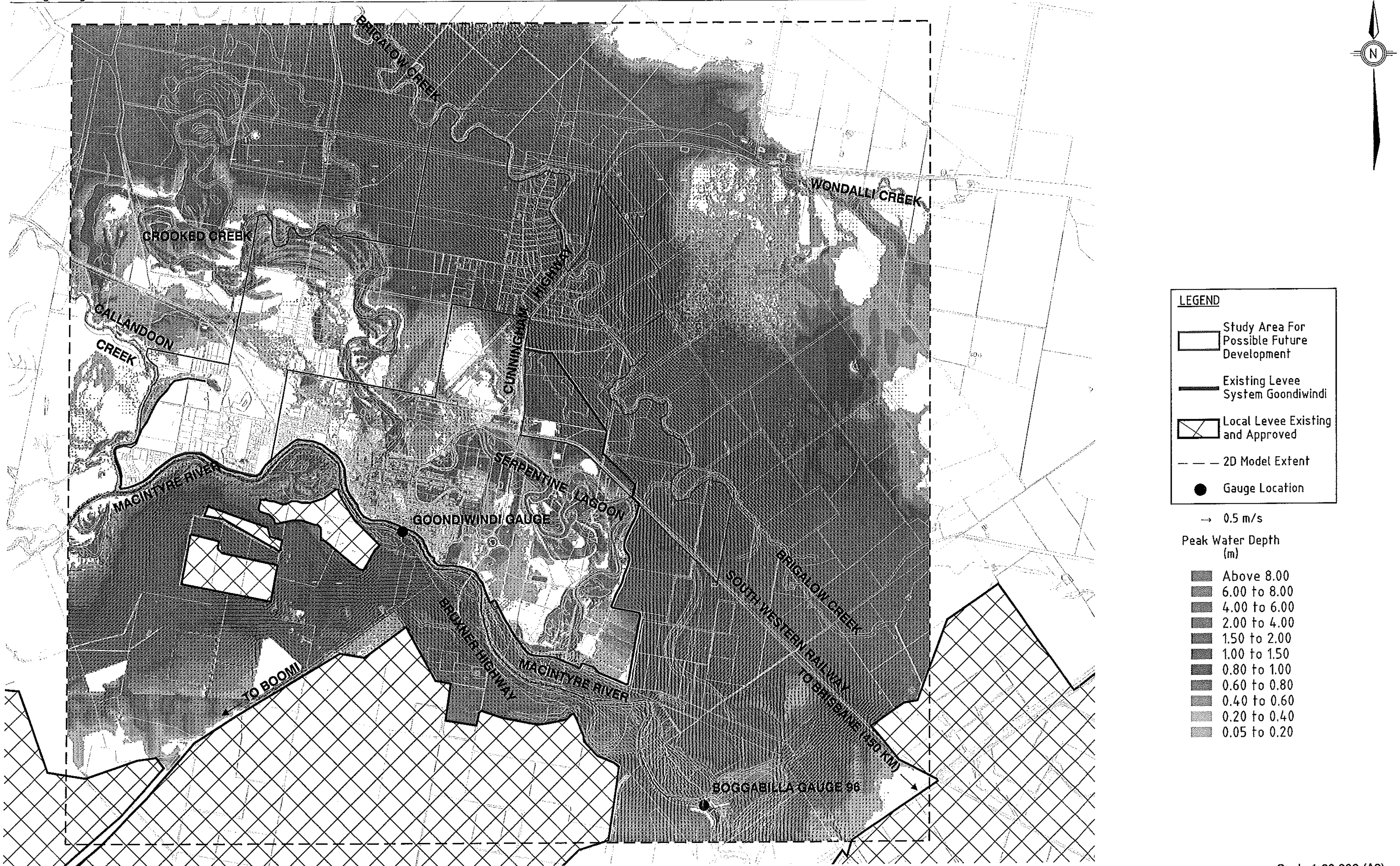

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FIGURE 5.2

2*1976 FLOOD (ASSUMED PMF) FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 4:03pm

Waggamba Shire Council
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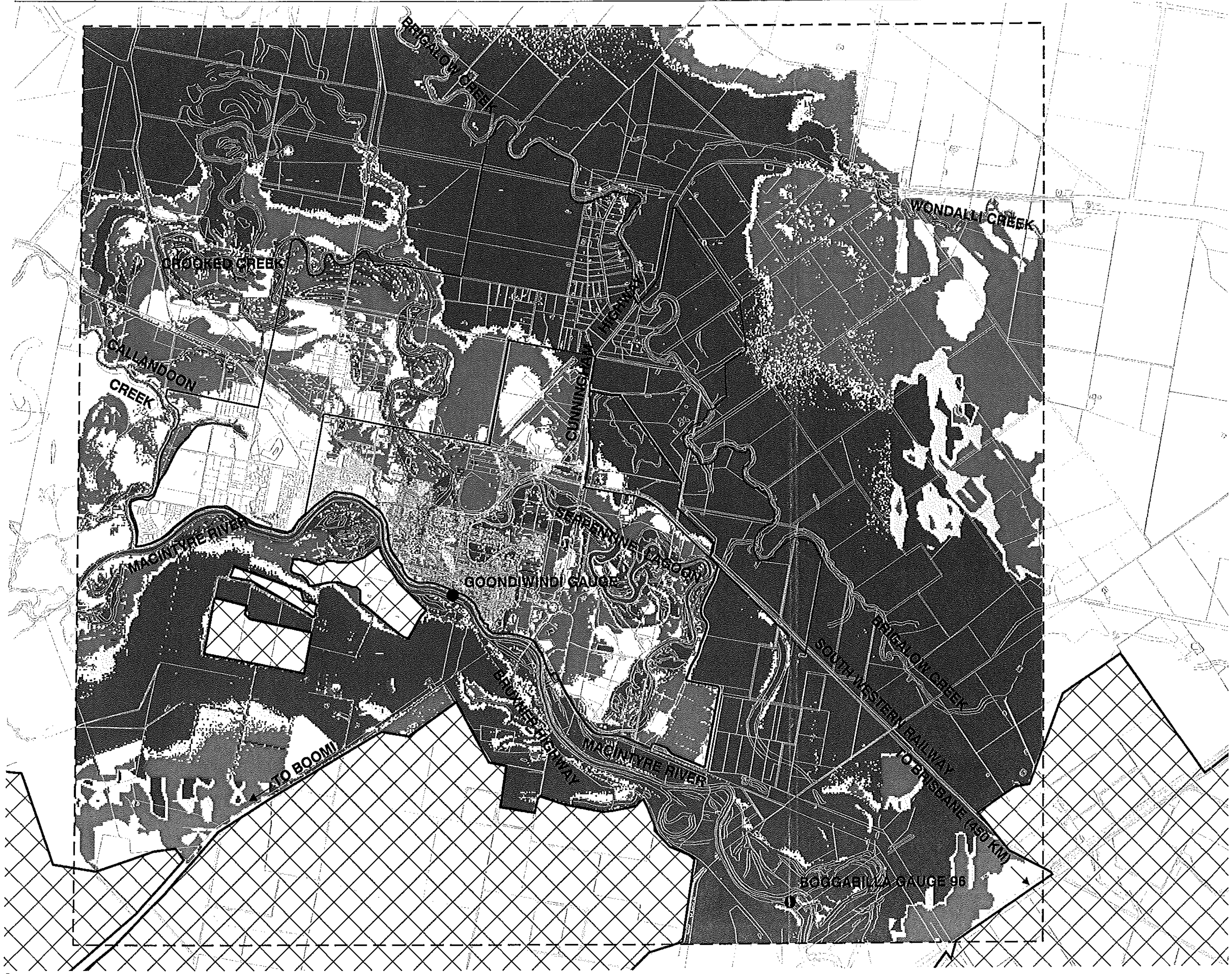

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Flood Hazard

- High Hazard
- Medium Hazard
- Low Hazard

Scale 1:60,000 (A3)

FIGURE 5.3

2*1976 (ASSUMED PMF) FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 4:10pm

Waggamba Shire Council

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Cardno Lawson Treloar

Scale 1:30,000 (A3)

FIGURE 5.4

2*1976 (ASSUMED PMF) FLOODING EVENT - TIME TO FLOOD FROM START OF OVERTOPPING OF LEVEE BANKS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 – 4:11pm

Waggamba Shire Council

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Cardno Lawson Treloar

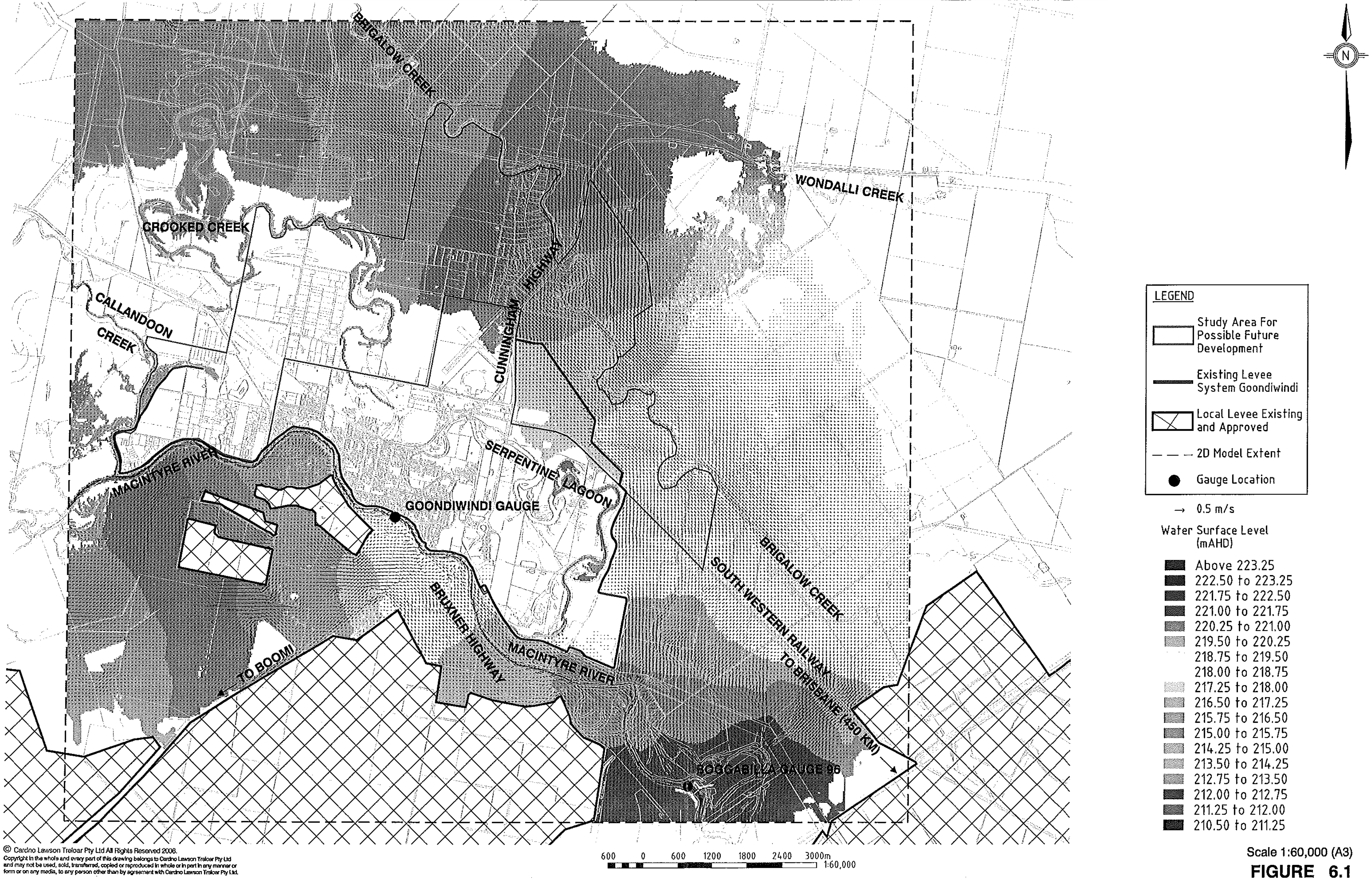

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FIGURE 6.1

0.2% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 6 2005 0500.dwg
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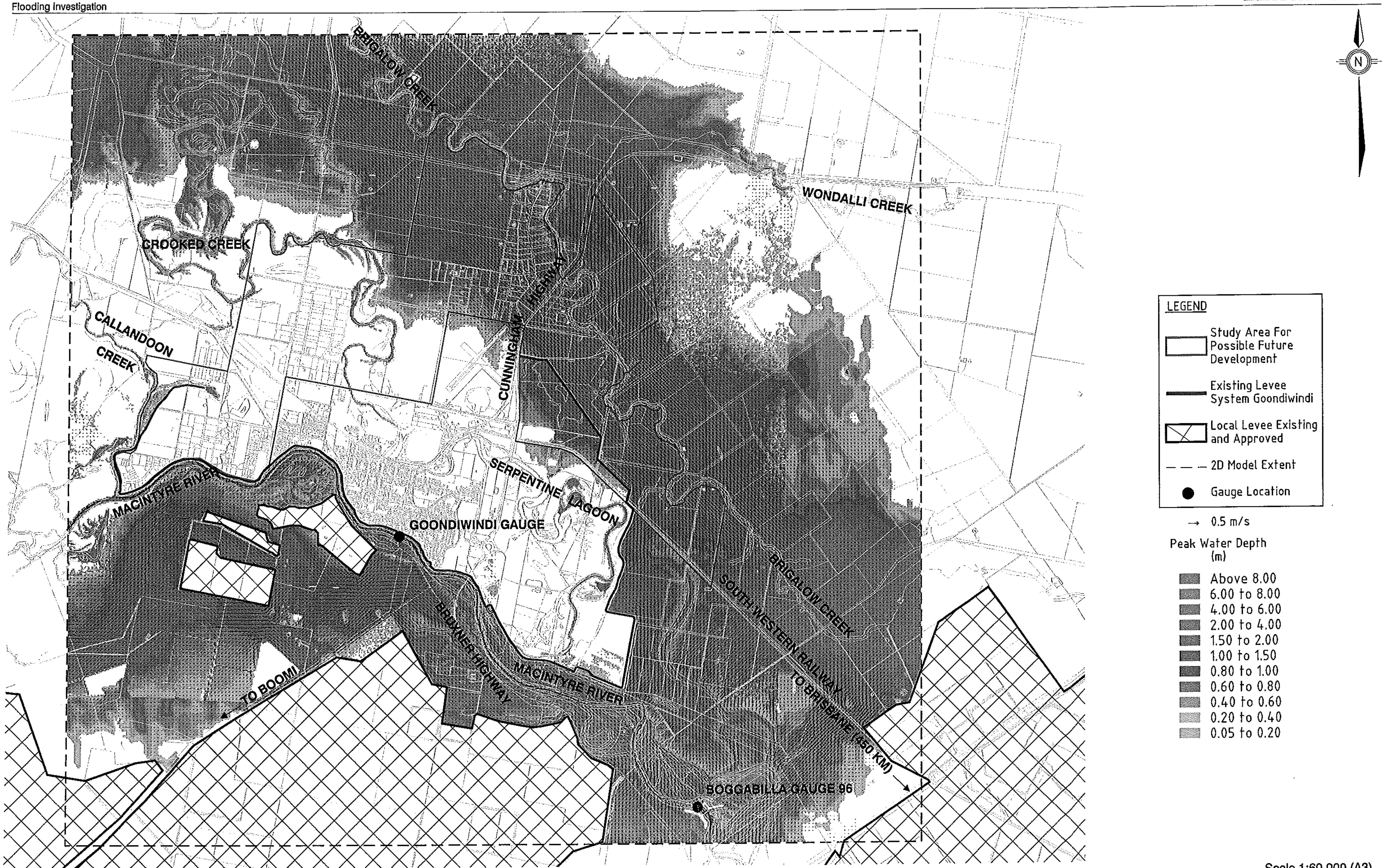

