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Tamworth Regional Council

Report for Barraba Flood Study

April 2012

FINAL

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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1. Introduction

1.1 NSW Flood Prone Land Policy

The primary objective of the New South Wales Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.

Through the Office of Environment and Heritage (OEH) previously the Department of Environment, Climate Change and Water (DECCW) the Department of Planning (DoP) and the State Emergency Service (SES), the NSW Government provides technical assistance to local government on all flooding and land use planning matters. The Floodplain Development Manual (NSW Government, 2005) is provided to assist Councils to meet their obligations through the preparation of floodplain risk management plans. Figure 1-1 from the Manual documents the process for plan preparation, implementation and review.

Tamworth Regional Council is responsible for local land use planning in Barraba. Through its Floodplain Risk Management Committee, Tamworth Regional Council proposes to prepare a comprehensive floodplain risk management plan for the study area in accordance with the NSW Government's "Floodplain Development Manual: the management of flood liable land", April 2005 .

1.2 Key Issue

Barraba town is located on the Manilla River which drains to Split Rock Dam in the New England region of NSW. Barraba is located 90 km to the northwest of Tamworth and has a population of approximately 1400 (Australian Bureau of Statistics Census Data, 2006). The river draining through Barraba commands a considerable catchment area of some 771 km^2. The catchments are primarily rural, with a number of towns located in the catchment.

Floodwaters in both catchments tend to rise quickly and isolate communities and properties for several days. Many houses can be inundated in flood events necessitating evacuations. Some rainfall and river gauging data in the catchment is available, and significant events have been recorded in Barraba. Significant events noted in the literature and mentioned by residents, most notably the 1964 flood. The 1964 flood was considered the worst in 100 years at the time.

1.3 Study Objectives

The primary objective of this study was to define the main-stem flood behaviour under historical conditions and design flood behaviour under existing and future climate conditions in the study area. The study produced information on flood levels, depths, velocities, flows, hydraulic categories, and provisional hazard categories for a full range of design and historical flood events. In addition, the study produced estimates of flood damage.

To achieve this objective the study collected, compiled and reviewed all available relevant data (including survey, aerial photography and satellite imagery). The design events included the 0.5%,1%, 2%, 10% and 20% AEP events together with the Probable Maximum Flood (PMF). In addition, the potential

impacts of climate change on flooding were assessed together with a number of other sensitivity analysis.

Hydrologic and hydraulic modelling was undertaken to satisfy the study objectives. The models and results produced in this study are intended to form the basis for subsequent floodplain risk management studies by Tamworth Regional Council, where detailed assessment of flood mitigation options and floodplain risk management measures will be undertaken.

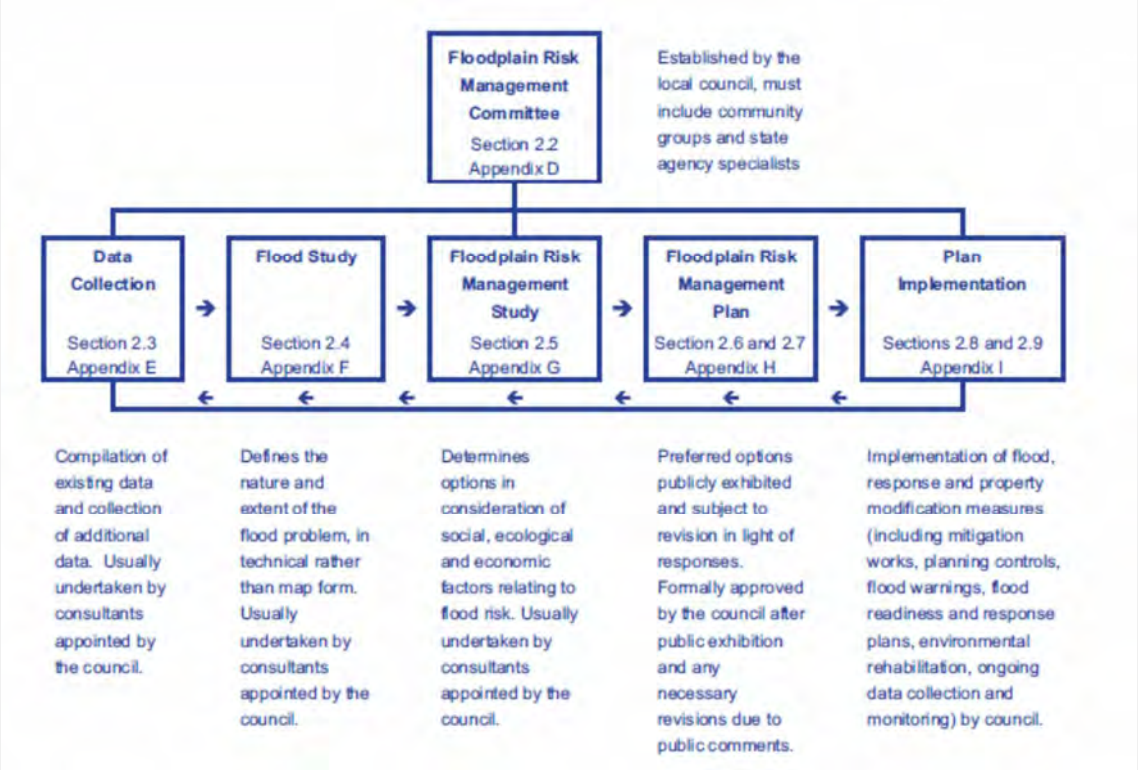


Figure 1-1 Floodplain Risk Management Process (NSW Government, 2005)

2. Background

2.1 Catchment Description

The upper catchments of the Manilla River are located to the northwest of Tamworth in the New England region of the NSW (Appendix A). The river drains a large (771 km^2) catchment before flowing through the town of Barraba.

The Manilla River headwaters are located near Split Yard Mountain in the Nandewar Range and drains in a north easterly direction to the Plumthorpe area, before turning south-east towards the town of Barraba. Approximately 20km south of Barraba, the Manilla River discharges into Split Rock Dam (400GL). From Split Rock Dam, the Manilla River drains southwards for a further 25km before it confluences with the Namoi River within the town of Manilla.

A number of significant tributaries discharge to the Manilla River as follows:

- Barraba Creek at Barraba;
- Mille Creek at Barraba; and
- Connor's Creek at Barraba.

The catchments in the upstream reaches of these creeks are generally steep and heavily forested. Lower reaches are mostly rural in nature. In many areas, particularly towards Barraba, the river generally has a deep, well defined, channel with a wide floodplain. River slopes vary from 1% to 2%.

A number of significant floods have occurred in Barraba as follows:

- A significant event in February 1864;
- The February 1955 flood was a major event;
- The January 1964 was also a major event and is enshrined in many residents' memories. It was noted as the worst in 100 years; and
- More recent flood events in 1971, 1974, 1984, 1998, 2003 and 2004.

Floodwaters in the catchment tend to rise quickly and isolate communities and properties for several days. Many houses can be inundated in flood events necessitating evacuations. The nature of flooding varies considerably from in-stream flood ways to areas where the floodwaters inundate floodplains at bends in the river and where floodwaters backup into the lower reaches of tributary creeks. There are a number of rainfall and river gauging data in the catchment, with records dating back as far as 1971.

2.2 Previous Studies

The 2007 study, Assessment of Flood Risk in Various Towns and Villages (Bewsher 2007), provides a comprehensive synopsis of the historical flooding at Manilla and was undertaken with the following scope:

Tamworth Regional Council commissioned Bewsher Consulting Pty Ltd to conduct a preliminary assessment of the flood problem at 11 towns and villages throughout the Local Government Area (LGA). The principle aim of the assessment was to identify flood problems, prioritise the towns and villages according to the general scope of the problem, and to develop a strategic plan for the preparation of

detailed flood studies and floodplain management studies and plans, as stipulated in the New South Wales Government's Floodplain Development Manual (April 2005).

A prioritised plan for future flood studies and floodplain management studies and plans within the Tamworth Regional Council LGA was presented. The principal factor for allocating priorities was the number of buildings located within the historic flood extent. The typical flood velocities and available warning times at each location were also been considered. Another important consideration is the frequency of the historical event under consideration.

By this method, the town of Barraba was given a high priority for future studies. The 1964 flood inundated many homes, with significant flood depths and velocities. (Bewsher 2007),

The 2007 study, Assessment of Flood Risk in Various Towns and Villages provided the following synopsis of flooding at Barraba:

The town of Barraba has a population of about 1,200 people. It is located upstream of the junction of Manilla River and Connors Creek (combined catchment area 568 km2). The township was surveyed in 1852.

The record flood occurred in January 1964. The Barraba Chronicle at the time reported that the flood was the sixth major flood in the area and the worst in 100 years. Long-time resident and former SES Unit Controller Wes Brodbeck confirmed that the flood occurred almost exactly 100 years later than the (February) 1864 flood. Lesser floods are reported to have occurred in 1955, when one life was lost, and in 1971.

The Local Flood Plan reports that about 30 homes were flooded in Barraba in the 1964 event. About 80 buildings from the SPOT image are located within the 1964 flood extent. This discrepancy may be due to many of these buildings experiencing only shallow flooding that was insufficient to inundate floors. The main concentration of houses within the 1964 flood extent is located in Cherry Street, with other groupings at the eastern end of Savoy Street and near the caravan park in Bridge Street.

The Barraba Chronicle estimated the loss as in excess of £250,000. Homes, furniture, floor coverings, fences, stock, roads and bridges were damaged. The Barraba Council was considering demolishing four houses where the flood had weakened foundations and walls.

Little warning was received of the 1964 flood. Fortunately the flood rose in the morning, facilitating rescue operations. Ominously, Wes Brodbeck expressed the view that, "Had it been at night-time, we'd have lost lives". A house at 71 Cherry Street was flooded to a depth of 0.3m over the floor, and another house was flooded to the level of its roof gutter.

Barraba is also considered a high priority for future flood studies. It appears that about 80 buildings are today located within the extent of the 1964 flood, and reports from the event suggest that there could well have been loss of life, had the flood arrived at night. (Bewsher 2007).

3. Data

3.1 Introduction

For the purposes of undertaking the flood study, and to calibrate models, it was necessary to source the following key data:

- Concurrent rainfall and runoff data for significant flood events that can be used for calibration of the hydrological model parameters;
- Pluviographic rainfall data at 6 minute intervals to provide information on historic storm temporal patterns;
- Daily rainfall data to provide spatial distribution of rainfall events;
- Runoff gauge data, including gauge history and rating curves, to determine hydrographs of flood events; and
- Topographic survey data for the compilation of flood models and for the purposes of flood modelling.

3.2 River Data

3.2.1 Runoff Gauges

A number of river gauges are located along the Manilla, Namoi and Macdonald Rivers (Refer to Appendix B). A number of these gauges were suitable for calibration, as tabulated below, as they:

- Are located at appropriate positions along the river channels for the purposes of the study;
- Had captured significant flood events;
- Had reasonable gauging data and rating tables to provide information on reported hydrographs during flood events. It is important to note, that while operational dates may span a number of years, for some of the gauges earlier measurements were only captured as daily totals; and
- Had data periods that were concurrent with pluviographic rainfall data in the catchment.

Table 3-1 Runoff Gauge Data

Gauge Number	Gauge Name	River	Operational Dates	Comments
419053	Manilla River At Black Springs	Manilla River	01/01/1972 – Present	Manilla River 5km D/S Barraba
419030	Barraba	Manilla River	01/01/1985 – 25/03/1987, 17/11/2009 – Present	No Reliable Period Of Flow Gaugings/Ratings

3.2.2 Flood Frequency Analysis

Flood frequency analysis was undertaken using the data provided by the Pinneena (Version 9.3) software, for the Manilla River at Black Springs gauge (419053). While the Pinneena software provides the ability to undertake flood frequency analysis, this has no ability to screen data and assess impacts of data outliers. To this end the flood frequency analysis was undertaken manually. In respect to the flood frequency, the following was noted referring to Appendix B:

- From 1972 onwards automatic stage recordings were available, providing a measurement of the instantaneous flood peak;
- Of the gaugings undertaken from 1972 to calculate the rating curves, a large number of measurements are noted as being “doubtful” and in the range of flow less than approximately 100 m^3/s. Thus the rating curve for larger flows needs to be treated with circumspection;
- The more extreme gaugings were measured during the 1990 event, with a measured discharge of less than approximately 110 m^3/s. The maximum gauged stage measured was approximately 2.5m. This is significantly less than the extrapolated rating curve which extends to 5.5m. Thus, again, the rating curve for extreme events needs to be treated with circumspection;

The results of the flood frequency analysis are shown in the figures and tables below. Further supporting information is provided in Appendix B. From the results, the 1% AEP event could be expected to be approximately 1450 m^3/s at the Black Springs gauge, approximately 5km downstream of Barraba. It must be noted that the flood frequency analysis could potentially have a significant variance at the extreme event range.

Flood volumes were also estimated for particular events using measured gauging of water level and flow at various gauges to develop a stage-flow relationship. From this relationship flow hydrographs at 15-minute increments for the Manilla and Namoi rivers were developed for the purposes of calibration.

Figure 3-1 Flood frequency analysis

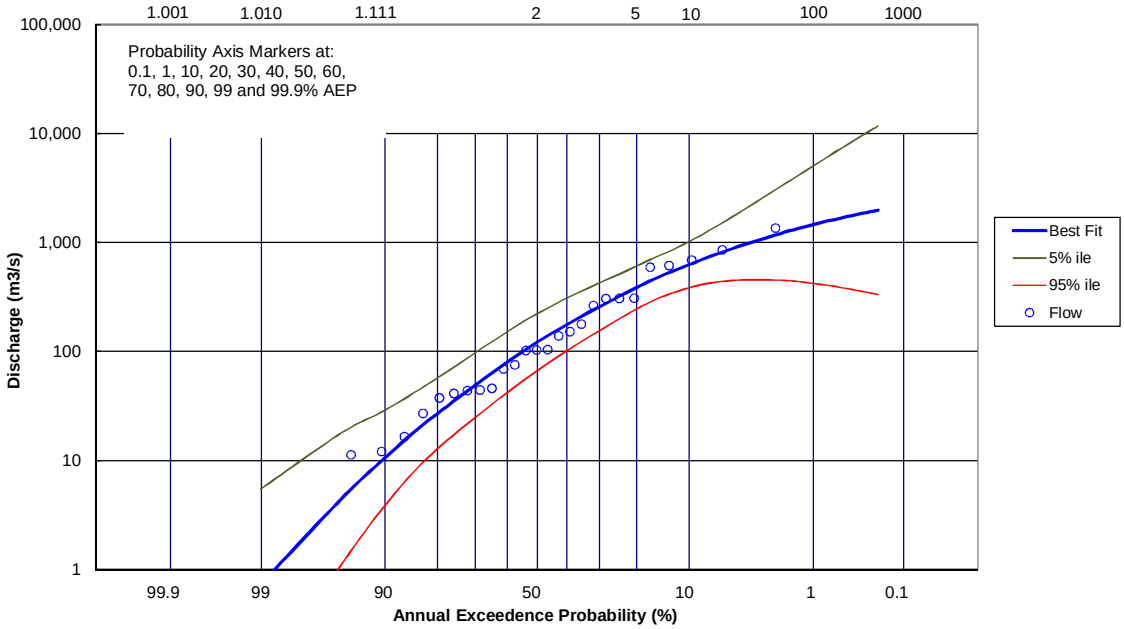


Table 3-2 Flood frequency analysis results at Black Springs gauge

AEP	Flood Peak (m^3/s)
20%	385
10%	620
2%	1200
1%	1450
0.5 %	1680

3.3 Rainfall Data

A number of rainfall gauges (Refer to Appendix B) are located within the Manilla and Namoi river catchments as tabulated below. While the daily rainfall data gauges are numerous, there are only a few pluviograph gauges in the catchment that provide temporal information on historic storms. The daily rainfall gauges are useful to determine any spatial distributions of rainfall that may have occurred during a significant storm event. The pluviographic rainfall station 54102 (Barraba) was primarily used for the purposes of calibration, as this station:

- Had the longest period of record, coincidental with the runoff gauge data;
- Provided 6 minute rainfall data for a number of significant storm events;
- Is located at an appropriate position along the river channel for the purposes of the study; and
- Is located within the catchment.

Table 3-3 A selection of available Rainfall Data

Gauge Number	Type	Operational Dates	Comments
Barraba - 54102	Pluvio	1971 – Present	Calibration With Manilla River
Barraba Post Office - 054003	Daily	1964 – Present	Confirmation of rainfall distribution with Barraba Gauge

3.4 Calibration Event Data

The flow gaugings in Table 3-1 were interrogated to abstract significant events for calibration purposes, for which concurrent pluviographic rainfall data was available. Events that were considered appropriate for calibration are listed in Table 3-4 below, with concurrent pluviographic rainfall data provided in Appendix B.

Unfortunately none of the gauges on the Manilla River recorded data for the 1964 flood event, with exception of a gauge at Brabri shortly upstream of Manilla town. Comparing the 1964 event to the 1974 event, shows that the Manilla River could have experienced approximately 4 times the flood peak in 1964. Thus a flood peak in the order of approximately 2400 m^3/s could have occurred in 1964.

Table 3-4 Calibration Event Data (at Black Springs)

Event	Flood Peak Date/Time	Flood Peak Level (m)	Rated flow (m3/s)
1974	08.01.1974 5:31	4.978 m	625
1984	30.01.1984 12:44	5.311 m	724
1998	05.09.1998 18:40	5.502 m	783
2004	17.01.2004 2:30	4.259 m	437

3.5 Topographic Survey

As part of the study, survey data was compiled as follows:

- DTM data to describe the topography and floodplains of the Manilla and Namoi Rivers through the town of Manilla;
- Terrestrial survey of key features such as bridges and areas where the methodology used to produce the DTM were limited; and
- Survey of floor levels, for the purposes of flood damage assessments.

The survey was undertaken by Aerometrex and Baxter Geo Consulting, using Tamworth Regional Council's orthorectified photography for both towns. A survey QA report is provided in Appendix I. This photography was surveyed at 20cm pixel resolution (GSD) in March 2008 and had the following specifications:

- Flying Height: 7670 ft;
- Horizontal Accuracy (Ortho): +/- 0.40m RMSE;
- Horizontal Accuracy (Feature): +/- 0.20m RMSE;
- Vertical Accuracy of 0.17m (to 68% or 1 Sigma confidence); and
- Vertical accuracy of 0.34m (to 95% or 2 Sigma confidence).

Aerometrex processed the data and:

- Provided coded breaklines in dxf (for input into Civil 3D & 12D)
- Spot heights at an interval of 10m in a digital format which will be suitable for input into Civil 3D & 12D
- Provided four spot heights adjacent to houses or buildings in the expected flood area approximately 350 per site; and
- Provide a georeferenced image in ecw format.

Thereafter Baxter Geo Consulting:

- Undertook additional survey control under instruction from Aerometrex;
- Provide survey control to Aerometrex;
- Receive processed data from Aerometrex and loaded it into Civil 3D for validation;

- Undertook field validation of selected points;
- Located features, such as bridges, weirs and extra points along the river banks; and
- Established floor levels within the PMF when it has been determined by modelling.

4. Community Consultation

4.1 Overview

The primary objectives of the flood study consultation activities were as follows:

- Informing the relevant government agencies that the study is being undertaken, outlining its objectives and inviting agencies to provide any relevant data they may hold and / or advise of any particular issues of concern;
- Similarly informing relevant local community groups; and
- Similarly informing the general public.

4.2 Floodplain Risk Management Committee

The purpose of the Floodplain Risk Management Committee is to:

- Act as both a focus and forum for the discussion of technical, social, economic, environmental and cultural issues and for the distillation of possibly differing viewpoints on these issues into a management plan; and
- Ensure that all stakeholders (often with competing desires) are equally represented. As such, the composition and roles of committee members are matters of key importance.

The Floodplain Risk Management Committee does not have any formal powers. Rather, it has an advisory role, but an important one. The principal objective of the committee is to assist the Council in the development and implementation of a management plan for the area(s) under its jurisdiction.

A Floodplain Risk Management Committee was convened by Tamworth Regional Council and included representatives from Council State Government and the committee. The committee met on:

- 20 July 2011;
- 3 August 2011;
- 16 September 2011; and
- 20 October 2011

Minutes of the meeting are provided in Appendix C.

4.3 Consultation Activities

4.3.1 2011.08 - Project Notification, Newsletter and Survey

A public notice was placed in the local Barraba Gazette newspapers in August 2011. In addition a project information sheet and survey was forwarded to the residents in Barraba (Appendix C). A total of 65 survey responses were received. Key issues raised in the survey were:

- A large number of the residents had experienced flooding in the town of Barraba first hand;
- Flood levels tend to rise and recede very rapidly, often within the space of a day. One resident noted a 5m rise in 1 hour;

- Preparation for flooding includes regular observation of river levels and lifting of belongings. In addition, listening to advice on local radio stations and from the SES. Stock, vehicles and other equipment is moved to higher ground. Although a number of residents have noted that the fast rising flood water leaves little time for preparation in a flood;
- Isolation of residents is less common than Manilla;
- Residents often mentioned the 1964 floods and these have been etched in memories of residents in Barraba.
- One resident noted that main flooding occurs when Manilla and Connor River flood simultaneously
- Another resident noted over 1 m of flood waters through the house;
- A number of residents noted damages associated with flooding to dwellings;
- For the school, a key response was to get school children home safely;
- Residents noted desire to have creeks cleaned of debris and vegetation;
- In additions a number of surveys provided flood markers around town.

4.3.1 2011.10.20 - Meeting with the Floodplain Management Committee

A meeting was held with the Floodplain Management Committee at the offices of Tamworth Regional Council. The meeting discussed the approach of the study and the program. A number of issues pertaining to the survey were discussed. In attendance were Council officers, OHE and SES. Minutes of the meeting can be found in Appendix C together with a transcript of the presentation.

4.3.2 2011.12.14 - Meeting with the Barraba Community

A meeting was held at the Barraba Council Chambers with the Barraba Community and the Floodplain Management Committee. A presentation of the overall project was provided and the community had the opportunity to provide input to the study. In particular the purpose of the Flood Study in the context of the overall Floodplain Risk Management Process was highlighted. The community provided valuable input with regards to experiences during flood events. In particular a number of the community had experienced the 1964 flood event.

At the meeting preliminary flood maps were presented to the community to identify any issues relating to their experiences. In attendance were Council officers, OHE and SES. The attendance can be found in Appendix C, together with a transcript of the presentation.

5. Hydrologic Model Configuration and Calibration (RORB)

5.1 General

The hydrology for the Barraba flood study was developed using the RORB hydrological model. The model was setup as an end of catchment model, producing flood hydrographs for the Manilla River upstream of the Barraba town.

RORB is a general runoff and stream flow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce runoff hydrographs at any location. It can also be used to design retarding basins and to route floods through channel networks.

The program requires a data file to describe the particular features of the stream network being modelled and is run interactively. It can be used both for the calculation of design hydrographs and for model calibration by fitting to rainfall and runoff data of recorded events.

The model is aerially distributed, nonlinear, and applicable to both urban and rural catchments. It makes provision for temporal and areal variation of rainfall and losses and can model flows at any number of gauging stations. In addition to normal channel storage, specific modelling can be provided for retarding basins, storage reservoirs, lakes or large flood plain storages. Base flow and other channel inflow and outflow processes, both concentrated and distributed, can be modelled. (RORB 6 User Manual).

5.2 Configuration

Compilation of the RORB model included:

- Catchment delineation, in accordance with the RORB procedures. For the Barraba model a total of 18 subcatchments were delineated;
- Catchment parameter determination, namely subcatchment area and reach lengths and slopes;
- Event rainfall and concurrent flow data compilation, for calibration; and
- Design rainfall determination for generating design storm rainfall events, for the 0.5%,1%, 2%, 10% and 20% AEP events together with the Probable Maximum Flood (PMF).

The RORB model was simulated for a range of durations ranging up to 72 hours. For each event the critical duration was reported. Lag times were based on average slopes and flow velocities, ranging between 1 m/s and 2 m/s depending on slope. Percentage of impervious areas, used in the hydrology model, was 5% to represent the rural nature of the catchment. Catchment maps and sub-catchment delineation are provided in Appendix D.

5.3 Calibration

5.3.1 General

The RORB model was calibrated by variation of model parameters to obtain a good fit of the calculated to the measured hydrograph. The parameter kc is the main means of achieving a fit. The parameter, kc,

can be decreased to increase the hydrograph peaks and decrease the lag time. Conversely, increasing kc does the opposite. In addition to kc, varying the initial loss is also an important means of achieving a fit. A further means is by altering the m value however use of this parameter for calibration is less common.

5.3.2 Regional kc Parameter

A number of regional estimates for the determination of kc are available throughout the literature and in the Australian Rainfall and Runoff (AR&R 2001). A number of these are offered within the RORB model for use in calibration. For the Barraba RORB model, possible regional estimates of kc parameters are tabulated below.

Table 5-1 Manilla RORB model Regional kc Parameter Estimates

Method	kc Estimate
Eastern NSW (Kleemola) (Eqn 3.20, ARR (Book V)	25.97
Australia Wide – Dyer (1994) data (Pearse et al, 2002)	38.35
Australia Wide – Yu (1989) data (Pearse et al, 2002)	32.29
RORB Default – Eqn 2.4 (RORB Manual)	61.10

5.3.3 Calibration – 1998 Storm (05/09/1998)

The 1998 event started with rainfall on 05/09/1998 which lasted for 5 days. The peak rainfall intensity recorded at the pluviographic rainfall station 54102 was 4.77 mm in 6 minutes recorded at 11:30pm on the 4th September 1998. Preceding the storm, the antecedent conditions within the catchment were dry. Figure 5-1 below shows the rainfall recorded at the Barraba station. The best fit calibration achieved for this event was using a kc value of 20, and an m value of 0.8, as shown in Figure 5-1 and the calibration statistic in Table 5-2. This kc compares favourably to the recommended Kleemola regional kc estimate. Initial and continuing loss parameters at the Manilla gauge were 25mm and 1.2 mm/hr respectively, which are within acceptable range according to the *RORB user manual version 6 (Section 3.5)*. From the figure and Table 5-2 below, the following is noted:

- Good approximation of the hydrograph shape;
- Flood peak approximation is considered good with a difference of 0.5%;
- Good approximation of the flood volume, to within 2.1%.

Figure 5-1 1998 Rainfall Event

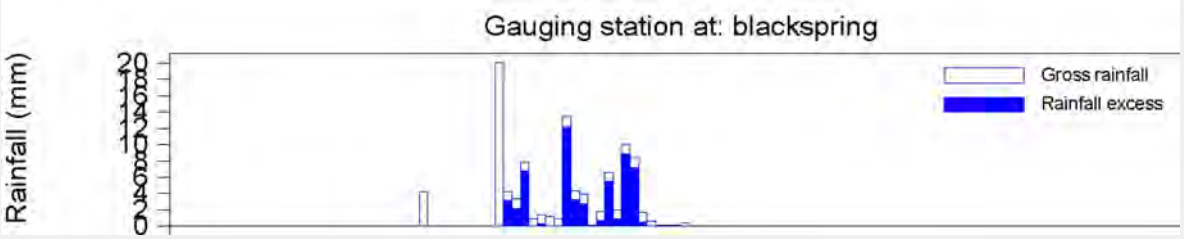
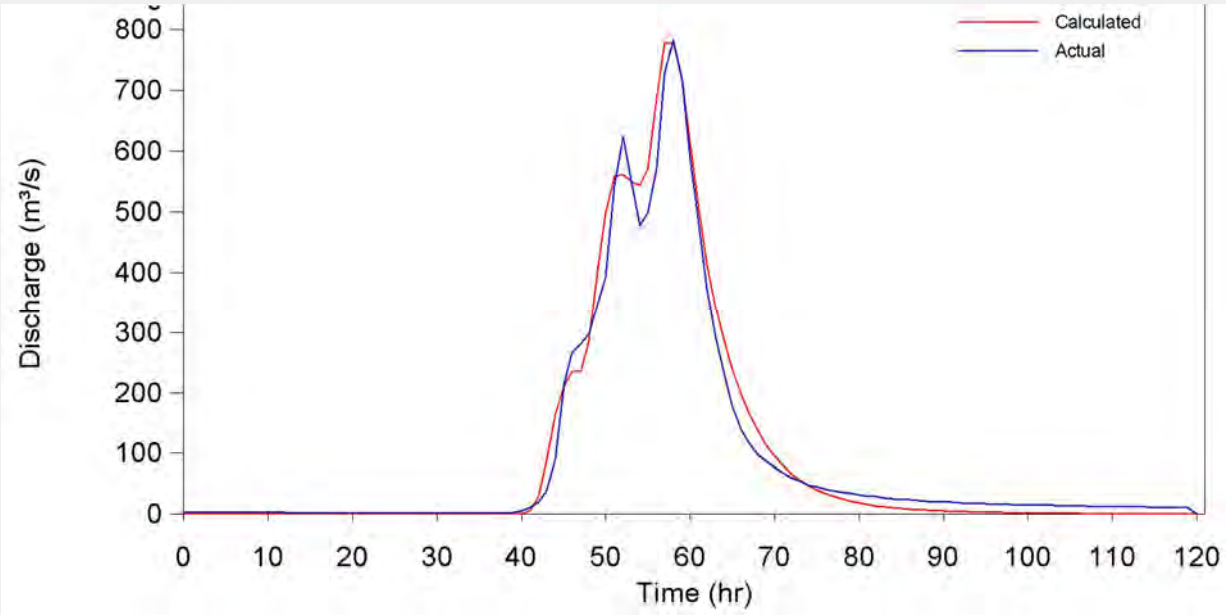


Table 5-2 1998 Storm Calibration Statistics

Item	Observed	Simulated	Difference
Storm Peak	783.5	779.2	-0.5%
Storm Volume	0.41E+08	0.41E+08	+2.1%
Lag	58	58	0%

Figure 5-2 1998 Calibrated hydrograph at Barraba Gauge 541022



5.3.4 Calibration – 1974 Storm (05/01/1974)

The 1974 event started with rainfall on 05/01/1974 which lasted for 5 days. The peak rainfall intensity recorded at the pluviographic rainfall station 54102, was 2.16mm in 6 minutes recorded at 9:30 am on 07/01/1974. Preceding the storm, the antecedent conditions within the catchment were rather dry. Figure 5-3 below shows the rainfall recorded at the Barraba station. The best fit calibration achieved for this event was using a kc of 20, and an m value of 0.8, as shown in Figure 5-4 and the calibration statistic in Table 5-2. Again, this kc compares favourably to the recommended Kleemola regional kc estimate. For this calibration, 4 rainfall bursts were configured in the RORB model. Initial and continuing loss parameters at the Manilla gauge were 25mm and 4 mm/hr respectively, with lower continuing and initial losses specified for subsequent rainfall bursts in order to provide a calibration fit with flow hydrographs extrapolated from river water level data. The loss parameters used are within acceptable range according to the *RORB Version 6 User Manual*. From the figure and the table, the following is noted:

- Good approximation of the 4 rainfall bursts in the hydrograph shape although some difference in hydrograph lag;
- Flood peak approximation is considered good with a difference of 0.2%;
- Good approximation of the flood volume, to within 2.1%.

Figure 5-3 1974 Rainfall Event

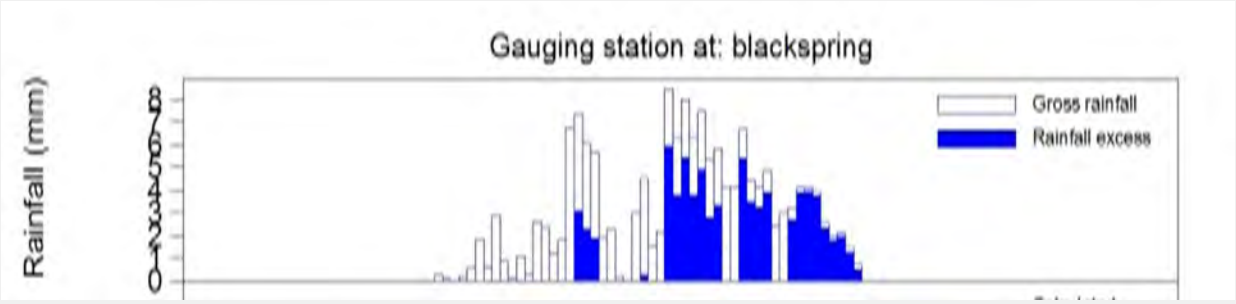
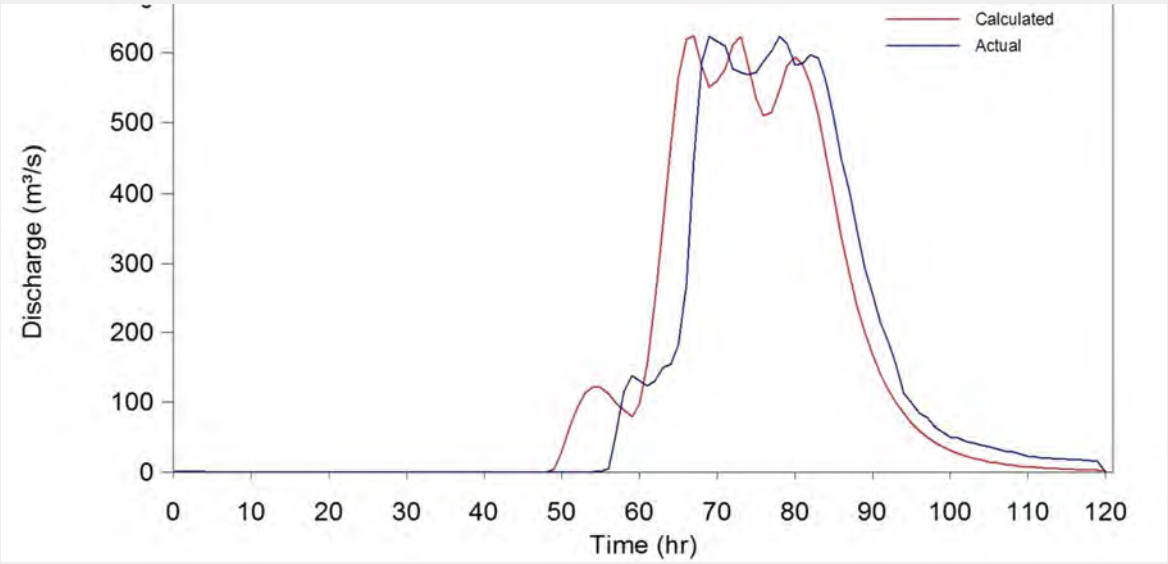


Table 5-3 1974 Storm Calibration Statistics

Item	Observed	Simulated	Difference
Storm Peak	623.5	624.6	+0.2%
Storm Volume	0.57E+08	0.58E+08	+1.3%
Lag	69	67	-2.9%

Figure 5-4 1974 Calibrated hydrograph at Barraba Gauge 541022



5.3.5 Calibration – 1984 Storm (30/01/1984)

The 1984 event started with rainfall on 30/01/1984 which lasted for 2 days. It produced a hydrograph peak approximately half of the 1998 and 1974 events. The peak rainfall intensity recorded at the Barraba pluviographic rainfall station 54102 was 5.4 mm in 6 minutes recorded at 11:30pm on 29/01/1984. Preceding the storm, the antecedent conditions within the catchment were dry. Figure 5-5 below shows the rainfall recorded at the Barraba station. The best fit calibration achieved for this event was using a kc

value of 20, and an m value of 0.8, as shown in Figure 5-6 and the calibration statistic in Table 5-4. Again, this kc compares favourably to the recommended Kleemola regional kc estimate. For this calibration, 2 rainfall bursts were configured in the RORB model. Initial and continuing loss parameters at the Manilla gauge were 23 mm and 6 mm/hr respectively, with lower continuing and initial losses specified for subsequent rainfall bursts in order to provide a calibration fit with flow hydrographs extrapolated from river water level data. The loss parameters used are within acceptable range according to the *RORB Version 6 User Manual)*. From the figure and Table 5-4 below the following is noted:

- Reasonable approximation of the 2 rainfall bursts in the hydrograph shape although some difference in hydrograph lag;
- Flood peak approximation is considered reasonable with a difference of 4%;
- Good approximation of the flood volume, to within 5.8%.