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FIGURE 6.2

0.2% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

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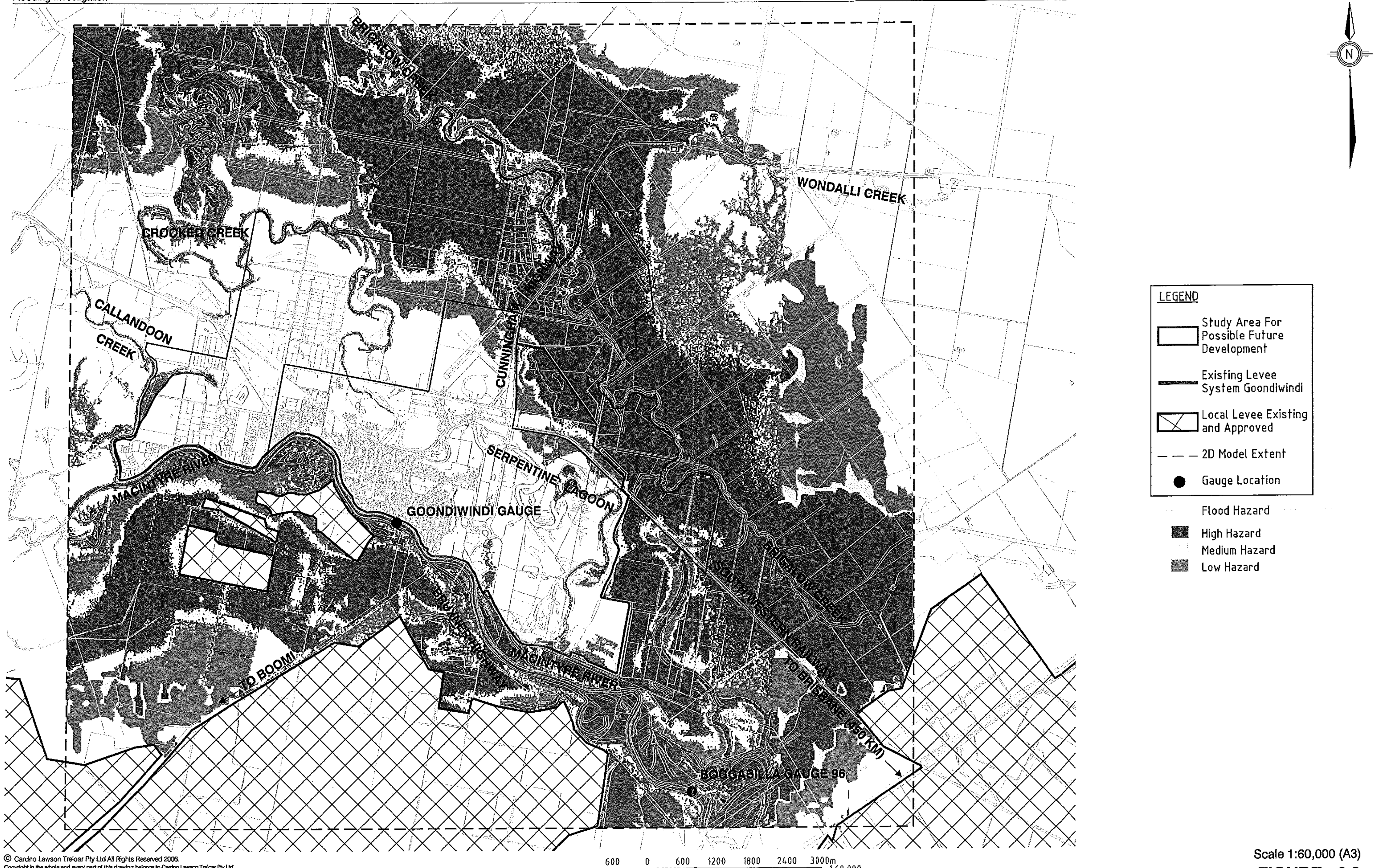

Scale 1:60,000 (A3)

FIGURE 6.3

0.2% AEP FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council
CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 6 2005 0500.dwg
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PRINT DATE: 29 March, 2007 - 4:13pm

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 7.1

0.5% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

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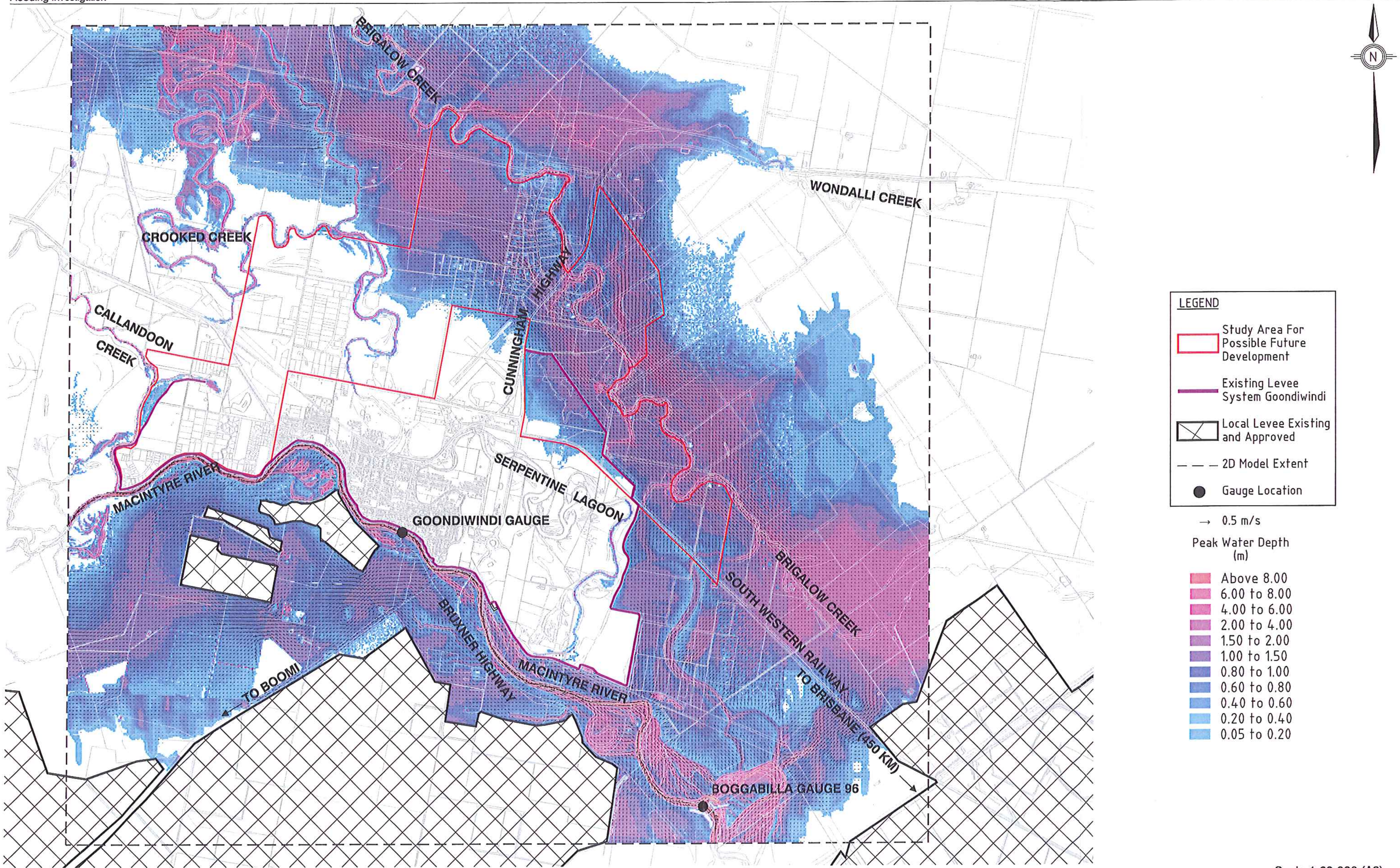


Scale 1:60,000 (A3)

FIGURE 7.2

0.5% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

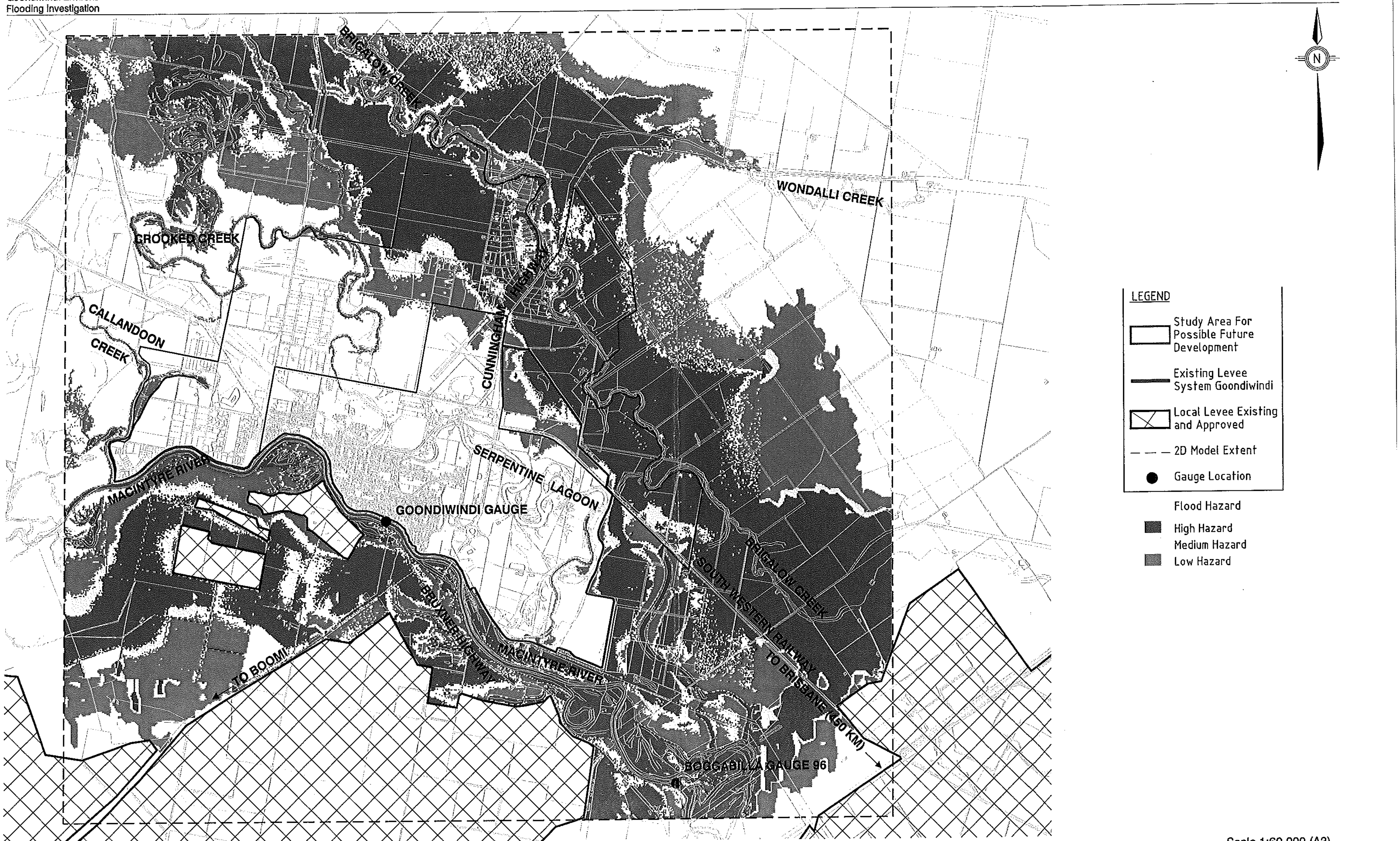
Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 4:15pm

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 7 2006 0200.dwg
XREF's: J7803FigureBase; Levees 1996; Results; Waggamba_Shire_2005, HAZARD, R1_text

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 7.3

0.5% AEP FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 4:46pm

Waggamba Shire Council

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XREF's: J7843FigureBase; Levees 1995; Results, Waggamba_Shire_2005, HAZARD, R1_text

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 8.1

1% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 4:17pm

Waggamba Shire Council
CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 8 2005 0100.dwg
XREF's: J7803FigureBase; Levees 1995; Results; Waggamba_Shire_2005, HAZARD, R1_text

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 8.2

1% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Project No.: LJ8651/R1

Rev: Orig. Date: March 2007

PRNT DATE: 29 March, 2007 - 4:18pm

Waggamba Shire Council

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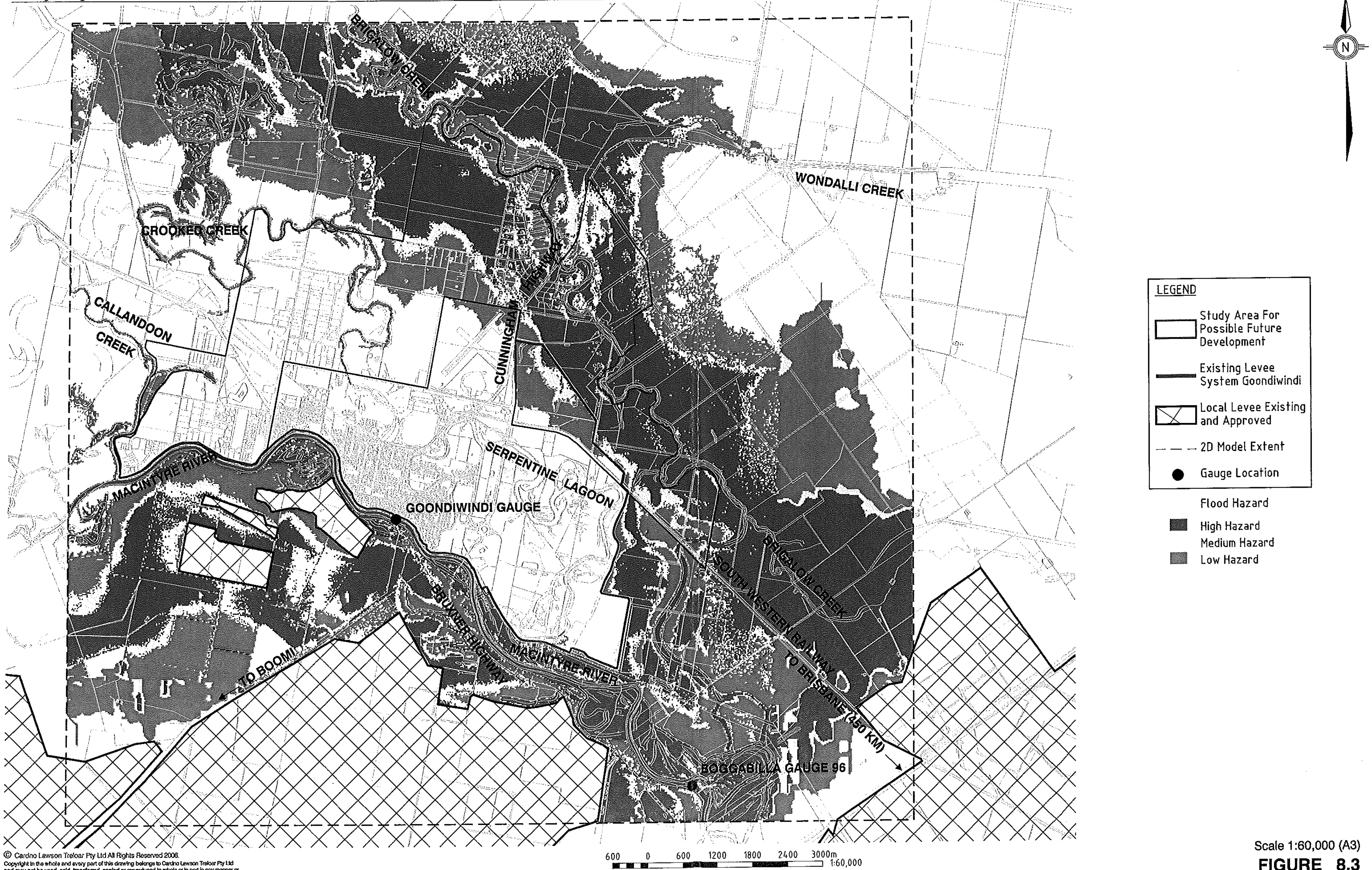
Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 8.3

1% AEP FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 4:18pm

Rev: Orig. Date: March 2007

Waggamba Shire Council

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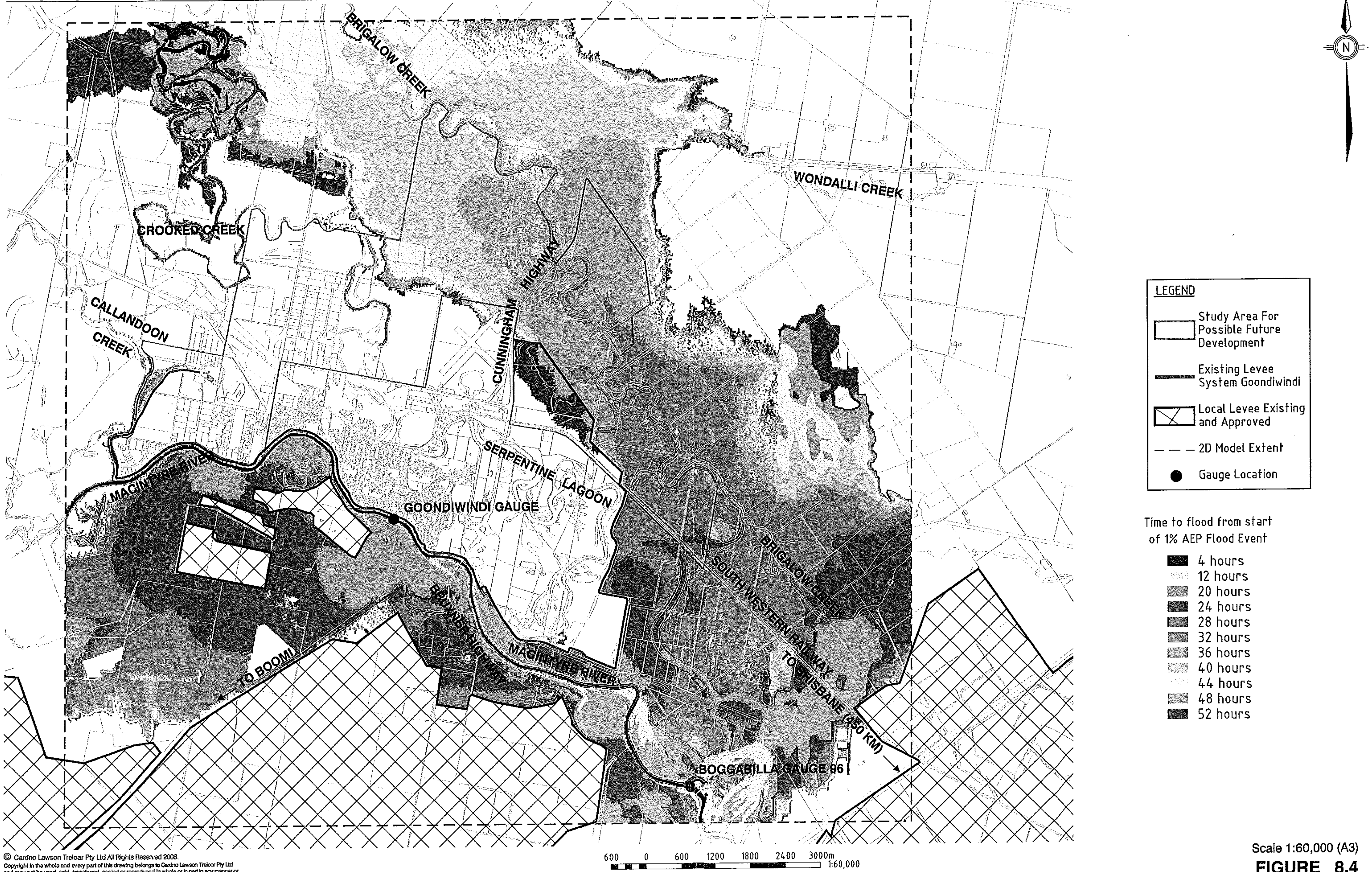
Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 8.4

1% AEP FLOODING EVENT - TIME TO FLOOD FROM START OF 1% AEP FLOOD EVENT AT BOGGABILLA GAUGE

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 4:21pm

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 8.4 2006 Q100 Time To Flood.dwg
XREF's J7803FigureBase, Levees 1996, Waggamba_Shire_2005; R1_text; Results4h; Results52h; Results8h; Results12h, Results16h, Results20h, Results24h, Results28h, Results32h; Results36h; Results40h, Results44h, Results48h, Color_legend

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 9.1

2% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 4:47pm

Rev: Orig. Date: March 2007

Waggamba Shire Council
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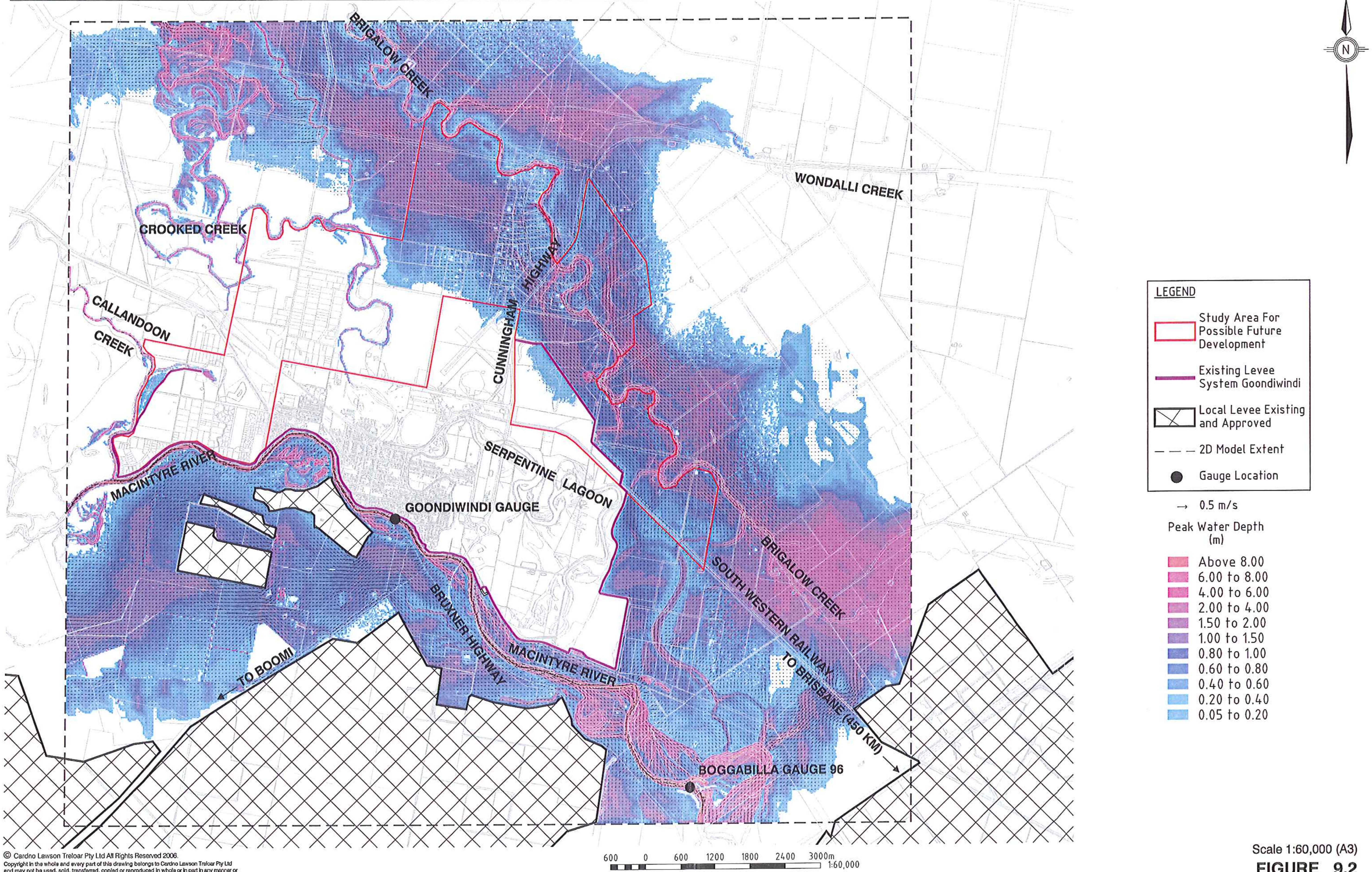
Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 9.2

2% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

PRINT DATE: 29 March, 2007 - 4:49pm

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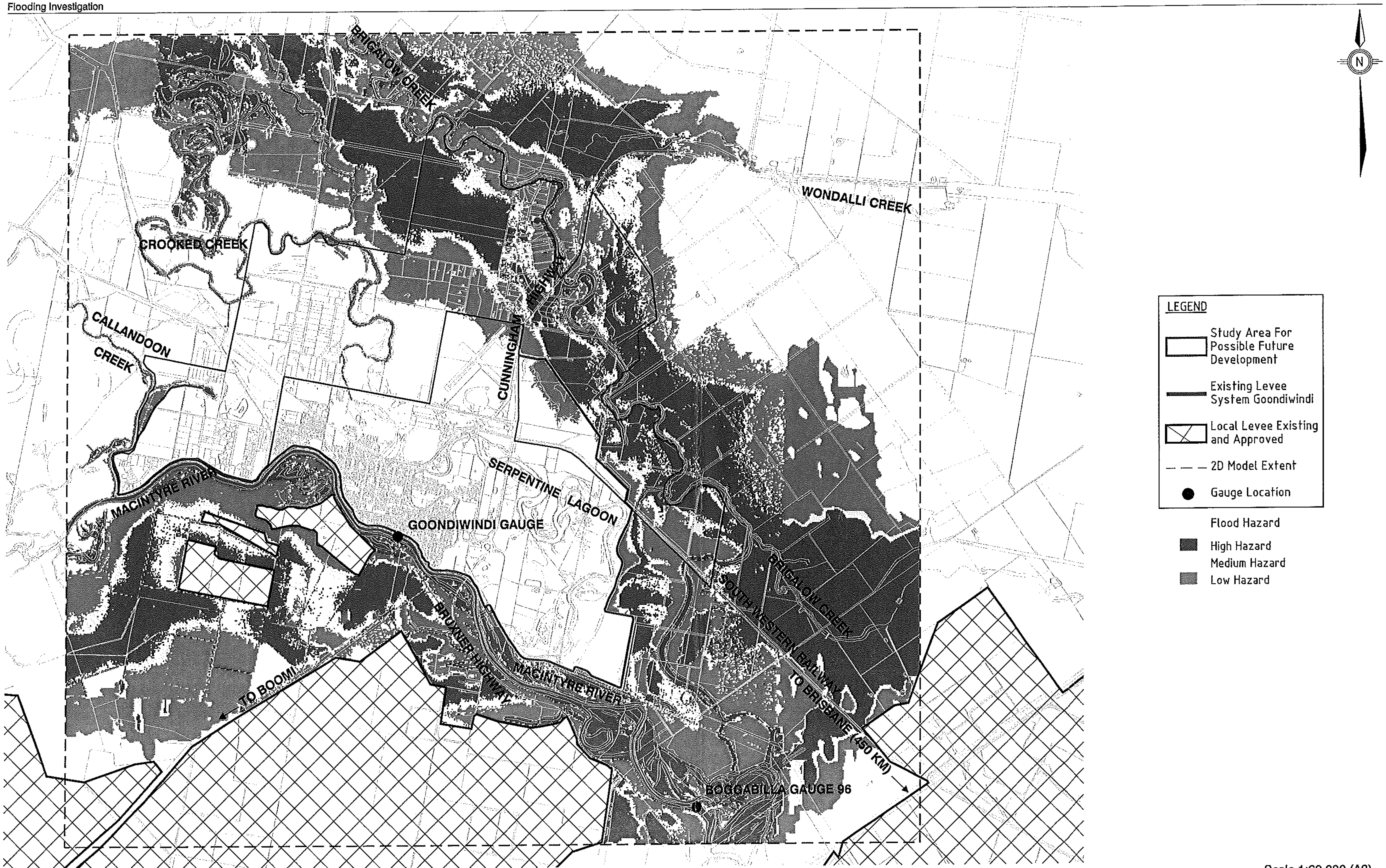
Cardno Lawson Treloar