Figure 5-5 1984 Rainfall Event

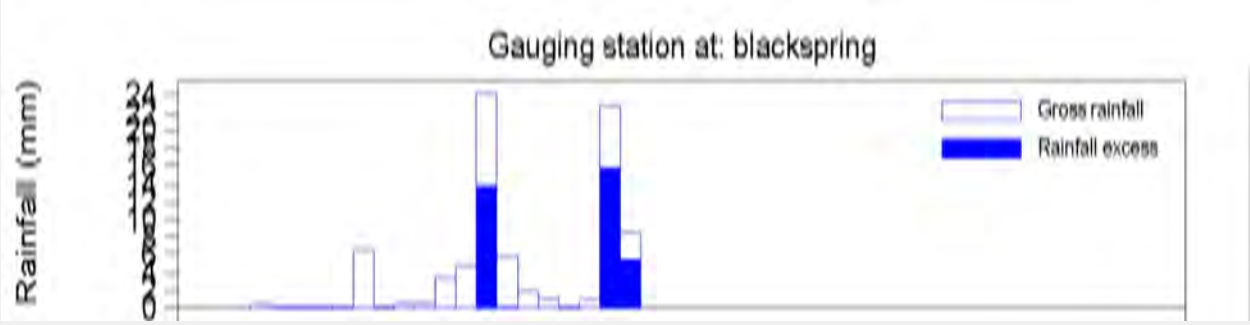
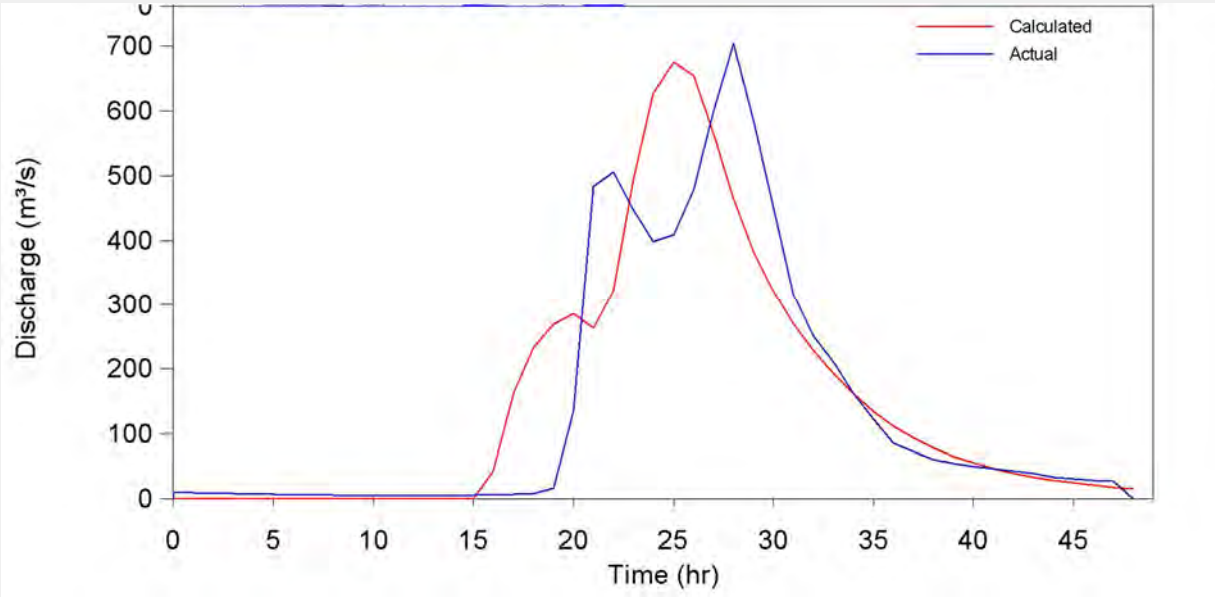


Table 5-4 1984 Storm Calibration Statistics

Item	Observed	Simulated	Difference
Storm Peak	704.2	675.9	- 4.0%
Storm Volume	0.25E+08	0.27E+08	+ 5.8%
Lag	28.0	25.0	- 10.7%

Figure 5-6 1984 Calibrated hydrograph at Barraba Gauge 541022



5.3.6 Calibration – 2004 Storm (18/01/2004)

The 2004 event started with rainfall on 18/01/2004 which lasted for 7 days. The peak rainfall intensity recorded at the pluviographic rainfall station 54102 was 8.16 mm in 6 minutes recorded at 12:30am on 17/01/2004. Preceding the storm, the antecedent conditions within the catchment were rather dry. Figure 5-7 below shows the rainfall recorded at the Barraba station. The best fit calibration achieved for this event was using the recommended Kleemola kc of 20, and an m value of 0.8, as shown in Figure 5-8 and the calibration statistic in Table 5-5. Again, this kc compares favourably to the recommended Kleemola regional kc estimate. For this calibration, 2 rainfall bursts were also configured in the RORB model.. Initial and continuing loss parameters at the Manilla gauge were 25mm and 12.7 mm/hr respectively, which are within acceptable range according to the *RORB user manual version 6 (Section 3.5)*.

From the figure and Table 5-5 below the following is noted:

- Good approximation of the overall hydrograph shape;
- Flood peak approximation is considered good with a difference of 1.1%; and
- Good approximation of the flood volume, to within 1.2%.

Figure 5-7 2004 Rainfall Event

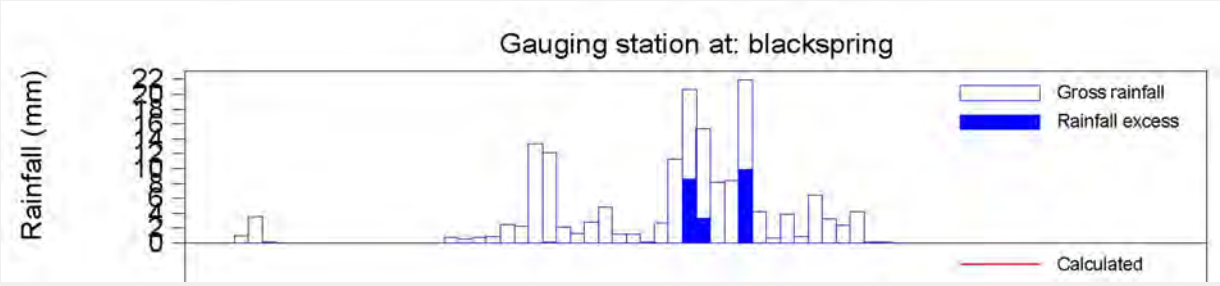
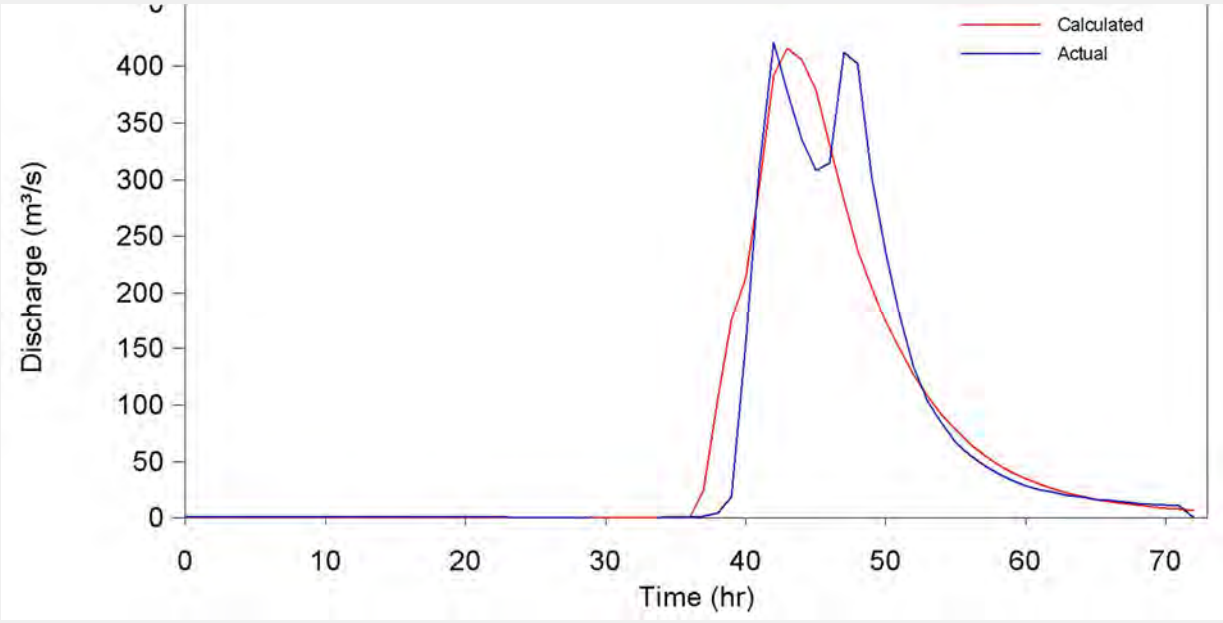


Table 5-5 2004 Storm …. Calibration Statistics

Item	Observed	Simulated	Difference
Storm Peak	420.9	415.9	+1.1%
Storm Volume	0.16E+08	0.17E+08	+1.2%
Lag	42	43	+2.4%

Figure 5-8 2004 Calibrated hydrograph at Barraba Gauge 541022



5.3.7 Summary

The RORB manual (RORB Manual, Section 7.3) stresses that users need to be realistic in expectations of accuracy for calibrations, indicates that accuracies in the order of ±15% could be expected in the underlying flow data used for calibrations.

In general the RORB calibrations achieved a difference in flood peak and flood volume of approximately ±5%,using the regional (Kleemola) kc value of 20.

Given the matters raised in Section 3.2 relating to gauging and rating curve accuracies, it was considered that the calibrations achieved were acceptable and further optimisation of the calibration was not warranted. On this basis, it was decided to accept the kc parameter of 20.

6. Hydraulic Model Configuration and Calibration (TUFLOW)

6.1 General

The flood conveyance through Barraba was calculated using the TUFLOW hydraulic model.

TUFLOW is a computer program for simulating depth-averaged, two and one-dimensional free-surface flows such as occurs from floods and tides. TUFLOW was originally developed for modelling two-dimensional (2D) flows, and stands for Two-dimensional Unsteady FLOW. However, it incorporates the full functionality of the ESTRY 1D network or quasi-2D modelling system based on the full one-dimensional (1D) free-surface St Venant flow equations (see below). The 2D solution algorithm is based on Stelling 1984, and is documented in Syme 1991. It solves the full two-dimensional, depth averaged, momentum and continuity equations for free-surface flow. The scheme includes the viscosity or sub-grid-scale turbulence term that other mainstream software omit. The initial development was carried out as a joint research and development project between WBM Oceanics Australia and The University of Queensland in 1990. The project successfully developed a 2D/1D dynamically linked modelling system (Syme 1991). Latter improvements from 1998 to today focus on hydraulic structures, flood modelling, advanced 2D/1D linking and using GIS for data management (Syme 2001a, Syme 2001b). TUFLOW has also been the subject of extensive testing and validation by WBM Pty Ltd and others (Barton 2001, Huxley, 2004).

TUFLOW is specifically orientated towards establishing flow and inundation patterns in coastal waters, estuaries, rivers, floodplains and urban areas where the flow behaviour is essentially 2D in nature and cannot or would be awkward to represent using a 1D model.A powerful feature of TUFLOW is its ability to dynamically link to 1D networks using the hydrodynamic solutions of ESTRY, ISIS and XP-SWMM. The user sets up a model as a combination of 1D network domains linked to 2D domains, ie. the 2D and 1D domains are linked to form one overall model. (BMT WBM 2010).

6.2 Configuration

The model extent for the purposes of flood mapping was defined in collaboration with Tamworth Regional Council. The actual model extends slightly beyond these limits to negate the effects of boundary conditions, as shown in Appendix E. The TUFLOW model compilation configured the key parameters as described in Table 6-1, using the following methodology:

- DTM data for the local area was imported into a digital terrain-modelling program (12D) and triangulated to represent the ground surface;
- A TUFLOW grid was generated with a cell size of 5 m^2. Each point in the grid was given an elevation based on its location in the DTM. The grid size was chosen because this is a compromise between the accuracy of the DTM data, simulation run time, model stability, and the accuracy of the results;
- All bridges within the floodplain were configured using the terrestrial survey data. These were configured within the 2D model grid;
- The flood hydrographs output by the RORB model were configured as inflows, distributed over the upstream floodplain cross-sections for the Manilla River. Downstream boundary conditions were configured as a flow stage relationship, with key boundary estimates provided in Figure 6-1; and

- Based on aerial photography and site inspections, hydraulic roughness coefficients for the floodplain were digitised for the floodplain and input to the model. These coefficients were digitised as a range of surfaces. Table 6-1 lists the roughness categories used in this model.

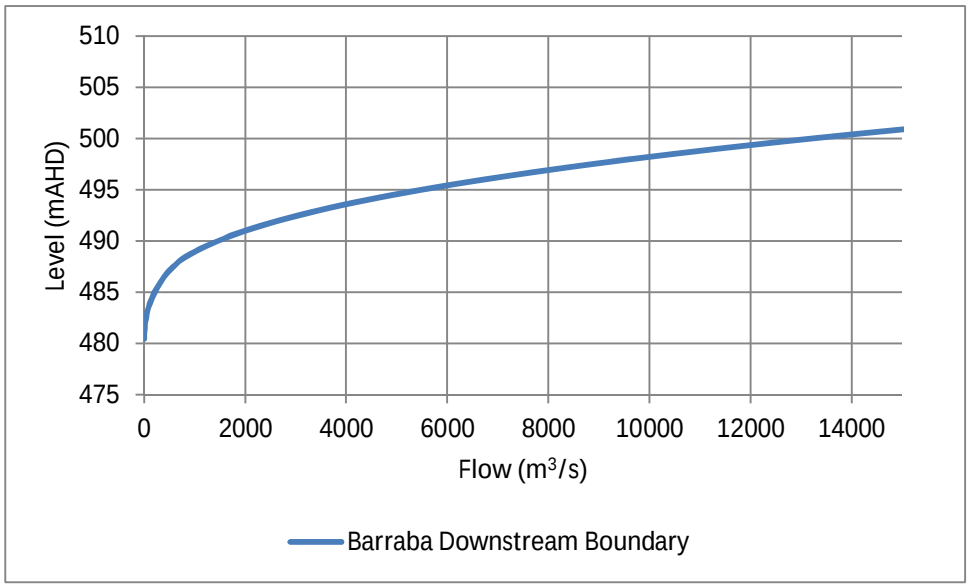
Table 6-1 TUFLOW Modelling Parameters

Feature	Value
Time step	1 second
Grid size	5m x 5m
Manning's "n" – roads	0.02
Manning's "n" – light to medium vegetation, with some trees	0.06
Manning's "n" – medium vegetation, thicker trees and some bush	0.10
Manning's "n" –dense vegetation, mostly dense bush	0.12
Manning's "n" – creeks and natural channels	0.03
Manning's "n" – developed areas (residential, commercial, industrial, farm sheds)	0.5
Manning's "n" – houses or blocked out with storage areas (zero conveyance)	2

6.2.1 Downstream Boundary Conditions

Downstream boundary conditions were configured in the TUFLOW model as a stage discharge relationship. To facilitate this, the model extended 250m downstream of the area identified by Council for flood mapping. This would minimise the effects of any boundary condition inaccuracies on the modelled results. This location was also identified as a natural flow constriction *(natural valley with steep slopes at the toe of a ridgeline)*. Figure 6-1 shows the adopted elevation – discharge relationship used for the downstream boundary condition.

Figure 6-1 Adopted stage-flow relationship for Barraba downstream boundary condition



6.2.2 Significant Structures in the Floodplain

The only significant structure located in the Barraba floodplain, configured in the TUFLOW model, was the Barraba Bridge. This 64m spanning structure consists of a single 2-lane deck span and 2 pairs of circular concrete piers with headstocks. This results in a waterway opening of 32m and a diagonal waterway opening of 26m. The road overflow level is 496.13m AHD. Approach roads to the structure are lower/ than the bridge deck on the western side and overflow would be initiated before inundation of the deck.

6.3 Observed Flood Markers

A number of flood markers exist around Barraba town that record flooding history associated with the 1964 event. In consideration of the comments in Section 3.4 and the design events in Table 7-4, the 1964 event peak would be expected to be slightly larger than the 1% AEP event. The flood markers have therefore been overlaid on the 0.5% AEP event. Referring to Figure F.6.1 in Appendix F, Reasonable agreement of the 1964 flood is noted with the 0.5% AEP event, with exception of the most downstream 2 flood markers which are 0.5m to 0.8m higher. However in the context of the unknown origin of the markers this comparison is considered reasonable.

7. Design Flood Behaviour

7.1 Overview

To determine the design flood behaviour, both the RORB and TUFLOW models were simulated, using the parameters derived through the calibrations together with design rainfall in accordance with the Australian Rainfall and Runoff (AR&R 2001). The simulations were undertaken as follows:

- The RORB model was simulated using a kc value of 20 together with design rainfall and rainfall loss estimates in accordance with the Australian Rainfall and Runoff. Each event was simulated for a range of durations and the critical duration storm hydrograph was input to the model; and
- The results from the RORB model were used as boundary conditions for the TUFLOW model which was simulated for each event.

Further details on the input used for the simulations are provided below.

7.2 Flood Hydrographs

7.2.1 Design Rainfall

Design rainfall events were derived in accordance with the procedures of the Australian Rainfall and Runoff, Region 2 (AR&R 2001). The Intensity Frequency Duration parameters adopted for the Barraba catchment are listed in Table 7-1.

Table 7-1 Barraba IFD Parameters

Parameter	Value
2 yr 1 hr	30.72
2 yr 12 hr	5.58
2 yr 72 hr	1.34
50 yr 1 hr	62.51
50 yr 12 hr	10.12
50 yr 72 hr	2.69
Skew	0.32
F2	4.33
F50	16.08
Zone	E

7.2.2 Probable Maximum Precipitation and Flood (PMP & PMF)

Given the size of catchment and recommended thresholds, the Probable Maximum Precipitation was compiled using both the Bureau of Meteorology Australia Generalised Short Duration Method (GSDM)

for durations less than 12hrs and the Generalised Tropical Storm Method – Revised Version (GTSMR – BOM 2003) for durations greater than 12hrs. The PMP rainfall depths derived for a range of durations using the method are tabulated below.

Table 7-2 PMP Rainfall Depths

Duration (hrs)	PMP Rainfall Depth (mm)
3	**370**
4	**420**
5	**450**
6	**480**
24	**699**
36	**833**
48	**958**
72	**1178**
96	**1327**
120	1400

The PMP rainfall depths were simulated in the RORB model to calculate the PMF. Loss factors as discussed in Section 7.2.3 were applied.

The PMF flood peak at Black Springs was calculated to be 15440m^3/s with a critical duration of 4 hours.

7.2.3 Rainfall Losses

Rainfall losses were adopted in accordance with the Australian Rainfall and Runoff (AR&R 2001) Book 2 and Book 6. These recommend the losses as listed in Table 7-3.

Table 7-3 Rainfall Losses

Event	Initial Loss	Continuing Loss
Up to and including the 1% AEP event	15 mm	2.5 mm/hr
1% event up to the PMF	15 mm	1 mm/hr
PMF	15 mm	1 mm/hr

7.2.4 Design Flood Peaks at Barraba

The simulation of the RORB model was undertaken for a number of events and a number of durations, up to and including the PMF. For each event the critical duration design flood hydrograph was identified, and input as upstream boundary condition inflow. The flood peaks determined for each event are

summarised below. It must be noted that the flood peaks at the black springs gauge would be expected to be dependent on the timing of the tributary inflows.

Table 7-4 RORB Design Flood Peaks

Flood event AEP	Manilla River Flood Peak (u/s of Barraba) m^3/s	Mille Creek Flood Peak m^3/s	Connor's Creek Flood Peak m^3/s	Manilla River Flood Peak at Black Springs m^3/s
20%	450	135	190	800
10%	585	170	240	1035
5%	770	220	310	1370
2%	955	260	375	1700
1%	1160	300	460	2045
0.5%	1925	410	755	3340
PMF	9100	1540	2975	15440

7.2.5 Probabilistic Rational Method

The Probabilistic Rational Method was used to provide an additional estimate of the flood peak for the 1% AEP event. This method is not suitable for catchment sizes of area greater than 250 km^2 and inherently does not necessarily account for catchment effects such as attenuation. However the method gives an indication of the flood peak order of magnitude.

Using the Probabilistic Rational Method, the 1% AEP flood peak was estimated as 1450 m3/s.

7.2.6 Comparison of 1% AEP Flood Peak Estimates

The derived flood peak estimates for a range of events using a number of methods has been tabulated below. Referring to the table below, it is noted that the calibrated RORB model provides a flood peak somewhat larger than other methods. However as discussed previously, the flood frequency analysis could potentially have a significant variance at the extreme event range. Since the peak of the RORB model is heavily dependent on timing of a number of inflows and is conservative, the calibrated RORB model was accepted.

Table 7-5 Comparison of 1% AEP Flood Peak Estimates at Black Springs

Flood event AEP	Flood Frequency Analysis (Section 3.2.2)	Calibrated RORB Model (Section 7.2.4)	Probabilistic Rational Method (Section 7.2.5)
1%	1450 m^3/s	2045 m^3/s	1450 m^3/s

7.3 Flood Behaviour

7.3.1 Upstream Boundary Conditions - Flood Peaks

For the upstream boundary conditions to the TUFLOW model, the design flood hydrographs discussed in Section 7.2.4 were input to the model.

7.3.2 Downstream Boundary Conditions

Downstream boundary conditions were configured in the TUFLOW model as per the existing conditions simulations, namely by using a stage discharge relationship

7.3.3 Results

The results of the design flood simulations have been provided as a series of flood maps (Appendix F), namely as:

- A series of maps showing flood depth in blue, overlain by flood level contours;
- A series of maps showing flood velocities; and
- A series of maps showing flood hazard in accordance with the NSW Floodplain Development Manual.

Referring to the flood maps, the following is noted:

- In a 20% AEP event, flow is mostly contained to the river channels. Some spillage onto the floodplain could be expected in the floodplain areas of Lillies and Star Lanes. In a 1% AEP event, significant flooding would be expected in the floodplains north and east of Barraba, the Cherry Street area and Bridge Street near the Barraba Bridge. Wide spread flooding would be expected in the floodplain areas of Lillies and Star Lanes. Flood depths vary, from shallow depths along the edge of the floodplain to depths in excess of 5 to 10 m near the creek channel;
- Flow velocities associated with the river channel and immediately adjacent floodplain, are high, around 2 m/s and greater. There are a number of areas in the northern and southern floodplains, where flow velocities are in the order of 1 m/s to 2 m/s. Further away from the main channels, the flow velocities are much lower at around 0.5 to 1 m/s;
- Large areas of the floodplain can be designated as high hazard, on account of deep flow and/or rapid flow velocities. This includes areas of town in particular along Cherry Street and on the northern and eastern floodplains; and
- In larger events inundation across the study area is extensive and in a PMF wide spread flooding would be expected. Flood depths would be in excess of 10m, immediately adjacent to the creeks and for large areas of the floodplain. In a PMF it would appear that a floodplain breakout may occur, in the Orchard and Alice Street area, with overflows in the direction of Cherry Street.

The results of the 1% AEP flood simulations have been used to derive the Flood Planning Area, namely the land below the Flood Planning Level on a Flood Planning Map. The Flood Planning Level refers to the level of a 1% AEP flood event plus 0.50m freeboard. For the current study, the Flood Planning Area Extent has been determined by abstracting the peak 1% AEP flood level plus 0.5m, at approximately 100m to 150m intervals across the entire floodplain, perpendicular to the flow. This has been intersected with the topography to produce the Flood Planning Area Extent line. In determining this Flood Planning

Area Extent line some anomalies could exist on the edge of the floodplain, when comparing to the 2D flood model results, where localised flood effects could exist. The Flood Planning Map for Barraba is provided in Appendix H.

7.4 Sensitivity Analyses

7.4.1 Overview

A number of sensitivity analysis were undertaken to determine the impacts of parameters and assumptions on flood behaviour. This was achieved by making the adjustments to the models and re-simulation of both the RORB and TUFLOW models where appropriate. Since the most important event used in planning in NSW is the 1% AEP event, the assessments were done primarily for this event. The results are presented as difference maps in Appendix G. The items/assumptions assessed in the sensitivity analysis were:

- Sensitivity of rainfall loss parameters on the design flood hydrographs and flood levels;
- Sensitivity of Manning's roughness assumptions on flood levels;
- Sensitivities of culvert and bridge blockages and loss assumptions; and
- Future Climate impacts on rainfall and flood levels.

7.4.2 Sensitivity of Rainfall Loss Parameters

To assess the impacts of rainfall loss parameter assumptions, both the RORB and the TUFLOW models were re-simulated using the amended assumptions tabulated below. The impacts on the simulated flood peaks using the RORB model are shown in Table 7-7, generally showing a 10% to 25% increase in flood peak. The impacts on the 1% AEP flood level is presented in Appendix G, showing that:

- A reduction in rainfall losses as tabulated below could lead to increases of approximately 200 mm across a number of areas in the floodplain; and
- These increases would result in minor increases in the extent of flooding, where a few additional properties would be inundated.

Table 7-6 Rainfall Loss Sensitivity Values

Event	Initial Loss	Continuing Loss	Initial Loss	Continuing Loss
	Default Value		Sensitivity Value	
Up to and including the 1% AEP event	15 mm	2.5 mm/hr	10 mm	2.0 mm/hr
1% event up to the PMF	15 mm	1 mm/hr	10 mm	0.5 mm/hr
PMF	15 mm	1 mm/hr	10 mm	0.5 mm/hr

Table 7-7 Rainfall Loss Sensitivity impacts on Flood Peaks at Black Springs

Flood event AEP	Default Value	Sensitivity Value
20%	800	995
10%	1035	1210
5%	1370	1545
2%	1700	1890
1%	2045	2260

7.4.3 Sensitivity to Manning's Roughness Assumptions

To assess the impacts of roughness assumptions, the TUFLOW model was re-simulated using the amended roughness assumptions tabulated below. These generally represent between a 10% and 40% increase in topography roughness. The impacts on the 1% AEP flood level is presented in Appendix G showing that:

- Increases in roughness as defined in the table below could lead to increases of up to 1 m across large areas of the flood plain; and
- A number of areas in the flood plain would be expected to increase in extent, where a few additional properties would be inundated.

Table 7-8 Roughness Sensitivity Values

Feature	Default Value	Sensitivity Value
Manning's "n" – roads	0.02	0.025
Manning's "n" – light vegetation mostly grass	0.06	0.08
Manning's "n" – medium vegetation, thicker trees and some bush	0.10	0.12
Manning's "n" –dense vegetation, mostly dense bush	0.12	0.15
Manning's "n" – creeks and natural channels	0.03	0.045
Manning's "n" – developed areas (residential, commercial, industrial, farm sheds)	0.5	0.5
Manning's "n" – houses or blocked out with storage areas (zero conveyance)	2	2

7.4.4 Sensitivities of Culvert and Bridge Blockages and Loss Assumptions

To assess the impacts of culvert and bridge blockages, the TUFLOW model was re-simulated using the amended waterway opening assumption tabulated below. This generally represents the impacts should debris block the bridge during flood events, potentially resulting in local increase in upstream flood levels and potential redistribution of flood flows. To simulate the blockage, the flood level at the structure was determined, and half of the flow depth was blocked below the bridge structure, starting at the flood water surface. The impacts on the 1% AEP flood level are presented in Appendix G, showing that:

- Flood level increases in the order of 0.2 to 0.4m could be expected upstream of Barraba Bridge, increasing to as much as 0.8m to 1m, immediately upstream of the bridge. This is due to local attenuation at the bridge crossing; and
- The localised blockage and attenuation at the Barraba Bridge could result in reduction in flood levels downstream of the bridge by up to 0.2 to 0.4m.

Table 7-9 Culvert and Bridge Blockages and Loss Values

Structure	Default Value	Sensitivity Value
Barraba Bridge	64m spanning structure Waterway opening of 32m and a diagonal waterway opening of 26m 2 pairs of circular concrete piers with headstocks	50% blockage has been assumed from the flood water surface

7.4.5 Future Climate Impacts on Rainfall

Future climate impacts on rainfall have been assessed generally in accordance with the NSW Government, Department of Environment & Climate Change, Practical Consideration of Climate Change (NSW DECC 2007) guideline. For this assessment the hydrological RORB models were updated to represent future climate rainfall intensities based on the suggestions in the guideline. This recommends simulating 10%, 20% and 30% increases in rainfall intensities. On the basis of this guideline, the estimated future climate rainfall simulated in the RORB model is tabulated below.

The impacts on the simulated flood peaks using the RORB model are shown in Table 7-11, generally showing a significant increase in flood peak. The impacts on the 1% AEP flood level are presented in Appendix G showing that:

- A future climate with a 10% increase in rainfall could lead to flood level increases of up to between 0.2m and 0.4m across large areas of the flood plain. For a 30% increase in rainfall, increases of up to between 1.0m and 1.2m across large areas of the flood plain could be expected; and
- A number of areas in the flood plain would be expected to increase in extent.

Table 7-10 Existing and Future Climate 100-yr Rainfall

Rainfall	Critical Duration	Existing Climate	Future Climate (mm)		
			10%	20%	30%
mm/hr	100yr 6 hr	121.7	133.8	146.0	158.2

Table 7-11 Future Climate 100-yr Rainfall Sensitivity impacts on Flood Peaks at Black Springs

Flood event AEP	Default Value	Sensitivity Value		
		10%	20%	30%
20%	798	967	1142	1315
10%	1036	1234	1435	1637
5%	1368	1604	1833	2060
2%	1700	1961	2238	2528
1%	2046	2366	2692	3024

8. Flood Damage Estimates

8.1 Flood Damage Extents

In order to provide a benefit-cost assessment of floodplain management options, it is necessary to estimate the costs of flood damages. Flood damages are determined by assessing the number of flood affected properties and then estimating a direct damage cost for a range of flooding events (in terms of flood depth). The resulting depth-damage curves are used as a basis for estimating other direct and indirect costs from flooding.

Flood affected properties were estimated from the results of hydraulic simulations from the flood study, together with floor level survey data collected as part of this study. For each design flood, flood levels were determined at each property location based on these surveyed floor levels. Numbers of inundated properties are shown in Table 8-1, and flood inundation mapping is provided in Appendix F. This mapping shows the depth of floor level inundation for a range of events. From the mapping the following is noted:

- In events up to the 5% AEP event (Figure D.1) floor levels of properties are not expected to be inundated across the floodplain;
- In a 2% AEP event, 4 properties are expected to experience flooding above the floor level. In a 1 % AEP event the number of properties expected to experience floor level inundation is 30. The properties are primarily in the vicinity of Cherry and Orchard Streets;
- Beyond the 1% event, the numbers of floor levels inundated increases rapidly with 110 floor levels inundated in a 0.5% event and 475 floor levels expected to be inundated in a PMF.

Table 8-1 Flood Affected Properties

Flood event AEP	Number of Residential Dwellings Inundated
20%	0
10%	0
5%	0
2%	4
1%	30
0.5%	110
PMF	475

8.2 Depth-Damage Relationship

For most residential dwellings, flood damage increases with the depth of flooding. The Floodplain Management (FDM) and Coastal Support Section of the Department of Natural Resources (DNR, now

Office of Environment and Heritage) has developed relationship between flood depth and damage based on various parameters for house and contents value, and flooding characteristics.

The resulting relationship is illustrated in Figure 8-1. Parameters used to derive this relationship are shown below in Table 8-2.

Figure 8-1 Typical Depth Damage Relationships (OEH, 2007)

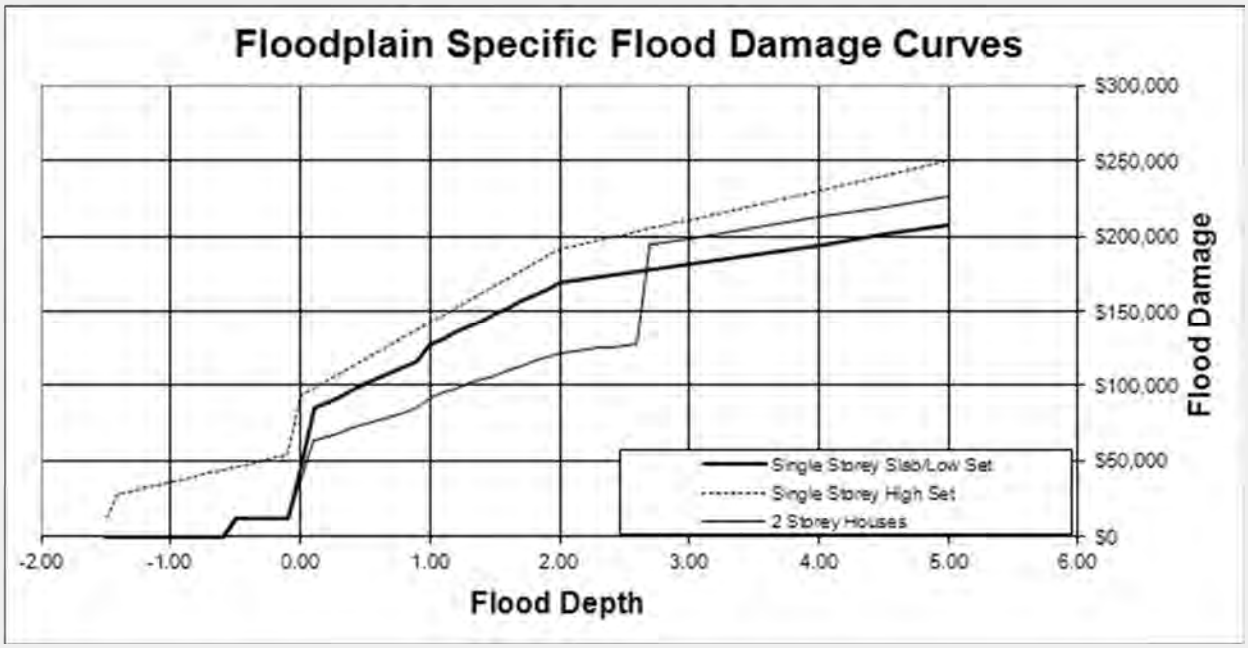


Table 8-2 Parameters for Depth-Damage Relationship

Parameter	Value
Additional accommodation/ loss of rent	$220 per week
Average contents value	$60,000
Average house size	240 m^2
Clean up costs	$4,000
External damage	$6,700
Typical duration of inundation	5 hours
Typical table/bench height	0.9 m
Design Life of Options	20 year
Discount factor for Cost Calculations	7 %

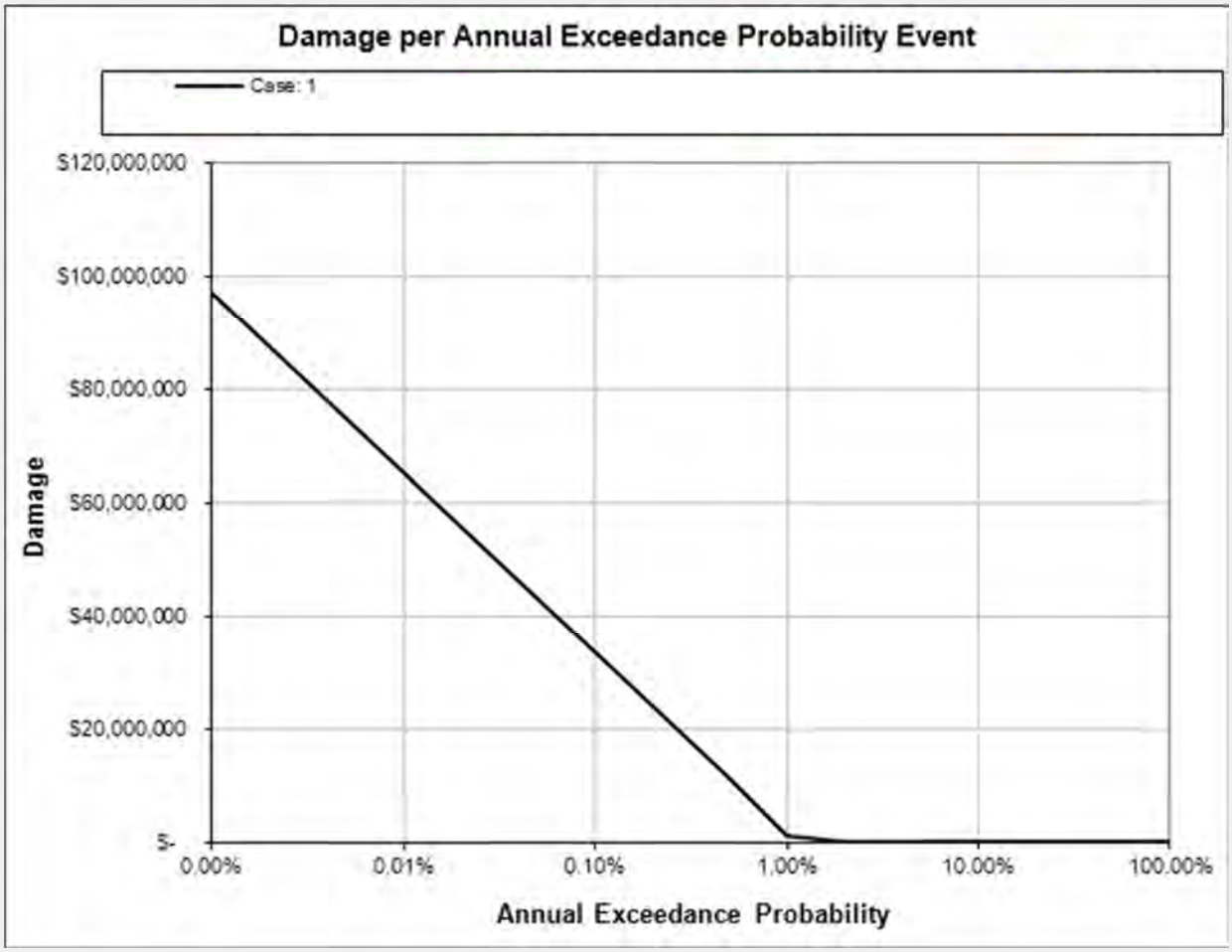
8.3 Flood Damage Calculations

The following methodology was used to estimate the Average Annual Damage (AAD) and present value (PV) of the AAD over a 20-year period:

- The floor levels of properties affected by flooding for a range of flood events were estimated from the flood simulations and floor level survey;
- The cost of damage for the flooding was estimated for each flood event and depth range, using typical house and contents damage cost and the percentage of damage for the particular depth;
- A direct damage bill for each storm event was calculated;
- Flood recurrence interval was plotted against total damage and integrated to find the area under the graph, which provides the AAD; and
- A present value for the AAD was estimated based on a 7% discount rate over a 20-year period

For Barraba the Annual Average Damage Curve for residential properties is shown in Figure 8.2. The Annual Average Damage is estimated at $308k. Over a 20-year period, this has a Net Present Value of $3.26 million.