Rev: Orig. Date: March 2007

Waggamba Shire Council
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XREF's: J7893FigureBase; Levees 1996; Results; Waggamba_Shire_2005_HAZARD_R1_text

Scale 1:60,000 (A3)

FIGURE 9.3
2% AEP FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1
PRINT DATE: 29 March, 2007 - 4:50pm

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 10.1

5% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 4:52pm

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 10 2005 Q20.dwg
XREF's: J7803FigureBase; Levees 1996; Results; Waggamba Shire 2005, HAZARD, R1 text

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 10.2

5% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

CAD FILE: D:\WorkLAT\J8551\Acad\Rev3\Figure 10 2006 Q20.dwg
XREF's: J7803FigureBase, Levees 1996; Results; Waggamba_Shire_2005, HAZARD, R1 text

PRINT DATE: 29 March, 2007 - 4:53pm

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 10.3

5% AEP FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 4:53pm

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 10 2026 020.dwg
XREF's: J7803FigureBase; Levees 1955; Results, Waggamba_Shire_2005; HAZARD, R1_text

Cardno Lawson Treloar

600 0 600 1200 1800 2400 3000m 1:60,000

Scale 1:60,000 (A3)

FIGURE 11.1

LEVEE FAILURE BRENNANS ROAD - 1% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

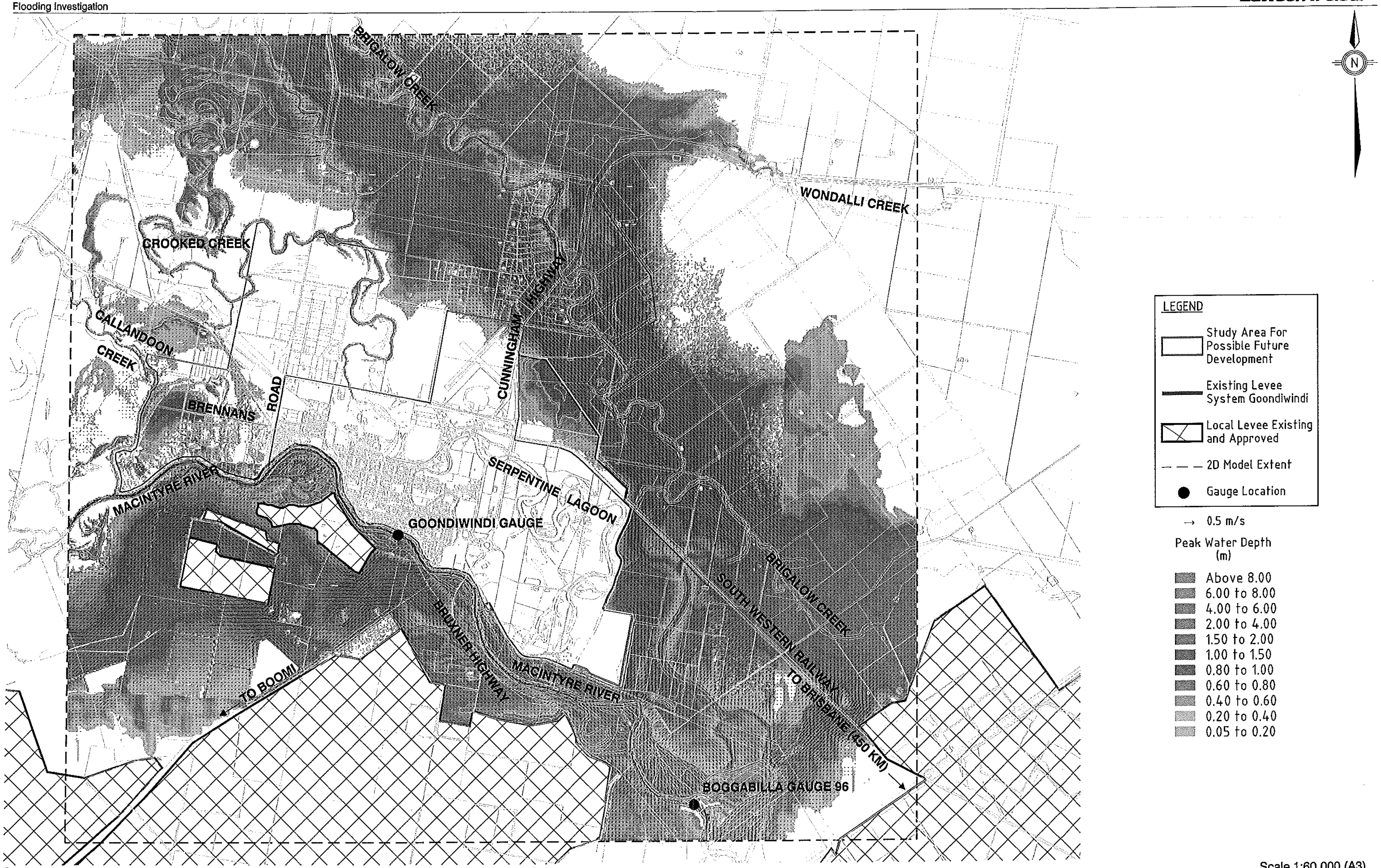
Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 5:25pm

Waggamba Shire Council
CAD FILE: O:\Work-LAT\J8651\Acad\R1v3\Figure 11 2006 0100 BREN.dwg
XREF's: J7803FigureBase; Levees 1936; Results, Waggamba_Shire_2005, HAZARD, R1_text

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 11.2

LEVEE FAILURE BRENNANS ROAD - 1% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 5:25pm

Waggamba Shire Council

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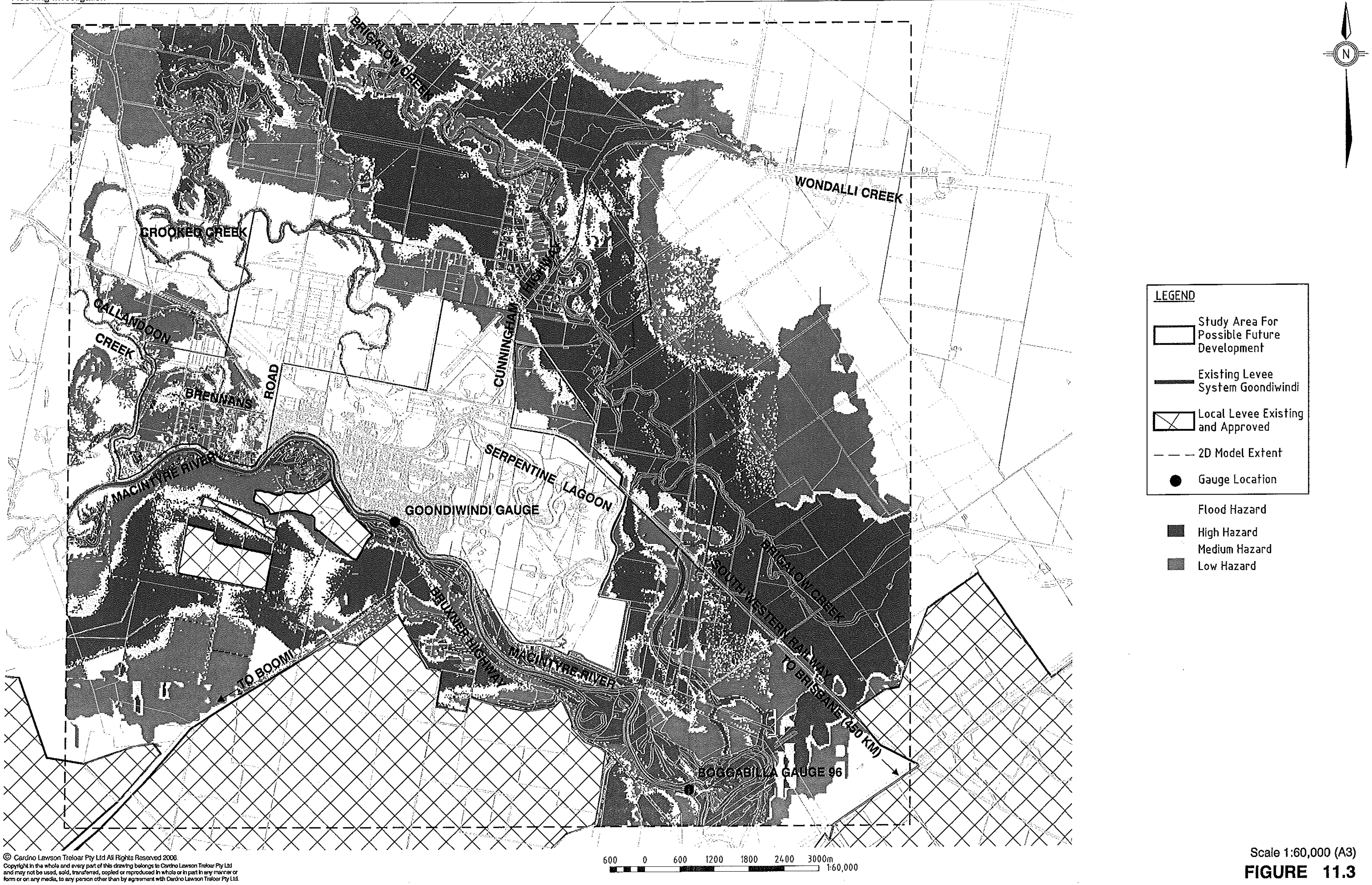
Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 11.3

LEVEE FAILURE BRENNANS ROAD - 1% AEP FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 5:26pm

Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J3651\Acad\R1v3\Figure 11 2006 Q100 BREN.dwg
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Goondiwindi Environs
Flooding Investigation

Cardno Lawson Treloar

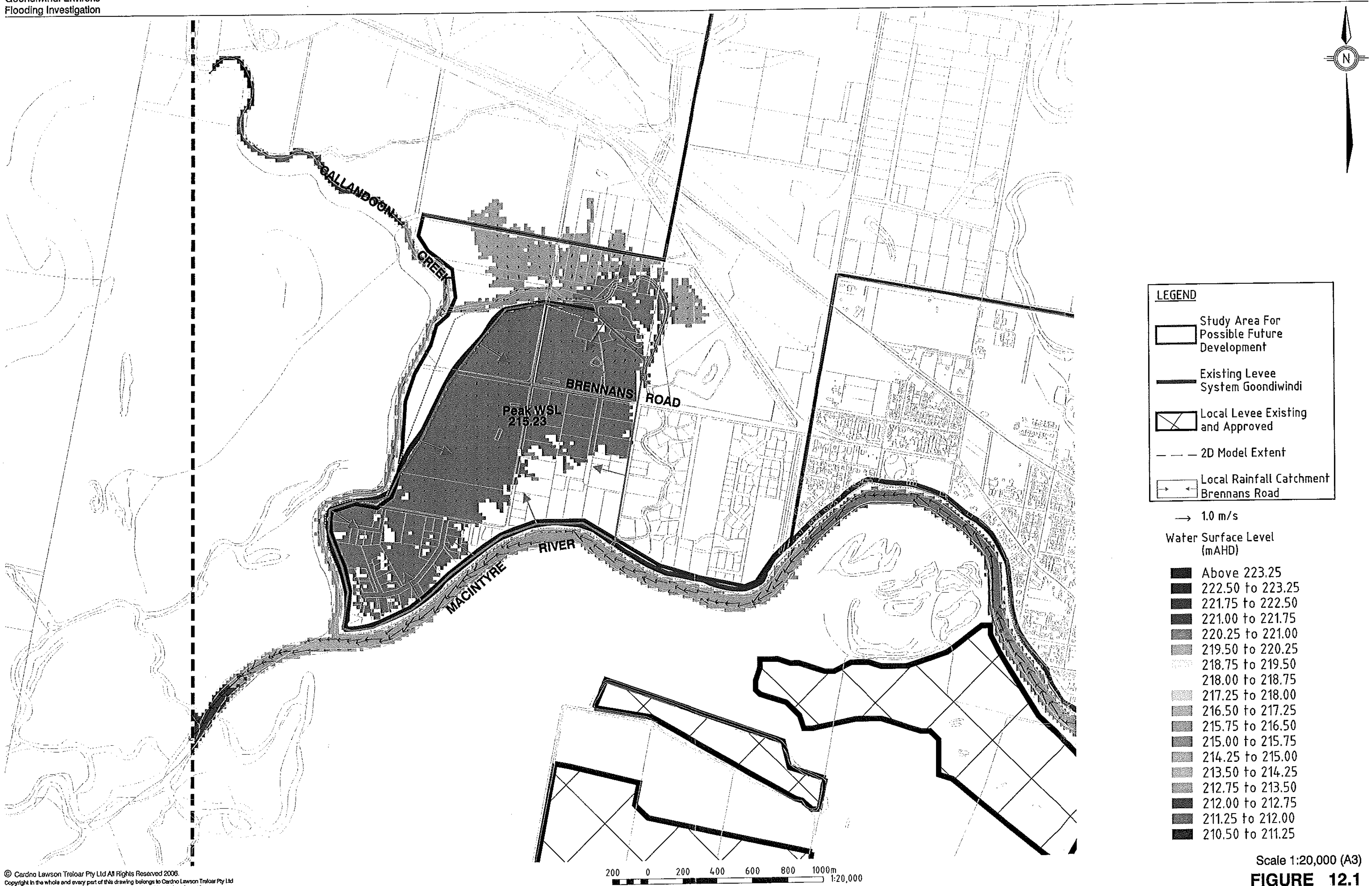

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FIGURE 12.1

LOCAL PMP FLOODING BRENNANS ROAD - PEAK WATER LEVELS AND FLOW PATTERNS

Project No.: LJ8651/R1

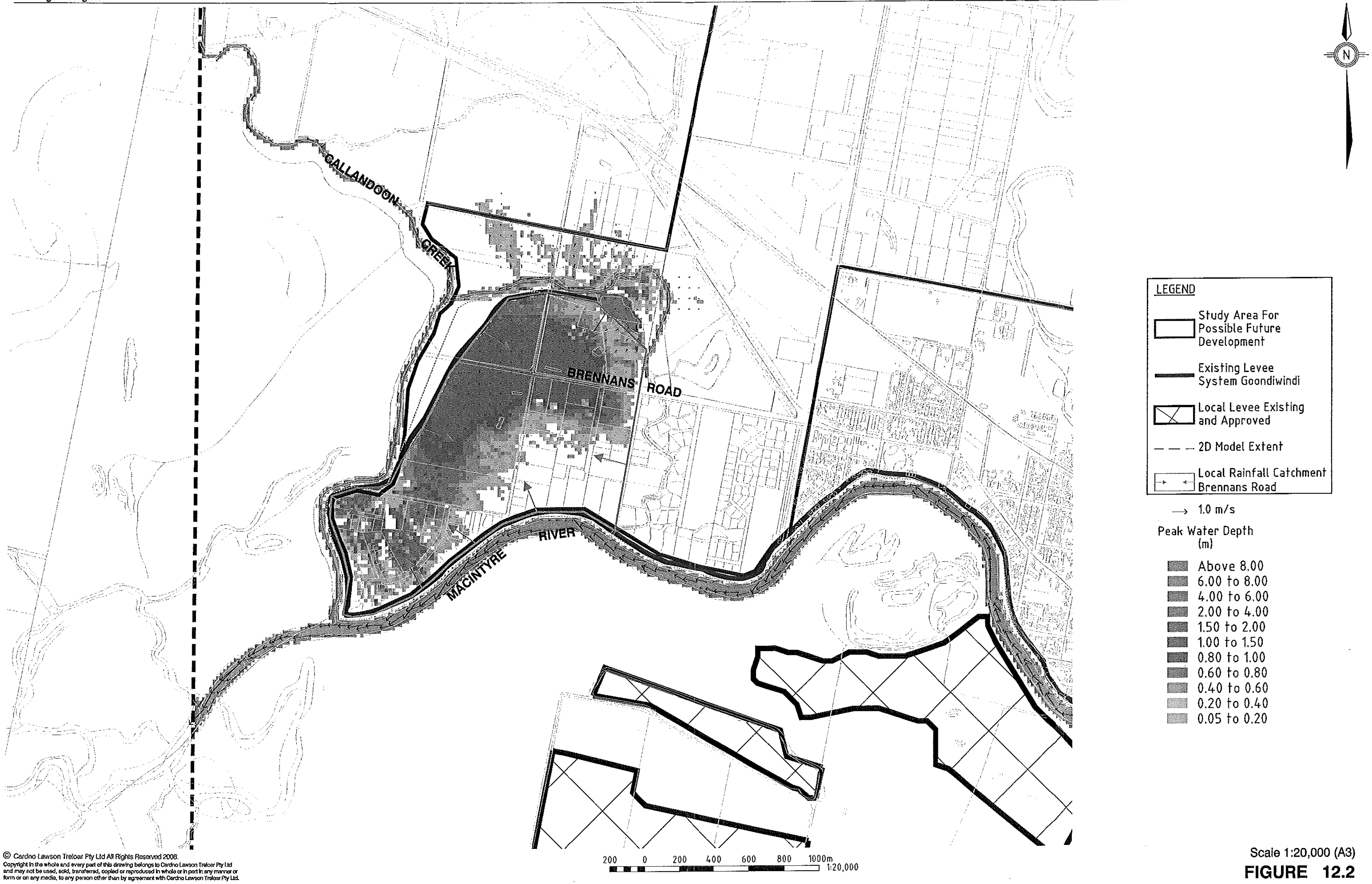
PRNT DATE: 23 March, 2007 - 5:40pm

Rev: Orig. Date: March 2007

'aggamba Shire Council

FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 24__12 2006 PMP BREN.dwg

Cardno Lawson Treloar



Scale 1:20,000 (A3)

FIGURE 12.2

LOCAL PMP FLOODING BRENNANS ROAD - PEAK WATER DEPTHS AND FLOW PATTERNS

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 5:40pm

Rev: Orig. Date: March 2007

Waggamba Shire Council

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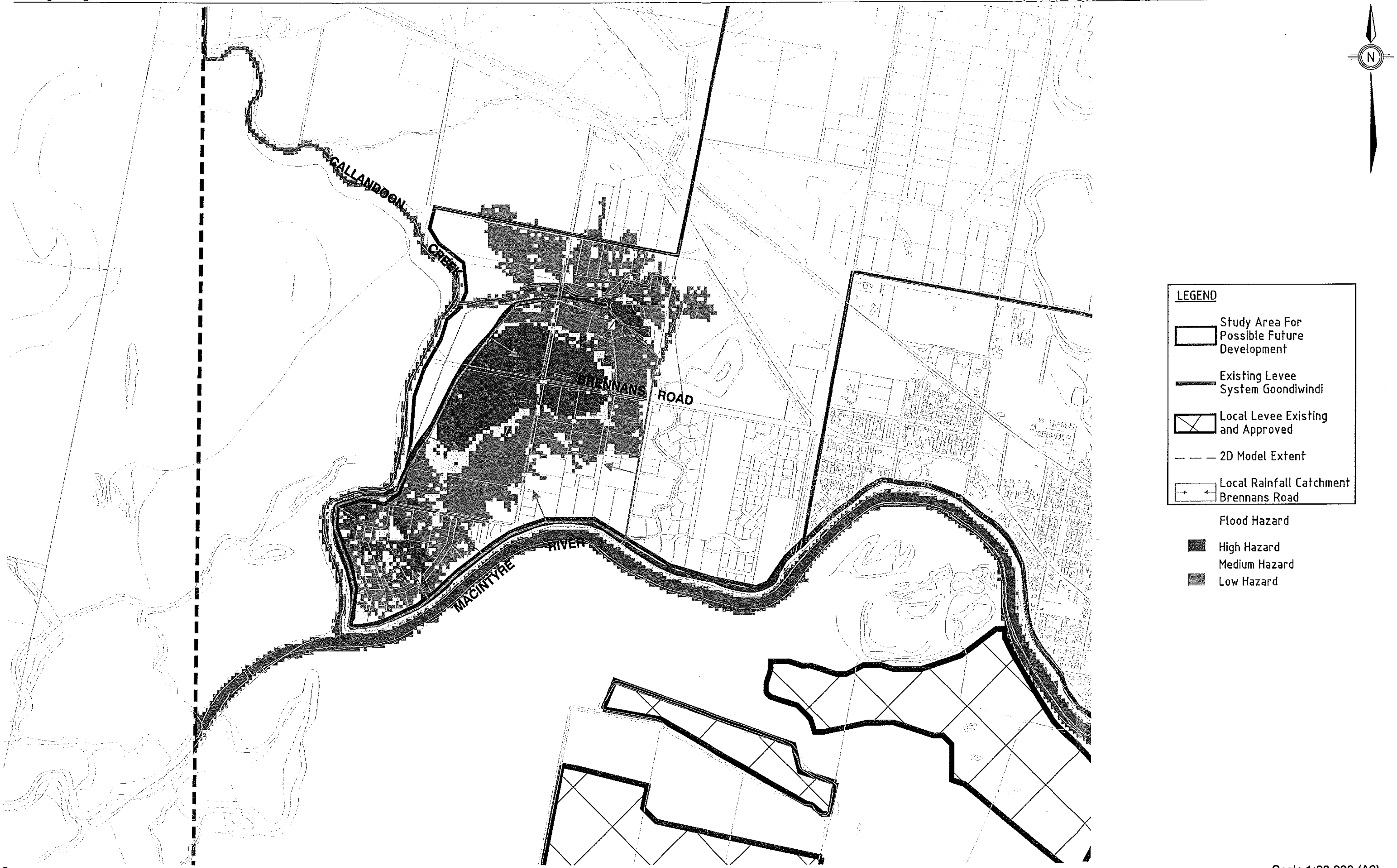
Cardno Lawson Treloar



Scale 1:20,000 (A3)

FIGURE 12.3

LOCAL PMP FLOODING BRENNANS ROAD - FLOOD HAZARD

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

PRINT DATE: 29 March, 2007 - 5:40pm

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Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 13.1

RAISED AND EXTENDED LEVEES - 0.2% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 6:01pm

Waggamba Shire Council

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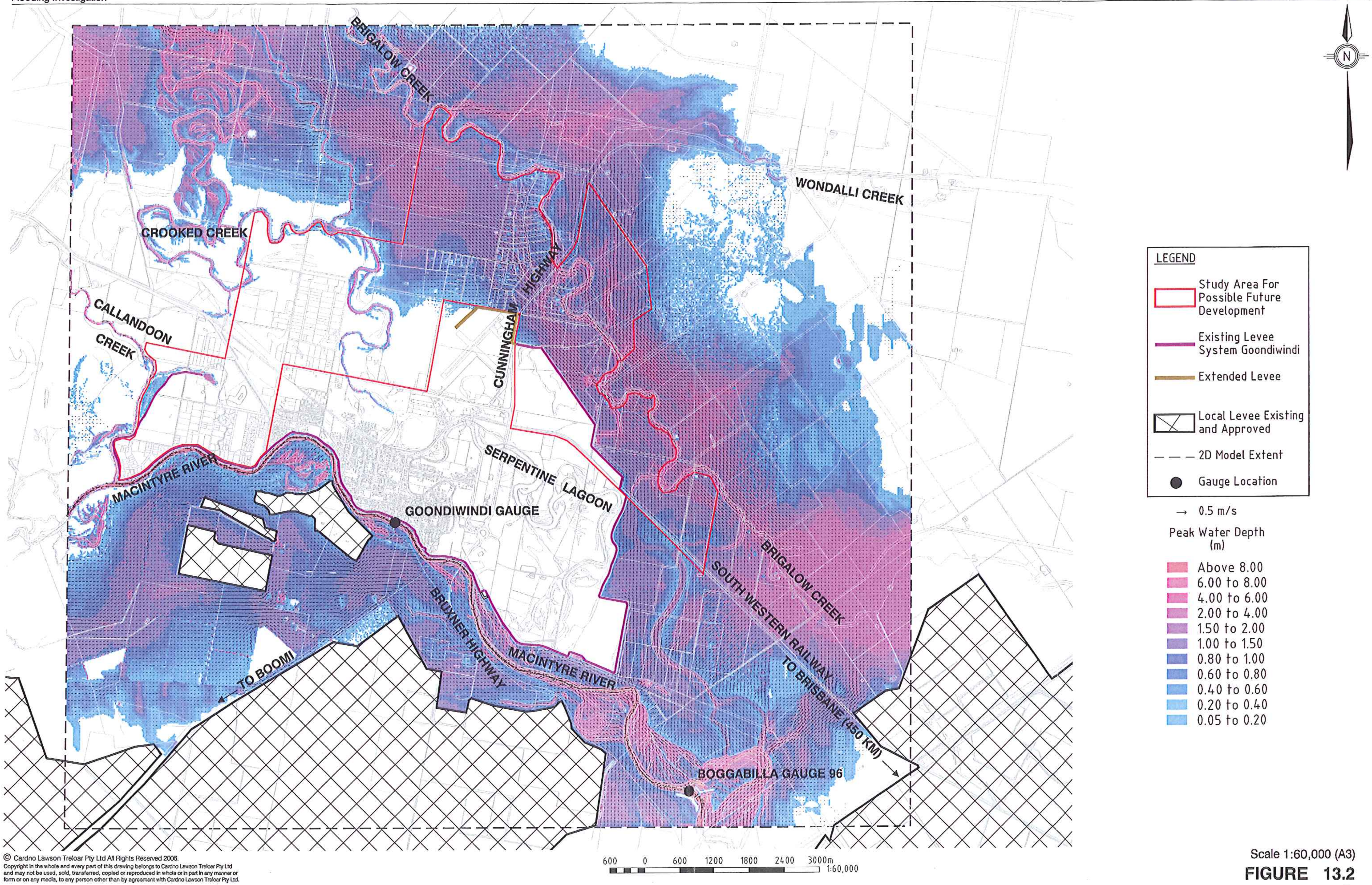

Scale 1:60,000 (A3)

FIGURE 13.2

RAISED AND EXTENDED LEVEES - 0.2% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 6:01pm

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 13 2006 Q500 M05A.dwg
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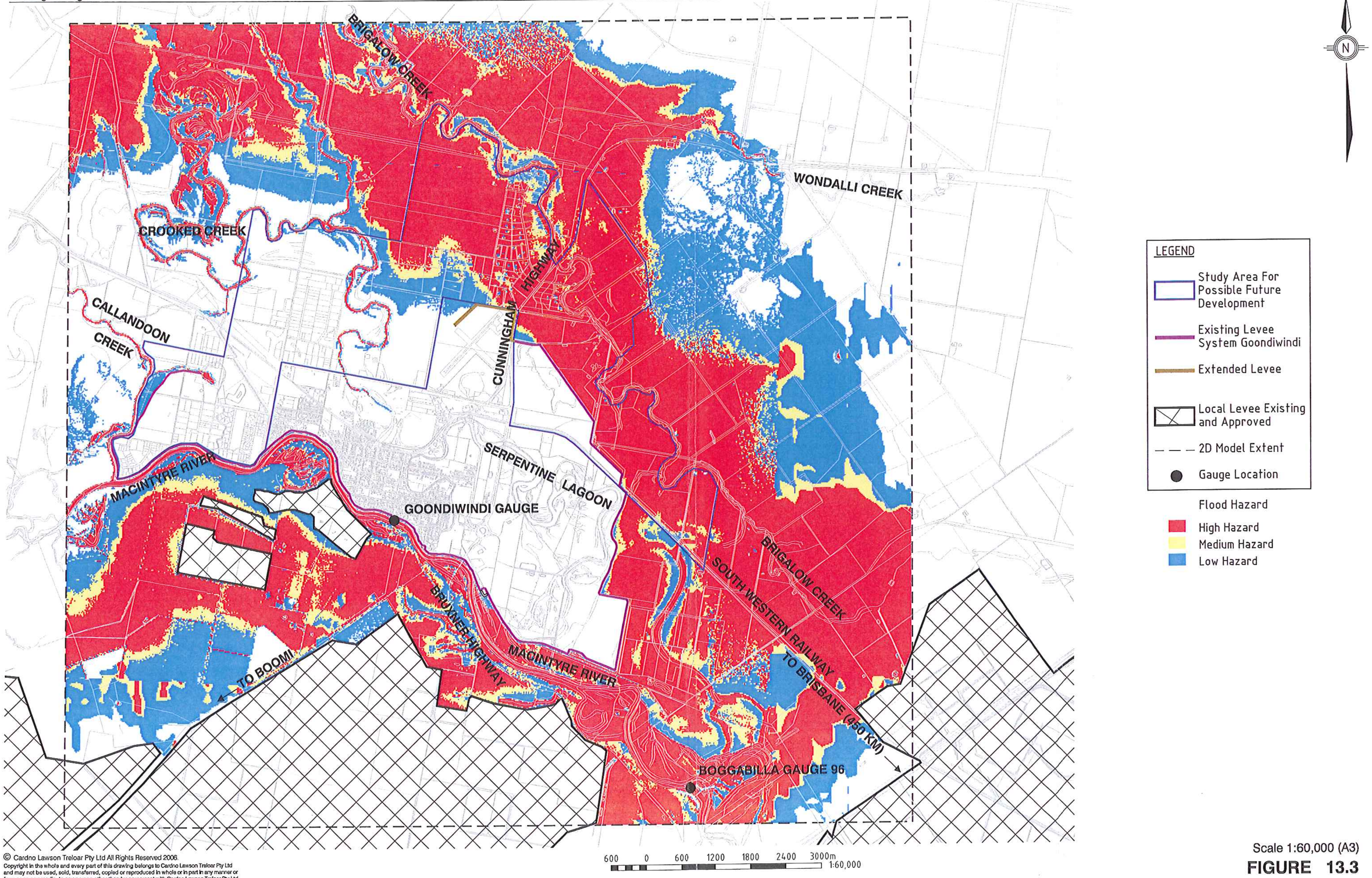