Figure 8-2 Barraba Damage Curve



9. Summary and Conclusions

- The Barraba town is located on the Manilla River which drains to Split Rock Dam in the New England region of NSW. Barraba is located 85 km to the northwest of Tamworth and has population of approximately 1400. The Manilla River draining through Barraba commands a considerable catchment area of some 771 km. The catchments are primarily rural in nature. Floodwaters tend to rise quickly and isolate communities and properties for several days. Many houses can be inundated in flood events necessitating evacuations. Some rainfall and river gauging data in the catchment is available, and significant events have been recorded in Barraba. Significant events noted in the literature and mentioned by residents, most notably the 1955 event and the 1964 flood. The 1964 flood was considered the worst in 100 years;
- Tamworth Regional Council is responsible for local land use planning in Barraba. Through its Floodplain Risk Management Committee, Tamworth Regional Council proposes to prepare a comprehensive floodplain risk management plan for the study area in accordance with the NSW Government's "Floodplain Development Manual: the management of flood liable land", April 2005 (The Manual);
- The primary objective of this study was to define the main-stem flood behaviour under historical conditions and design flood behaviour under existing and future climate conditions in the study area (Figure A2) in Appendix A. The study produced information on flood levels, depths, velocities, flows, hydraulic categories, and provisional hazard categories for a full range of design and historical flood events. In addition, the study produced estimates of flood damage;
- A number of community consultation activities were undertaken as part of the study. The primary objectives of the flood study consultation activities were to inform the relevant government agencies that the study is being undertaken, informing relevant local community groups, and informing the general public. The information provided by the community, showed that a large number of the residents had experienced flooding in the town of Barraba, first hand and flood levels tend to rise and recede very rapidly. Preparation for flooding includes regular observation of river levels and lifting of belongings. In addition, listening to advice on local radio stations and from the SES. Many residents often mentioned the 1964 floods and these have been etched in memories of the Barraba community;
- The hydrology for the Barraba flood study was developed using the RORB hydrological model. The model was setup as an end of catchment model, producing flood hydrographs for the Manilla River at the town of Barraba. The RORB model was calibrated by variation of model parameters to obtain a good fit of the calculated to the measured hydrograph. A number of sensitivity analysis were undertaken on model parameters and the RORB model was simulated for a range of durations ranging up to 72 hours;
- The flood conveyance through Barraba was calculated using the TUFLOW hydraulic model. The model extent for the purposes of flood mapping was defined in collaboration with Tamworth Regional Council. The TUFLOW model compilation configured the key parameters including DTM data for the local area, triangulated to represent the ground surface. All bridges within the floodplain were configured using the terrestrial survey data. These were configured within the 2D model grid;

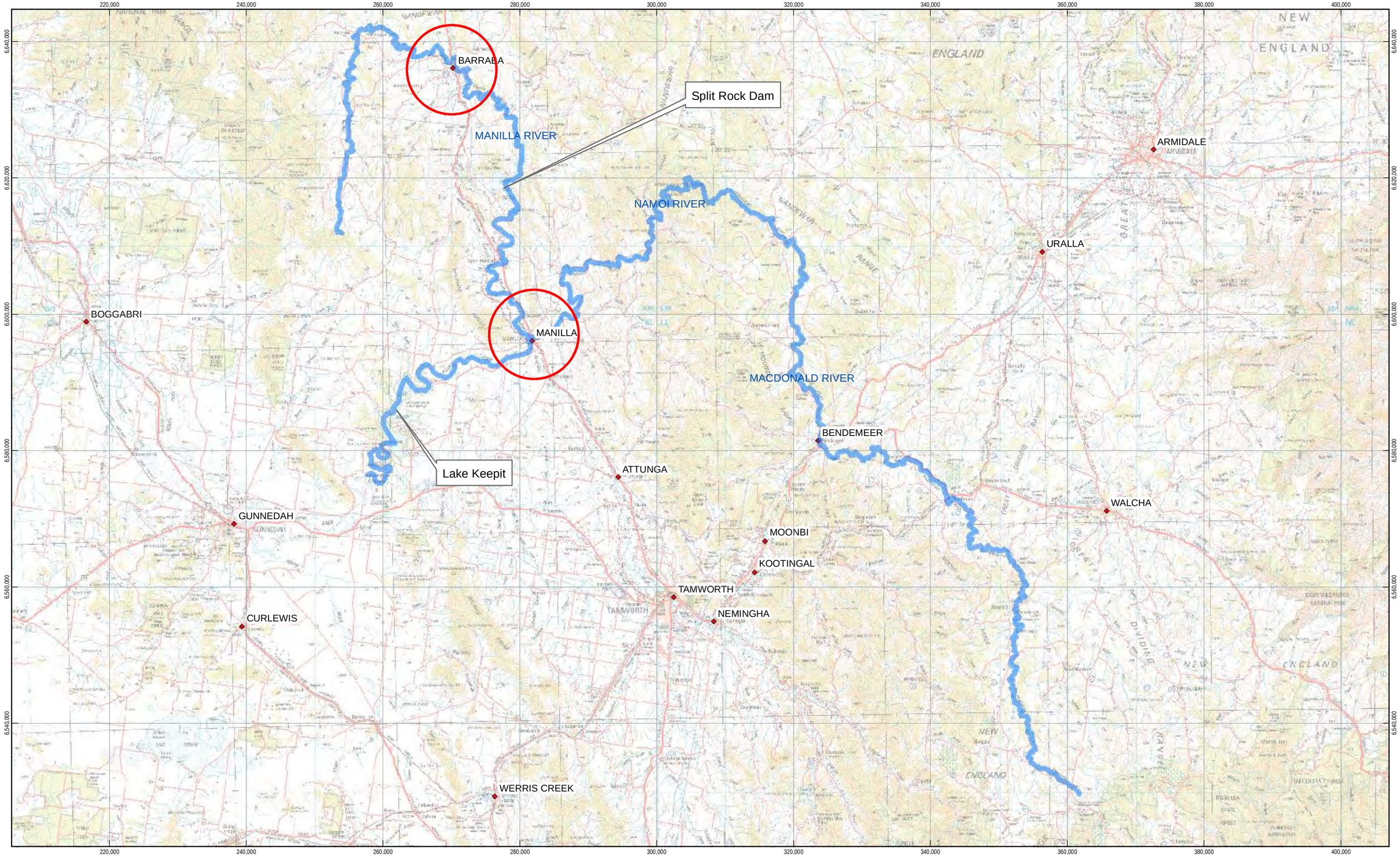
- To determine the design flood behaviour, both the RORB and TUFLOW models were simulated, using the parameters derived through the calibrations together with design rainfall in accordance with the Australian Rainfall and Runoff (AR&R 2011);
- The results show that in a 20% AEP event, flow is mostly contained to the river channels. Some spillage onto the floodplain could be expected in the floodplain areas of Lillies and Star Lanes. In a 1% AEP event, significant flooding would be expected in the floodplains north and east of Barraba, the Cherry Street area and Bridge Street near the Barraba Bridge. Wide spread flooding would be expected in the floodplain areas of Lillies and Star Lanes. Flood depths vary, from shallow depths along the edge of the floodplain to depths in excess of 5 to 10 m near the creek channel. Flow velocities associated with the river channel and immediately adjacent floodplain, are high, around 2 m/s and greater. There are a number of areas in the northern and southern floodplains, where flow velocities are in the order of 1 m/s to 2 m/s. Further away from the main channels, the flow velocities are much lower at around 0.5 to 1 m/s. Large areas of the floodplain can be designated as high hazard, on account of deep flow and/or rapid flow velocities. This includes areas of town in particular along Cherry Street and on the northern and eastern floodplains. In larger events inundation across the study area is extensive and in a PMF wide spread flooding wold be expected. Flood depths would be in excess of 10m, immediately adjacent to the creeks and for large areas of the floodplain. In a PMF it would appear that a floodplain breakout may occur, in the Orchard and Alice Street area, with overflows in the direction of Cherry Street;
- A sensitivity assessment was undertaken on a number of key parameters. A reduction in rainfall losses could lead to increases of 200 mm across a number of areas in the floodplain. Increases in roughness could lead to increases of up to 1 m across large areas of the flood plain and a number of areas in the flood plain would be expected to increase in flood extent. A future climate with a 10% increase in rainfall could lead to flood level increases of up to between 0.2m and 0.4m across large areas of the flood plain. For a 30% increase in rainfall, increases of up to between 1.0m and 1.2m across large areas of the flood plain could be expected. Depending on the severity of blockage, flood level increases in the order of 0.2 to 0.4m could be expected upstream of Barraba Bridge increasing to 0.8 to 1,.0 m immediately upstream of the bridge. This blockage could result in reduction in flood levels downstream of the bridge by up to 0.2 to 0.4m; and
- A flood damage assessment was undertaken using the Floodplain Management (FDM) and Coastal Support Section of the Department of Natural Resources (DNR, now Office of Environment and Heritage) relationships between flood depth and damage based on various parameters for house and contents value. From this assessment, the Annual Average Damage is estimated at $ 308k. Over a 20-year period, this has a net present value of $3.26 million.

10. References

- NSW Government, 2005, Floodplain Development Manual, Management of Flood Liable Land;
- NSW DECC 2007, Practical Consideration of Climate Change, NSW Department of Environment & Climate Change;
- AR&R 2001, Australian Rainfall and Runoff, 2001;
- Bernard RL, Flood Report Namoi River 1955;
- Bewsher Consulting, 2007, Assessment of flood risk in various towns and villages, undertaken for Tamworth Regional Council;
- RORB 6 User Manual, Monash University Department Of Civil Engineering In Conjunction With Sinclair Knight Merz Pty. Ltd. And The Support Of Melbourne Water Corporation, Rorb Version 6 Runoff Routing Program User Manual;
- BMT WBM 2010, TUFLOW User Manual
- BOM 2003, Bureau of Meteorology Australia Generalised Tropical Storm Method – Revised Version, November 2003;
- OEH 2007, Department of Environment and Climate Change, Flood Risk Management Guideline, Residential Flood Damages;
- NVFIT 1964, Namoi Valley Flood Investigation Trust, Namoi River Flood Investigation – Report 1, SKM, July 1964;
- WRC, Flood Information Reports, Floods in the Namoi Valley (1955, 1962, 1964, 1971, 1974, 1976), NSW Water Resources Commission

Appendix A

Location Maps



1:500,000

0 1 2 4 6 8 10

Kilometres (at A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

LEGEND

Study Area

Tamworth Regional Council
Manilla and Barraba Flood Study

Job Number 22-15815/16
Revision A
Date 23 December 2011

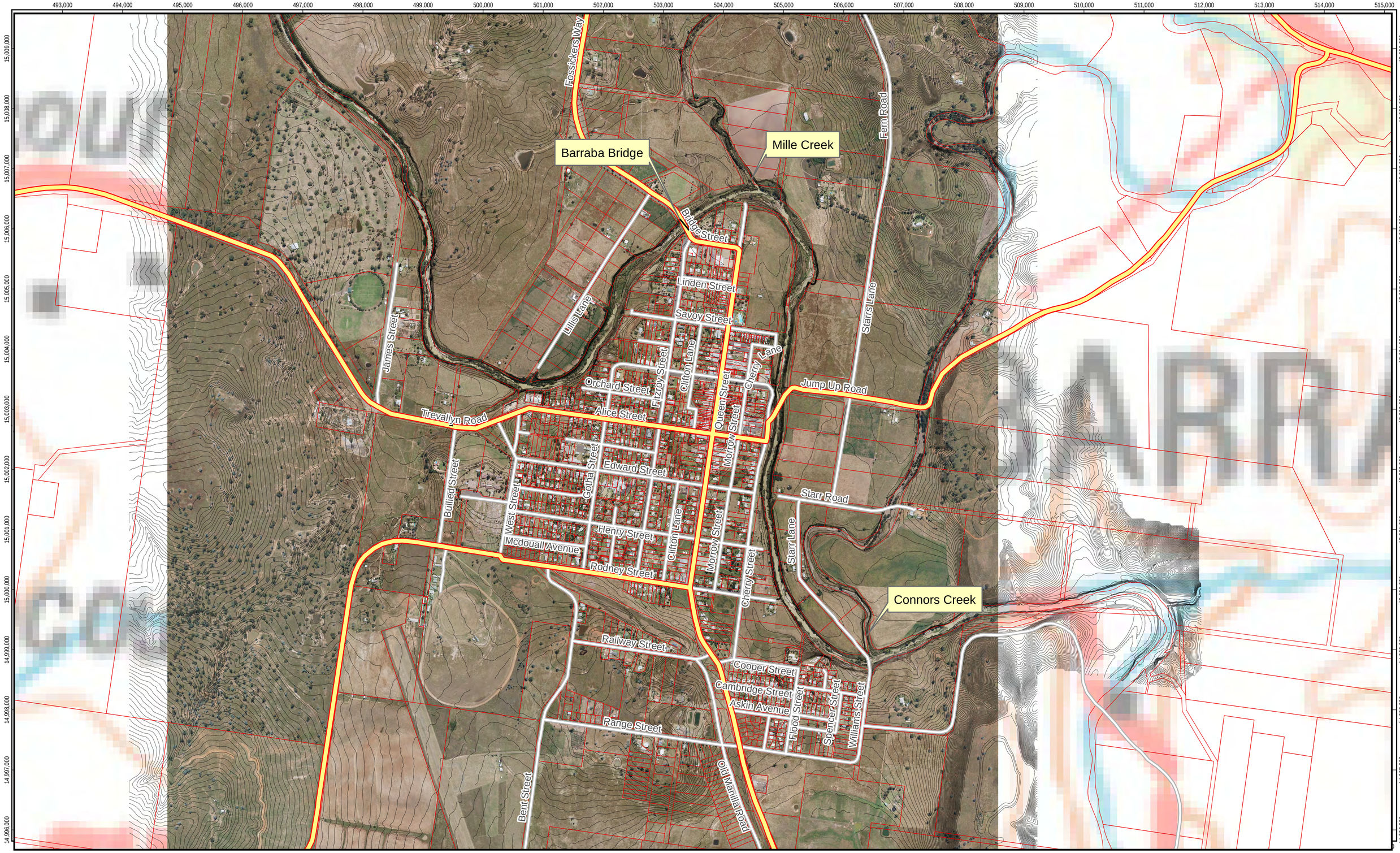
Locality Map

Figure A.1

G:\14\0102799\FINAL TEMPLATES\Rev 001\ArcGIS\GHD-A3-LANDSCAPE.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by: C Pappin

10 Bond Street Sydney NSW 2000 Australia **T** 61 2 9239 7000 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au



1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

O

TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Job Number	22-15816
Revision	A
Date	13.01.2012

Study Area

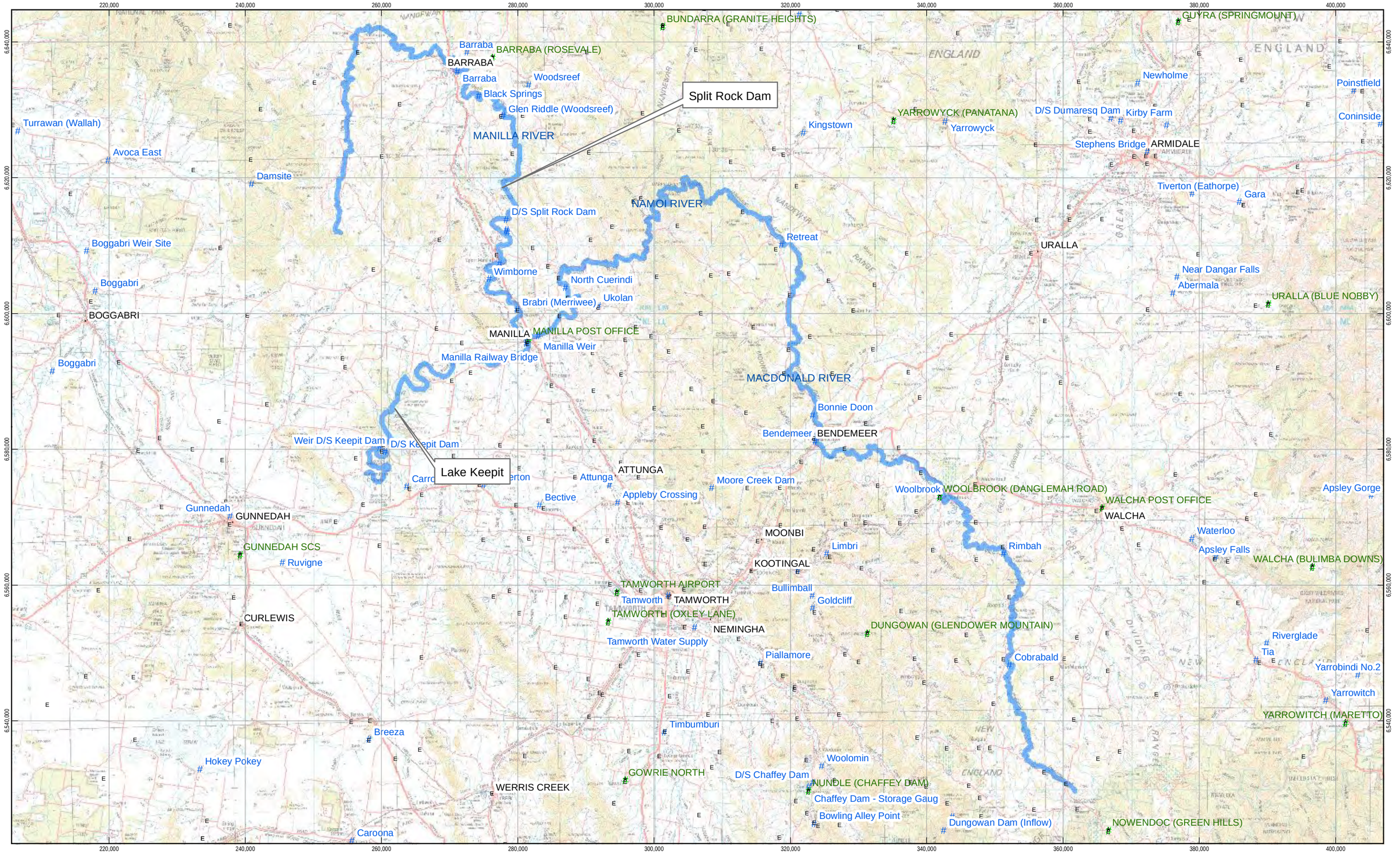
Figure A.2

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au

Appendix B

River Gauging Information and Flood Frequency Analysis



1:500,000

0 1 2 4 6 8 10

Kilometres (at A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

LEGEND

- Daily Rainfall Data
- Pluvio-Rainfall Data
- River Gauging Data

Tamworth Regional Council
Manilla and Barraba Flood Study

Job Number	22-15815/16
Revision	A
Date	23 Dec 2011

Gauging Information

Figure B.1

G:\14\0102799\FINAL TEMPLATES\Rev 001\ArcGIS\GHD-A3-LANDSCAPE.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by: C Pappin

10 Bond Street Sydney NSW 2000 Australia **T** 61 2 9239 7000 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

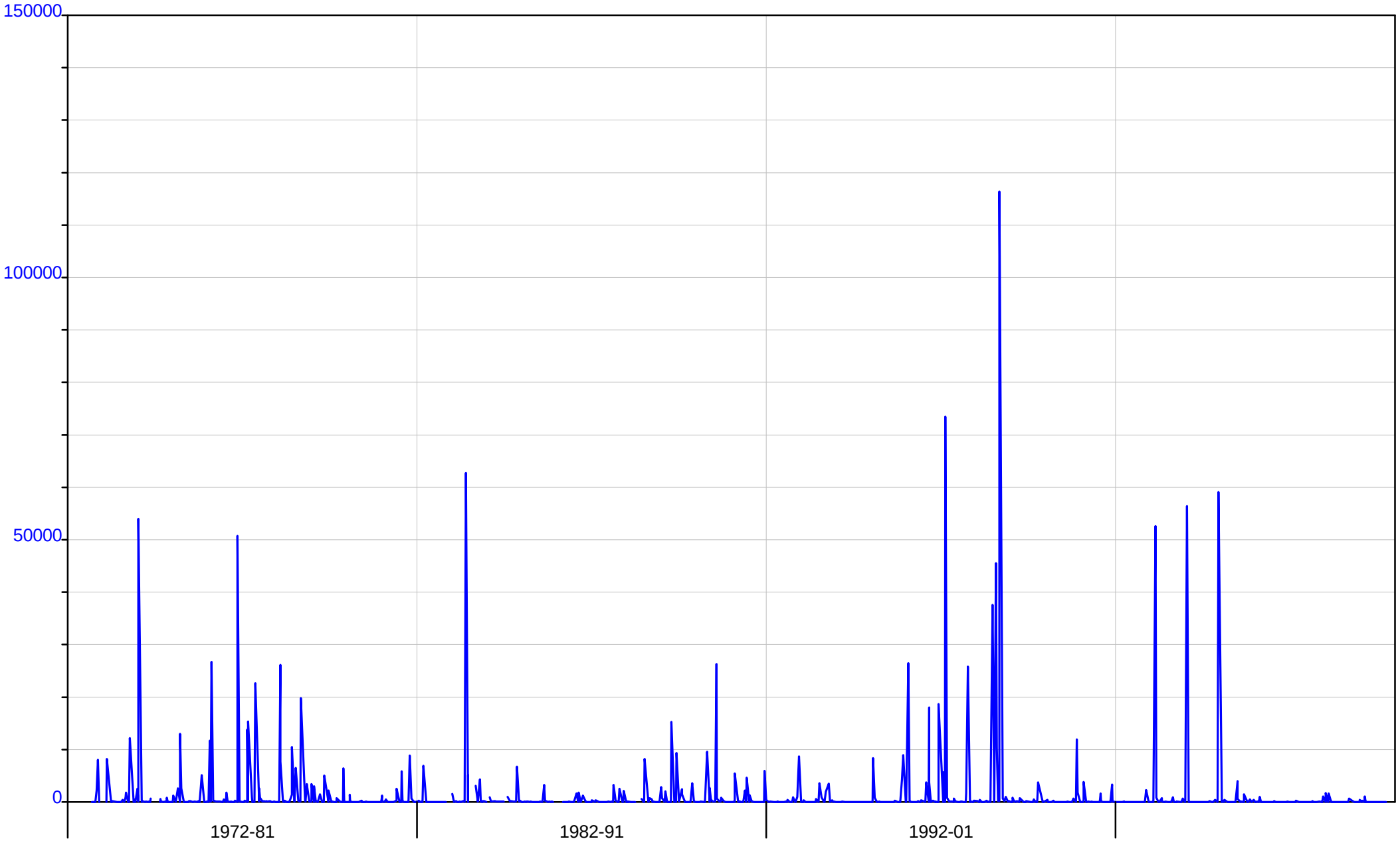
NSW Office of Water PINNEENA 9.3

HYPLOT V132 Output 23/12/2011

Period	38 Year	Plot Start	00:00_01/01/1972
Interval	1 Month	Plot End	00:00_01/01/2010

1972-10

— 419053 MANILLA BLACK SPRING 141.00 Max & Min Discharge (ML/d)



Site 419053 MANILLA RIVER AT BLACK SPRINGS
VarFrom 100.00 Stream Water Level
VarTo 141.00 Stream Discharge
Period 01/10/1970 - 30/09/2011

Date	Number		Stage	Flow	Deviation	Rating	-100% Deviation 100%
00:00_21/03/1972	1.0	*	0.613	13.896000	[N/A]	{none}	.....|.....
00:00_12/04/1972	2.0	*	0.628	23.878000	[N/A]	{none}	.....|.....
00:00_16/05/1972	3.0	*	0.649	24.367000	[N/A]	{none}	.....|.....
00:00_11/07/1972	4.0	*	0.607	16.880000	[N/A]	{none}	.....|.....
00:00_05/09/1972	5.0	*	0.591	10.887000	-3.81	100	.....*.....
00:00_03/10/1972	6.0	*	0.591	12.158000	7.41	100	.....|*.....
00:00_10/10/1972	7.0	*	0.561	6.752000	3.30	100	.....*.....
00:00_13/12/1972	8.0	*	0.671	37.922000	-5.99	105	.....*|.....
00:00_12/02/1973	9.0	*	1.222	995.756000	4.74	110	.....*.....
00:00_20/03/1973	10.0	*	0.610	11.914000	-3.19	110	.....*.....
00:00_12/04/1973	11.0	*	0.655	35.474000	7.79	115	.....|*.....
00:00_06/06/1973	12.0	*	0.588	15.168000	5.17	115	.....|*.....
00:00_04/07/1973	13.0	*	0.604	18.105000	4.77	115	.....*.....
00:00_24/07/1973	14.0	*	0.607	17.125000	-4.07	115	.....*.....
00:00_28/08/1973	15.0	*	0.966	369.436000	-0.43	115	.....*.....
00:00_15/10/1973	16.0	*	0.746	84.652000	-1.17	115	.....*.....
00:00_04/12/1973	17.0	*	0.619	18.348000	-11.62	115	.....*|.....
00:00_16/01/1974	18.0	*	0.881	199.395000	0.00	120	.....*.....
00:00_06/03/1974	19.0	*	0.732	29.603000	-47.70	120	.....*....|.....
00:00_07/04/1974	20.0	*	0.680	28.135000	-4.43	120	.....*.....
00:00_19/06/1974	21.0	*	0.655	33.028000	0.36	125	.....*.....
00:00_16/07/1974	22.0	*	0.680	40.300000	9.31	130	.....|*.....
00:00_05/09/1974	23.0	*	0.671	36.700000	10.56	130	.....|*.....
00:00_02/10/1974	24.0		0.640	15.700000	-10.22	135	.....*|.....
00:00_29/10/1974	25.0		0.616	12.200000	5.98	135	.....|*.....
00:00_25/11/1974	26.0		0.619	12.700000	3.62	135	.....*.....
00:00_04/02/1975	27.0		0.552	1.580000	-3.46	135	.....*.....
00:00_08/04/1975	28.0		0.701	46.000000	-0.94	140	.....*.....
00:00_06/05/1975	29.0		0.647	29.200000	-0.49	145	.....*.....
00:00_24/06/1975	30.0		0.723	57.300000	-1.18	155	.....*.....
00:00_06/08/1975	31.0		0.641	18.600000	4.74	160	.....*.....
00:00_23/09/1975	32.0		0.615	10.900000	-3.31	160	.....*.....
00:00_28/10/1975	33.0		0.742	68.300000	-1.56	165	.....*.....
00:00_02/12/1975	34.0		0.610	17.000000	-2.06	170	.....*.....
00:00_05/02/1976	35.0		1.006	381.000000	-2.23	170	.....*.....
00:00_10/08/1976	36.0		0.697	42.500000	-4.61	175	.....*.....
00:00_15/09/1976	37.0		0.657	26.300000	-5.65	175	.....*|.....
00:00_26/10/1976	38.0		0.712	38.800000	-5.20	180	.....*|.....
00:00_23/11/1976	39.0		0.741	79.000000	-2.04	185	.....*.....
00:00_12/01/1977	40.0		0.645	25.800000	9.15	190	.....|*.....
00:00_15/02/1977	41.0		0.600	11.900000	5.29	190	.....|*.....
00:00_17/02/1977	42.0		0.646	26.100000	8.88	190	.....|*.....
00:00_31/03/1977	43.0		0.710	50.200000	-1.56	190	.....*.....
00:00_04/05/1977	44.0		0.740	43.500000	8.73	195	.....|*.....
00:00_07/06/1977	45.0		0.864	179.000000	-0.27	200	.....*.....
00:00_19/07/1977	46.0		0.805	123.000000	2.42	200	.....*.....
00:00_23/08/1977	47.0		0.748	73.500000	-0.13	200	.....*.....
00:00_27/09/1977	48.0		0.728	48.200000	0.16	205	.....*.....
00:00_08/11/1977	49.0		0.696	24.400000	-1.28	210	.....*.....
00:00_06/12/1977	50.0		0.664	23.100000	-4.30	215	.....*.....
00:00_02/02/1978	51.0		1.193	799.000000	0.91	220	.....*.....
00:00_28/02/1978	52.0		0.690	55.600000	11.33	220	.....|*.....
00:00_11/04/1978	53.0		0.710	44.200000	10.28	225	.....|*.....
00:00_09/05/1978	54.0		0.670	31.900000	-2.70	230	.....*.....
00:00_01/06/1978	55.0		1.503	1910.000000	-0.14	230	.....*.....

* after gauge number indicates Weighted Mean Gauge Height method

Site 419053 MANILLA RIVER AT BLACK SPRINGS
VarFrom 100.00 Stream Water Level
VarTo 141.00 Stream Discharge
Period 01/10/1970 - 30/09/2011

Date	Number	Stage	Flow	Deviation	Rating	-100% Deviation 100%
00:00_20/06/1978	56.0	0.816	131.000000	0.61	230	.....*.....
00:00_15/08/1978	57.0	0.759	85.300000	4.33	230	.....*.....
00:00_26/09/1978	58.0	0.837	142.000000	-5.71	230	.....*|.....
00:00_24/10/1978	59.0	0.827	71.800000	-11.10	235	.....*|.....
00:00_29/11/1978	60.0	0.770	68.800000	-2.79	240	.....*.....
00:00_25/01/1979	61.0	0.724	58.200000	-0.59	245	.....*.....
00:00_28/02/1979	62.0	0.656	26.000000	-5.46	245	.....*|.....
00:00_19/04/1979	63.0	0.678	36.600000	1.58	245	.....*.....
00:00_31/05/1979	64.0	0.676	36.000000	2.27	245	.....*.....
00:00_10/07/1979	65.0	0.682	38.400000	1.79	245	.....*.....
00:01_11/09/1979	66.0	0.651	25.600000	-0.38	245	.....*.....
00:01_01/11/1979	67.0	0.644	18.900000	2.00	250	.....*.....
00:01_04/12/1979	68.0	0.607	18.400000	11.10	255	.....|*.....
00:01_14/01/1980	69.0	0.603	15.400000	-0.90	255	.....*.....
00:01_21/02/1980	70.0	0.555	4.830000	-0.16	255	.....*.....
00:01_20/03/1980	71.0	0.580	4.000000	-9.15	260	.....*|.....
00:01_23/04/1980	72.0	0.555	4.600000	-4.91	265	.....*.....
00:01_12/06/1980	73.0	0.592	11.100000	-10.97	265	.....*|.....
00:01_10/07/1980	74.0	0.595	13.800000	3.70	265	.....*.....
00:01_14/08/1980	75.0	0.582	10.500000	5.46	265	.....|*.....
00:01_18/09/1980	76.0	0.550	4.340000	2.48	265	.....*.....
00:01_23/10/1980	77.0	0.567	2.960000	4.09	270	.....*.....
00:01_27/11/1980	78.0	0.548	1.350000	-3.44	270	.....*.....
00:01_15/01/1981	79.0	0.512	1.510000	11.86	275	.....|*.....
00:01_26/02/1981	80.0	0.520	1.060000	-0.08	280	.....*.....
00:01_21/04/1981	81.0	0.540	1.000000	-0.04	285	.....*.....
00:01_11/06/1981	82.0	1.036	370.000000	-5.95	285	.....*|.....
00:01_23/07/1981	83.0	0.870	148.000000	-1.66	285	.....*.....
00:01_03/09/1981	84.0	0.585	9.940000	-6.80	290	.....*|.....
00:01_26/10/1981	85.0	0.635	20.500000	-0.01	295	.....*.....
00:01_14/12/1981	86.0	0.497	0.800000	-0.41	300	.....*.....
00:01_02/02/1982	87.0	0.517	1.370000	-13.92	300	.....*|.....
00:01_11/03/1982	88.0	1.450	1710.000000	1.67	300	.....*.....
00:00_19/03/1982	89.0	0.650	27.500000	-9.81	300	.....*|.....
00:01_31/05/1982	90.0	0.597	12.600000	-9.30	300	.....*|.....
00:01_05/07/1982	91.0	0.570	8.040000	10.28	300	.....|*.....
00:01_30/08/1982	92.0	0.548	4.760000	18.69	300	.....|.*.....
00:01_11/11/1982	93.0	0.563	1.020000	-9.56	305	.....*|.....
00:01_01/02/1983	94.0	0.541	5.880000	0.96	310	.....*.....
00:01_28/03/1983	95.0	0.520	3.670000	-0.86	310	.....*.....
00:01_16/05/1983	96.0	0.935	233.000000	-2.36	315	.....*.....
00:00_12/07/1983	97.0	0.737	58.900000	0.66	315	.....*.....
00:01_06/09/1983	98.0	1.483	1720.000000	-5.71	315	.....*|.....
00:01_01/11/1983	99.0	0.757	70.900000	1.85	315	.....*.....
00:00_20/12/1983	100.0	0.690	39.700000	4.56	315	.....*.....
00:00_14/02/1984	101.0	0.808	101.000000	-3.28	315	.....*.....
00:00_02/04/1984	102.0	0.743	65.100000	5.62	315	.....|*.....
00:00_14/05/1984	103.0	0.710	58.800000	-4.43	320	.....*.....
00:00_25/06/1984	104.0	0.680	41.200000	-7.36	320	.....*|.....
00:01_27/08/1984	105.0	0.848	134.000000	5.39	325	.....|*.....
00:01_15/10/1984	106.0	0.778	65.400000	-6.20	325	.....*|.....
00:01_18/12/1984	107.0 *	0.695	49.000000	3.72	330	.....*.....
00:01_12/02/1985	108.0	0.632	18.700000	-9.05	330	.....*|.....
00:01_11/04/1985	109.0	0.618	17.800000	7.72	330	.....|*.....
00:01_19/06/1985	110.0	0.628	20.700000	7.10	330	.....|*.....