Scale 1:60,000 (A3)

FIGURE 13.3

RAISED AND EXTENDED LEVEES - 0.2% AEP FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 6:02pm

Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 13 2006 Q500 MI06A.dwg
XREF's: J7803FigureBase; Levees 1996; Results; Waggamba_Shire_2005; HAZARD; R1_text

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 13.4

RAISED AND EXTENDED LEVEES - 0.2% AEP FLOODING EVENT - PEAK WATER LEVEL IMPACTS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 13 2006 Q500 M06A.dwg
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PRINT DATE: 29 March, 2007 - 6:03pm

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 14.1

RAISED AND EXTENDED LEVEES - 1% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRNT DATE: 29 March, 2007 - 6:15pm

Waggamba Shire Council

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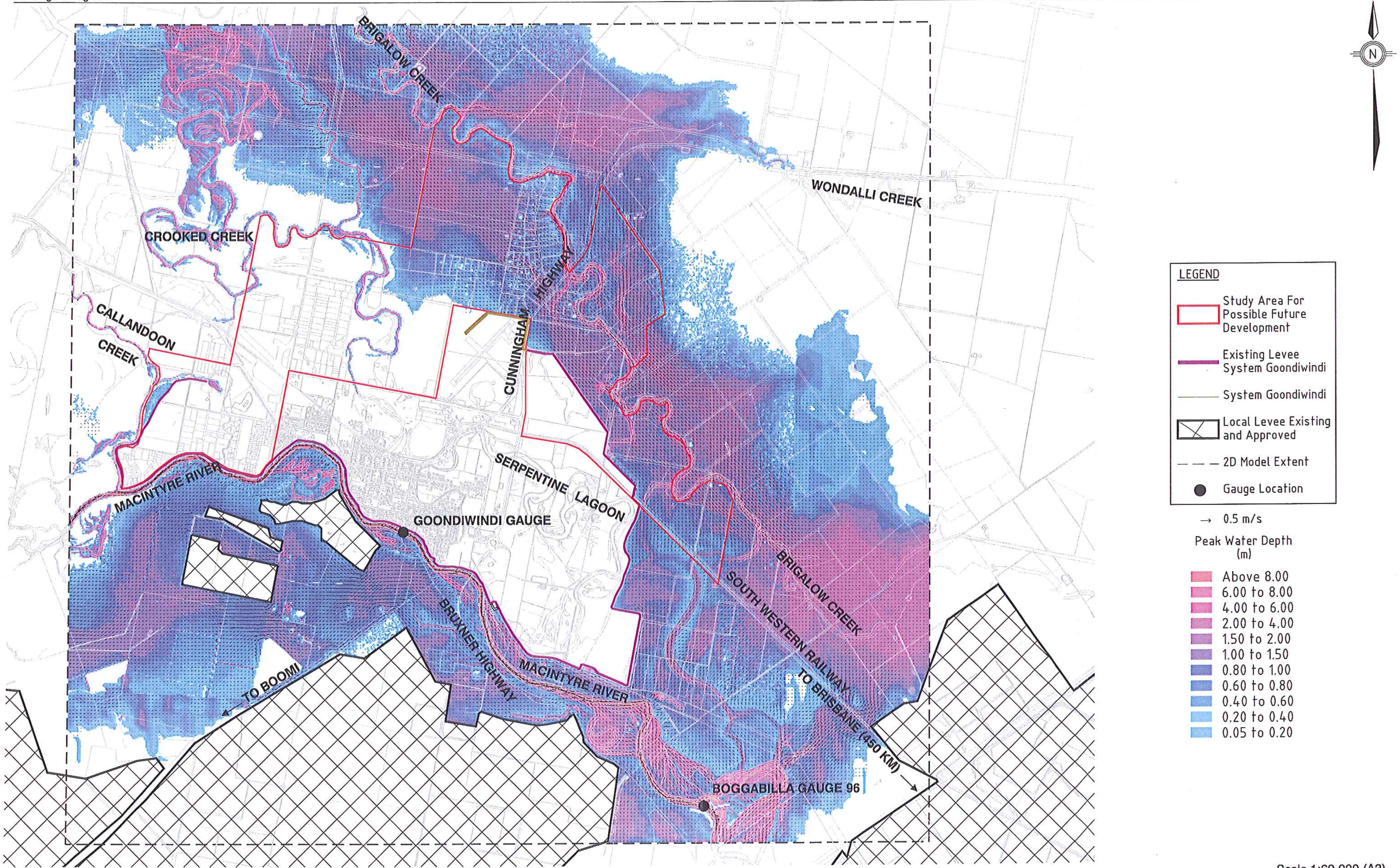

Scale 1:60,000 (A3)

FIGURE 14.2

RAISED AND EXTENDED LEVEES - 1% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

PRINT DATE: 29 March, 2007 - 6:16pm

Waggamba Shire Council

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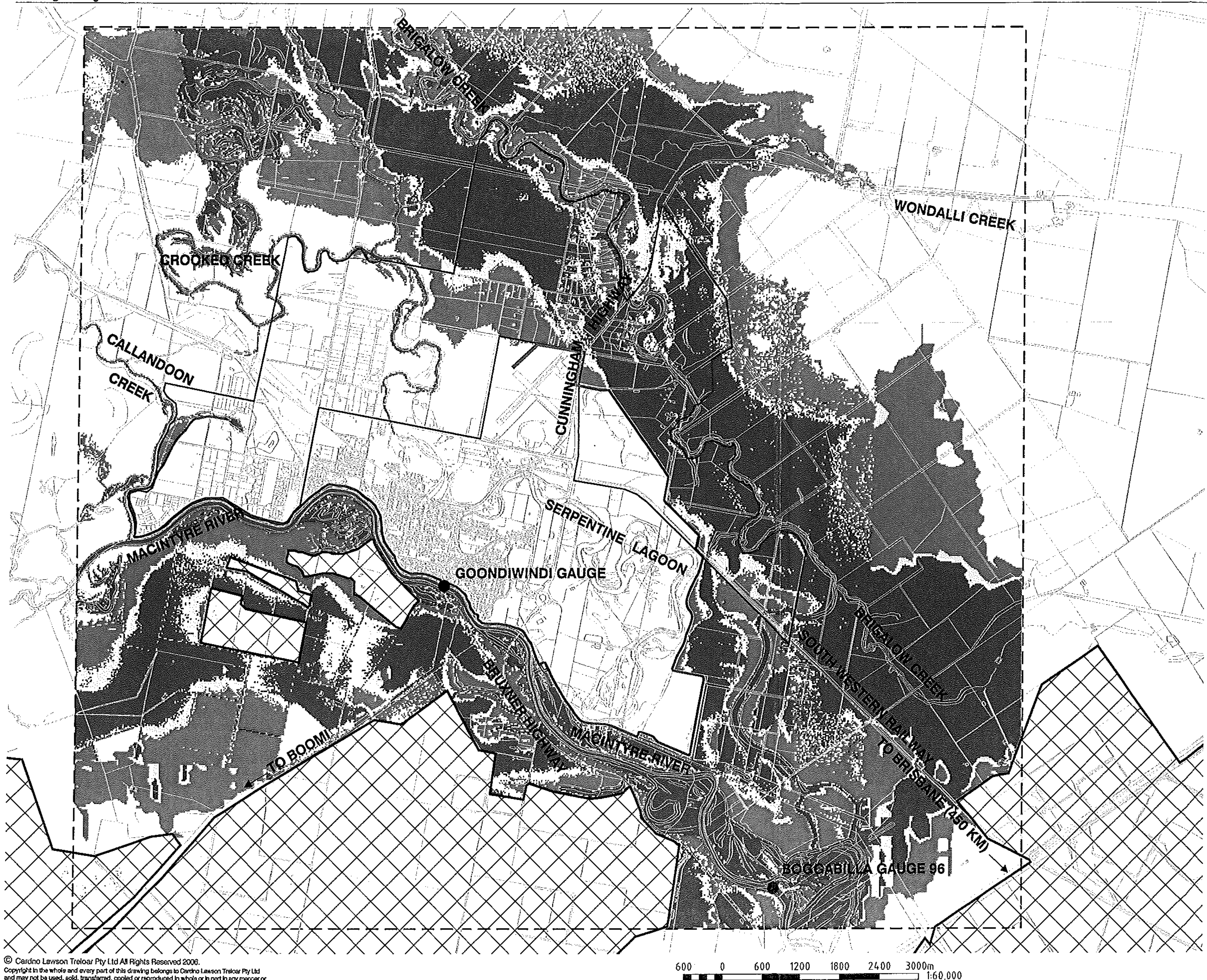
XREF's: J7803FigureBase; Levees 1996; Results, Waggamba_Shire_2005, HAZARD, R1_text

Cardno Lawson Treloar



LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Flood Hazard

- High Hazard
- Medium Hazard
- Low Hazard

Scale 1:60,000 (A3)

FIGURE 14.3

RAISED AND EXTENDED LEVEES - 1% AEP FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 14 2006 Q100 M06A.dwg
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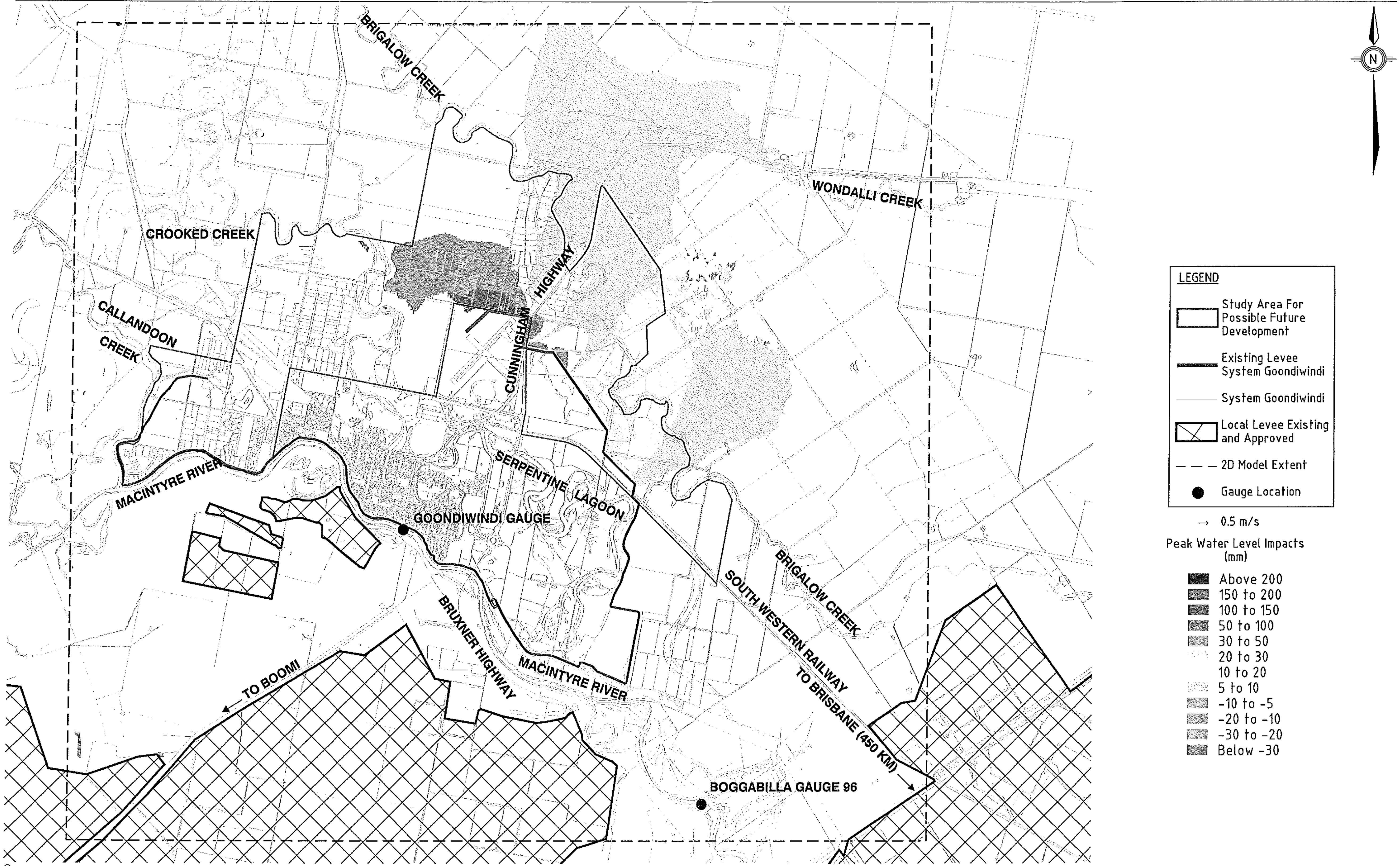
PRINT DATE: 29 March, 2007 - 6:16pm