* after gauge number indicates Weighted Mean Gauge Height method

Site 419053 MANILLA RIVER AT BLACK SPRINGS
VarFrom 100.00 Stream Water Level
VarTo 141.00 Stream Discharge
Period 01/10/1970 - 30/09/2011

Date	Number	Stage	Flow	Deviation	Rating	-100% Deviation 100%
00:01_03/09/1985	111.0	0.743	66.800000	-7.02	330	.....*|.....
00:01_10/12/1985	112.0	1.130	570.000000	-8.32	330	.....*|.....
00:01_24/02/1986	113.0	0.564	6.100000	5.19	330	.....|*.....
00:01_05/05/1986	114.0	0.568	3.820000	-0.21	335	.....*.....
00:01_14/07/1986	115.0	0.587	9.300000	-6.03	340	.....*|.....
00:01_29/09/1986	116.0 *	1.290	1180.000000	8.63	340	.....|*.....
00:01_06/01/1987	117.0 *	0.719	53.300000	-9.66	340	.....*|.....
00:01_24/03/1987	118.0 *	0.538	2.520000	-4.34	340	.....*.....
00:01_02/06/1987	119.0	0.568	6.100000	-5.25	340	.....*|.....
00:01_19/08/1987	120.0	1.028	409.000000	1.70	340	.....*.....
00:01_13/10/1987	121.0 *	0.588	10.700000	6.04	340	.....|*.....
00:00_14/12/1987	122.0	0.620	16.400000	0.61	345	.....*.....
00:00_15/02/1988	123.0	0.609	12.500000	-9.67	345	.....*|.....
00:00_19/04/1988	124.0	0.664	27.800000	-2.80	345	.....*.....
00:00_31/05/1988	125.0	0.635	19.000000	-5.14	345	.....*|.....
00:00_27/07/1988	126.0	0.671	31.200000	0.75	345	.....*.....
00:00_28/09/1988	127.0	0.681	45.300000	31.13	345	.....|..*.....
00:00_23/11/1988	128.0	0.544	7.710000	-0.03	346	.....*.....
00:00_18/01/1989	129.0	0.560	11.100000	0.00	346	.....*.....
00:00_01/03/1989	130.0	0.501	1.950000	-10.33	346	.....*|.....
00:00_19/04/1989	131.0	0.697	52.900000	-5.48	346	.....*|.....
00:00_06/06/1989	132.0	2.150	7050.000000	4.26	346	.....*.....
00:00_02/08/1989	133.0	1.008	365.000000	-0.66	346	.....*.....
00:00_27/09/1989	134.0	0.651	23.000000	-6.17	347	.....*|.....
00:00_28/11/1989	135.0	0.606	22.600000	4.06	348	.....*.....
00:00_02/01/1990	136.0	0.478	1.600000	30.95	348	.....|..*.....
00:00_27/03/1990	137.0	0.501	2.380000	9.45	348	.....|*.....
00:00_23/05/1990	138.0	1.262	1110.000000	11.60	348	.....|*.....
00:00_26/07/1990	139.0	0.732	75.900000	1.22	348	.....*.....
15:40_27/07/1990	140.0	2.405	9620.000000	-1.48	348	.....*.....
11:50_13/09/1990	141.0	0.721	66.100000	-6.28	349	.....*|.....
12:50_20/11/1990	142.0	0.547	10.100000	-3.17	349	.....*.....
12:30_22/01/1991	143.0	0.562	14.000000	5.31	349	.....|*.....
15:00_13/03/1991	144.0	0.506	4.630000	0.18	349	.....*.....
14:40_15/05/1991	145.0	0.535	6.530000	6.51	350	.....|*.....
09:45_10/07/1991	146.0	1.342	1520.000000	20.29	350	.....|.*.....
13:00_04/09/1991	147.0	0.604	18.700000	-11.52	350	.....*|.....
13:05_06/11/1991	148.0	0.532	7.220000	-9.48	351	.....*|.....
12:10_08/01/1992	149.0	0.558	11.800000	-5.59	351	.....*|.....
11:20_11/03/1992	150.0	0.517	4.420000	20.91	352	.....|.*.....
10:35_13/05/1992	151.0	0.570	13.400000	3.41	352	.....*.....
12:40_09/07/1992	152.0	0.554	8.400000	-13.62	352	.....*|.....
11:15_09/09/1992	153.0	0.538	7.360000	10.81	352	.....|*.....
11:30_18/11/1992	154.0	0.670	42.600000	-3.24	352	.....*.....
09:55_21/01/1993	155.0	0.474	1.180000	9.79	352	.....|*.....
11:35_17/03/1993	156.0	0.460	0.320000	-50.77	352	.....*....|.....
16:10_18/05/1993	157.0	0.470	1.020000	8.58	352	.....|*.....
08:40_21/07/1993	158.0	0.610	24.400000	6.48	352	.....|*.....
11:30_03/08/1993	159.0	1.060	493.000000	8.41	352	.....|*.....
11:50_21/09/1993	160.0	0.636	31.900000	0.42	352	.....*.....
13:15_17/11/1993	161.0	0.504	4.730000	96.25	352	.....|.....*
15:30_19/01/1994	162.0	0.488	0.550000	-65.48	352	...*.....|.....
16:55_16/03/1994	163.0	0.519	3.860000	-0.58	352	.....*.....
15:25_11/05/1994	164.0	0.449	0.259000	-40.98	352	.....*...|.....
08:25_13/07/1994	165.0	0.458	1.700000	179.55	352	.....|.....*

* after gauge number indicates Weighted Mean Gauge Height method

Site 419053 MANILLA RIVER AT BLACK SPRINGS
VarFrom 100.00 Stream Water Level
VarTo 141.00 Stream Discharge
Period 01/10/1970 - 30/09/2011

Date	Number	Stage	Flow	Deviation	Rating	-100% Deviation 100%
15:40_14/09/1994	166.0	0.441	0.447000	42.37	352	.....|...*.....
14:30_21/11/1994	167.0	0.405	0.020000	-14.50	352	.....*|.....
09:30_17/01/1995	167.1	0.386	0.000000	0.00	352	.....*.....
15:10_15/03/1995	168.0	0.416	0.038000	-48.71	352	.....*....|.....
15:50_07/06/1995	169.0	0.453	0.857000	11.51	353	.....|*.....
11:20_09/08/1995	170.0	0.467	1.330000	-21.19	353	.....*.|.....
13:15_18/10/1995	171.0	0.440	0.374000	6.86	353	.....|*.....
12:40_29/11/1995	172.0	0.667	43.900000	-0.04	353	.....*.....
14:30_12/12/1995	173.0	0.822	134.000000	-5.68	353	.....*|.....
13:40_21/02/1996	174.0	0.576	21.100000	1.21	353	.....*.....
12:00_09/05/1996	175.0	0.621	31.000000	-0.20	353	.....*.....
11:10_10/07/1996	176.0	0.559	17.600000	1.19	353	.....*.....
17:15_04/09/1996	177.0	0.845	163.000000	0.06	353	.....*.....
14:40_24/10/1996	178.0	0.576	19.000000	-8.86	353	.....*|.....
12:40_19/12/1996	179.0	1.084	520.000000	4.20	353	.....*.....
14:40_05/03/1997	180.0	0.825	127.000000	-12.20	353	.....*|.....
14:00_13/05/1997	181.0	0.671	35.000000	-22.49	353	.....*.|.....
09:10_23/07/1997	182.0	0.609	25.500000	-9.31	353	.....*|.....
09:30_23/09/1997	183.0	0.717	68.500000	3.25	353	.....*.....
10:10_31/10/1997	184.0	0.580	26.000000	4.00	354	.....*.....
08:00_16/01/1998	185.0	0.518	11.900000	1.14	354	.....*.....
16:00_25/03/1998	186.0	0.460	5.690000	-0.18	354	.....*.....
11:20_08/05/1998	187.0	0.626	37.600000	-0.73	354	.....*.....
11:50_15/07/1998	188.0	0.623	38.400000	4.00	354	.....*.....
12:20_17/03/1999	189.0	0.639	42.900000	1.75	354	.....*.....
14:00_11/05/1999	190.0	0.594	26.100000	-8.28	354	.....*|.....
13:55_14/07/1999	191.0	0.594	28.800000	1.21	354	.....*.....
15:20_13/09/1999	192.0	0.581	24.600000	-2.54	354	.....*.....
15:05_17/05/2000	193.0	0.515	12.200000	6.87	354	.....|*.....
09:30_13/07/2000	194.0	0.586	22.700000	-7.15	355	.....*|.....
07:30_09/11/2000	195.0	0.516	10.400000	-3.35	355	.....*.....
14:00_28/03/2001	196.0	0.588	25.100000	0.63	355	.....*.....
09:30_15/08/2001	197.0	0.542	16.200000	6.78	355	.....|*.....
08:00_17/10/2001	198.0	0.556	17.200000	-3.84	355	.....*.....
07:30_13/12/2001	199.0	0.495	8.440000	3.07	355	.....*.....
10:45_21/02/2002	200.0	0.431	1.540000	-3.60	355	.....*.....
14:10_23/04/2002	201.0	0.438	2.290000	7.32	355	.....|*.....
10:30_20/06/2002	202.0	0.457	4.210000	2.10	355	.....*.....
16:20_15/08/2002	203.0	0.425	1.560000	4.17	356	.....*.....
09:00_23/10/2002	204.0	0.380	0.000000	0.00	356	.....*.....
12:00_27/02/2003	205.0	0.672	56.800000	6.31	357	.....|*.....
11:55_19/03/2003	206.0	0.436	2.800000	7.52	357	.....|*.....
15:35_01/05/2003	207.0	0.664	49.400000	-2.07	357	.....*.....
09:00_26/06/2003	208.0	0.501	8.638000	2.40	357	.....*.....
09:35_13/08/2003	209.0	0.496	7.789000	-2.64	357	.....*.....
14:30_29/10/2003	210.0	0.419	1.573000	9.23	357	.....|*.....
14:40_24/02/2004	211.0	0.521	12.096000	6.44	357	.....|*.....
09:00_21/04/2004	212.0	0.428	1.868000	-8.21	357	.....*|.....
09:00_08/06/2004	213.0	0.453	4.283000	4.48	357	.....*.....
08:50_12/08/2004	214.0	0.447	3.792000	7.63	358	.....|*.....
12:05_27/10/2004	215.0	0.492	10.647000	3.18	358	.....*.....
07:55_09/12/2004	216.0	0.757	97.998000	-1.34	358	.....*.....
11:20_23/02/2005	217.0	0.480	8.289000	2.33	358	.....*.....
09:40_19/04/2005	218.0	0.422	1.331000	-5.95	358	.....*|.....
12:30_06/06/2005	219.0	0.445	3.235000	-2.10	358	.....*.....

* after gauge number indicates Weighted Mean Gauge Height method

Site 419053 MANILLA RIVER AT BLACK SPRINGS
VarFrom 100.00 Stream Water Level
VarTo 141.00 Stream Discharge
Period 01/10/1970 - 30/09/2011

Date	Number	Stage	Flow	Deviation	Rating	-100% Deviation 100%
08:40_10/08/2005	220.0	0.547	18.890000	-8.54	358	.....*|.....
08:40_13/10/2005	221.0	0.470	7.025000	7.32	358	.....|*.....
07:45_20/12/2005	222.0	0.577	27.235000	-1.74	358	.....*.....
07:50_20/12/2005	223.0	0.577	26.928000	-2.84	358	.....*.....
12:45_29/01/2006	226.0	0.308	0.000000	0.00	358	.....*.....
14:45_19/06/2006	224.0	0.478	7.142000	-8.10	358	.....*|.....
08:15_18/10/2006	225.0	0.355	0.130000	0.00	358	.....*.....
12:45_29/01/2007	226.0	0.308	0.000000	0.00	358	.....*.....
09:15_11/04/2007	227.0	0.356	0.128000	-7.69	358	.....*|.....
10:35_20/06/2007	228.0	0.428	3.000000	7.26	359	.....|*.....
11:00_18/10/2007	229.0	0.344	0.000000	0.00	359	.....*.....
06:54_13/12/2007	230.0	0.771	117.618000	-6.23	359	.....*|.....
06:57_13/12/2007	231.0	0.771	115.185000	-8.17	359	.....*|.....
10:39_13/02/2008	232.0	1.075	553.500000	3.98	359	.....*.....
10:45_13/02/2008	233.0	1.075	562.567000	5.69	359	.....|*.....
08:00_17/04/2008	234.0	0.365	0.220000	2.45	359	.....*.....
11:50_19/06/2008	235.0	0.447	4.807000	7.87	359	.....|*.....
11:55_19/06/2008	236.0	0.447	4.670000	4.79	359	.....*.....
09:30_06/08/2008	237.0	0.449	4.244000	-8.82	359	.....*|.....
09:46_22/10/2008	238.0	0.511	13.232000	-2.97	359	.....*.....
09:51_22/10/2008	239.0	0.511	13.557000	-0.59	359	.....*.....
13:42_16/12/2008	240.0	0.696	64.790000	-4.73	360	.....*.....
12:09_16/02/2009	241.0	0.635	38.500000	-1.49	360	.....*.....
09:52_07/04/2009	242.0	0.555	17.000000	-8.27	360	.....*|.....
11:00_16/06/2009	243.0	0.446	5.720000	8.81	361	.....|*.....
14:55_05/08/2009	244.0	0.434	2.910000	-0.25	362	.....*.....

* after gauge number indicates Weighted Mean Gauge Height method

NSW Office of Water PINNEENA 9.3

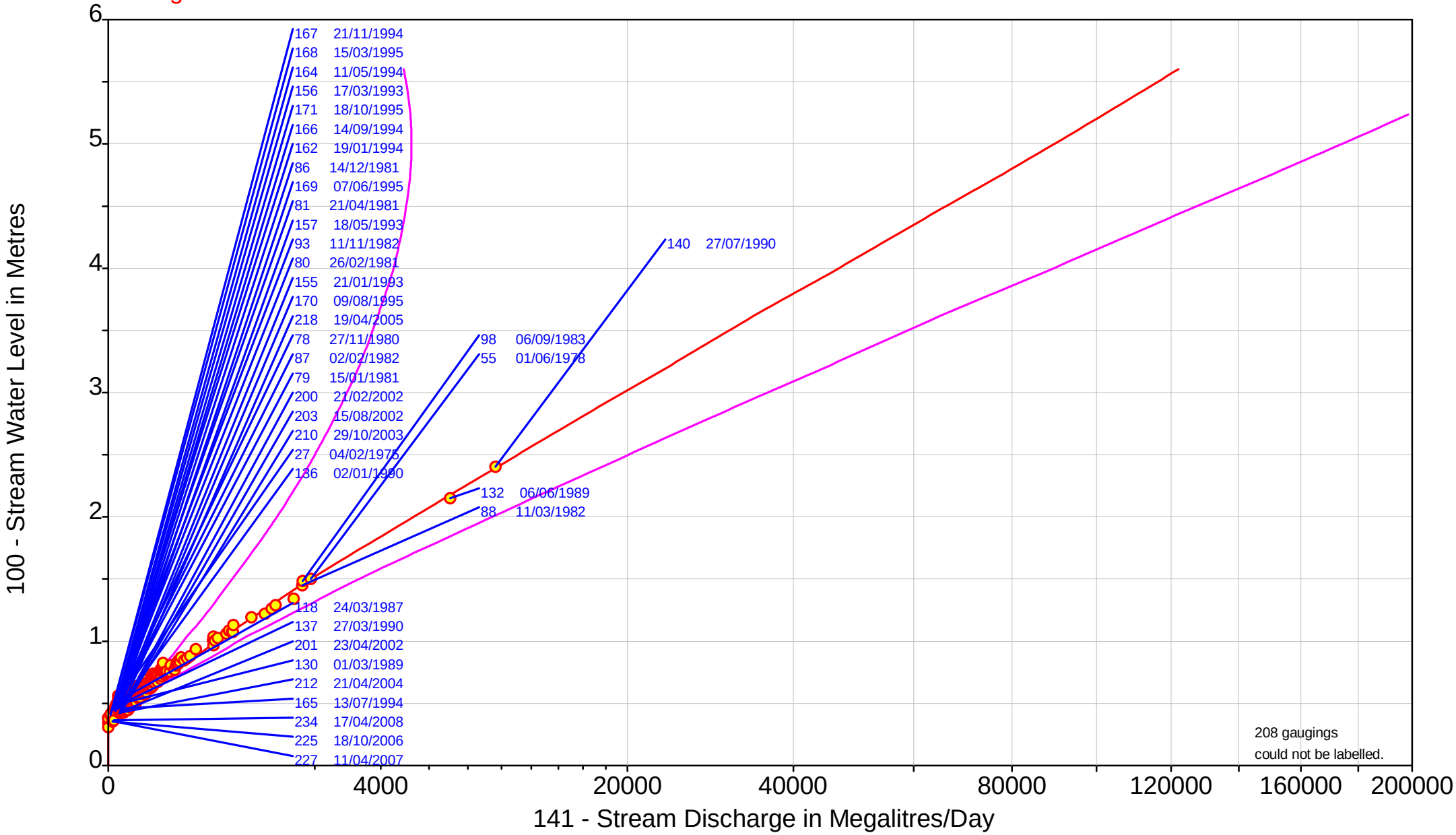
HYGPLOT V128 Output 23/12/2011

419053 MANILLA RIVER AT BLACK SPRINGS

Gaugings from 21/03/1972 to 05/08/2009

Good Doubtful Bad

Rating Table 362.00 01/07/2009 to Present



Appendix C

Community Consultation

BARRABA FLOOD STUDY
CONSULTANT MEETING No 1

12 NOON, 20 JULY 2O11, LEVEL 2, RAY WALSH HOUSE, TAMWORTH

PRESENT:-

James McPherson [JM] - GHD

Dr Rainer Berg [RB] - GHD [by phone link]

Murray Russell [MR] - TRC

Graeme McKenzie [GM] - TRC

William Ash [WA] - TRC

1. INTRODUCTION

The meeting was convened to confirm the Barraba Flood Study methodology and Programme and to respond to any (RFIs) GHD may have raised.

RB joined the meeting by phone link.

The Barraba meeting was run in conjunction with the Manilla Flood Study meeting [minuted separately]

2. PROJECT PLAN

RB briefed the meeting on the proposed methodology.

Methodology is to comply with Section 4 Flood Study of the Consultants Brief and RB outlined the following components:-

- Modelling Platform.

  RB reported that the level of detail in the Modelling Platforms was still to be determined. GHD will liaise with (OEH) to finalise the model details.

  All communication between GHD and OEH is to be documented and copied to TRC.

- Hydrology

  RB stated (RORB) model set up GHD will develop the model then using hydraulic information including Frequency Analysis and measurements of events in creeks compare the actuals to the results of the model. The model will then be calibrated against a number of recorded historical and observed flood peaks using river gauging stations as benchmarks.

  Survey information is not essential in building this model.

- Community Consultation

  RB briefed the meeting on the consultation process and information sought from the Barraba community. GHD will draft the questionnaire and media material to be issued, TRC will review, approve and issue under cover of TRC letterhead and include contact details. Current documentation and process being employed on Coffs Harbour Flood Study will be amended and utilized for Barraba

  Issue of material will be by post based on TRC Rates database for property owners. Community Groups will be contacted. Letterboxing may be considered. Time frame/s for response will be specified.

  Information requested will include historical floods, levels and impacts on property.

  This item needs to be actioned ASAP.

- Hydraulic Models

RB reported GHD had built 2 'raw' models [Tuflow and Mikell] in the previous week. Models are to be tested using rainfall events and flood peaks. RB stated the type of model is yet to be determined and the level of information to be included in the model [2 Flow or 2D] will be clarified within 2 weeks. The concurrence of OEH is required as to the type of model.

Both Hydrology and survey are required to be complete in order that the selected hydraulic model can be completed and calibrated against identified flood marks determined from TRC information and community knowledge.

GHD has obtained rainfall records from the Bureau of Meteorology [BOM] and has purchased flow data for waterways. This information will be used by GHD to determine the event it will use to calibrate the model/s. Results from 3-4 gauges with data periods with co-incidental large events would be utilized to determine large events for the purposes of calibration.

Once calibrated flood events can be modelled, properties at risk identified and estimates of damage prepared.

- Mapping

  Maps are to be able to be interfaced with TRC GIS capability. GHD is to liaise with TRC GIS operator the ensure compatibility.

  [Note following the meeting JM and WA met with TRC, GIS operator Joe Bagster to establish the lines of communication to ensure mapping meets with TRC requirements]

  GHD is programming to have mapping complete by last week of October 2011.

- Climate Change

  GHD stated the impact of climate change is difficult to model due to inputs being estimates only. Accordingly GHD is running its model with practical considerations as inputs.

  In respect of predicted increased rainfall, GHD is proposing to run 200 and 500 year events through the model to estimate future flood levels and the impact of such events on the town.

  Final inputs to be identified following further search of relevant data.

- Programme

  GHD stated it would prepare and issue to TRC the community questionnaire during the last week of July 2011.

  TRC requested that the programme show the Christmas/ New Year break.

  TRC requested the programme include milestones, hold points and meetings, including meetings with Floodplain Management Committee.

  A list of deliverables and dates of issue to TRC are to be included.

3. SURVEY

RB reported GHD can continue to progress without survey at this time.

GHD has issued a brief to the preferred Surveyor [Peter Baxter] and is waiting on final pricing before advising TRC. This is expected during the first week of August with field work to commence immediately with a 6 week programme to complete.

Survey information is required to build the hydraulic model.

Initial tasks include site visit and walk to determine the information required is identified and ensure such information is correct. Information will include ground and creek levels and properties at risk locations and floor levels.

Information from survey will be used to further develop the hydraulic model/s and calibrate the model/s against historic flood levels established from historical information including TRC records and community response.

On completion of these tasks GHD will run the hydrographs through the model and map the flood effected areas.

4. CLIENT [TRC] INFORMATION

GHD requested TRC to provide the following information:-

- TRC LEP Map
- Plan of Cadesta
- Contour maps [if available]
- Ariel Photos
- Previous flood information and estimates
- Information on bridges, openings in culverts etc
- Historical and general information on previous flood events held by TRC and/or Community Groups.
- Bridges blocked in previous flood events giving levels if available.

GHD requested it be allowed to access and use information available under Licence Agreements. TRC will facilitate this request.

GHD will email WA with a comprehensive list of requested information by 27 July 2011.

5. DOCUMENTATION LISTING

GHD to prepare a list of documents, issue to TRC and integrate into the programme.

6. OTHER BUSINESS

GHD requested TRC Purchase Orders for the Study.

There being no further business the meeting closed at 1.15 pm.

Next meeting to be advised.

WA and JM met with Joe Bagster following the meeting to discuss mapping information and interface with TRC GIS System.

BARRABA FLOOD STUDY

NEWSLETTER NO.1, August 2011

About the project

As part of the NSW Government's Floodplain Risk Management Process, Tamworth Regional Council is developing a Flood Study for Barraba.

Barraba is located on the Manilla River upstream of Split Rock Reservoir in the Manilla River catchment. The town is located south of the river along Fossickers Way. The Manilla River passes through Split Rock Reservoir downstream of the tow.

Floodwaters rise quickly and can isolate properties and communities for several days. Many houses could be affected during a flood, necessitating evacuations.

Rainfall and river gauging data in the catchment is limited, however significant events have been recorded on a number of stream gauges.

The objective of this Flood Study is to define the flood behaviour under recent historical conditions and design flood behaviour under existing and future conditions in the study area. The output will provide flood levels, depths, velocities, flows, hydraulic categories, and provisional hazard categories.

GHD has been contracted by Council to carry out the Barraba Flood Study.

Study Tasks

In general terms, the following key tasks will be undertaken:

- Collect, compile and review available flood data relating to the study area in order to obtain a full understanding of flooding issues in the study area;
- Undertake community consultation to gather information on historical flooding in the area and the impact of flooding on the local community;
- Gather additional survey of watercourses, structures (for example bridges, culvert, road levels);
- Develop flood models to simulate historical and design floods. Calibrate and validate these model against recent historical flood data (for example the April 2009 event; and
- Flood map flood extents, flood level contours and provisional flood hazards for the study area.

Community Information

Council and GHD are committed to listening to the concerns and issues of the community and stakeholders, and strategies are in place to ensure that this information is integrated into the study. There will be opportunities throughout the study for the local community and stakeholders to feedback their concerns and issues.

As a first step, the project team is keen to learn when and where previous flooding has occurred in Barraba and the surrounding areas, and how you and your property were affected.

Attached is a survey questionnaire that all members of the community are encouraged to complete and return (postage paid). This is an opportunity to ensure that you have your say and that the information is captured.

For more information contact:

Lynne Clayton
Stakeholder Engagement
Barraba Flood Study
Reply Paid 83475
GHD, Level 15, 133 Castlereagh Street
Sydney NSW 2000

Facsimile – 02 9239 7199
Email – community.input@ghd.com.au

Project Information Line
1800 810 680 (free call)

BARRABA FLOOD STUDY
CONSULTANT MEETING No 2

3.00 PM, 3 AUGUST 2O11,

LEVEL 2, RAY WALSH HOUSE, TAMWORTH

PRESENT:-

James McPherson [JM] - GHD

Dr Rainer Berg [RB] - GHD

William Ash [WA] - TRC

APOLOGIES

Murray Russell [MR] - TRC

Graeme McKenzie [GM] - TRC

1. INTRODUCTION

The meeting was convened to discuss progress on the Barraba Flood Study, confirm methodology and to respond to any Request for Information (RFIs) GHD may have raised.

Note the Barraba meeting was held concurrently with the Manilla meeting.

2. PROJECT PLAN

RB confirmed the proposed methodology for the Study.

Methodology is to comply with Section 4 Flood Study of the Consultants Brief and RB outlined the following components:-

- Modelling Platform.

  RB reported that the level of detail in the Modelling Platforms was still to be determined. GHD will liaise with Office of Environment and Heritage (OEH) to finalise the model details and reported he would be meeting with Neal Albert [NA] of OEH immediately following this meeting. Matters concerning the methodology would be discussed with OEH.

  WA confirmed communication between GHD and OEH is to be documented and copied to TRC.

- Hydrology

  RB stated RORB model set up GHD will develop the model then using hydraulic information including Frequency Analysis and measurements of events in creeks compare the actuals to the results of the model. The model will then be calibrated against a number of recorded historical and observed flood peaks using river gauging stations as benchmarks.

  Survey information is not essential in building this model.

- Community Consultation

  RB briefed the meeting on the consultation process and information sought from the Barraba community. GHD will draft the questionnaire and media material to be circulated to Barraba residents and issue drafts to TRC on 5 Aug 2011. TRC will review, approve and issue under cover of TRC letterhead and include GHD contact details.

  TRC confirmed Issue of material will be by post, based on TRC Rates database for property owners. In addition each property will be contacted to ensure tenants are included in the survey. Community Groups will be contacted. Time frame/s for response will be specified.

Information requested will include historical floods, levels and impacts on property.

This item needs to be actioned ASAP. GHD confirmed issue of draft documents by 5 Aug

- Hydraulic Models

  RB confirmed GHD had built 2 'raw' models [Tuflow and Mikell] during the first week of the Study. Models are to be tested using rainfall events and flood peaks. RB stated the type of model is yet to be determined and the level of information to be included in the model [2 Flow or 2D] will be clarified in the immediate future. The concurrence of OEH is required as to the type of model. This will be an item for discussion with OEH following this meeting.

  Both Hydrology and survey are required to be complete in order that the selected hydraulic model can be completed and calibrated against identified flood marks determined from TRC information and community knowledge.

  GHD has obtained rainfall records from the Bureau of Meteorology [BOM] and has purchased flow data for waterways. This information will be used by GHD to determine the event it will use to calibrate the model/s. Results from 3-4 gauges with data periods with co-incidental large events would be utilized to determine large events for the purposes of calibration.

  Once calibrated flood events can be modelled, properties at risk identified and estimates of damage prepared.

- Mapping

  Maps to be interfaced with TRC GIS capability. GHD and TRC GIS operator are in communication to ensure compatibility.

  GHD is programming to have mapping complete by last week of October 2011.

- Climate Change

  GHD stated the impact of climate change is difficult to model due to inputs being estimates only. Accordingly GHD is running its model with practical considerations as inputs.

  In respect of predicted increased rainfall, GHD is proposing to run 200 and 500 year events through the model to estimate future flood levels and the impact of such events on the town.

  Final inputs to be identified following further search of relevant data.

- Programme

  TRC had previously requested that the programme show the Christmas/ New Year break.

  GHD tabled a revised programme including milestones, hold points, deliverables and meetings.

  A list of and dates of issue to TRC have been included.

3. SURVEY

RB confirmed GHD can continue to progress without survey at this time.

GHD has issued a brief to the preferred Surveyor [Peter Baxter] and is conducting a site inspection with Baxter tomorrow, 4 Aug 2011. Following the site inspection GHD will prepare draft plans showing survey limits and issue to TRC and OEH for approval.

The model areas have to be determined prior to preparing final pricing for the survey. Field work will commence on TRC approval of the survey limits and survey cost with a 6 week programme to complete.

GHD confirmed survey information is required to build the hydraulic model.

Initial tasks are to determine the information required is identified and ensure such information is correct. Information will include ground and creek levels and properties at risk locations and floor levels.

Information from survey will be used to further develop the hydraulic model/s and calibrate the model/s against historic flood levels established from historical information including TRC records and community response.

On completion of these tasks GHD will run the hydrographs through the model and map the flood effected areas.

4. CLIENT [TRC] INFORMATION

GHD confirmed it had signed the Licence Agreements that allowed accessing and using information held by TRC and that information is being made available.

GHD confirmed TRC has provided the following information:-

- TRC LEP Map
- Plan of Cadesta
- Contour maps
- Ariel Photos [limited]

GHD confirmed it required the following information ASAP

- Previous flood information and estimates
- Information on bridges, openings in culverts etc
- Local historical information held by Community Groups etc
- Bridges and/or other structures blocked in previous flood events, giving levels if available.

GHD has issued TRC with a comprehensive list of information requested.

TRC handed to GHD copies of documents containing historical information on previous floods.

A catalogue of these documents will be issued to GHD.

TRC will continue to search its archives for further documents and/or information relating to historical flood information.

5. DOCUMENTATION LISTING

GHD has issued a list of documents to TRC and integrated the delivery of these into the works programme.

6. OTHER BUSINESS

GHD requested TRC Purchase Orders for the Study.

There being no further business the meeting closed at 3.45 pm.

Next meeting to be advised.

BARRABA FLOOD STUDY
CONSULTANT MEETING No 3

10.00 am FRIDAY 16 SEPTEMBER 2O11

LEVEL 2, RAY WALSH HOUSE, TAMWORTH

PRESENT:-

James McPherson [JM] - GHD

Dr Rainer Berg [RB] - GHD [by phone link]

Neal Albert [NA] - Office of Environment and Heritage

Andrew Falkenmire [AF] - Office of Environment and Heritage

Peter Baxter [PB] - Peter Baxter Surveyors, Sub-Consultant to GHD

Thomas Baxter [TB] - TRC

William Ash [WA] - TRC

APOLOGIES

Murray Russell [MR] - TRC

Graeme McKenzie [GM] - TRC

1. INTRODUCTION

The meeting was convened to review progress on and provide the management team with visibility of the technical aspects of the Barraba Flood Study and to respond to any Requests for Information (RFIs) GHD may have raised.

RB joined the meeting by phone link.

2. PROJECT PROGRAMME STATUS

RB briefed the meeting by phone link, on the progress against the programme and a summary of his report follows:-

2.1 Programme

- A site visit in concert with the ground survey team headed by PB has been carried out. The topography of the terrain was inspected. From on site observations the Survey Brief was confirmed by GHD and PB.
- Number of houses to have floor levels established for damage calculations will be calculated using the PMF + 0.5M.
- PB reported survey control points have been established. These will be used by both the ground survey team and to calibrate the existing aerial survey information. Areometrex 'holes' will be filled in and 'rough' contours established.
- PB. Model will be in HECRAS format. From the basic model areas inundated during PMF flood events can be delineated estimating from 100 yr x 3 beyond the form lines and the aerial information can be used to determine 'rough' DTM.
- PB reported GHD is on programme.

2.2 Hydrology

- RB has previously stated RORB model set up GHD will develop the model then using hydraulic information including Frequency Analysis and measurements of events in creeks compare the actuals to the results of the model. The model will then be calibrated against a number of recorded historical and observed flood peaks using river gauging stations as benchmarks. Survey information is not essential in building this model.

- RB reported Hydrology model has been built and is ready for calibration using information from previous rain and flood events and set systems flow gauges for calibration. RB stated GHD has a good understanding of flows from historical records from previous information providing basic information on the magnitude of flows.

2.3 Hydraulics

- Construction and accuracy of the Hydraulic Model is dependant on the provision of correct survey information. PB stated model would be TUFLOW and GHD would build a substantial part of the model using form lines the replace the inputted data with the more accurate DTM when this became available. PB stated GHD would commence to build the model/s during week commencing 19 September 2011.
- RB stated GHD Is considering 2 model options and would discuss this with OEH to ensure the model meets OEHs criteria before making the final decision. NA stated OEH concurs with GHDs approach with the proviso the OEH needs to be comfortable with the 'raw' models flood frequency. OEH and GHD would discuss this matter after the meeting and would inform the meeting on the outcome of the discussions.

2.4 Survey

- RB/PB confirmed site Information will include ground and creek levels and properties at risk locations and floor levels.

- PB confirmed that Barraba ground survey is substantially complete. Control points have been established to allow calibration of Areometrex and confirm ground survey.
- PB stated the Areometrex has an accuracy of +/- 150mm. This is to be confirmed.
- TB to follow up with Areometrex to expedite transfer of information.
- A brief of survey and how this integrates with the modelling software is to be provided. TB to review.
- TB stated all survey information is to be available for use by all levels of Government without limitations.
- PB requested any historical information TRC holds in respect of previous flood levels including flood markers [if any].
- Maps are to be able to be interfaced with TRC GIS capability. GHD is to liaise with TRC GIS operator the ensure compatibility. GHD is programming to have mapping complete by last week of October 2011.
- In respect of Climate Change GHD has previously stated the impact of climate change is difficult to model due to inputs being estimates only. Accordingly GHD is running its model with practical considerations as inputs. In respect of predicted increased rainfall, GHD is proposing to run 200 and 500 year events through the

model to estimate future flood levels and the impact of such events on the town. Final inputs to be identified following further search of relevant data.

COMMUNITY CONSULTATION

- WA reported Newsletter and questionnaire had been distributed to the Barraba area. RB stated that responses to the questionnaire had been received in GHDs Sydney office and these are currently being reviewed.
- WA advised TRC is establishing the Floodplain Management Committee and is seeking representatives of the community to sit on the committee. Adverts seeking Expressions of Interest local residents to join the committee have been placed in local newspapers.
- The first Committee meeting is scheduled for 6 Oct 2011. The meeting noted this matter is urgent**.**
- RB stated community involvement through the Committee is fundamental in gaining the communities approval of the Study and ongoing Management Plans. Local knowledge of historical flood events greatly assists with calibration of the models and this knowledge can be utilized by 'running' these known events through the model and gaining Committee/community acceptance as to the accuracy of the model/s and confidence as to predicting future flood events.

..

4. CLIENT [TRC] INFORMATION

- GHD requested TRC to expedite the Areometrex information

.

5. DOCUMENTATION LISTING

GHD to prepare a list of deliverables and issue to TRC and integrate into the programme.

6. OTHER BUSINESS

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There being no further business the meeting closed at 11.00 a.m.

Next meeting to be advised.

TAMWORTH REGIONAL COUNCIL
BARRABA FLOOD STUDY
FLOODPLAIN RISK MANAGEMENT COMMITTEE

INAUGRAL MEETING
MINUTES

2.00PM Thursday 20 October 2011
Ray Walsh House, Peel Street Tamworth

Attendees

Neal Albert	[NA]	Office of Environment and Heritage
Andrew Galvin	[AG]	State Emergency Services
Dr Rainer Berg	[RB]	GHD
Graeme McKenzie	[GM]	Tamworth Regional Council (TRC)
William Ash	[WA]	TRC
Tom Baxter	[TB]	TRC [part time]

Apologies

Peter Resch	[PR]	Tamworth Regional Council (TRC)
Andrew Falkenmire	[AF]	Office of Environment and Heritage
Murray Russell	[MR]	TRC
Ray Tait	[RT]	TRC (being detained on Council business)

Item 1 Introduction

Please note that a number of matters pertaining to Barraba were covered by RB during the presentation in the Manilla Meeting.

WA opened the Inaugral Floodplain Risk Management Committee Meeting for Barraba noting those attending and apologies.

WA stated there had been a lack of response from residents of Barraba to sit on the Floodplain Risk Management Committee [Committee] despite newspaper advertisements inviting locals to apply and direct approach to specific individuals. Therefore Barraba community was not represented at this meeting.

RB had previously stated a broad representation and community involvement through the Committee is fundamental in gaining the communities approval of the Study and ongoing Management Plans. Local knowledge of historical flood events greatly assists with calibration of the models and this knowledge can be utilized by 'running' these known events through the model/s, gaining Committee/community acceptance as to the accuracy of the model/s and a level of confidence as to predicting future flood events.

The Committee agreed that local representation is essential to the ultimate success of the Study in particular the Risk Management Plan and a number of actions to secure local members were canvassed including the drafting of TRC staff from the area and contact with the local Community Development Committees.

The meeting agreed that TRC Planning Department is to be represented on the Committee GM/WA to action.

Item 2 Election of Committee Chairman

The meeting noted that RT had been contacted and has agreed to Chair the Committee for Barraba.

The Committee confirmed RT as its Chairman.

The Committee has no formal powers and acts as a forum for the discussion and over viewing of the reports and dissemination of information from the studies findings to the community and other interested parties.

It is important that all stakeholders be equally represented.

Matters for discussion include the technical, social, environmental, economic and cultural impacts of flooding in the areas the subject of the study.

Item 3 Address by Dr Rainer Berg outlining the process, procedures and objectives of Flood Studies in flood prone areas.

As stated above RB has covered this item in respect of Barraba in his Presentation during the Meeting for Manilla.

Item 4 Report on current status of Barraba Flood Study and programme to completion of the Flood Study phase.

RB provided a status report on the progress of the Barraba Flood Study using the Gantt Chart Programme as the demonstration tool and briefed the Committee on information gained to date including historical events and Progress against the programme.

The salient points are:-

- The major flood events in Barraba since the commencement of river gauging as measured from the gauging stations were in 1955,1964, 1971, 1974 1984, 1998, 2003 and 2004 with 1964 being the worst flooding. RB stated that information from the gauges varied in content and usefulness depending on the length of time they had been in operation and the frequency of data collection. Only a small number of gauges provide sufficient data to assist with accurate modelling. A log of flood records from a number of gauges was included in GHDs presentation.
- The Study for Barraba is simpler than Manilla in that Barraba has a smaller catchment and a single major waterway, the Manilla River.
- A site visit determined the general topography of the area including vegetation and flood channels.
- From discussions with TRCs GIS operators and on-site observations the Survey Brief was confirmed as providing sufficient accurate information to build the models.
- In respect of flood damage assessment it is essential for each property deemed to be subject to flooding to have accurate information to determine the type of property [residential, commercial, industrial], type of construction and the height of the potential flood over the property using the PMF + 0.5m. The number of properties requiring floor levels to be determined for damage calculations have been estimated from previous events and extrapolating to PMF =0.5m
- PB reported survey control points have been established. These are being utilized to calibrate the existing aerial survey information. Areometrex ‘holes’ will be filled in and ‘rough’ contours established.
- PB reported that structures affected by flooding i.e. bridges and culverts will be surveyed next week and information ‘fed’ into the models.
- PB stated response from the community to the questionnaire had been good and the information provided processed for use in developing the models.
- Rainfall records from properly calibrated gauges is limited.

- RB has previously stated RORB model set up GHD will develop the model then using hydraulic information including Frequency Analysis and measurements of events in creeks compare the actuals to the results of the model. The model will then be calibrated against a number of recorded historical and observed flood peaks using river gauging stations as benchmarks. Complete survey information is not essential in finalising the construction of this model.
- RB stated OEH has approved the use of the TUFLOW model for the hydraulics as meeting its [OEHs] criteria.
- RB reported Hydrology model has been built and calibration is in train using information from previous rain and flood events and records from flow gauges for calibration. RB stated GHD has a good understanding of flows from historical records providing basic information on the magnitude of flows. The model will replicate rainfall events to match what happens in the waterways. The objective is to have the model able to replicate what actually happens in real terms.
- Construction and accuracy of the Hydraulic Model is dependant on the provision of correct survey information. PB confirmed the model is TUFLOW and GHD will build a substantial part of the model using form lines then replace the inputted data with the more accurate DTM when this became available. PB stated GHD had commenced the Model using current data. Model completion is dependant on finalisation of field survey and correlation with areometrex. First run of the model is scheduled for week commencing 24 October 2011.

  4.1 Survey

  - RB/PB confirmed site Information will include ground and creek levels and properties at risk locations and floor levels.
  - The programme notes that the survey is behind programme but this will not impact the programme as a whole.
  - NA raised the matter of Quality Assurance in respect of survey citing problems with previous aerial survey information provided to OEH and noted that survey information gathered during the Flood Studies is required for use by NSW Government and therefore the need for accuracy is paramount.
  - Thomas Baxter was invited to brief the Meeting on how QA of the survey information could be affected. TB stated that from previous experience LPI was not 'geared' to QA the form of information being obtained by the systems used on this project but he would contact the LPI to investigate if that organisation could assist with QA. In the absence of LPI assistance GHD to investigate how the survey information can be subjected to QA.

  The accuracy stated for areometrex as +/- 150mm is to be confirmed.

Item 5 Community Consultation

- RB stated that responses to the questionnaire had been received in GHDs Sydney office and the information contained is being processed and incorporated into the Study Data.
- As stated above there has been a lack of response from residents of Barraba to sit on the Committee despite newspaper advertisements and direct approach to specific individuals inviting locals to apply to be involved in the process.
- The Committee agreed that local representation is essential to the ultimate success of the Study in particular the Risk Management Plan and a number of actions to secure local members were identified including the drafting of TRC staff from the area and contact with the local Community Development Committees.

- RB proposed that the public meeting at Barraba be held on or about 7 December 2011. The Meeting concurred and TRC is to convene.

Item 6 Discussion on format, presentation and release of Study findings in Final Report

Report will comply with standards and format described in the Floodplain Risk Management Plan.

Item 7 Discussion on actions post Flood Study Final Report

Following acceptance of the Flood Study Final Report the actions will comply with the Flow Chart as contained in Appendix C of the Floodplain Risk Management Plan.

Item 8 General business.

There being no further business the Meeting closed at 2.30pm

Next Meeting: to be advised.

NEWSPAPER INSTRUCTIONS
REGIONAL COUNCIL NEWS ADS

PAPER	TO APPEAR (DATE)	JOB NUMBER	AUTHORISED BY
MANILLA EXPRESS	TUESDAY 13 DECEMBER 2011	AUF010-1598-400	BILL ASH

MANILLA FLOOD STUDIES – COMMUNITY INFORMATION SESSION

Tamworth Regional Council has engaged consultants to carry out the Manilla Flood Study, to define flooding in Manilla and inform Council's planning for the management of flooding.

Residents who have questions about the study, or who have been affected by flooding previously, are invited to a Community Information Session being held at 6.00pm, 14 December at the Manilla Town Hall.

Should you have any enquiries about the information session or the flood study, please contact William Ash, Senior Engineer, on 6767 5738 or 0417 964 972.

Churches of Manilla and Barraba. The program covers a variety of activities, these include: Surfing/Swimming, Sand Modelling, Talks by the guest speaker Rev. Chris Brennan of Glen Innes, Discussion Groups, Music and Competitions. There is an Extreme Team Challenge and many other things to do. Registration Forms have been distributed, but for anyone wanting more detailed information please contact one of the following: John Barwick phone 6785 1251, Robert Bowman 6785 7315, Rev. Vince Wall 6785 1627, Joe or Estelle McDonald 67697569.

XMAS LIGHTS REMINDER

A reminder that entries in the 2011 Christmas Lights competition close this Friday, 16th December. Entry form is published on page 5 of today's paper. Enter and you could be in the running for $400 worth of Coles Myers vouchers courtesy of Essential Energy.

ENGAGED

Di and Rod Taylor are delighted to announce that Bede and Nicole are engaged.

5 DAY WEATHER FORECAST

Wednesday - 12 to 24, partly cloudy.

Thursday - 12 to 23, possible afternoon shower.

Friday - 12 to 27, partly cloudy.

Saturday - 13 to 27, partly cloudy.

Sunday - 15 to 25, shower or two.

DAM LEVELS

Keepit: Storage 407,318 megalitres, 95.7 percent of capacity average discharge 3,631 megalitres per day. **Split Rock:** Storage 161,122 megalitres, 40.3 percent of capacity, discharge 10 megalitres per day.

Tamworth REGIONAL COUNCIL
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NEWSPAPER INSTRUCTIONS
REGIONAL COUNCIL NEWS ADS

PAPER	TO APPEAR (DATE)	JOB NUMBER	AUTHORISED BY
BARRABA GAZETTE	WEDNESDAY 14 DECEMBER 2011	AUD085-1598	BILL ASH

BARRABA FLOOD STUDIES – COMMUNITY INFORMATION SESSION

Tamworth Regional Council has engaged consultants to carry out the Barraba Flood Study, to define flooding in Barraba and inform Council's planning for the management of flooding.

Residents who have questions about the study, or who have been affected by flooding previously, are invited to a Community Information Session being held at 6.00pm, 15 December at the Barraba Council Chambers.

Should you have any enquiries about the information session or the flood study, please contact William Ash, Senior Engineer, on 6767 5738 or 0417 964 972.

...brations. Come along ... evening.

THE BARRABA GAZETTE & CHRISTMAS

December publishing dates for the Gazette are:

Wednesday 7th, 14th, 21st December

The final paper for the year, 21st December, will include our traditional Business House "Christmas Wish" section. Anyone wishing to place a advertisement in this section of the paper is asked to contact the Gazette Office before Thursday, 15th December.

The first paper for 2012 will be published on Wednesday 18th January.

... Community ... Barraba Artisans Inc is planning a meeting late January to begin the planning for Frost over Barraba. A notice for this meeting will be in the first Gazette of the new and Farmers' Market or Frost Over Barraba, please contact Helen Birt, BCI Publicity Officer, Ph 6782 1857 or email helen.birt@bigpond.com

Tamworth REGIONAL COUNCIL

ABN: 52 631 074 450

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BARRABA FLOOD STUDIES – COMMUNITY INFORMATION SESSION

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NEWSPAPER INSTRUCTIONS
REGIONAL COUNCIL NEWS ADS

PAPER	TO APPEAR (DATE)	JOB NUMBER	AUTHORISED BY
NORTHERN DAILY LEADER	SATURDAY 10 DECEMBER 2011	AUD085-1598	BILL ASH

BARRABA FLOOD STUDIES – COMMUNITY INFORMATION SESSION

Tamworth Regional Council has engaged consultants to carry out the Barraba Flood Study, to define flooding in Barraba and inform Council's planning for the management of flooding.

Residents who have questions about the study, or who have been affected by flooding previously, are invited to a Community Information Session being held at 6.00pm, 15 December at the Barraba Council Chambers.

Should you have any enquiries about the information session or the flood study, please contact William Ash, Senior Engineer, on 6767 5738 or 0417 964 972.

NEWSPAPER INSTRUCTIONS
REGIONAL COUNCIL NEWS ADS

PAPER	TO APPEAR (DATE)	JOB NUMBER	AUTHORISED BY
NORTHERN DAILY LEADER	SATURDAY 10 DECEMBER 2011	AUF010-1598-400	BILL ASH

MANILLA FLOOD STUDIES – COMMUNITY INFORMATION SESSION

Tamworth Regional Council has engaged consultants to carry out the Manilla Flood Study, to define flooding in Manilla and inform Council's planning for the management of flooding.

Residents who have questions about the study, or who have been affected by flooding previously, are invited to a Community Information Session being held at 6.00pm, 14 December at the Manilla Town Hall.

Should you have any enquiries about the information session or the flood study, please contact William Ash, Senior Engineer, on 6767 5738 or 0417 964 972.

You're Invited... COUNCIL MEETING

The public is invited to attend Council's DECEMBER Meeting as under:

Meeting	Day	Date	Time	Venue
Ordinary Council	Tuesday	132 December 2011	6.30pm	Council Chambers 4th Floor Ray Walsh House 437 Peel Street Tamworth

Community Consultation: Members of the public may address the Council on matters and issues listed in the Business Paper. Each speaker addressing the Council Meeting will be allowed three minutes.

Members of the public giving prior notification to Council's Administration Staff by 12 noon on the day of the Meeting of their intention to address the Council Meeting will be given priority.

Council's Administration Staff will be pleased to assist with enquiries – telephone 6767 5444 during normal business hours.

Business Papers are available from:

Friday afternoon prior to meeting date on Tamworth Regional Council Website www.tamworth.nsw.gov.au/Council OR

Monday Morning prior to Meeting for collection from Tamworth Regional Council Customer Services Counter at Barraba, Manilla, Nundle or Tamworth Offices and available at the Meeting at Tamworth.

PART CLOSURE OF TAMWORTH REGIONAL COUNCIL THURSDAY 15 DECEMBER 2011

Please be advised that all Tamworth Regional Council Offices and Facilities will be closed due to a Council Function as under:

Barraba Office will close on Thursday 15 December 2011 at 12:00pm
Manilla Office will close on Thursday 15 December 2011 at 12:00pm
Nundle Office will close on Thursday 15 December 2011 at 12:00pm
Tamworth Office will close on Thursday 15 December 2011 at 12:00pm

The following services will remain open to the public during normal operating hours for each facility:

Tamworth Airport/Kiosk, Basil Brown Drive, Tamworth
All Waste Depots which would be normally open
Recycling Centres
All Swimming Pool Complexes
Marsupial Park Endeavour Drive, Tamworth
Botanic Gardens, Piper Street, Tamworth
East Year Round Care, Tamworth Public School, Napier Street, Tamworth
South Year Round Care, Hillvue Public School, Tamworth
Community Centre, Darling Street, Tamworth
South Library, Robert Street, Tamworth
Library/Regional Gallery, Peel Street, Tamworth
Tamworth Sports Dome

For Emergency please phone 1300 733 625

BARRABA FLOOD STUDIES – COMMUNITY INFORMATION SESSION

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Residents who have questions about the study, or who have been affected by flooding previously, are invited to a Community Information Session being held at 6.00pm, 15 December at the Barraba Council Chambers.

Should you have any enquiries about the information session or the flood study, please contact William Ash, Senior Engineer, on 6767 5738 or 0417 964 972.

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Should you have any enquiries about the information session or the flood study, please contact William Ash, Senior Engineer, on 6767 5738 or 0417 964 972.

EXHIBITION OF A DEVELOPMENT APPLICATION

Notice is hereby given that a Development Application has been submitted to Council by Hibbards Pty Limited - Tamworth for Construction of a Single Storey Detached Dual Occupancy and Torrens Title Subdivision into two lots on Lot 134 DP 1153123, 4 Red Cedar Cove, Oxley Vale.

The application and accompanying plans will be exhibited in Council's Customer Services Section, Ray Walsh House, Peel Street, Tamworth, between 8.30am and 5.00pm, Monday to Friday, for a period of 14 days from Monday, 12 December 2011.

If you wish to advise Council of your views on the proposal, you should prepare a written submission, to be made prior to 5.00pm on Tuesday, 3 January 2012. Please Note: The exhibition period has been extended due to its coincidence with the festive season and Council offices being closed from Friday 23 December 2011 to Monday 2 January 2012 inclusive. The issues you raise will be included in the evaluation of the development application, along with the other matters Council must consider. Any submissions **must** include disclosure of any reportable political contribution or gift made in the previous two years.

It should be noted that you may request that your name and address not be disclosed (by stating prominently "OBJECTION IN CONFIDENCE" on your submission) for reason that disclosure would result in detriment to you, however, Council may be obliged to release details of your complaint excluding your personal information under the Government Information (Public Access) Act 2009 even if these words are used in the submission. Further, submissions that do not contain the author's name and address may not be considered as Council will be unable to validate their authenticity.

EXHIBITION OF A DEVELOPMENT APPLICATION

Notice is hereby given that a Development Application has been submitted to Council by Ms S Moore for the establishment of a Function Centre in the existing Wine Cellar on Lot 200 DP 1040669, 80 Wyndham Close, Daruka.

The application and accompanying plans will be exhibited in Council's Customer Services Section, Ray Walsh House, Peel Street, Tamworth, between 8.30am and 5.00pm, Monday to Friday from Monday, 12 December 2011.

If you wish to advise Council of your views on the proposal, you should prepare a written submission, to be made prior to 5.00pm on Monday, 9 January 2012. Please note, the exhibition period has been extended as Council offices will be closed for the Christmas New Year period from 26 December 2011 to 2 January 2012.

The issues you raise will be included in the evaluation of the development application, along with the other matters Council must consider. Any submissions must include disclosure of any reportable political contribution or gift made in the previous two years.

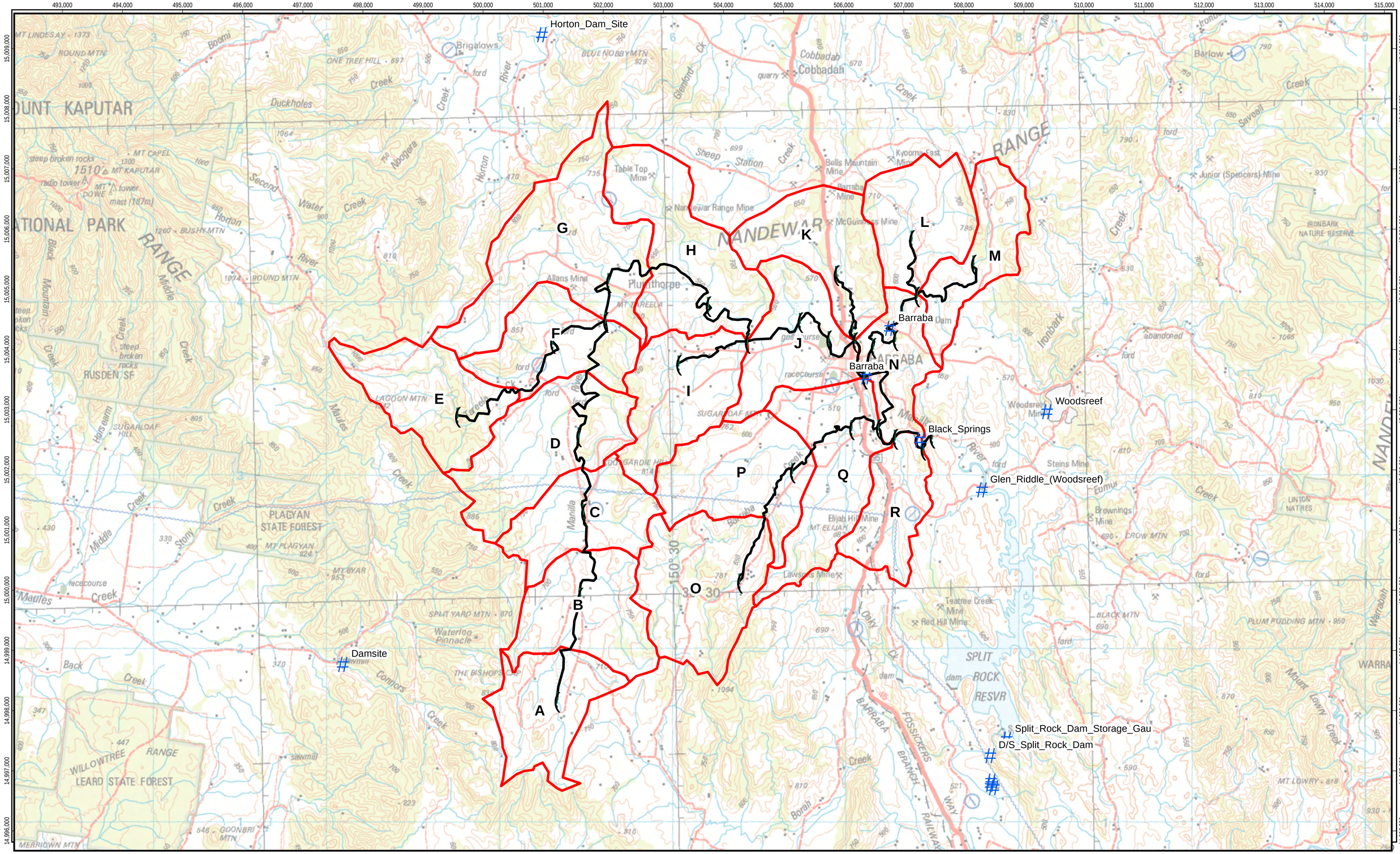
It should be noted that you may request that your name and address not be disclosed (by stating prominently "OBJECTION IN CONFIDENCE" on your submission) for reason that disclosure would result in detriment to you, however, Council may be obliged to release details of your complaint excluding your personal information under the Government

Information for Readers: TRC business information is available from council offices at *Tamworth, Barraba, Nundle and Ma* **www.tamworth.nsw.gov.au** All correspondence to TRC should be addressed

Northern Daily Leader 10 Dec 11

Appendix D

Hydrological Data (RORB)



CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Job Number	22-15816
Revision	A
Date	13.01.2012

TUFLOW Model

Figure E.1

N:\AU\Melbourne\Apps Resources\Local\ESRI\ArcGIS\Libraries_Templates\New_Templates_Rev3\Libraries_Templates\GHD-A3-LANDSCAPE TECH.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au

```
Barraba - 1
C RORB_GE 6.15
C WARNING - DO NOT EDIT THIS FILE OUTSIDE RORB TO ENSURE BOTH GRAPHICAL AND
CATCHMENT DATA ARE COMPATIBLE WITH EACH OTHER
C THIS FILE CANNOT BE OPENED IN EARLIER VERSIONS OF RORB GE - CURRENT
VERSION IS v6.15
C
C Barraba - 1
C
C #FILE COMMENTS
C   2
C File created using MiRORB version 1.1
C Original CATG file created on 12/12/2011 at 17:00:02
C
C #SUB-AREA AREA COMMENTS
C   1
C Sub-area areas in km2
C
C #IMPERVIOUS FRACTION COMMENTS
C   0
C
C #BACKGROUND IMAGE
C  T  F C:\Documents and Settings\sldouglas\Desktop\BARRABA
REVISED\BARRABA_REVISED.wmf
C
C #NODES
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C      1         40.355         16.815         1.000 1 0     2 A
36.595         0.050  0  0
C
C      2         42.178         30.445         1.000 1 0     3 B
42.742         0.050  0  0
C
C      3         42.445         41.402         1.000 1 0     4 C
36.304         0.050  0  0
C
C      4         42.055         51.471         1.000 1 0    19 D
52.578         0.050  0  0
C
C      5         40.017         63.658         1.000 1 0    19 F
38.467         0.050  0  0
C
C      6         32.546         54.013         1.000 1 0     5 E
42.781         0.050  0  0
C
C      7         44.400         71.582         1.000 1 0     8 G
71.856         0.050  0  0
C
C      8         52.216         68.470         1.000 1 0    20 H
59.313         0.050  0  0
C
C      9         49.906         60.816         1.000 1 0    20 I
42.356         0.050  0  0
C
C     10         59.426         66.385         1.000 1 0    28 J
38.787         0.050  0  0
C
C     11         68.188         77.116         1.000 1 0    25 L
37.096         0.050  0  0
C
```

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C     12          73.036          73.887          1.000 1 0    25 M
30.535          0.050  0  0
C
C     13          66.900          64.017          1.000 1 0    29 N
25.337          0.050  0  0
C
C     14          54.681          32.347          1.000 1 0    18 O
55.076          0.050  0  0
C
C     15          63.462          52.376          1.000 1 0    23 Q
46.934          0.050  0  0
C
C     16          66.884          51.138          1.000 1 0    24 R
26.476          0.050  0  0
C
C     17          62.259          72.505          1.000 1 0    27 K
41.613          0.050  0  0
C
C     18          58.830          46.744          1.000 1 0    15 P
46.383          0.050  0  0
C
C     19          44.163          66.396          1.000 0 0     7 G1
0.000          0.000  0  1
C
C Manilla River - Tareela Creek Confluence
C     20          55.287          63.661          1.000 0 0    10 J1
0.000          0.000  0  1
C
C West Barraba Confluence
C     21          63.727          63.760          1.000 0 0    22 N1
0.000          0.000  0  1
C
C Barraba Confluence
C     22          64.488          59.020          1.000 0 0    23 Q1
0.000          0.000  0  1
C
C Barraba Dam Confluence
C     23          65.569          52.445          1.000 0 0    16 Q2
0.000          0.000  0  1
C
C Barraba Creek Confluence
C     24          69.072          49.722          1.000 0 0    26 R1
0.000          0.000  0  1
C
C Barraba Gauge 419053
C     25          68.606          69.723          1.000 0 0    13 M1
0.000          0.000  0  1
C
C Confluence Upstream Barraba Dam
C     26          69.791          51.292          1.000 0 1     0 XS
0.000          0.000 70  1
C BLKSPRNG
C outlet
C     27          63.529          65.314          1.000 0 0    21 K2
0.000          0.000 70  0
C INFLOW2
C     28          61.676          63.998          1.000 0 0    21 J4
0.000          0.000 70  0
C INFLOW1
C     29          65.171          63.019          1.000 0 0    22 N5
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```
0.000          0.000 70  0
C INFLOW3
C
C #REACHES
C     28
C      1 A-B                      1     2              0 1 0          6.831
0.000    11  0
C          40.475         40.873         40.901         40.646
41.393         41.845         41.645         41.738         42.069
42.132         42.027
C          18.552         20.958         22.324         23.284
23.440         24.773         25.482         27.168         28.914
29.765         30.216
C      2 B-C                      2     3              0 1 0          6.369
0.000    22  0
C          42.150         42.230         42.390         42.816
43.255         43.428         43.401         43.162         43.268
43.335         43.282         42.989         42.989         42.377
42.723         42.643         42.669         42.696         42.510
42.496         42.536         42.445
C          31.049         32.025         32.491         32.513
32.402         32.712         33.067         33.577         34.287
34.819         35.174         35.573         36.061         36.150
36.904         37.725         38.811         39.477         39.832
40.497         40.630         41.402
C      3 C-D                      3     4              0 1 0          5.554
0.000    20  0
C          42.323         42.376         42.669         42.643
42.549         42.789         42.988         42.829         42.682
42.350         42.403         42.496         42.483         42.323
42.190         42.123         41.937         41.870         41.751
41.977
C          42.360         42.826         42.959         43.292
43.669         44.245         44.777         45.620         46.241
46.840         47.461         47.816         48.082         48.459
48.459         48.038         48.260         48.725         49.346
49.945
C      4 D-G1                     4    19              0 1 0         10.697
0.000    29  0
C          42.176         42.230         42.549         42.669
42.283         42.110         41.604         42.030         42.549
42.616         42.789         43.241         43.627         43.387
42.868         42.549         42.336         42.283         42.456
42.669         42.695         43.640         42.908         42.828
43.254         43.281         43.387         43.959         44.292
C          52.163         52.629         52.961         53.871
53.959         53.915         55.069         55.556         54.869
55.357         55.800         56.355         56.665         56.931
56.887         56.754         57.175         57.819         58.306
58.817         59.748         60.635         61.500         61.722
62.365         62.454         63.563         64.538         65.071
C      5 E-F                      6     5              0 1 0          9.950
0.986    43  0
C          33.247         33.513         33.899         34.205
34.604         34.990         35.070         34.950         34.897
35.136         35.522         35.709         35.842         35.948
36.108         36.294         36.427         36.667         36.760
36.893         36.999         37.106         37.226         37.332
37.612         37.891         38.184         38.383         38.530
38.796         38.942         38.849         38.836         38.929
```

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39.115          39.222          39.328          39.421          39.488
39.914          40.260          40.459          40.366
C           53.873          53.363          53.274          54.272
54.249          54.161          54.560          55.048          55.780
56.112          56.068          56.001          56.445          56.733
57.199          57.398          57.044          56.999          57.354
57.398          57.110          56.933          57.021          57.287
57.398          57.221          57.221          57.265          57.620
58.041          58.396          58.729          59.106          59.416
59.771          60.281          60.880          61.456          61.833
62.055          62.476          62.610          63.031
C       6 F-G1                      5    19              0 1 0           3.664
0.000     8  0
C           40.220          40.686          40.992          41.471
42.123          42.522          43.121          43.494
C           64.650          64.694          65.138          65.648
65.581          65.337          65.315          65.825
C       7 G1-G                     19     7              0 1 0           3.598
0.000    11  0
C           44.132          44.345          44.478          44.438
44.132          43.786          43.520          43.374          43.573
43.893          44.239
C           67.000          68.508          69.639          70.349
70.571          70.283          70.150          70.482          70.726
70.992          71.369
C       8 G-H                       7     8              0 1 0          10.066
0.000    35  0
C           44.638          44.704          45.104          45.570
45.756          45.969          46.168          46.248          46.408
46.727          46.874          46.887          46.900          47.033
47.353          47.566          47.819          48.178          48.484
48.790          49.269          49.722          50.108          50.440
50.760          51.106          51.651          52.064          52.210
51.904          51.558          51.332          51.372          51.572
51.864
C           72.722          73.077          73.143          72.921
72.877          72.877          73.298          73.720          74.163
74.185          73.609          72.921          72.411          72.189
72.367          72.832          73.276          73.165          73.675
73.764          73.586          73.298          72.654          72.344
71.922          71.146          70.946          70.503          70.037
69.815          69.172          68.573          68.130          68.107
68.595
C       9 H-J1                      8    20              0 1 0           5.695
0.000    19  0
C           52.450          52.237          51.931          52.184
52.636          52.956          53.142          53.528          53.834
53.794          54.100          54.553          55.005          55.351
55.591          55.498          55.365          55.444          55.285
C           68.041          67.730          67.131          66.621
66.289          66.643          67.153          67.885          67.597
66.798          66.554          66.466          66.554          66.532
66.332          66.066          65.534          65.068          64.669
C      10 I-J1                      9    20              0 1 0           4.681
0.000    17  0
C           50.228          50.547          51.040          51.386
51.732          52.078          52.290          52.477          52.743
53.009          52.863          53.275          53.515          53.701
53.994          54.340          54.420
C           61.077          61.432          61.609          61.543
```

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61.786          61.786          61.609          61.698          62.052
62.407          62.762          62.984          62.740          63.050
63.250          63.427          63.649
C     11 J1-J                     20    10              0 1 0          3.842
0.000     7  0
C           55.870          57.108          57.401          57.773
58.399          58.625          58.998
C           63.915          64.025          64.646          65.400
65.267          64.823          64.956
C     12 J4-N1                    28    21              0 1 0          2.751
0.000    13  0
C           61.728          61.728          61.728          61.728
61.728          61.728          61.853          61.834          61.862
62.487          62.705          62.908          63.002
C           63.756          63.756          63.756          63.756
63.756          63.756          63.209          62.741          62.048
61.642          61.736          62.235          62.772
C     13 K-K2                     17    27              0 1 0          4.116
0.000    20  0
C           62.281          62.491          62.800          62.793
63.243          63.416          63.399          63.555          63.525
63.682          63.389          63.572          63.625          63.835
63.786          63.805          63.779          63.616          63.529
63.529
C           71.972          71.451          71.279          70.774
70.297          70.034          69.272          68.900          68.501
68.118          67.595          67.214          66.494          66.161
65.744          65.426          65.364          65.468          65.314
65.314
C     14 N1-Q1                    21    22              0 1 0          2.481
0.000    10  0
C           64.002          64.115          64.128          64.015
63.962          63.935          63.909          63.895          64.075
64.248
C           63.314          62.948          62.394          61.917
61.263          61.174          60.509          59.799          59.322
59.067
C     15 Q1-Q2                    22    23              0 1 0          5.560
0.000    29  0
C           64.880          65.146          65.612          65.958
66.317          66.311          66.105          65.812          65.725
65.772          65.825          65.885          66.111          66.198
66.357          66.491          66.644          66.717          66.511
66.331          66.191          66.018          65.912          65.958
66.018          66.111          66.158          66.118          65.765
C           59.289          59.399          59.566          59.699
59.654          59.399          59.044          58.501          58.268
57.614          57.281          56.960          56.549          56.272
55.884          55.573          55.351          55.096          54.930
54.775          54.586          54.476          54.343          54.132
53.965          53.666          53.478          53.245          52.912
C     16 P-Q                      18    15              0 1 0          5.471
0.000    30  0
C           59.610          59.710          59.817          59.910
59.903          59.943          60.123          60.229          60.322
60.509          60.628          60.549          60.595          61.194
61.267          61.480          61.760          62.046          62.245
62.345          62.338          62.272          62.185          62.345
62.492          62.485          62.538          62.691          62.818
63.011
```

```
C          47.890          47.646          47.735          47.868
48.245          48.478          48.755          49.010          49.420
49.642          49.864          50.130          50.407          50.629
51.139          51.560          51.671          51.859          51.859
52.037          52.192          52.381          52.525          52.569
52.525          52.292          52.114          52.103          52.336
52.536
C     17 Q-Q2                    15    23              0 1 0          2.534
0.000    10  0
C          63.450          63.762          63.949          64.215
64.468          64.687          65.186          65.206          65.147
65.200
C          53.035          53.600          53.611          53.644
53.833          53.522          53.223          52.801          52.491
52.191
C     18 L-M1                    11    25              0 1 0          4.131
0.000    19  0
C          68.074          68.127          68.287          68.420
68.513          68.353          68.127          67.941          67.941
68.207          68.273          68.287          68.207          68.021
67.848          67.967          68.287          68.407          68.553
C          76.820          76.155          75.645          75.024
74.536          74.003          73.715          73.427          73.205
73.116          72.850          72.229          71.941          71.475
71.342          71.076          70.943          70.832          70.455
C     19 M-M1                    12    25              0 1 0          6.113
1.921    35  0
C          72.998          73.277          73.251          73.251
73.264          72.945          72.639          72.479          72.306
72.133          71.947          71.774          71.441          71.161
70.975          70.789          70.882          70.895          70.869
70.789          70.589          70.576          70.576          70.496
70.363          70.123          69.884          69.764          69.644
69.538          69.391          69.245          69.165          69.085
68.859
C          73.426          73.115          72.516          71.851
71.452          71.163          71.053          70.809          70.764
70.986          71.031          71.252          71.164          70.898
70.743          70.565          70.188          69.789          69.345
69.035          68.880          69.146          69.390          69.545
69.589          69.567          69.545          69.678          69.723
69.590          69.501          69.700          69.944          70.233
70.144
C     20 M1-N                    25    13              0 1 0          3.864
0.000    16  0
C          68.526          68.247          67.861          67.595
67.408          67.422          67.448          67.289          67.049
66.677          66.397          66.251          66.437          66.637
66.783          66.863
C          69.324          69.213          69.058          68.947
68.171          67.572          66.751          66.374          66.019
65.798          65.576          65.332          65.288          65.154
64.955          64.578
C     21 N5-Q1                   29    22              0 1 0          2.405
0.000    35  0
C          65.171          65.171          65.171          65.171
65.171          65.171          65.171          65.171          65.171
65.171          65.171          65.171          65.171          65.171
65.171          65.066          64.960          64.850          64.796
64.759          64.716          64.593          64.502          64.397
```

64.282 64.129 64.082 64.065 64.085
64.153 64.339 64.404 64.437 64.410
64.428
C 63.019 63.019 63.019 63.019
63.019 63.019 63.019 63.019 63.019
63.019 63.019 63.019 63.019 63.019
63.019 62.626 62.316 61.974 61.590
61.190 60.862 60.581 60.234 60.088
60.243 60.276 60.228 60.131 59.962
59.726 59.627 59.523 59.418 59.328
59.130
C 22 Q2-R 23 16 0 1 0 1.855
0.000 9 0
C 65.732 65.785 65.805 66.005
66.291 66.444 66.571 66.650 66.697
C 52.003 51.548 50.983 50.306
50.239 50.273 50.483 50.727 50.883
C 23 R-R1 16 24 0 1 0 2.613
0.000 13 0
C 67.063 67.276 67.695 67.961
68.227 68.653 68.740 68.720 68.553
68.553 68.607 68.687 68.826
C 51.559 51.781 51.869 51.925
51.747 51.658 51.481 51.281 50.971
50.694 50.150 49.884 49.795
C 24 O-P 14 18 0 1 0 8.056
1.274 40 0
C 54.913 54.980 55.046 55.166
55.339 55.538 55.592 55.671 55.844
55.831 56.017 56.204 56.284 56.363
56.510 56.563 56.550 56.669 56.563
56.816 56.816 56.709 56.669 56.896
57.188 57.335 57.375 57.481 57.481
57.455 57.620 57.594 57.700 57.934
57.974 57.947 58.173 58.359 58.506
58.668
C 32.776 33.464 34.395 35.127
35.748 35.992 36.258 36.679 37.056
37.367 37.766 38.010 38.476 38.853
39.252 39.585 39.829 40.450 41.226
41.403 41.780 41.913 42.113 42.423
43.089 43.488 43.710 43.643 43.909
44.286 44.665 45.103 45.380 45.617
45.905 46.061 46.304 46.837 47.014
47.082
C 25 R1-XS 24 26 0 1 0 0.951
0.000 3 0
C 69.246 69.260 69.556
C 50.150 50.526 51.231
C 26 K2-N1 27 21 0 1 0 0.925
0.000 9 0
C 63.440 63.399 63.341 63.410
63.507 63.574 63.562 63.518 63.590
C 65.192 65.109 64.867 64.419
64.461 64.372 64.320 64.234 64.120
C 27 J-J4 10 28 0 1 0 2.728
0.000 23 0
C 59.630 59.755 59.817 59.889
60.005 60.095 60.217 60.355 60.480
60.564 60.570 60.586 60.761 60.936

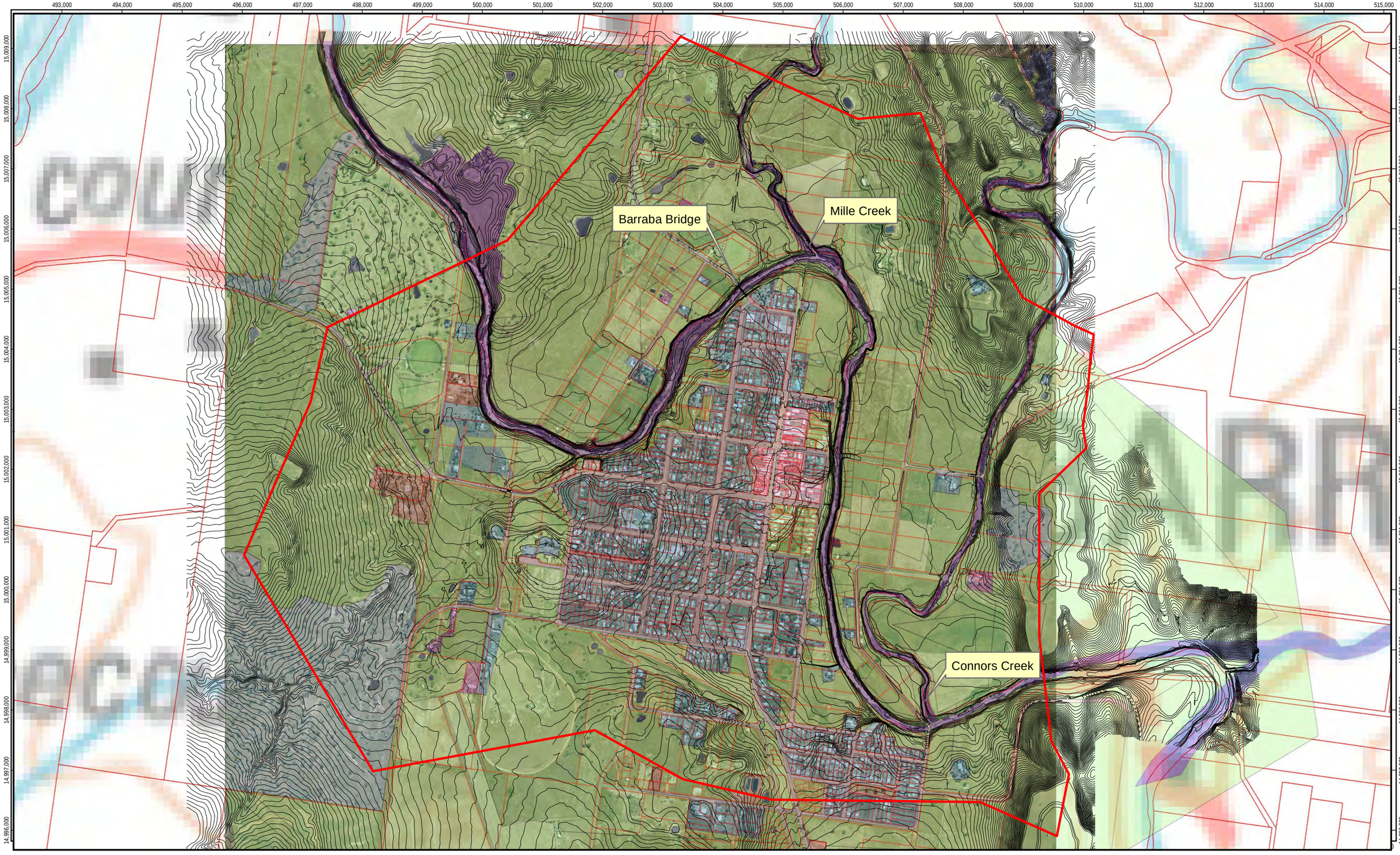
```
60.970         60.918         60.915         60.947         61.015
61.077         61.169         61.293         61.436
C          66.755         66.963         67.140         67.317
67.353         67.353         67.197         66.957         66.770
66.536         66.374         66.281         66.187         66.020
65.963         65.731         65.544         65.351         65.096
64.930         64.706         64.518         64.362
C     28 N-N5                    13    29              0 1 0          2.835
0.000    17  0
C          66.734         66.531         66.450         66.253
66.019         65.906         65.925         65.890         65.734
65.512         65.147         65.081         65.056         64.894
64.878         65.091         65.256
C          63.719         63.573         63.448         63.474
63.557         63.760         64.364         64.494         64.708
64.880         64.817         64.666         64.417         64.276
64.109         63.932         63.636
C
C #STORAGES
C      0
C
C #INFLOW/OUTFLOW
C      0
C
C END RORB_GE
C
C File created using MiRORB version 1.1
C Original CATG file created on 12/12/2011 at 17:00:02
1
1, 6.831,  -99                                        ,Reach 1 node 1
Sub-area A, Reach A-B - Generate rainfall excess h'graph and route
downstream
2, 6.369,  -99                                        ,Reach 2 node 2
Sub-area B, Reach B-C - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
2, 5.554,  -99                                        ,Reach 3 node 3
Sub-area C, Reach C-D - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
2, 10.697,  -99                                       ,Reach 4 node 4
Sub-area D, Reach D-G1 - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
3                                                     ,
Store running hydrograph
1, 9.950,  -99                                        ,Reach 5 node 6
Sub-area E, Reach E-F - Generate rainfall excess h'graph and route
downstream
2, 3.664,  -99                                        ,Reach 6 node 5
Sub-area F, Reach F-G1 - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
4                                                     ,
Add running h'graph to last stored h'graph
5, 3.598,  -99                                        ,Reach 7
Reach G1-G - Route running h'graph downstream
2, 10.066,  -99                                       ,Reach 8 node 7
Sub-area G, Reach G-H - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
2, 5.695,  -99                                        ,Reach 9 node 8
Sub-area H, Reach H-J1 - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
3                                                     ,
```