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 14.4

RAISED AND EXTENDED LEVEES - 1% AEP FLOODING EVENT - PEAK WATER LEVEL IMPACTS

Rev: Orig. Date: March 2007

Project No.: LJ8651/R1

REFERENCE DRAWINGS

J7803/Figures/Figures

SCALE 0 200 400 600 800 1000m 1:25,000

Figure 1 - Goondiwindi Township

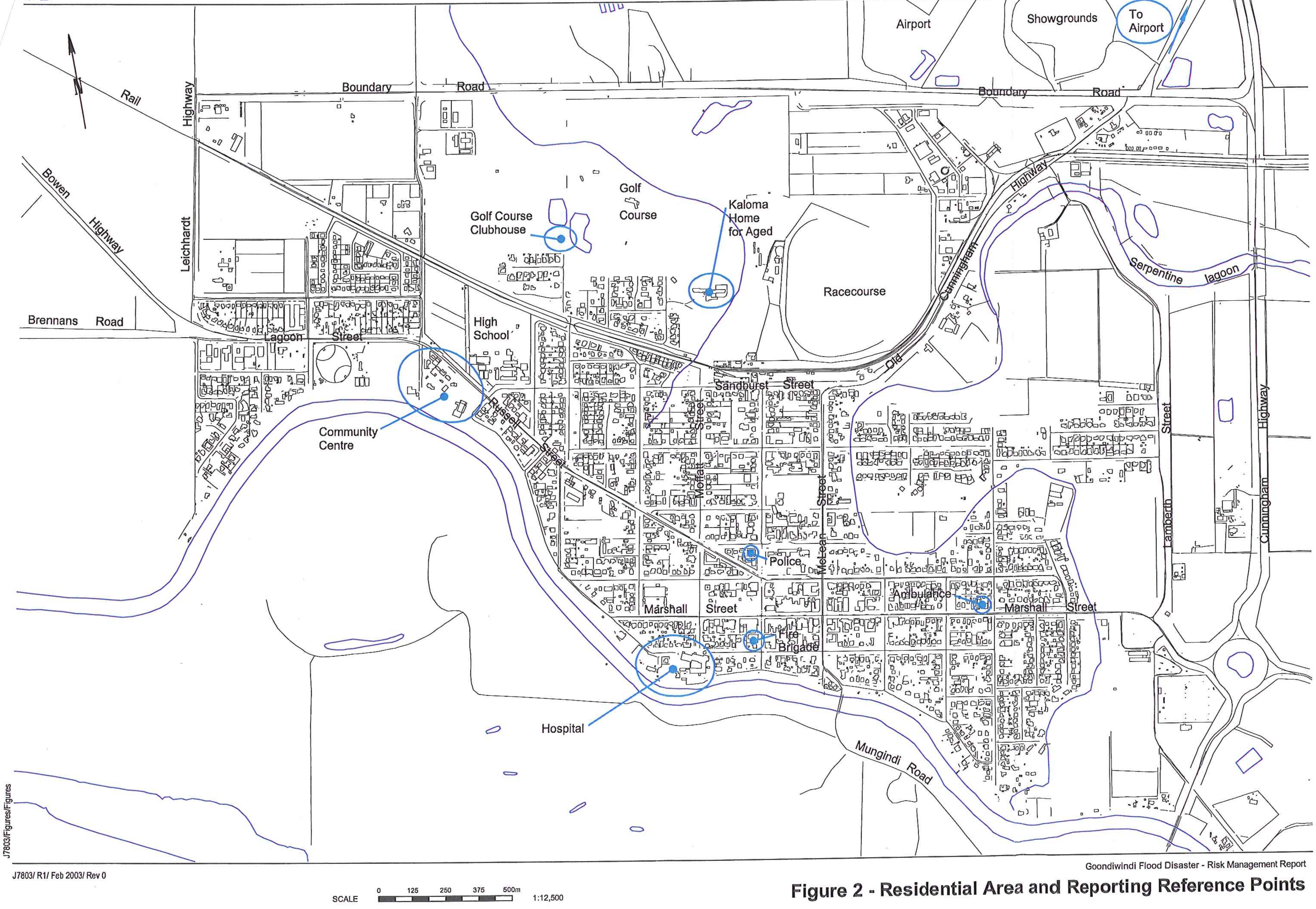


Figure 2 - Residential Area and Reporting Reference Points

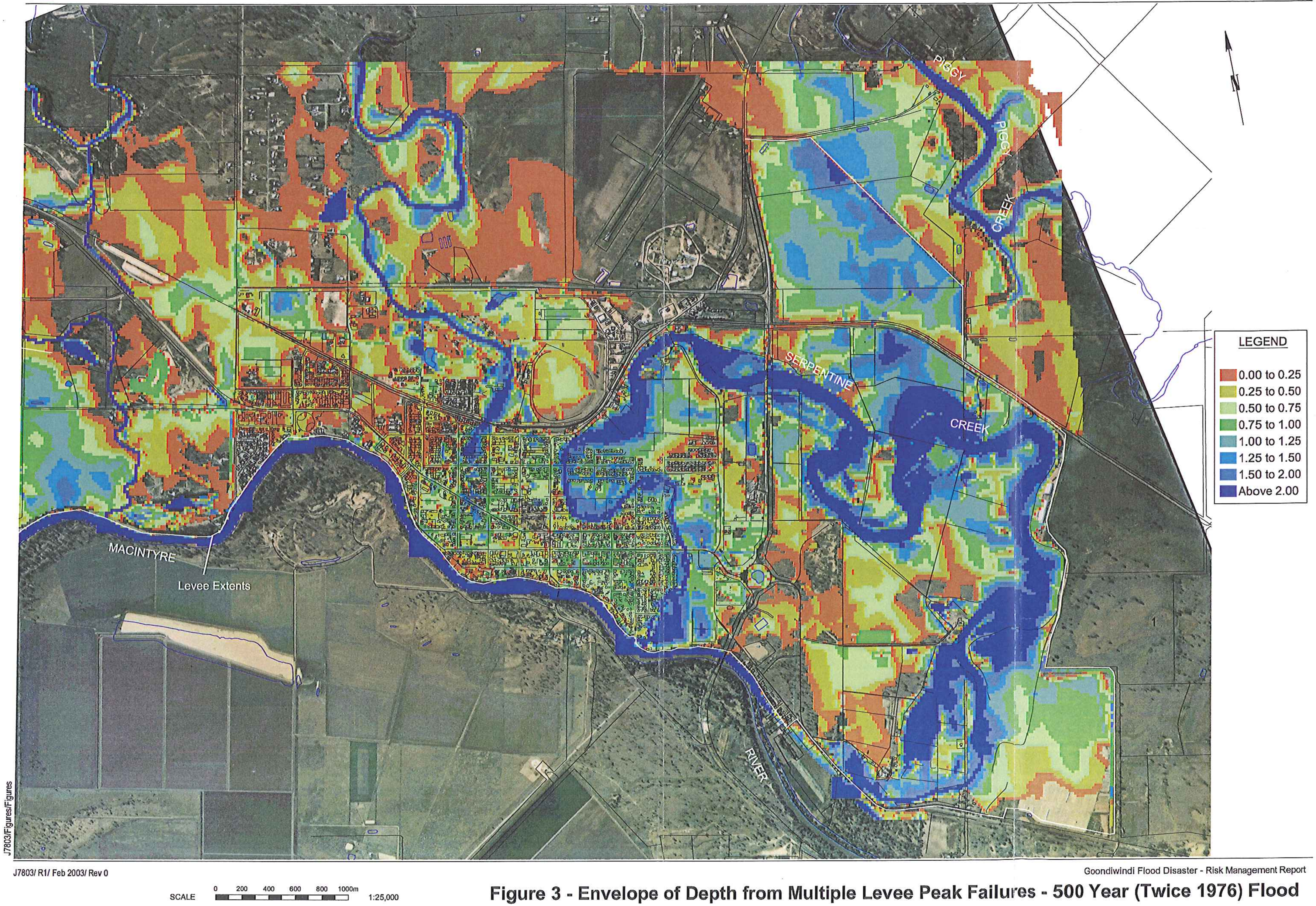


Figure 3 - Envelope of Depth from Multiple Levee Peak Failures - 500 Year (Twice 1976) Flood

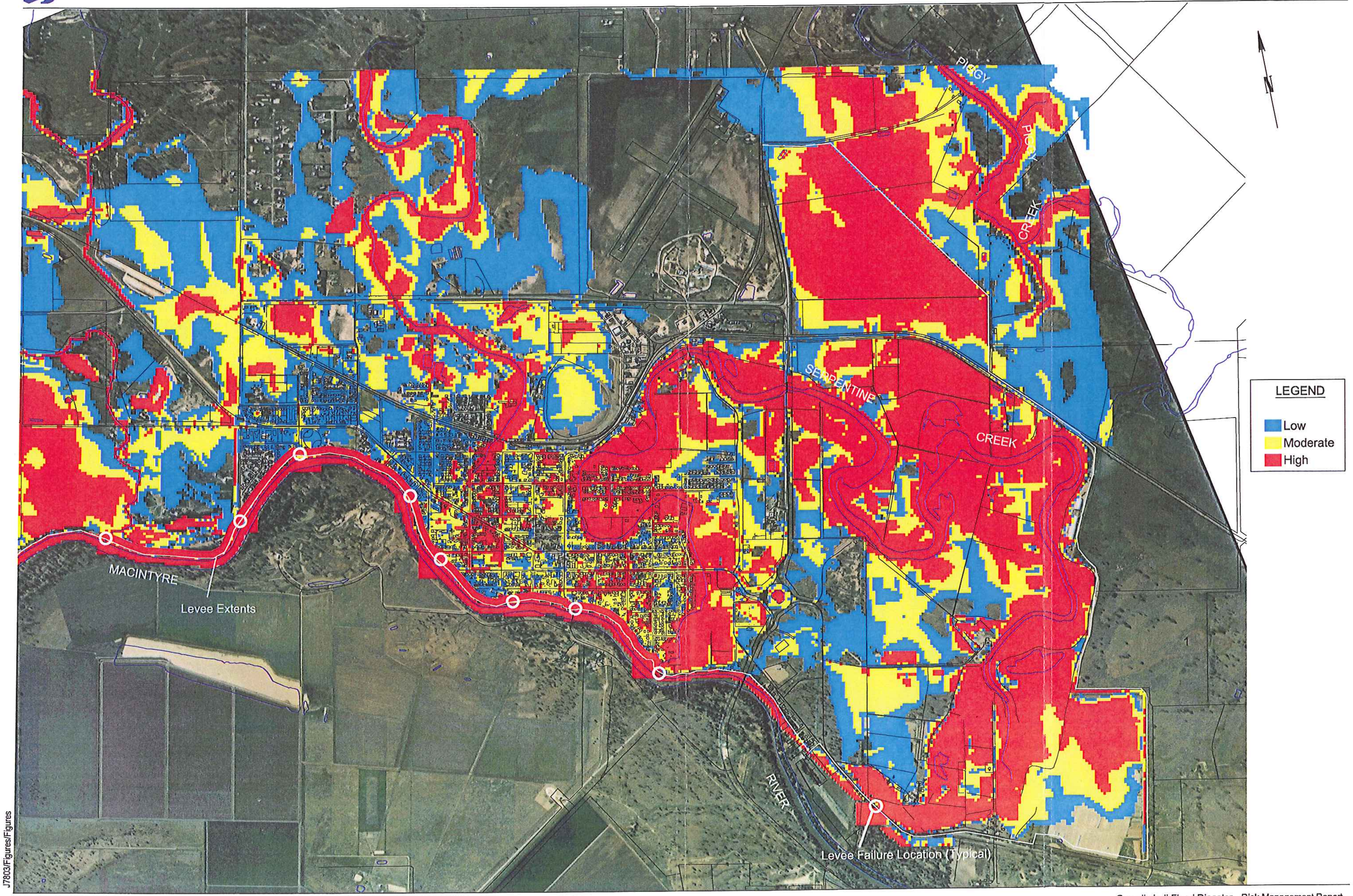


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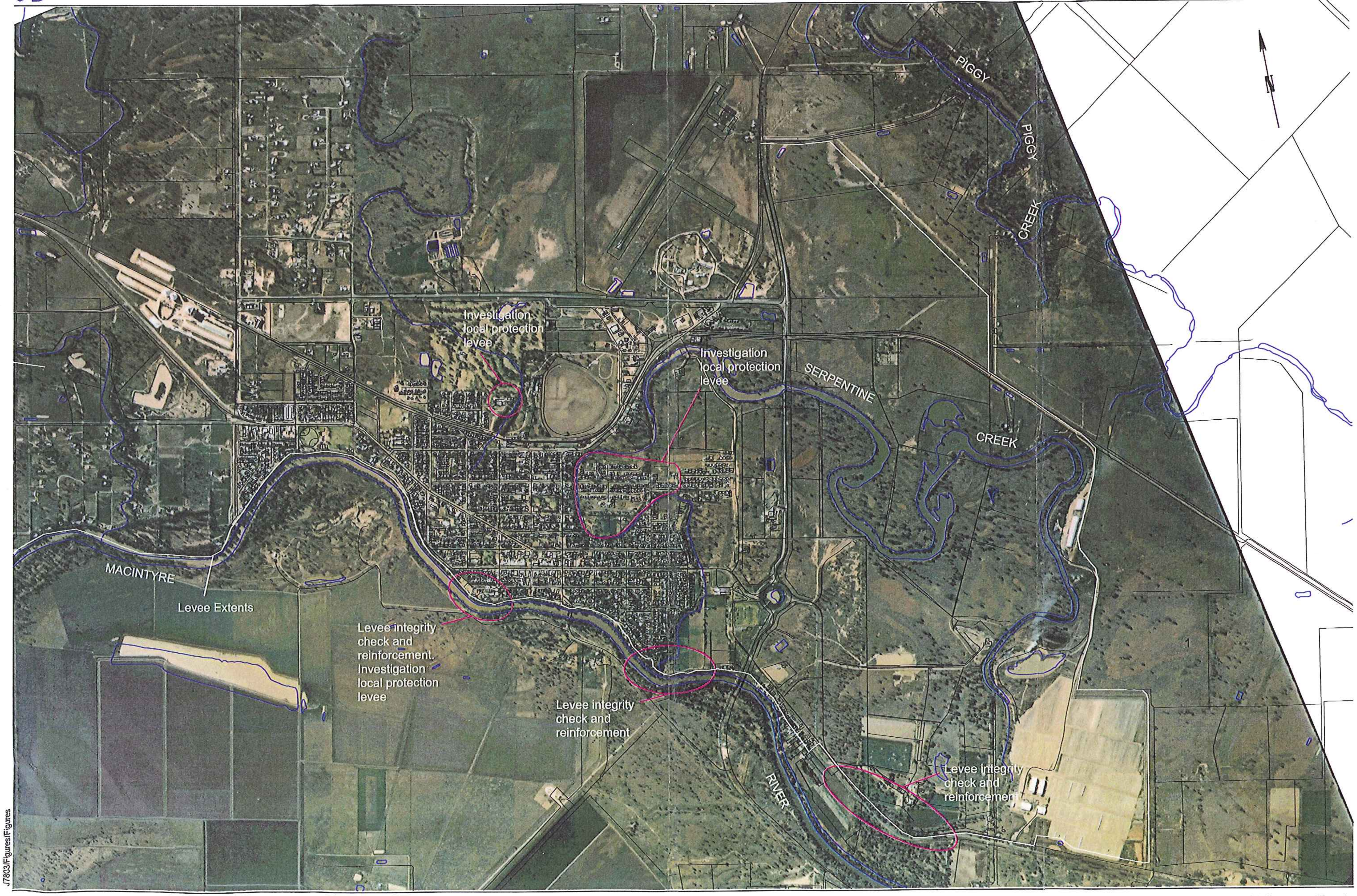
Figure 4 - Envelope of Hazard from Multiple Levee Peak Failures - 500 Year (Twice 1976) Flood