```
Store running hydrograph
1, 4.681,  -99                                      ,Reach 10 node 9
Sub-area I, Reach I-J1 - Generate rainfall excess h'graph and route
downstream
4                                                   ,
Add running h'graph to last stored h'graph
5, 3.842,  -99                                      ,Reach 11
Reach J1-J - Route running h'graph downstream
2, 2.728,  -99                                      ,Reach 27 node 10
Sub-area J, Reach J-J4 - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
7                                                   ,
PRINT
INFLOW1
5, 2.751,  -99                                      ,Reach 12
Reach J4-N1 - Route running h'graph downstream
3                                                   ,
Store running hydrograph
1, 4.116,  -99                                      ,Reach 13 node 17
Sub-area K, Reach K-K2 - Generate rainfall excess h'graph and route
downstream
7                                                   ,
PRINT
INFLOW2
5, .925,  -99                                       ,Reach 26
Reach K2-N1 - Route running h'graph downstream
4                                                   ,
Add running h'graph to last stored h'graph
5, 2.481,  -99                                      ,Reach 14
Reach N1-Q1 - Route running h'graph downstream
3                                                   ,
Store running hydrograph
1, 4.131,  -99                                      ,Reach 18 node 11
Sub-area L, Reach L-M1 - Generate rainfall excess h'graph and route
downstream
3                                                   ,
Store running hydrograph
1, 6.113,  -99                                      ,Reach 19 node 12
Sub-area M, Reach M-M1 - Generate rainfall excess h'graph and route
downstream
4                                                   ,
Add running h'graph to last stored h'graph
5, 3.864,  -99                                      ,Reach 20
Reach M1-N - Route running h'graph downstream
2, 2.835,  -99                                      ,Reach 28 node 13
Sub-area N, Reach N-N5 - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
7                                                   ,
PRINT
INFLOW3
5, 2.405,  -99                                      ,Reach 21
Reach N5-Q1 - Route running h'graph downstream
4                                                   ,
Add running h'graph to last stored h'graph
5, 5.560,  -99                                      ,Reach 15
Reach Q1-Q2 - Route running h'graph downstream
3                                                   ,
Store running hydrograph
1, 8.056,  -99                                      ,Reach 24 node 14
Sub-area O, Reach O-P - Generate rainfall excess h'graph and route
```

```
downstream
2, 5.471,  -99                                        ,Reach 16 node 18
Sub-area P, Reach P-Q - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
2, 2.534,  -99                                        ,Reach 17 node 15
Sub-area Q, Reach Q-Q2 - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
4                                                     ,
Add running h'graph to last stored h'graph
5, 1.855,  -99                                        ,Reach 22
Reach Q2-R - Route running h'graph downstream
2, 2.613,  -99                                        ,Reach 23 node 16
Sub-area R, Reach R-R1 - Generate rainfall excess h'graph, add to running
h'graph, and route downstream
5, .951,  -99                                         ,Reach 25
Reach R1-XS - Route running h'graph downstream
C outlet
7                                                     ,
PRINT
BLKSPRNG
0
C Sub-area areas in km2
  36.595,   42.742,   36.304,   52.578,   42.781,
  38.467,   71.856,   59.313,   42.356,   38.787,
  41.613,   37.096,   30.535,   25.337,   55.076,
  46.383,   46.934,   26.476,
 -99
C Impervious Fraction Data
 1 ,
   0.050,    0.050,    0.050,    0.050,    0.050,
   0.050,    0.050,    0.050,    0.050,    0.050,
   0.050,    0.050,    0.050,    0.050,    0.050,
   0.050,    0.050,    0.050,
 -99
```

Appendix E

Hydraulic Data (TUFLOW)



1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

O

2D Code Boundary
TOPO Contours (1m)

Roughness Layer
MATERIAL

- Roads
- Default, mostly grass
- Some Trees
- Thicker Trees, Some Bush
- Mostly Dense Bush
- Water Bodies
- Creeks, Waterways
- Rural/ Farm Sheds
- Residential
- Industrial
- Commercial

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Job Number	22-15816
Revision	A
Date	13.01.2012

TUFLOW Model

Figure E.1

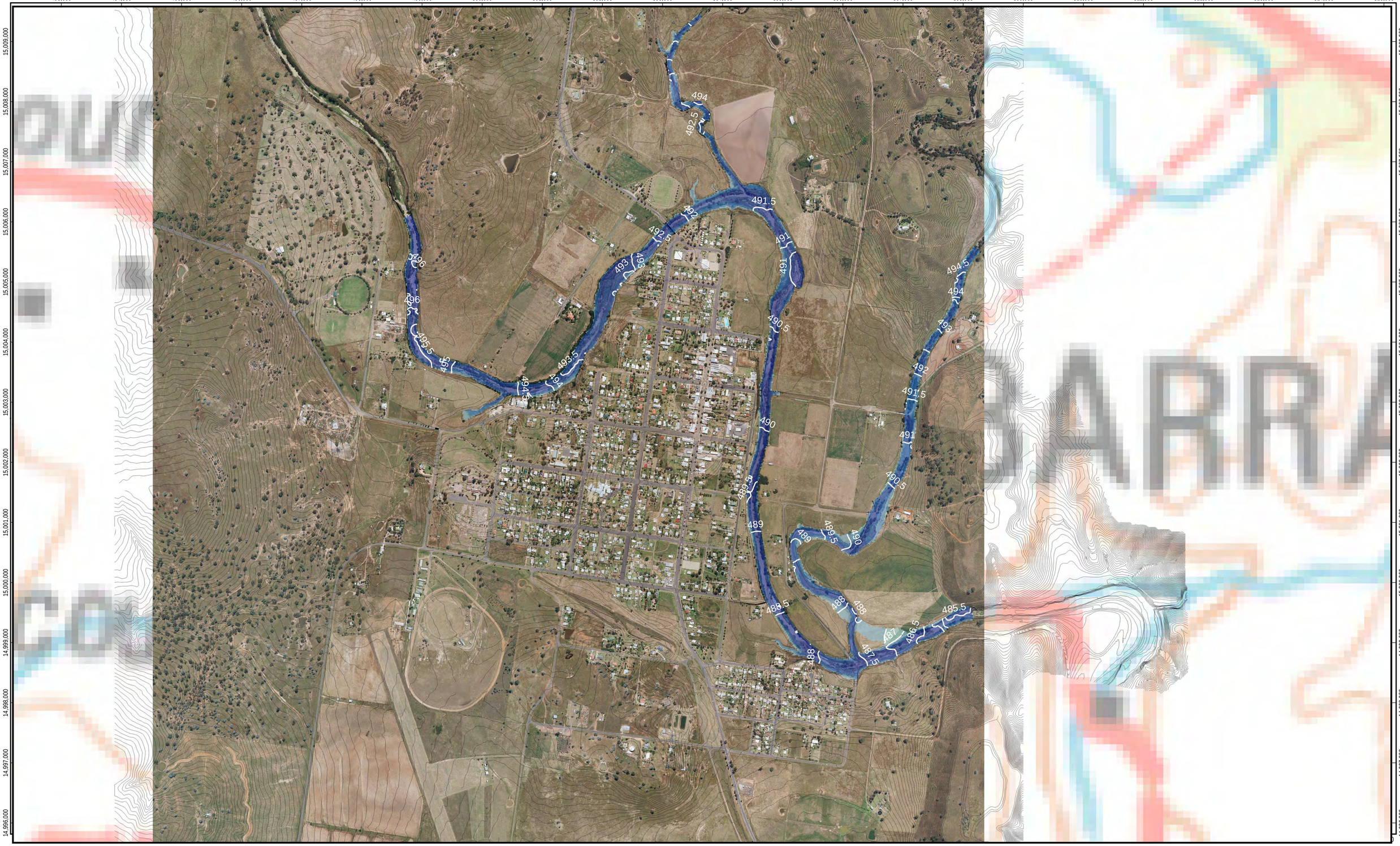
N:\AU\Melbourne\Apps Resources\Local\ESRI\ArcGIS\Libraries_Templates\New_Templates_Rev3\Libraries_Templates\GHD-A3-LANDSCAPE TECH.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au

Appendix F

Design Flood Results and Mapping



CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

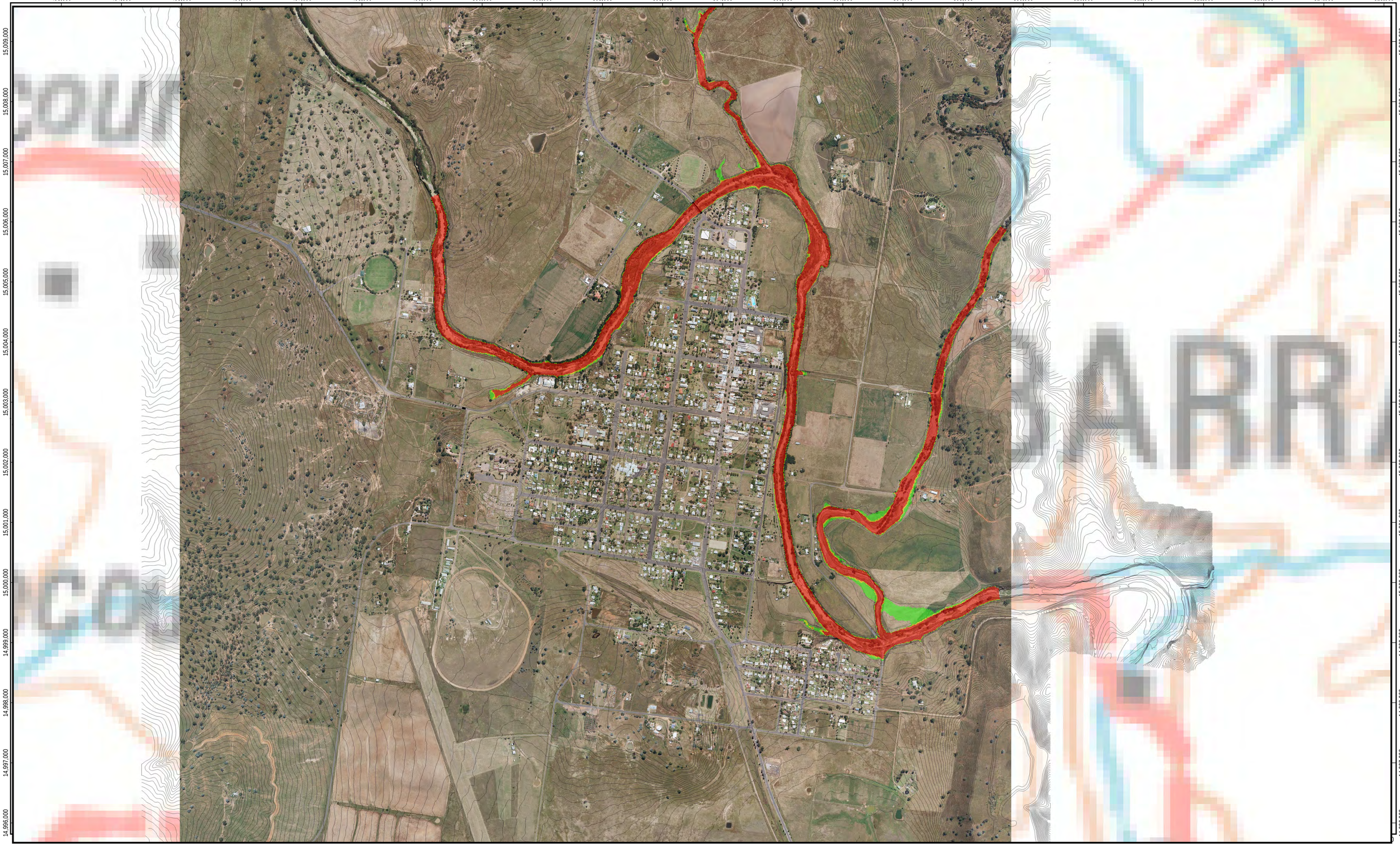
Flood Map
20% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.1.1

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au



1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Flood Hazard
- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- TOPO Contours (1m)

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

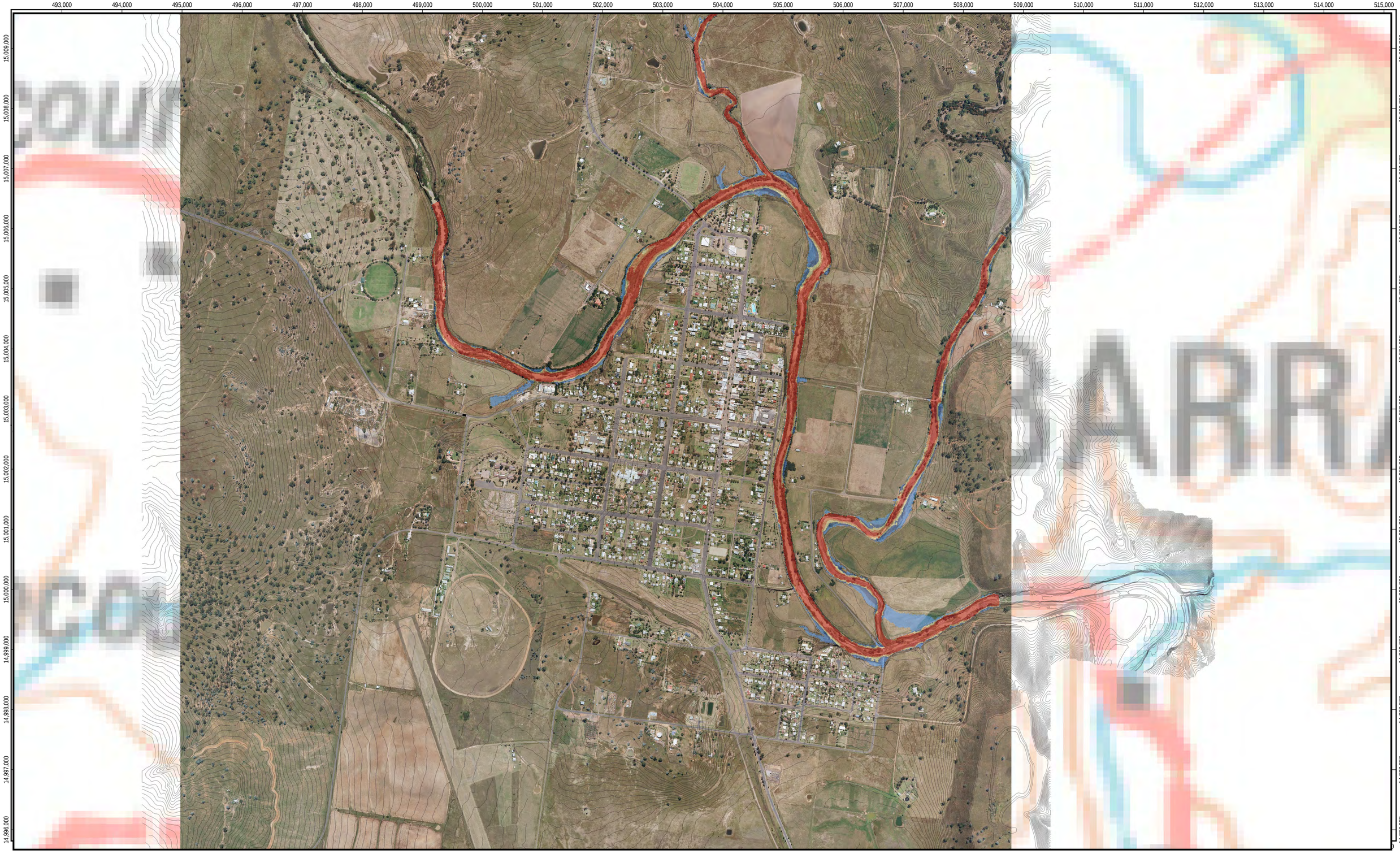
Flood Hazard Map
20% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.1.2

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au



1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Peak Flood Velocity (m/s)
- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- Greater than 2
- TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

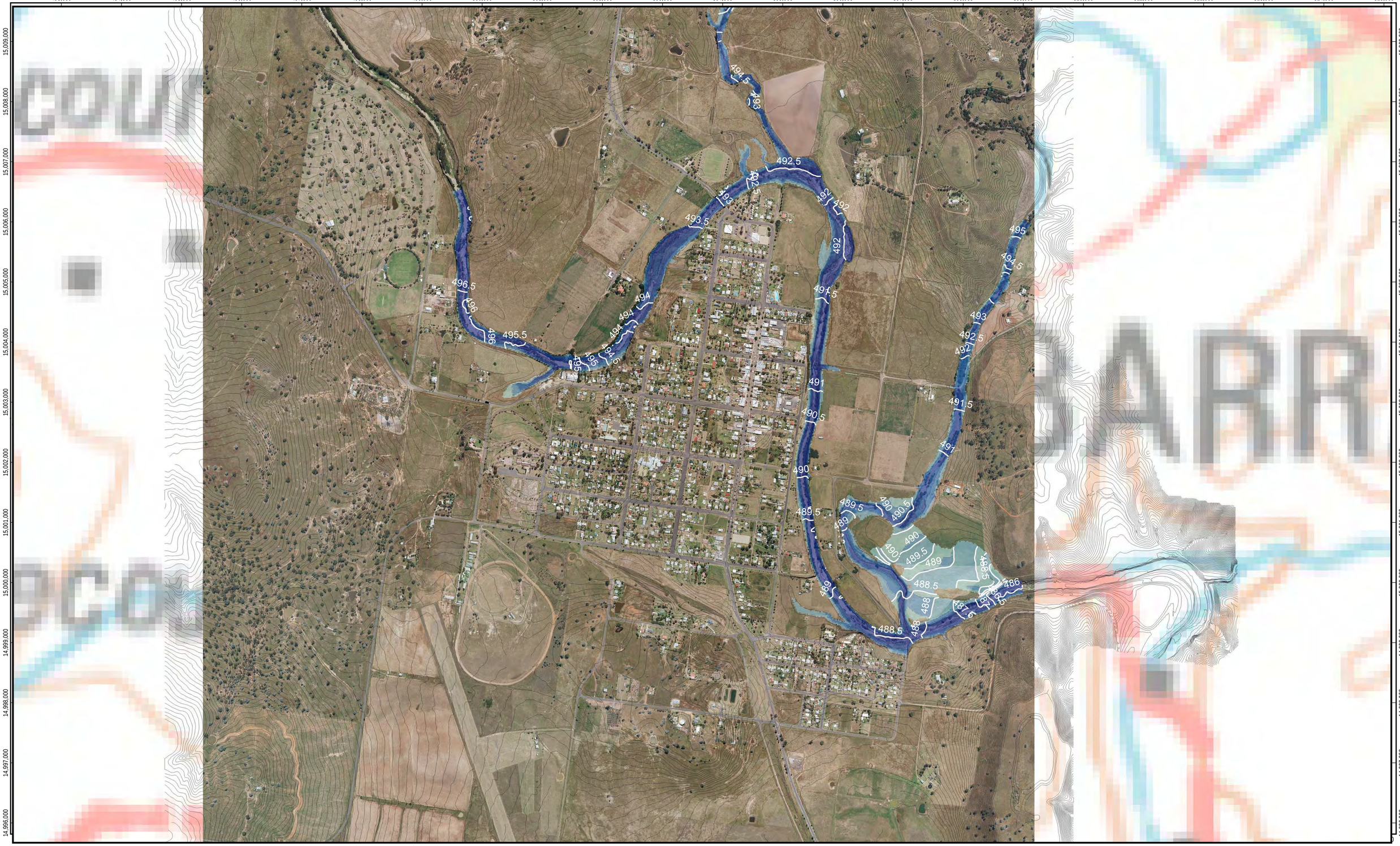
Tamworth Regional Council
Barraba Flood Study
Flood Velocity Map
20% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F1.3

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au



1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Flood Extent and Depth (m)
- 0.16 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20

Flood Level Contours (mAHD)
TOPO Contours (1m)

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Flood Map
10% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.2.1

N:\AU\Melbourne\Apps Resources\Local\ESRI\ArcGIS\Libraries_Templates\New_Templates_Rev3\Libraries_Templates\GHD-A3-LANDSCAPE TECH.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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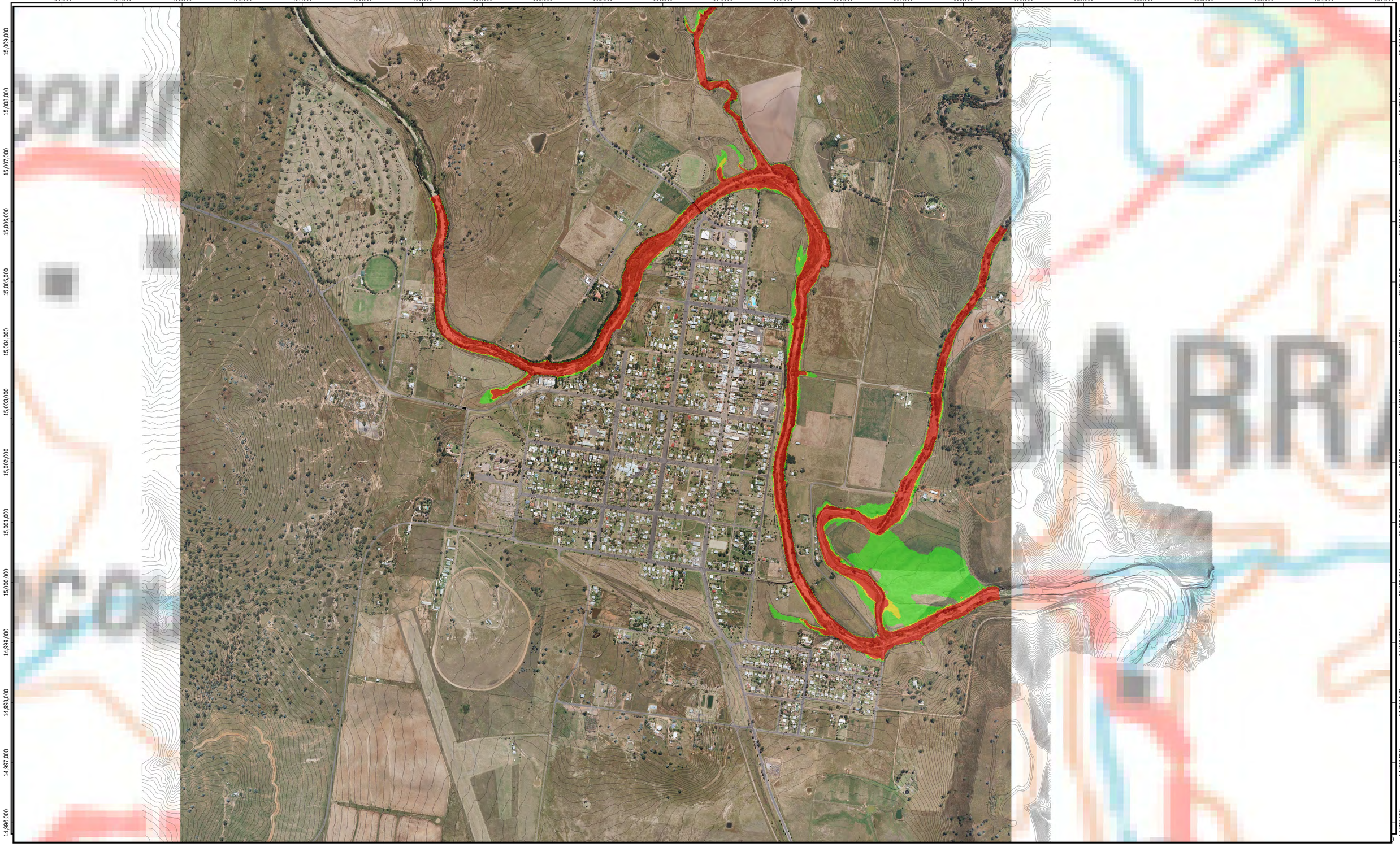


1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Flood Hazard
- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

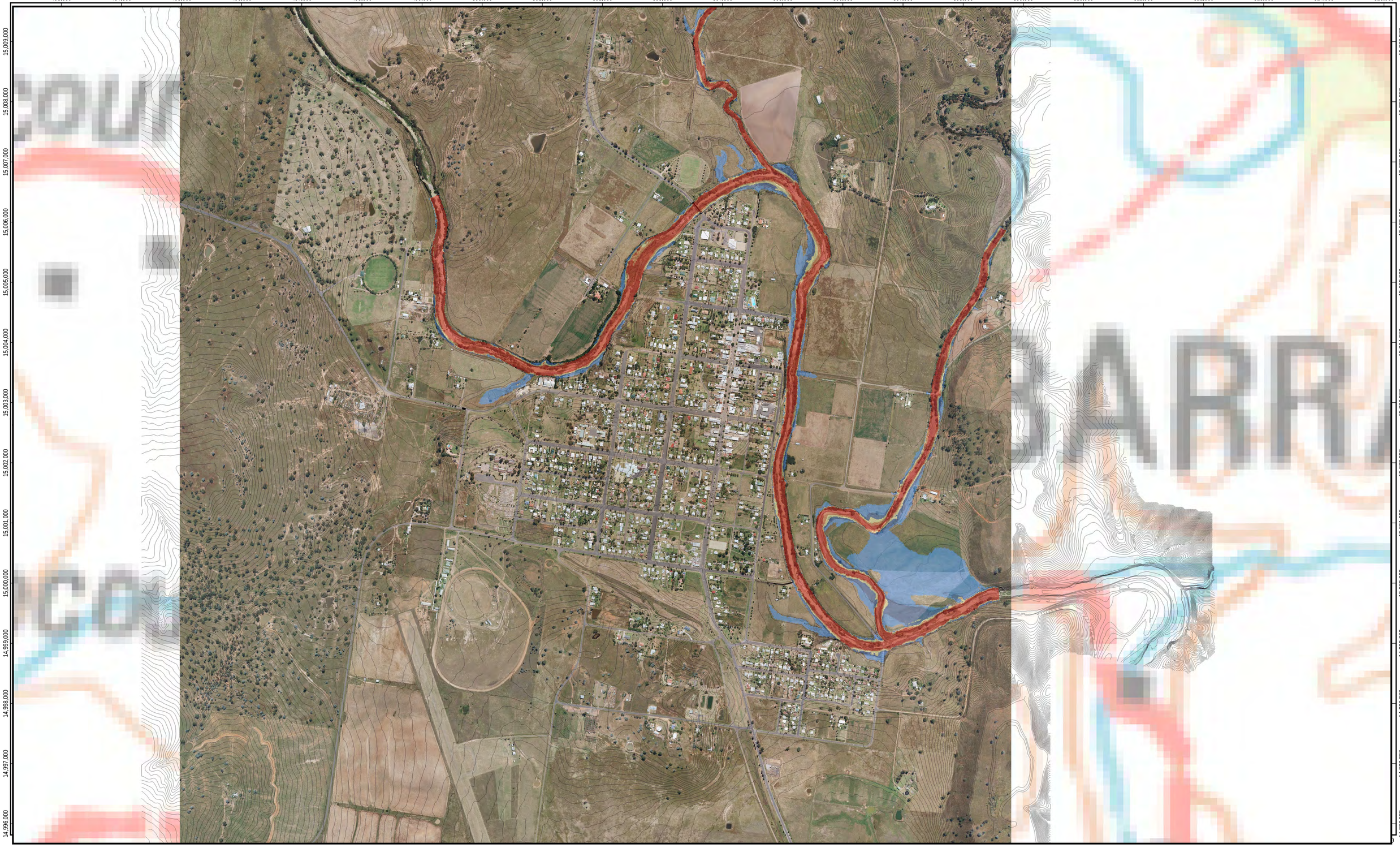
Tamworth Regional Council
Barraba Flood Study
Flood Hazard Map
10% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.2.2

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au



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0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Peak Flood Velocity (m/s)
- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- Greater than 2

TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study
Flood Velocity Map
10% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.2.3

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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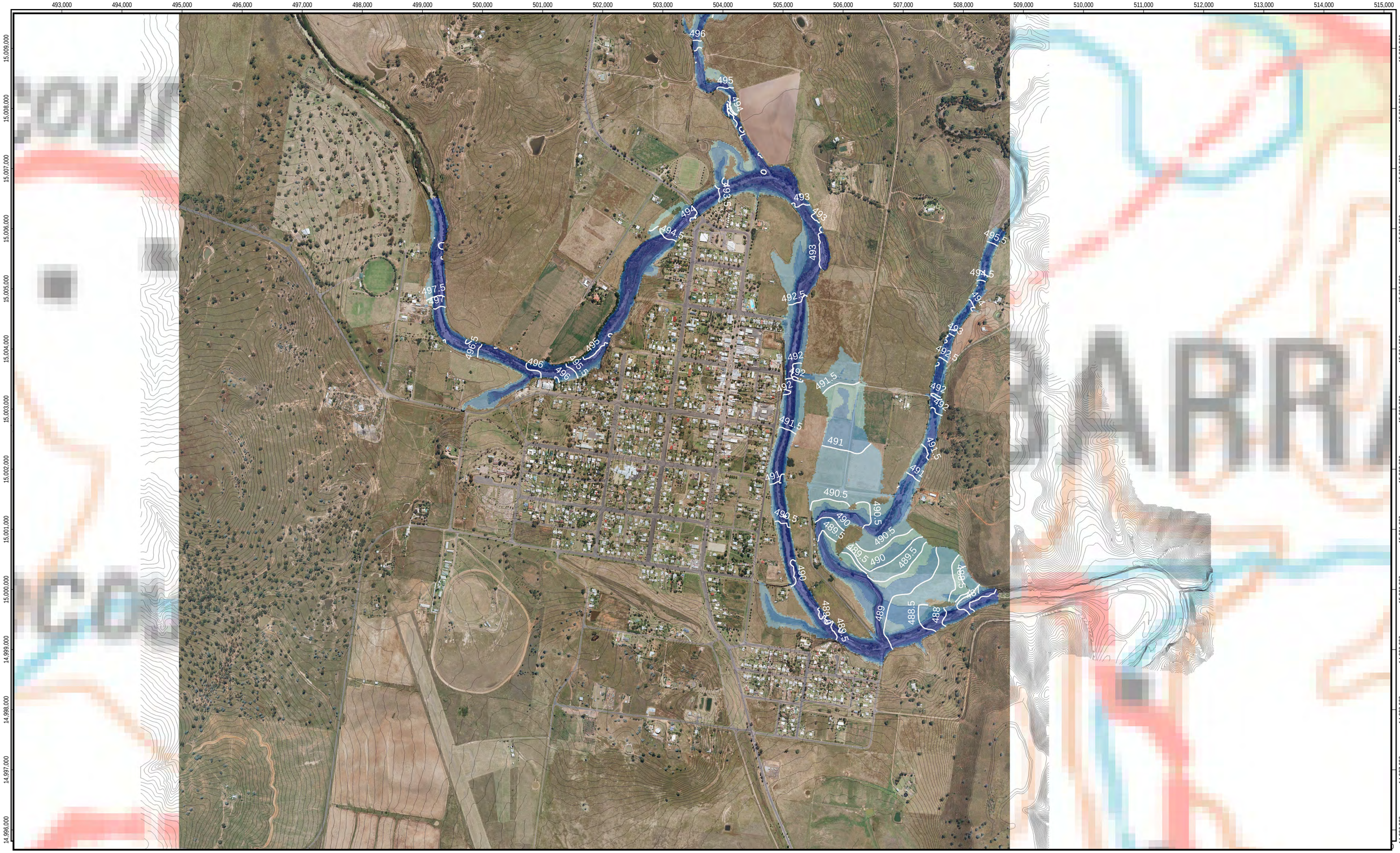

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Flood Extent and Depth (m)

- 0.16 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20

Flood Level Contours (mAHD)

TOPO Contours (1m)

GHD

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Flood Map
5% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.3.1

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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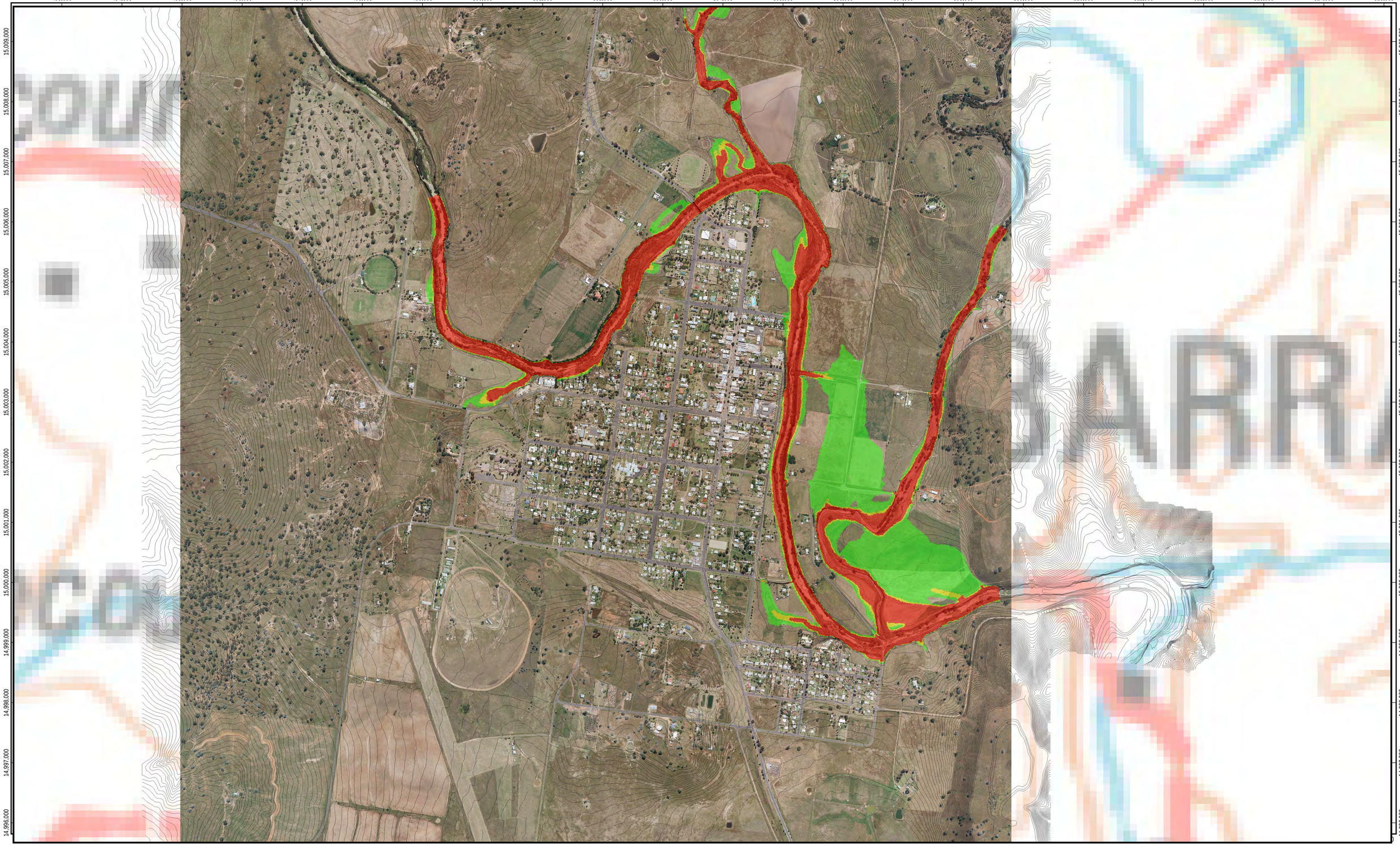

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Flood Hazard
- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study
Flood Hazard Map
5% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.3.2

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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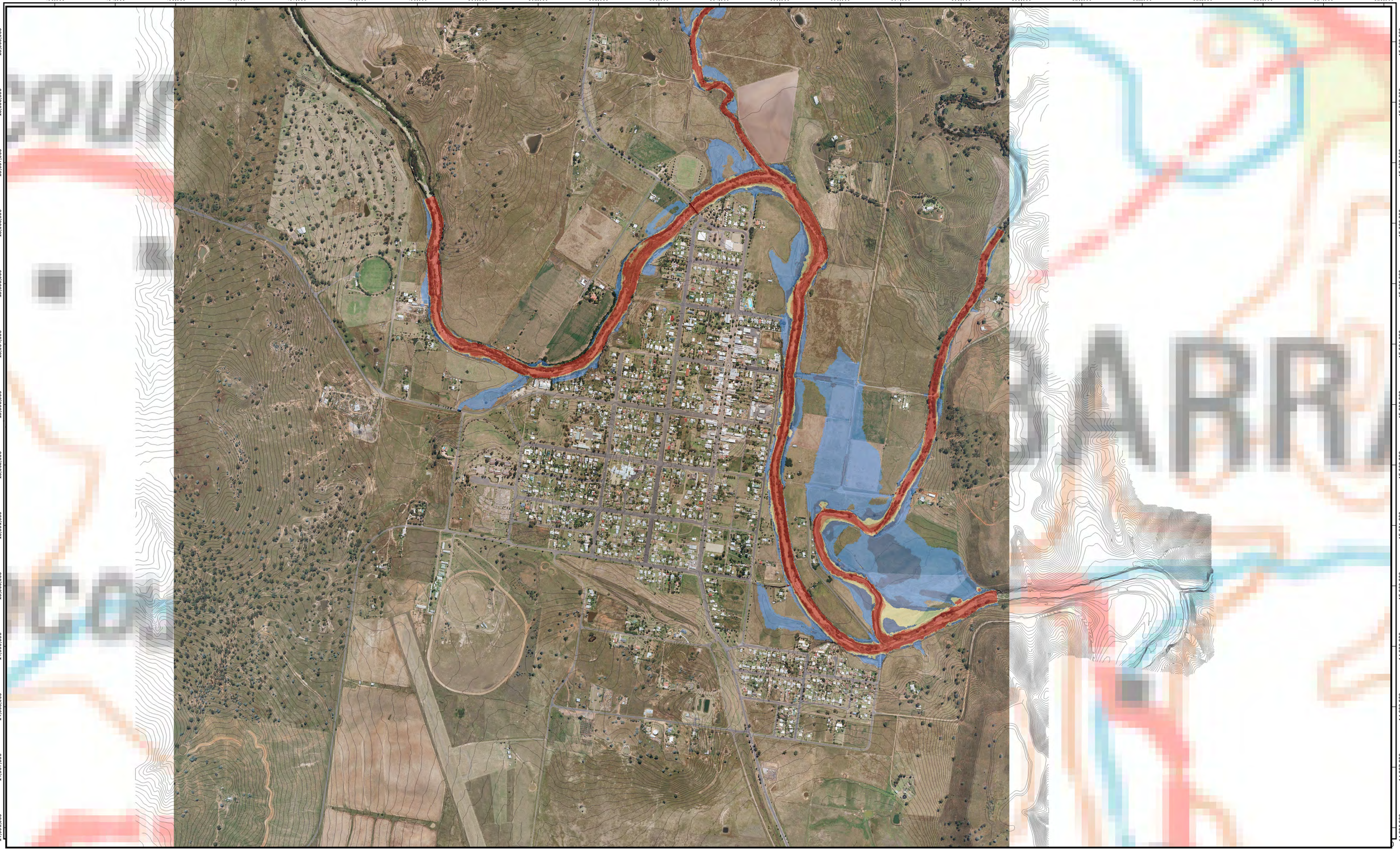
493,000 494,000 495,000 496,000 497,000 498,000 499,000 500,000 501,000 502,000 503,000 504,000 505,000 506,000 507,000 508,000 509,000 510,000 511,000 512,000 513,000 514,000 515,000

15,009,000 15,008,000 15,007,000 15,006,000 15,005,000 15,004,000 15,003,000 15,002,000 15,001,000 15,000,000 14,999,000 14,998,000 14,997,000 14,996,000



1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Peak Flood Velocity (m/s)
- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- Greater than 2
- TOPO Contours (1m)

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Flood Velocity Map
5% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.3.3

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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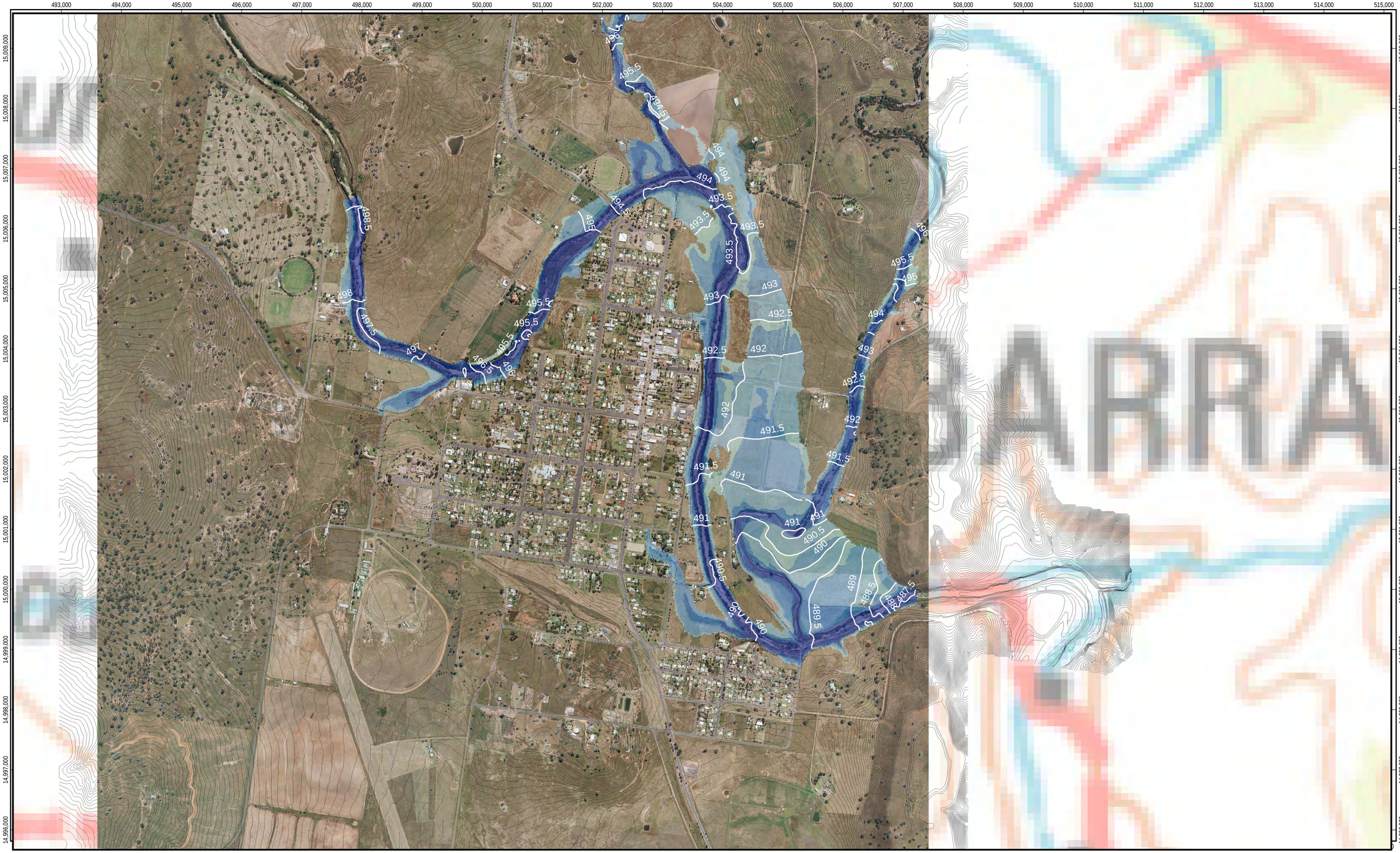

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Flood Extent and Depth (m)
- 0.16 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20

Flood Level Contours (mAHD)
TOPO Contours (1m)

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study
Flood Map
2% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.4.1

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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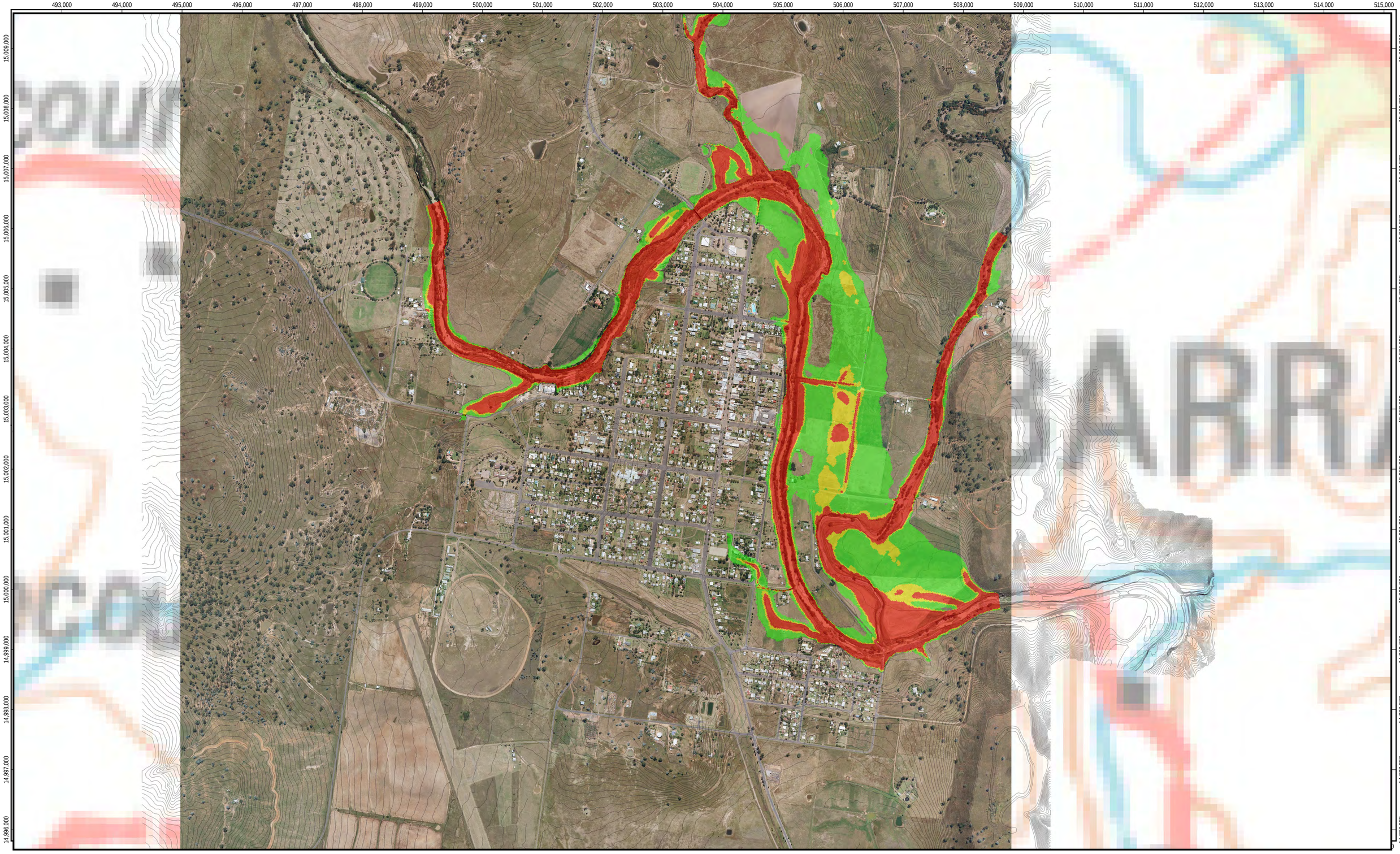

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Flood Hazard
- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Flood Hazard Map
2% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.4.2

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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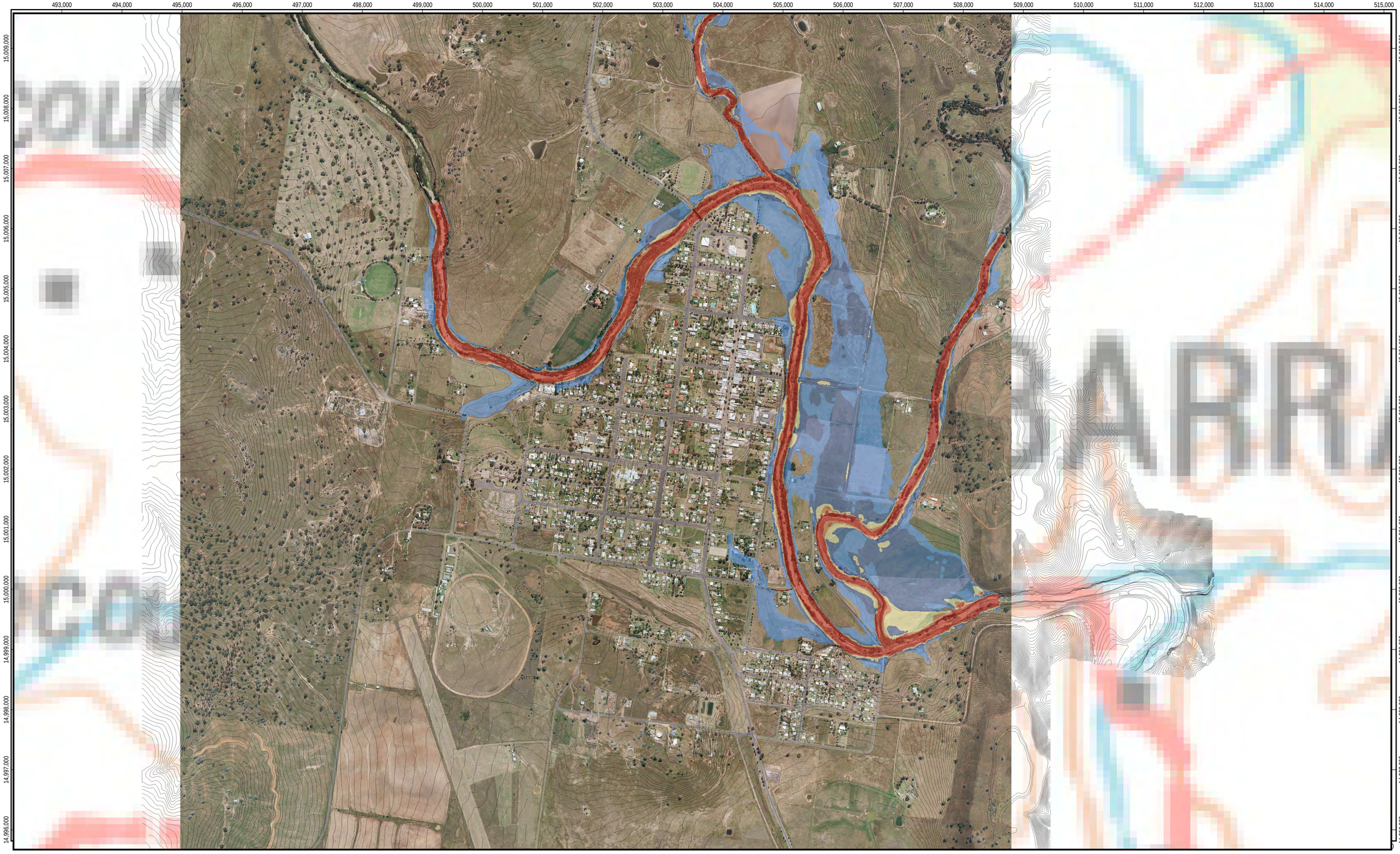

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Peak Flood Velocity (m/s)
- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- Greater than 2

TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study
Flood Velocity Map
2% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.4.3

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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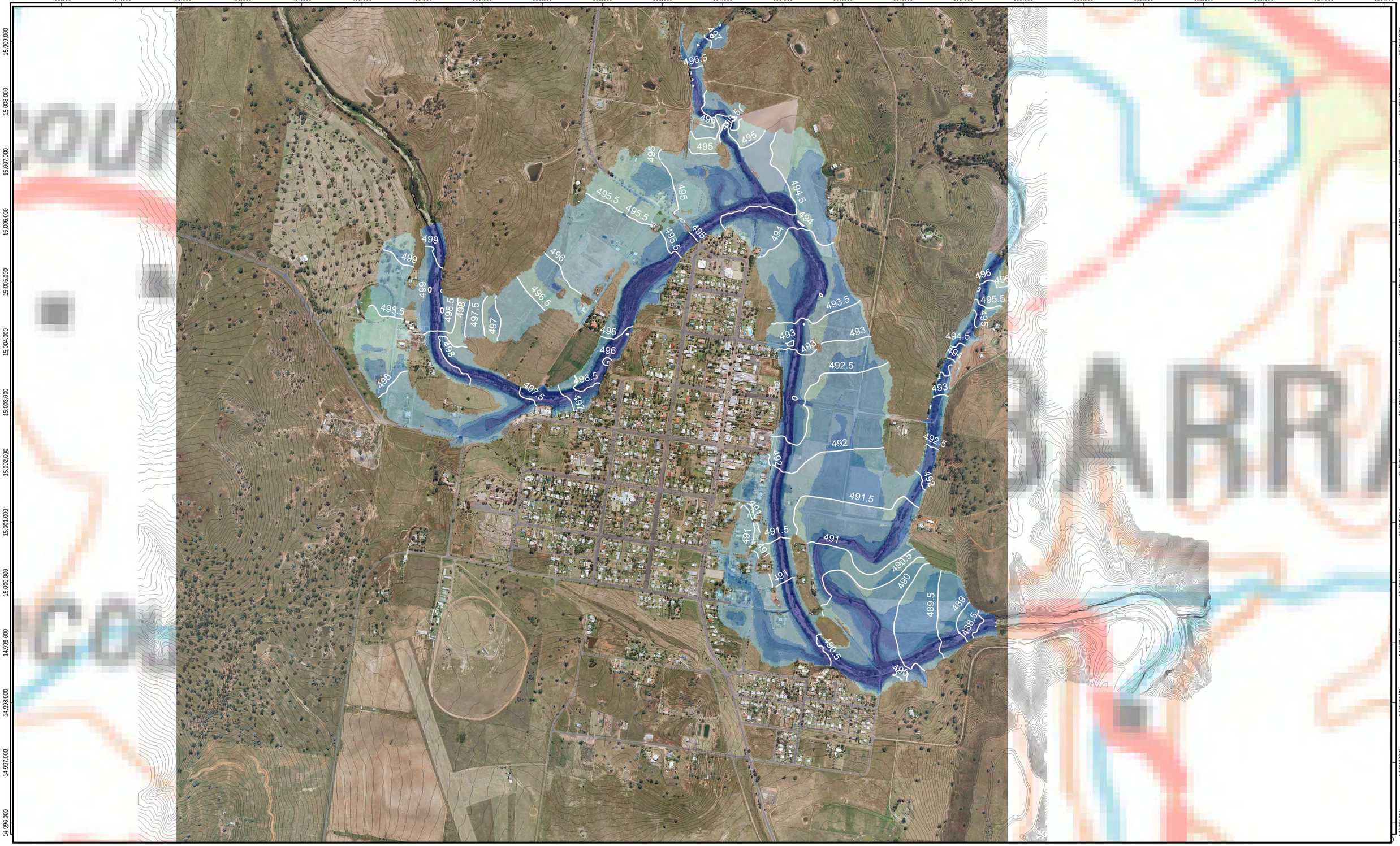