J7803/ R1/ Feb 2003/ Rev 0

J7803/Figures/Figures

Figure 5 - Treatment Options

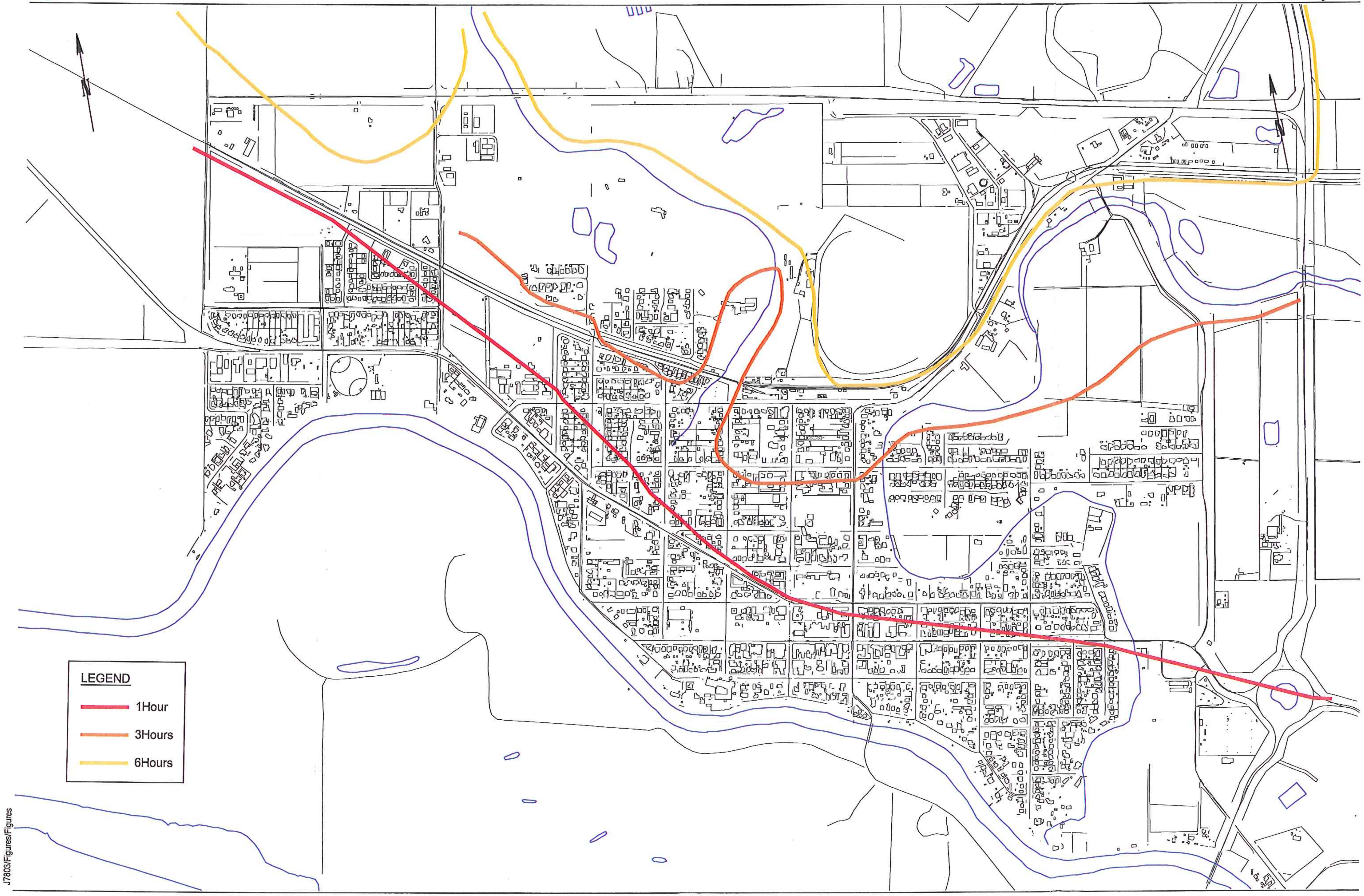


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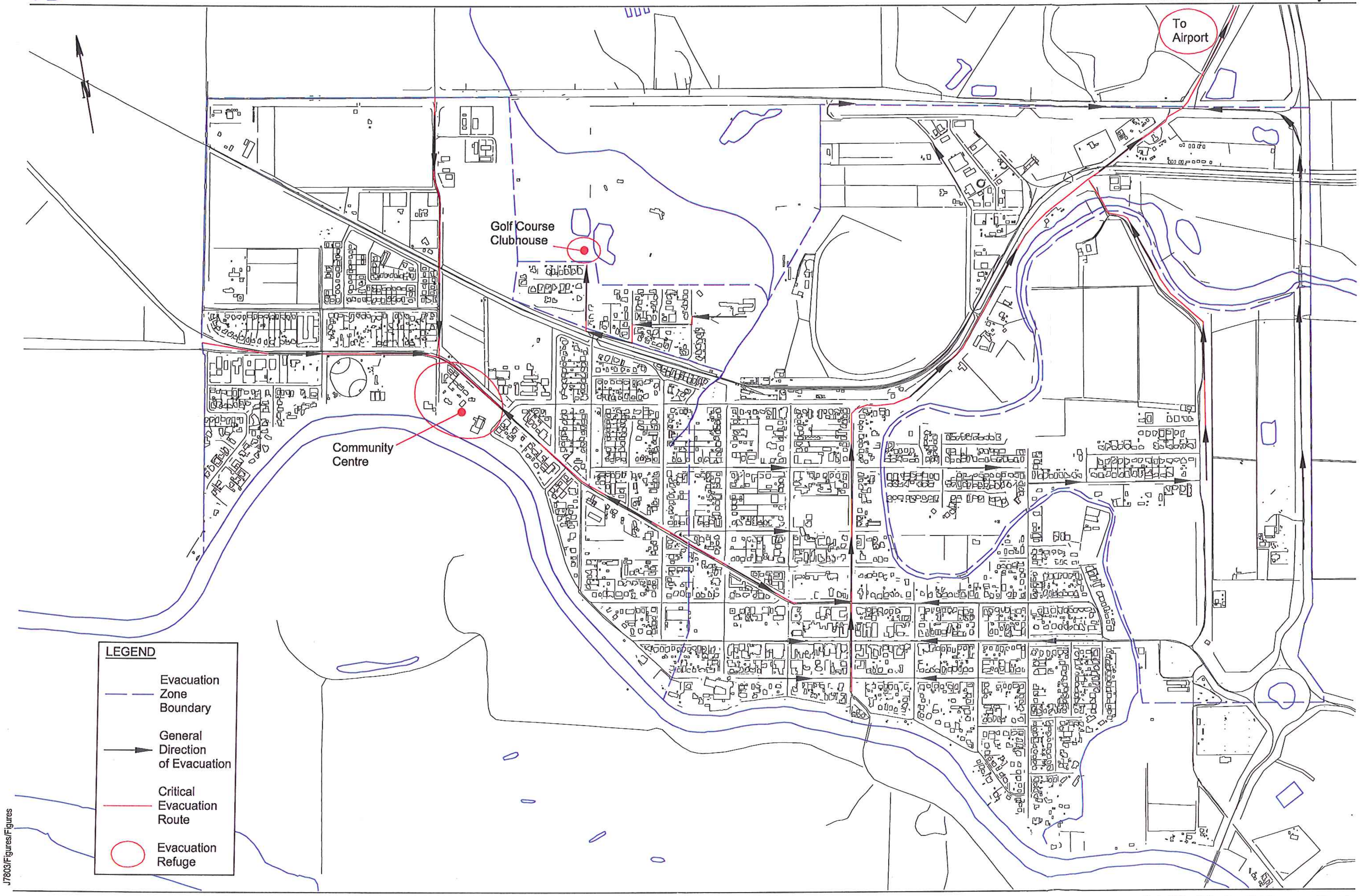
Figure 6 - Time to Flood From Levee Breaching



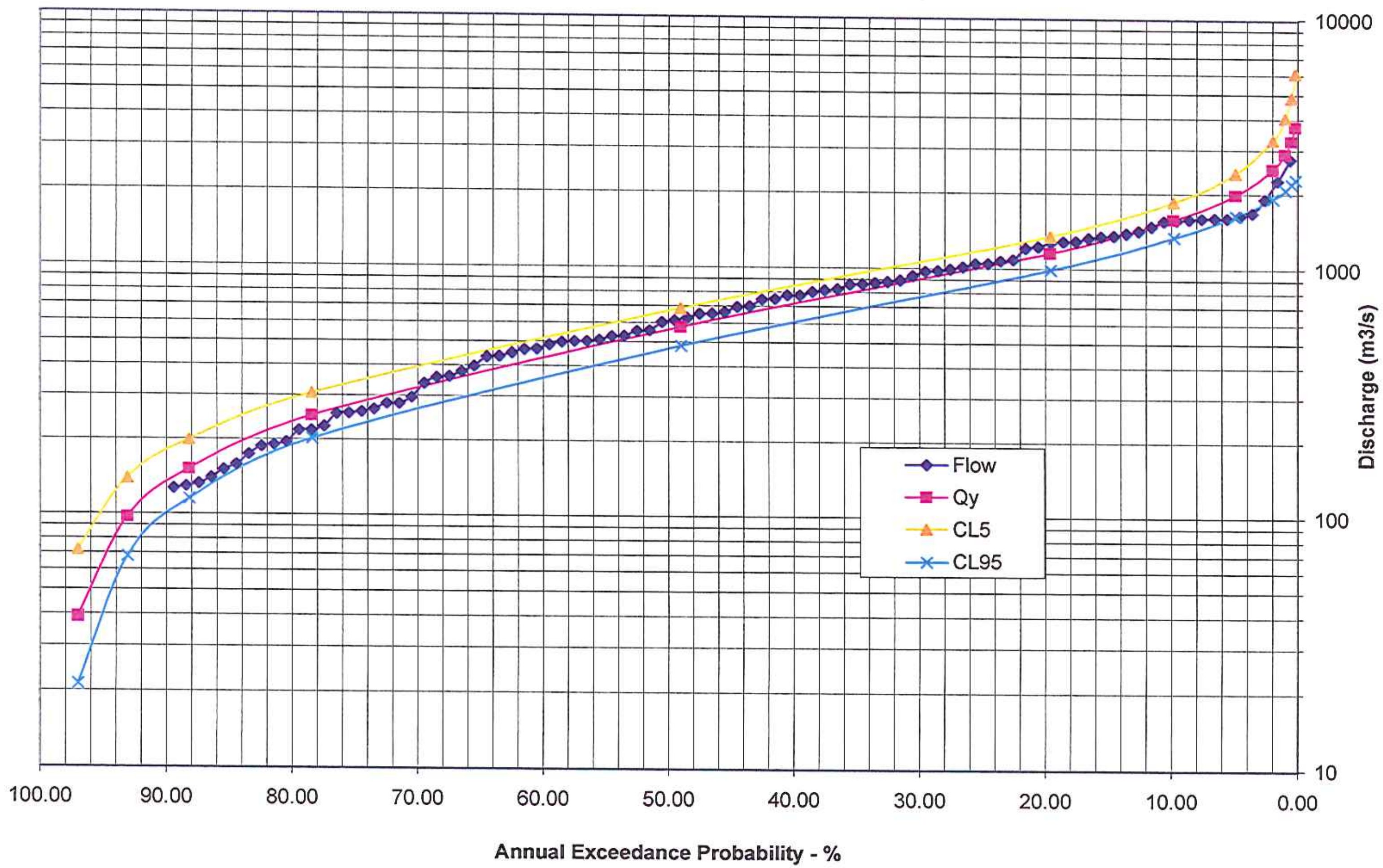
SCALE 0 125 250 375 500m 1:12,500

Figure 7 - Refuge Areas and Evaluation Routes

APPENDIX A

Boggabilla Flood Frequency Analysis

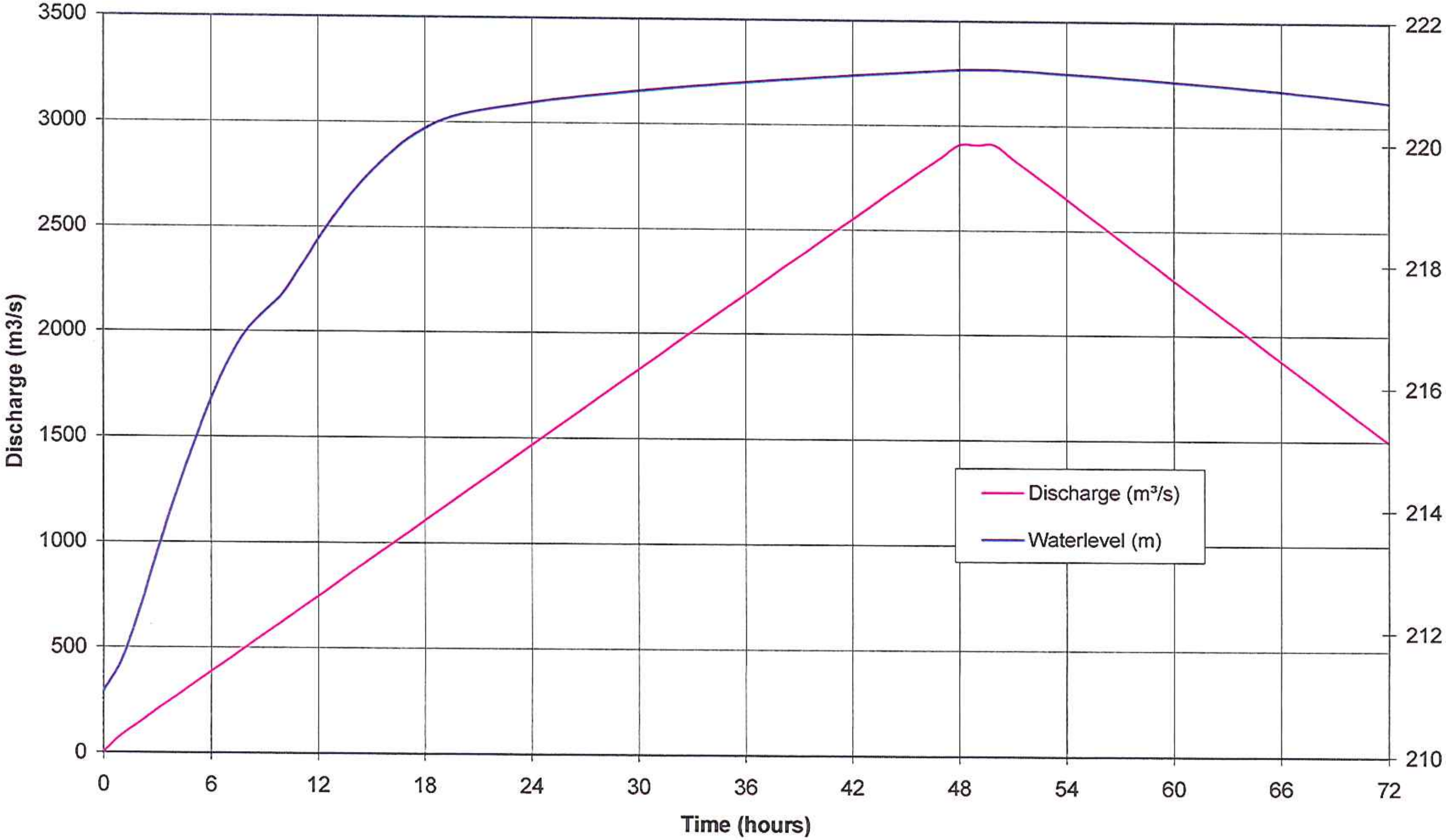
Boggabilla Gauge (flows > $20m^3/s$)



APPENDIX B

Flood Characteristics at Boggabilla Gauge and Flood Characteristics at Goondiwindi Gauge

Appendix B1 - Flood Characteristics at Boggabilla Gauge



Appendix B1 - Flood Characteristics at Boggabilla Gauge