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Flood Extent and Depth (m)
- 0.16 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20

Flood Level Contours (mAHD)
TOPO Contours (1m)

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study
Flood Map
1% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.5.1

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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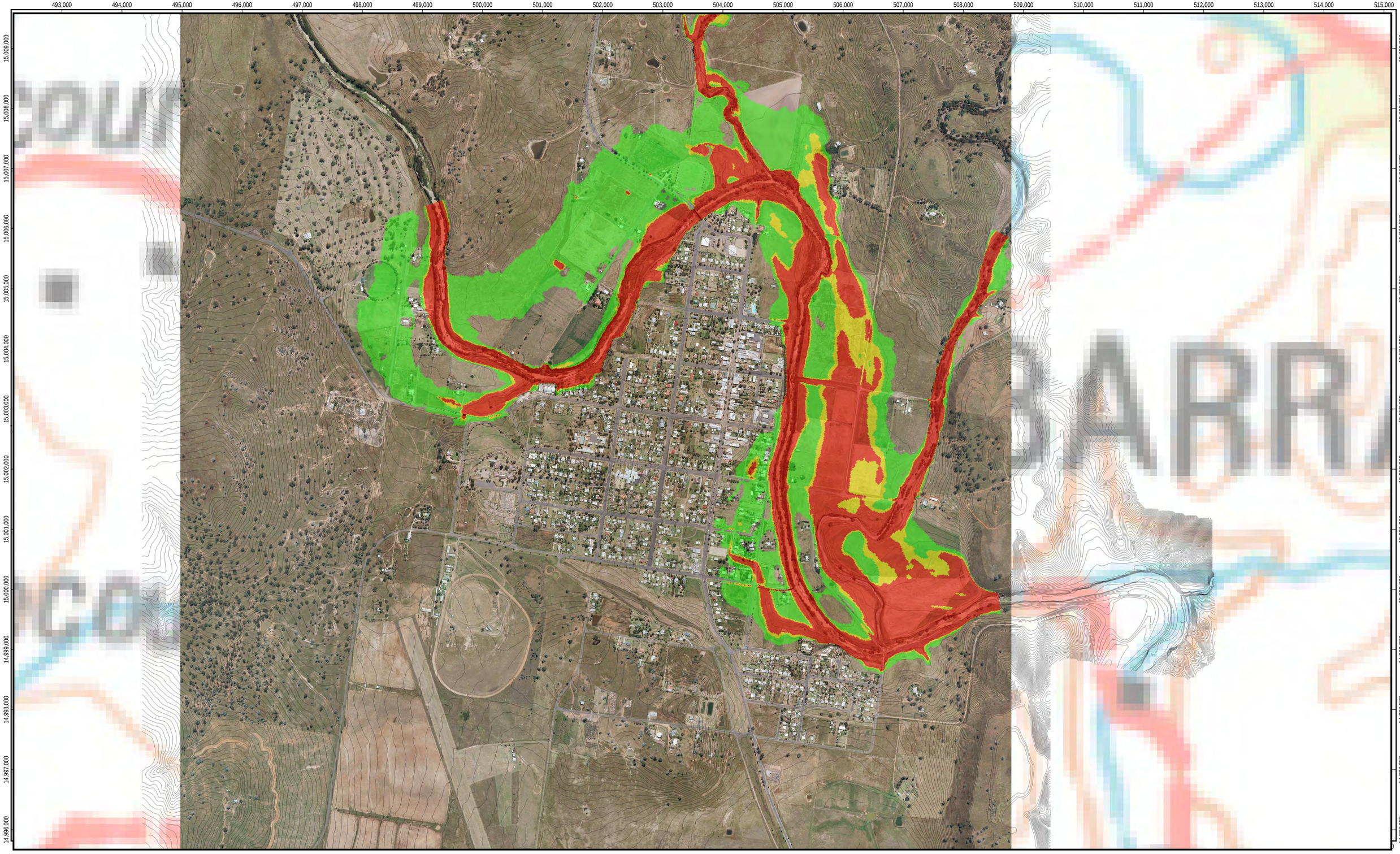

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Flood Hazard
- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- TOPO Contours (1m)

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Flood Hazard Map
1% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.5.2

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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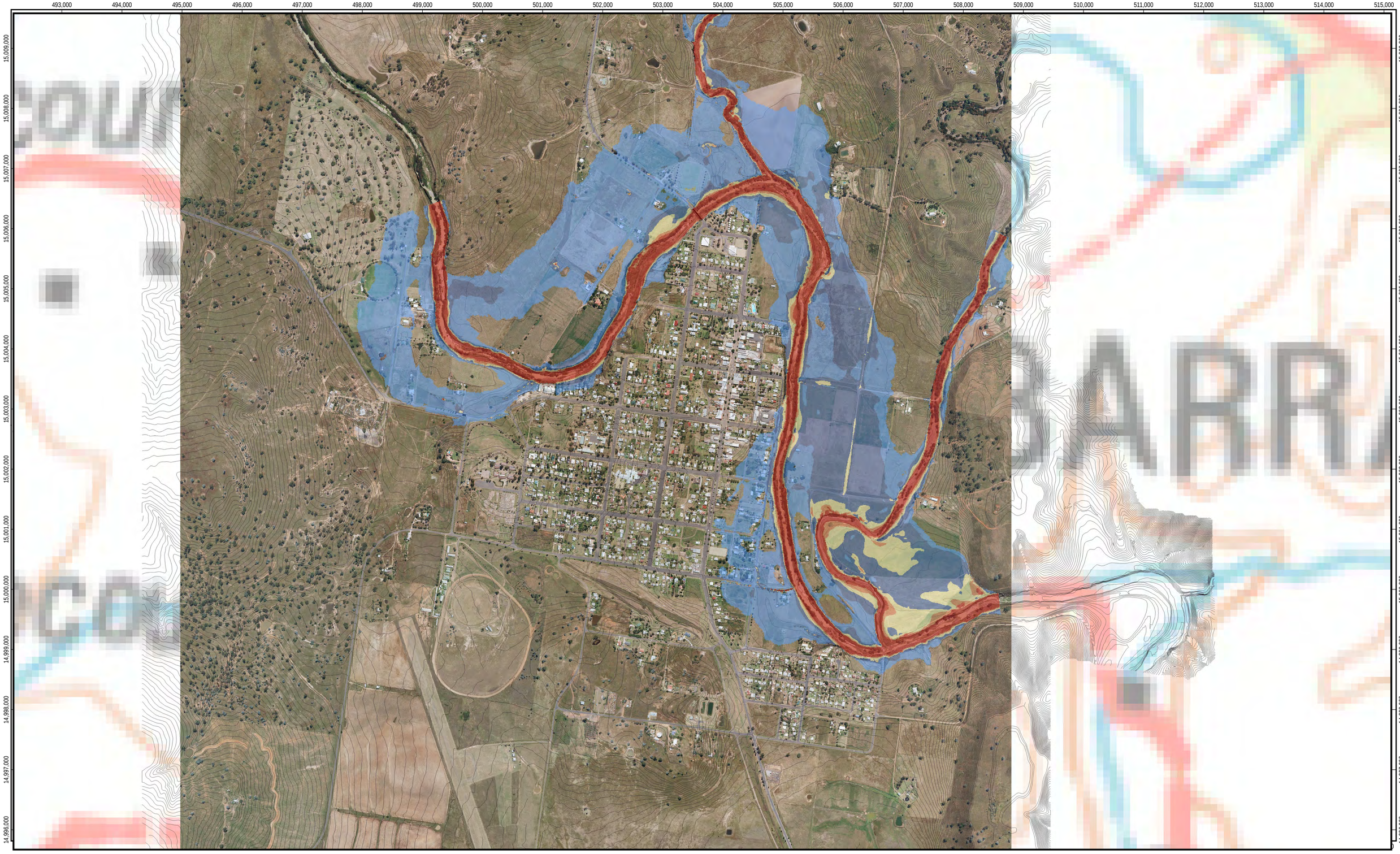

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Peak Flood Velocity (m/s)
- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- Greater than 2
- TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study
Flood Velocity Map
1% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.5.3

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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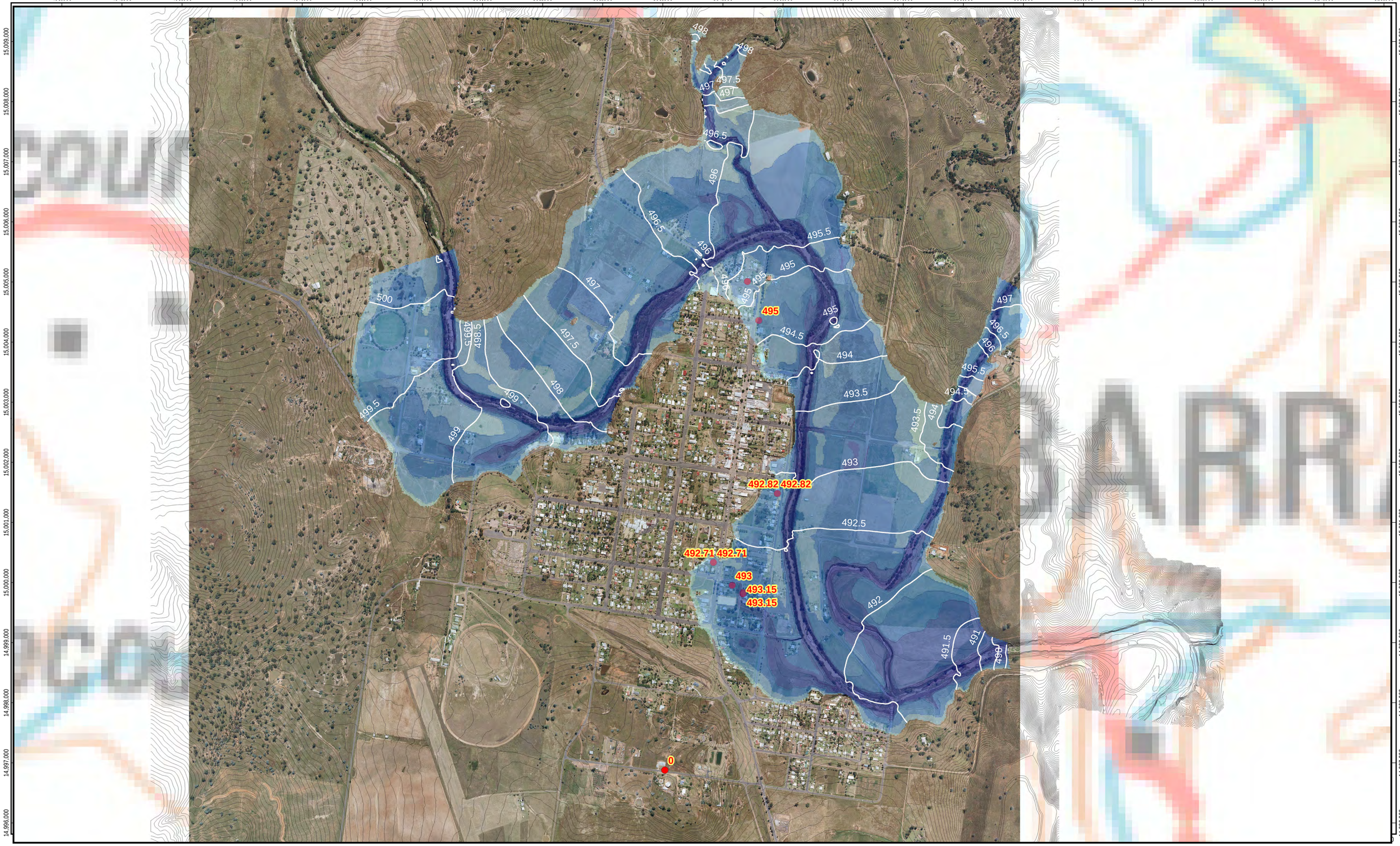

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Flood Extent and Depth (m)

- 0.16 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20

Flood Level Contours (mAHD)
TOPO Contours (1m)
1964 Flood Markers (mAHD)

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Flood Map
0.5% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.6.1

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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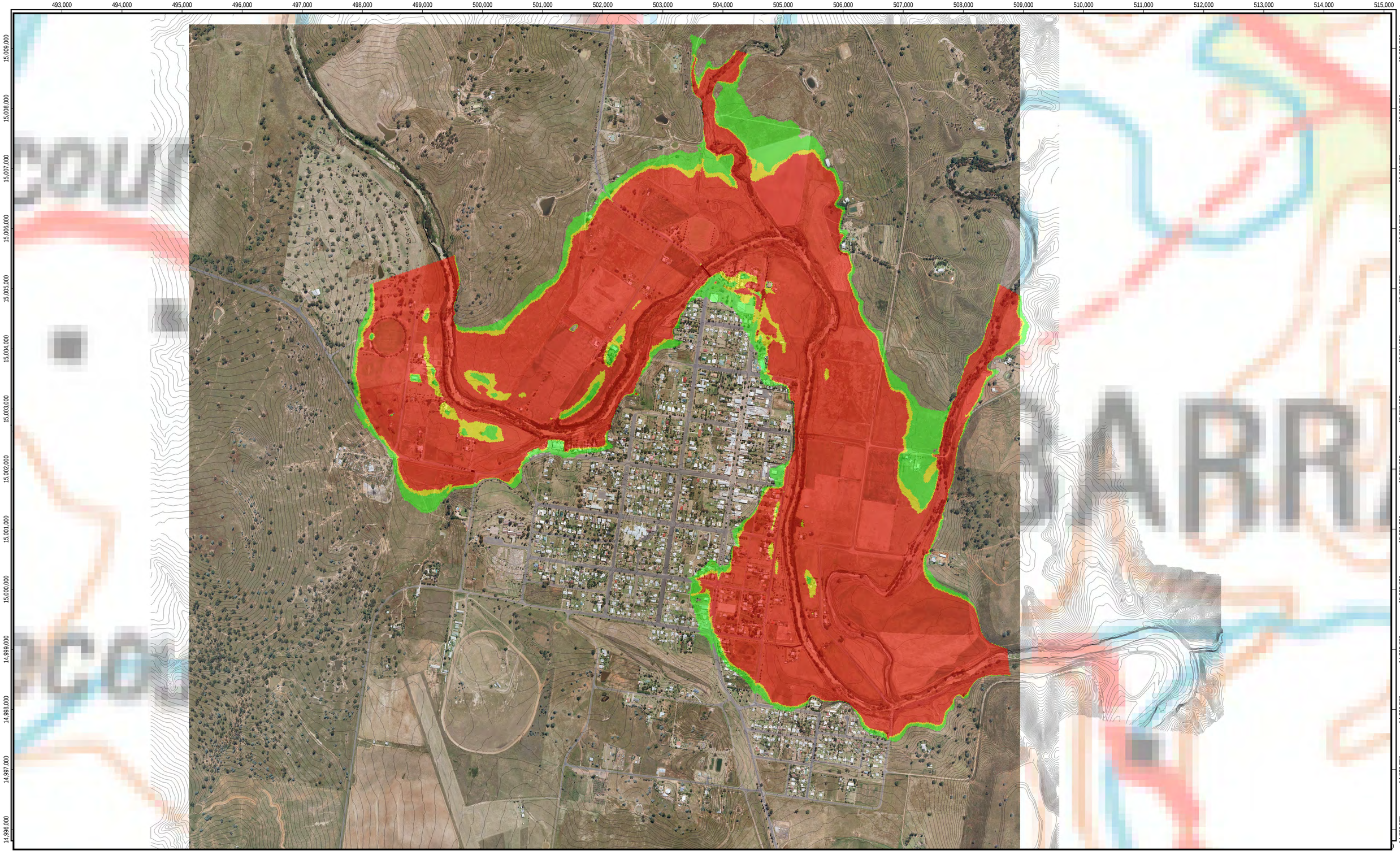

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Flood Hazard
- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- TOPO Contours (1m)

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Flood Hazard Map
0.5% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.6.2

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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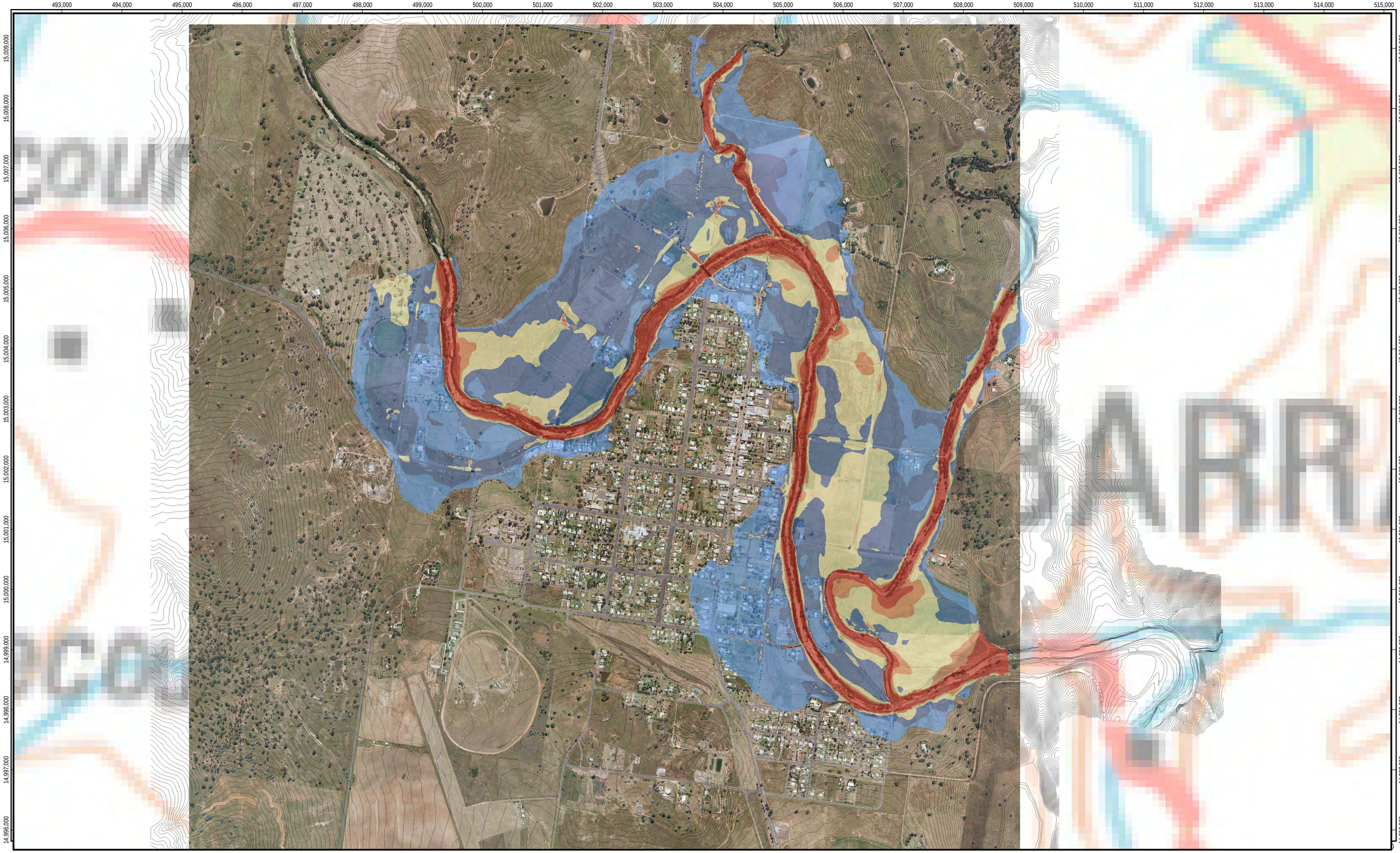

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Peak Flood Velocity (m/s)
- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- Greater than 2
- TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Flood Velocity Map
0.5% AEP Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F.6.3

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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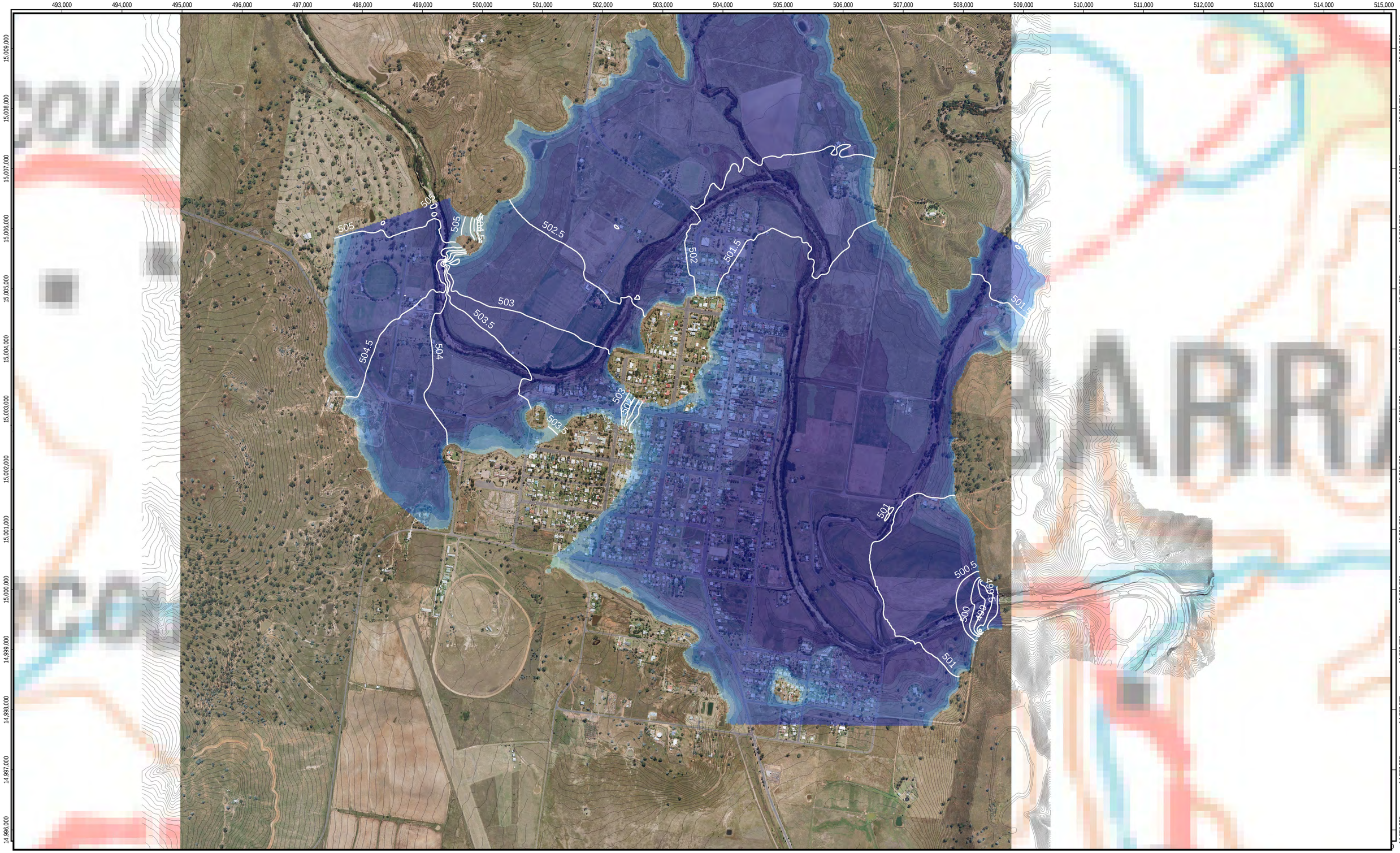

1:15,000

0 90 180 360 540 720 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

O

Flood Extent and Depth (m)
- 0.16 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20

Flood Level Contours (mAHD)
TOPO Contours (1m)

CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study
Flood Map
PMF Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F7.1

N:\AU\Melbourne\Apps Resources\Local\ESRI\ArcGIS\Libraries_Templates\New_Templates_Rev3\Libraries_Templates\GHD-A3-LANDSCAPE TECH.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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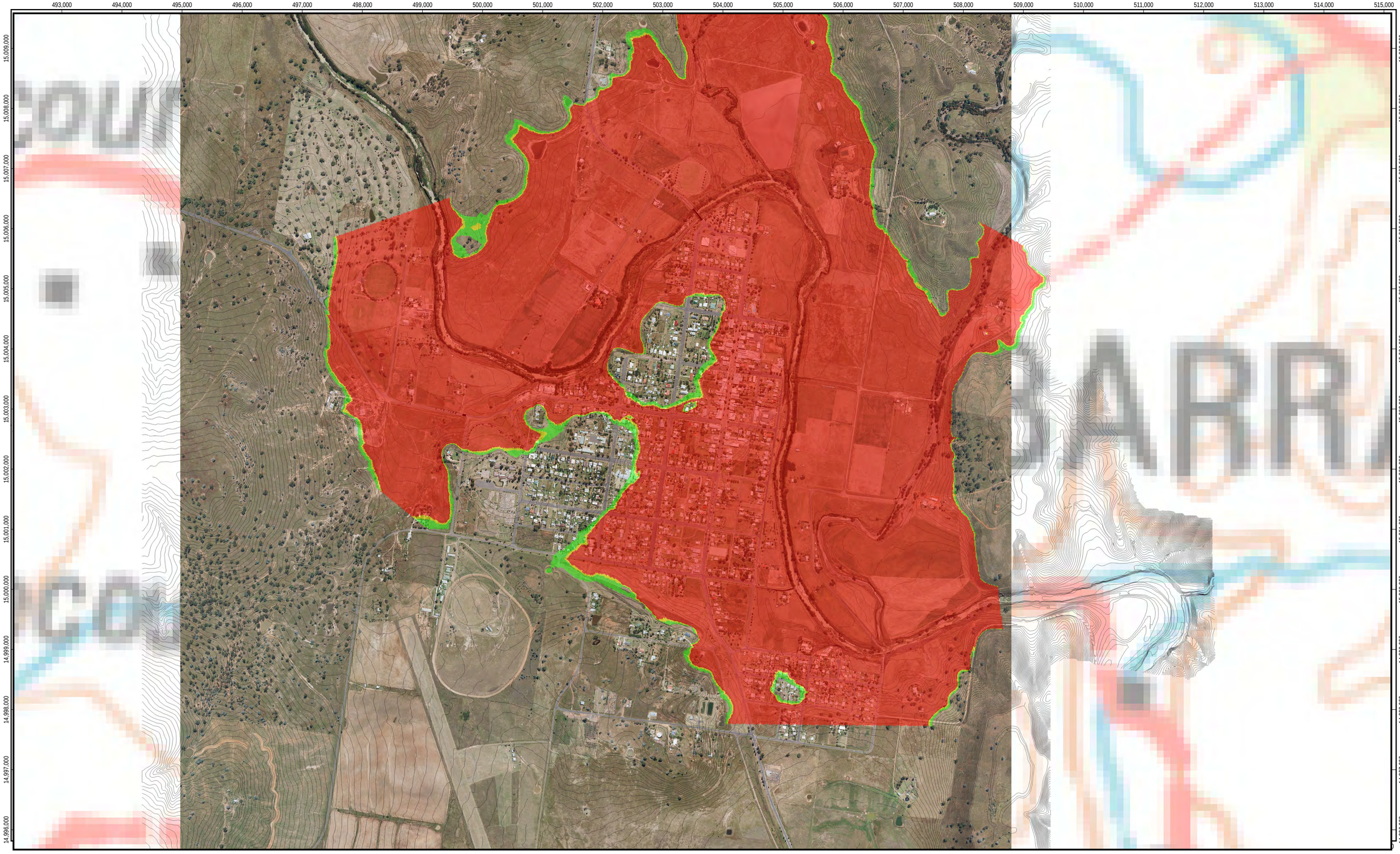

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Flood Hazard
- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study
Flood Hazard Map
PMF Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

Figure F7.2

N:\AU\Melbourne\Apps Resources\Local\ESRI\ArcGIS\Libraries_Templates\New_Templates_Rev3\Libraries_Templates\GHD-A3-LANDSCAPE TECH.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

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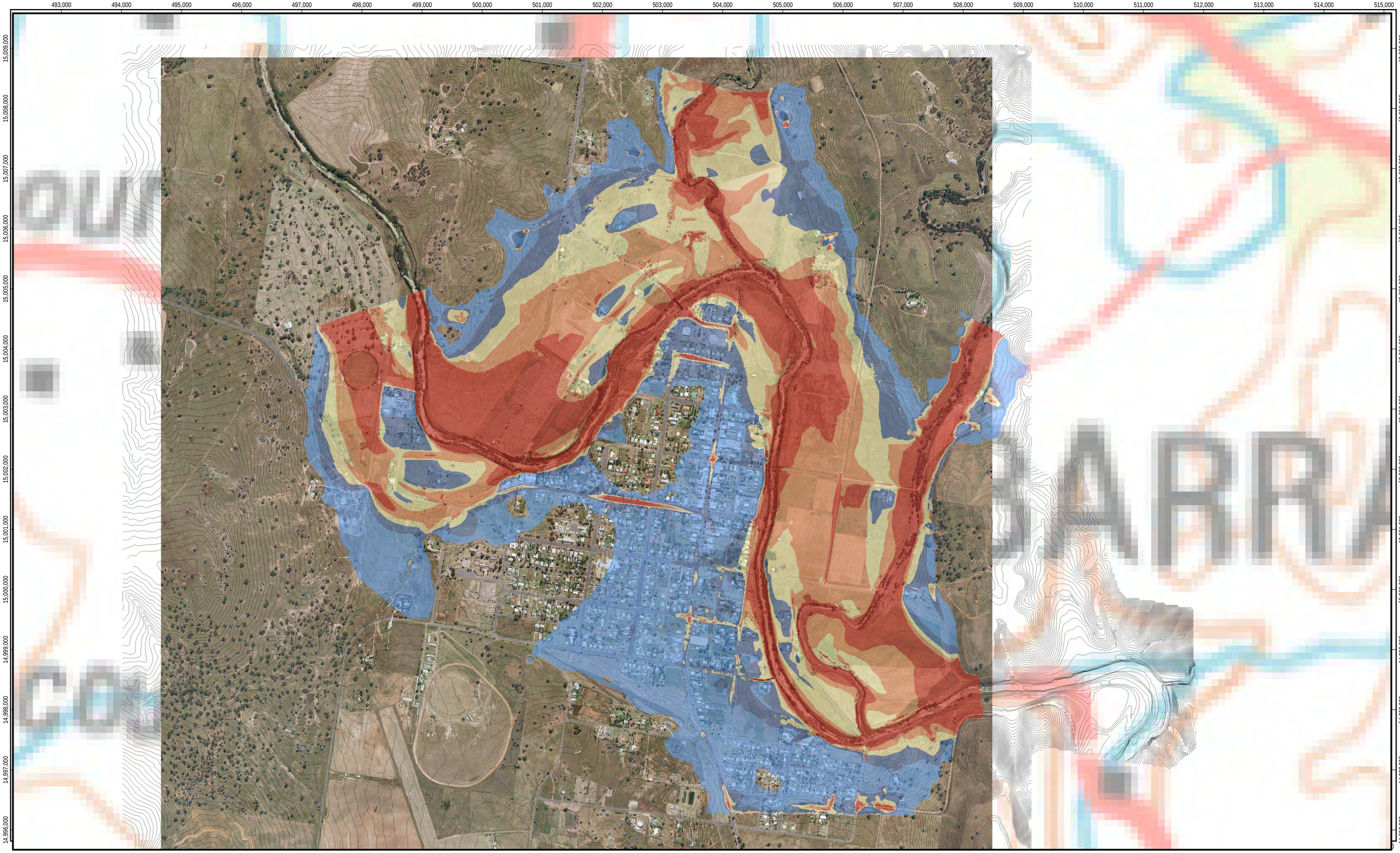

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Peak Flood Velocity (m/s)
- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- Greater than 2
- TOPO Contours (1m)

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Tamworth Regional Council
Barraba Flood Study

Flood Velocity Map
PMF Flood Event

Job Number	22-15816
Revision	A
Date	02.02.2012

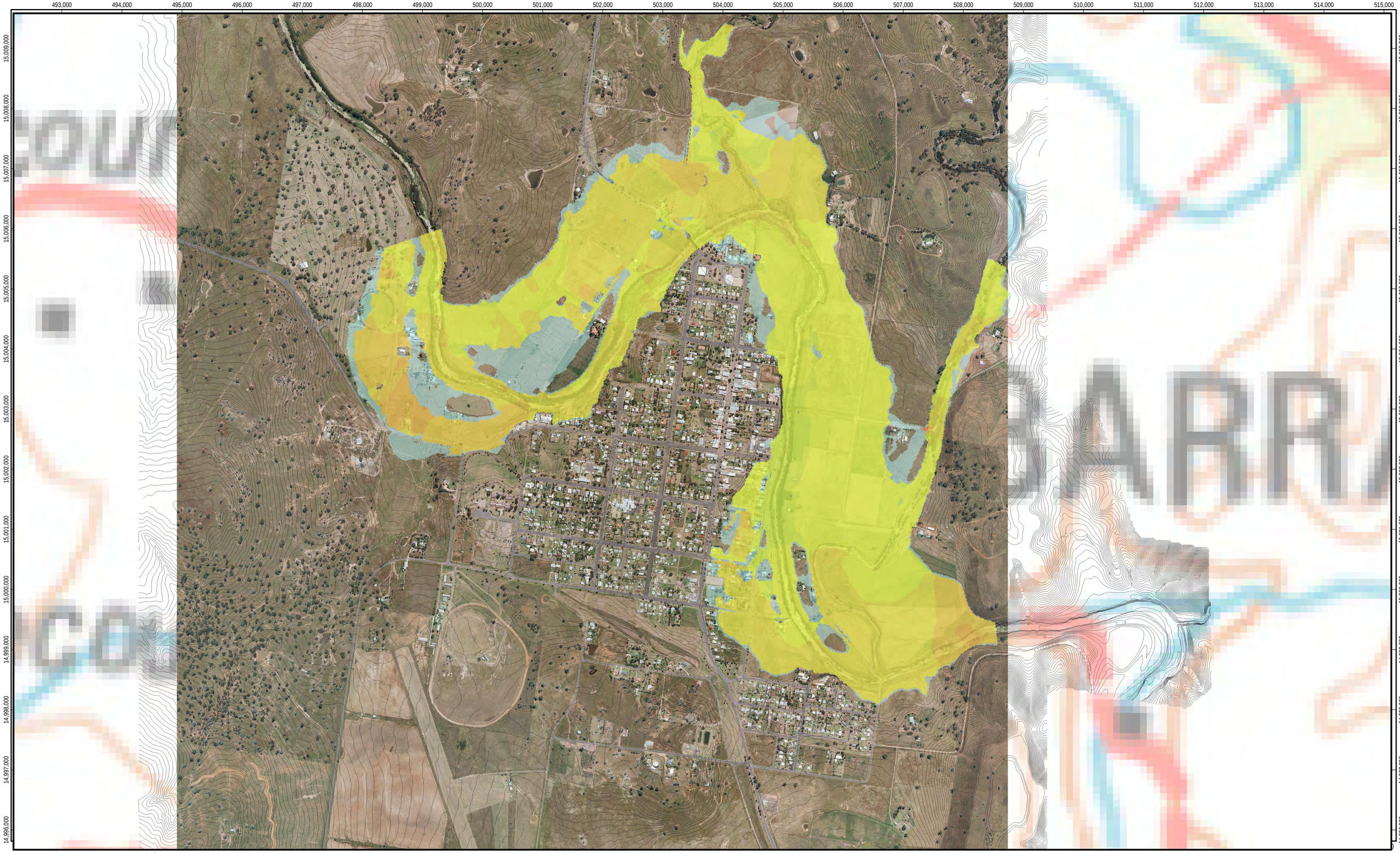
Figure F7.3

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au

Appendix G

Sensitivity Assessments



1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Change in Flood Depth (m)

-08 - -0.6	-0.3 - -0.2	0.2 - 0.3	0.7 - 0.8
-0.6 - -0.5	-0.2 - -0.1	0.3 - 0.4	0.8 - 0.9
-0.5 - -0.4	-0.1 - 0	0.4 - 0.5	0.9 - 1
-0.4 - -0.3	0 - 0.1	0.5 - 0.6	Additional Innundation
	0.1 - 0.2	0.6 - 0.7	TOPO Contours (1m)

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Tamworth Regional Council
Barraba Flood Study

Loss Sensitivity
1% AEP Flood Event

Job Number	22-15816
Revision	A
Date	06.02.2012

Figure G.1

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au

493,000 494,000 495,000 496,000 497,000 498,000 499,000 500,000 501,000 502,000 503,000 504,000 505,000 506,000 507,000 508,000 509,000 510,000 511,000 512,000 513,000 514,000 515,000

15,009,000 15,008,000 15,007,000 15,006,000 15,005,000 15,004,000 15,003,000 15,002,000 15,001,000 15,000,000 14,999,000 14,998,000 14,997,000 14,996,000

1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Change In Flood Depth (m)

-08 - -0.6
-0.6 - -0.5
-0.5 - -0.4
-0.4 - -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1
Additional Innundation
TOPO Contours (1m)

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Tamworth Regional Council
Barraba Flood Study

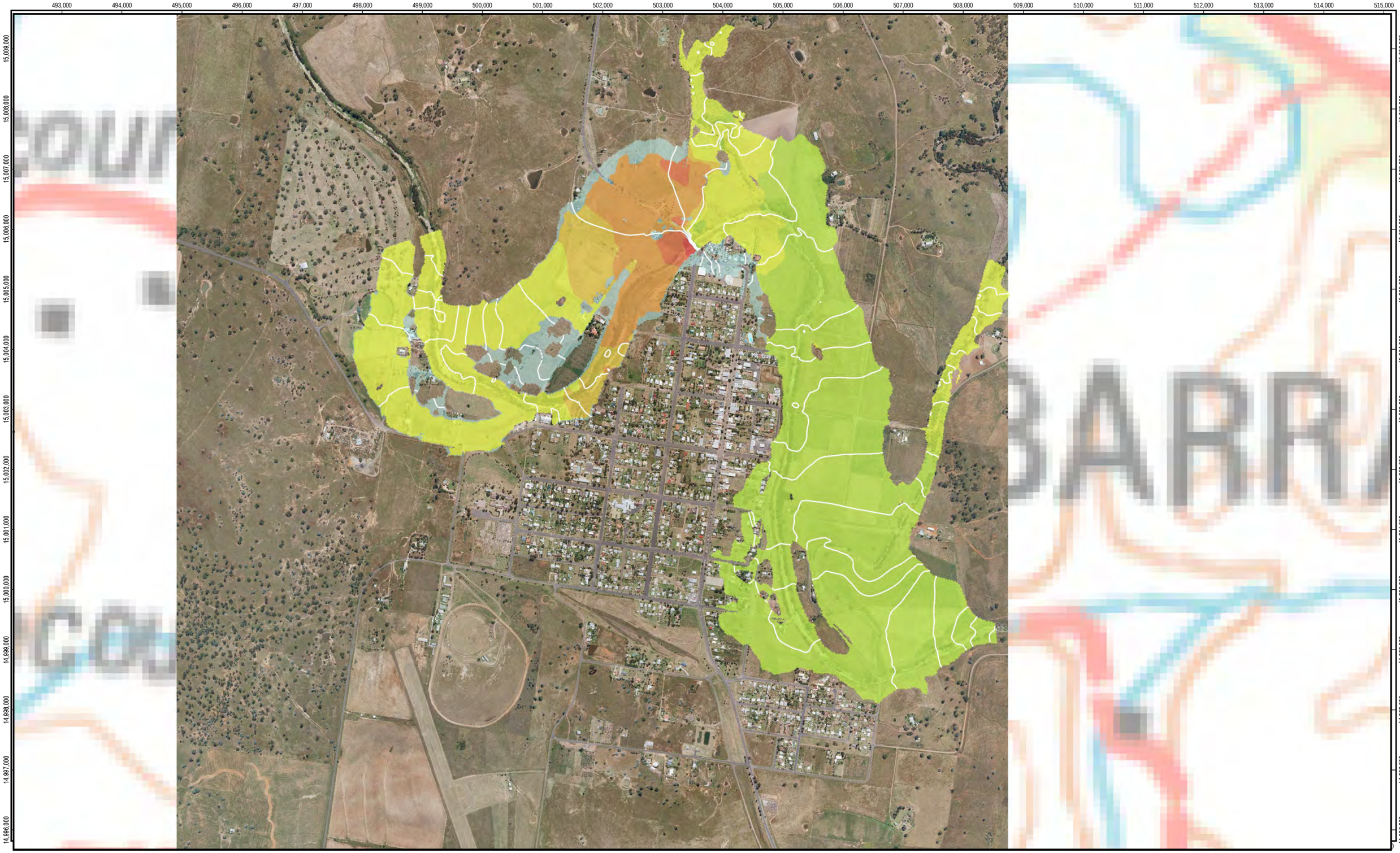
Mannings n Sensitivity
1% AEP Flood Event

Job Number	22-15816
Revision	A
Date	06.02.2012

Figure G.2

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au



1:15,000

0 87.5 175 350 525 700 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Change in Flood Depth (m)

- -0.8 - -0.6
- -0.6 - -0.4
- -0.4 - -0.2
- -0.2 - 0
- 0 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- Additional Innundation
- New Flood Level (mAHD)

GHD
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Tamworth Regional Council
Barraba Flood Study

Blockage Sensitivity
1% AEP Flood Event

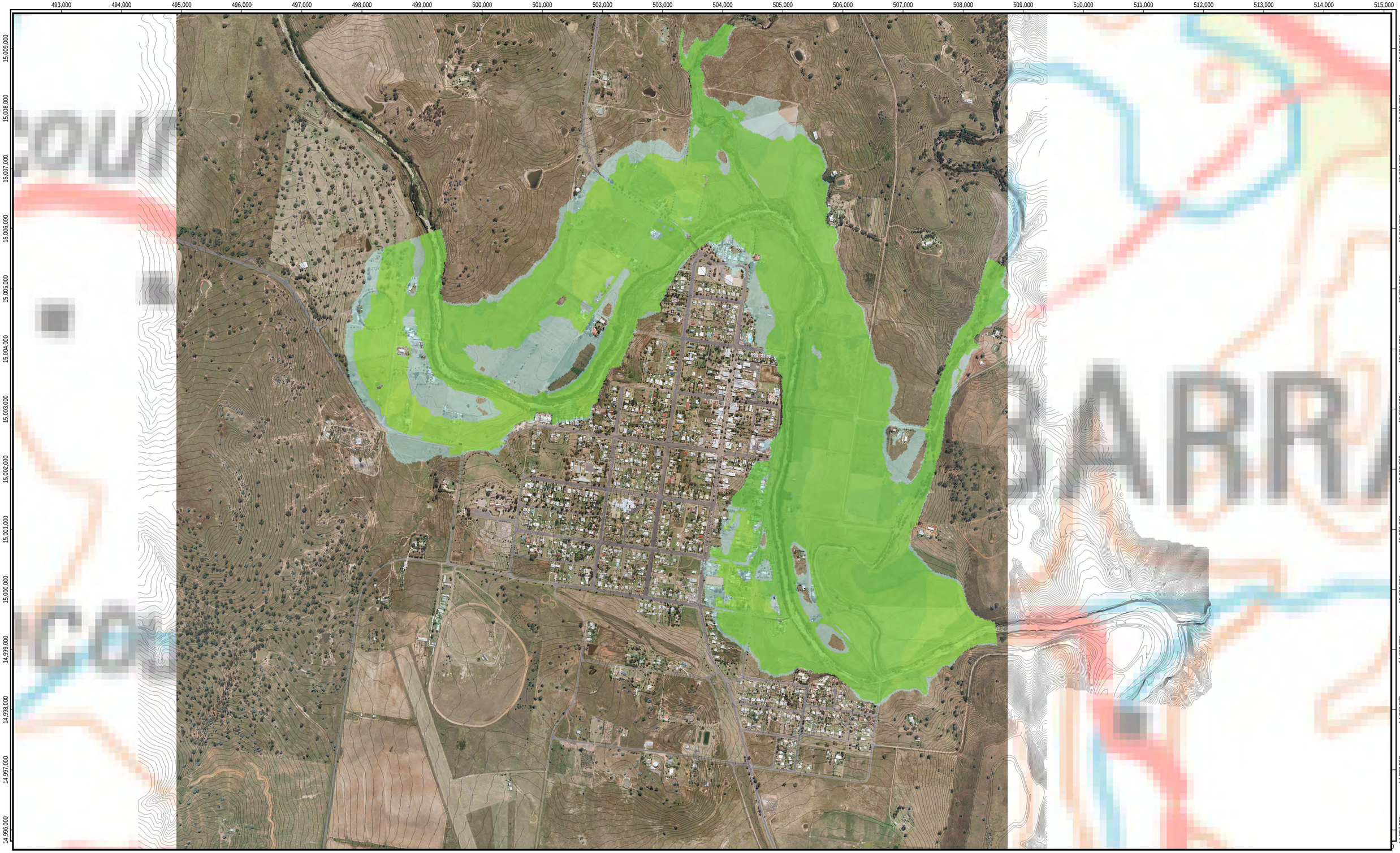
Job Number	22-15816
Revision	A
Date	06.02.2012

Figure G.3

N:\AU\Melbourne\Apps Resources\Local\ESRI\ArcGIS\Libraries_Templates\New_Templates_Rev3\Libraries_Templates\GHD-A3-LANDSCAPE TECH.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au



1:15,000

0 90 180 360 540 720 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Change in Flood Depth (m)

-0.02 - 0
0 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
1.0 - 1.2
1.2 - 1.4
1.4 - 1.6
1.6 - 1.8
1.8 - 2
2.0 - 2.2
2.2 - 2.4
2.4 - 2.6
Additional Innundation
TOPO Contours (1m)

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Tamworth Regional Council
Barraba Flood Study

Job Number 22-15816
Revision A
Date 06.02.2012

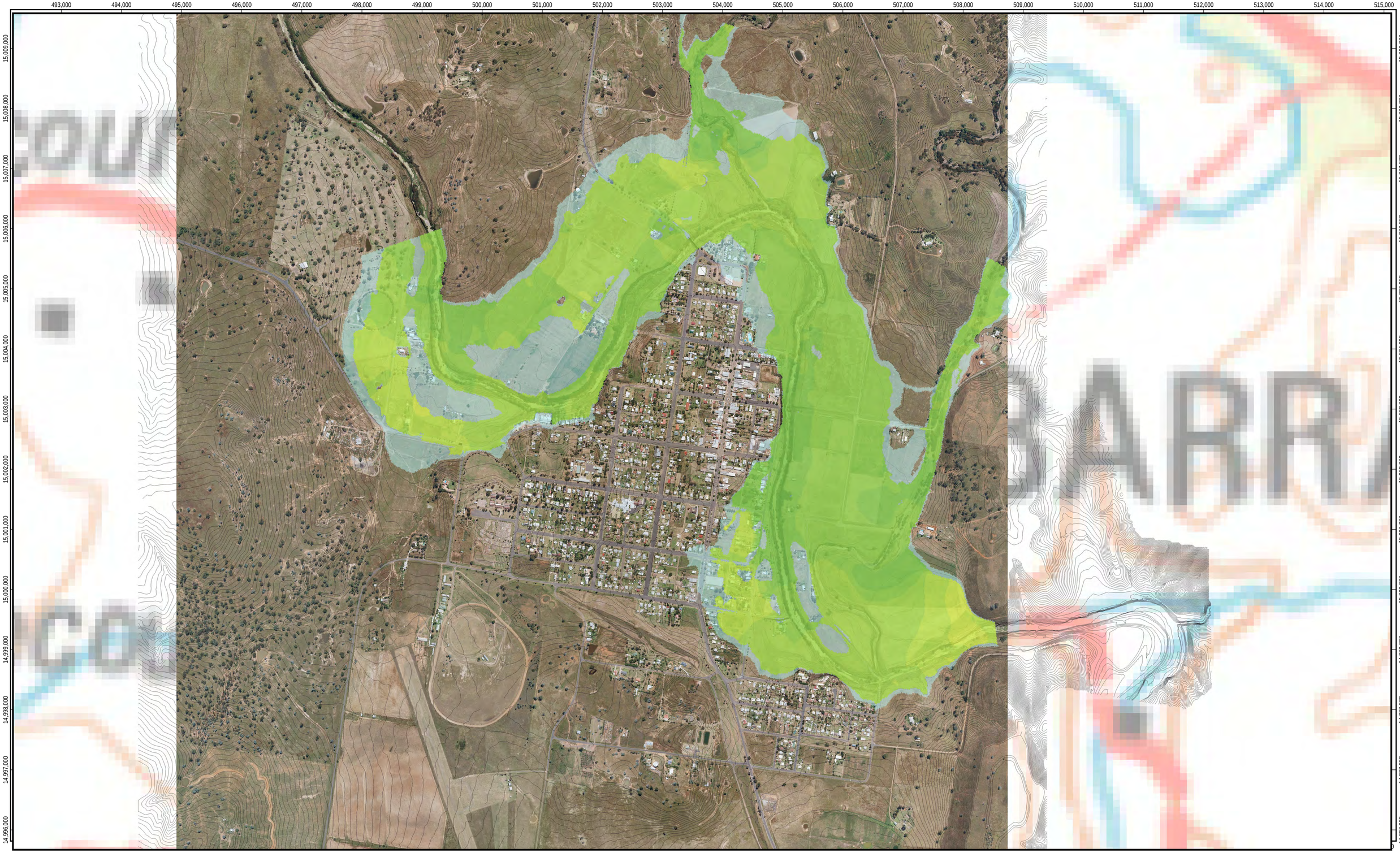
Climate Change Sensitivity (10%) 1% AEP Flood Event

Figure G.4

N:\AU\Melbourne\Apps Resources\Local\ESRI\ArcGIS\Libraries_Templates\New_Templates_Rev3\Libraries_Templates\GHD-A3-LANDSCAPE TECH.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au



1:15,000

0 90 180 360 540 720 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Change in Flood Depth (m)

- -0.02 - 0
- 0 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1.0 - 1.2
- 1.2 - 1.4
- 1.4 - 1.6
- 1.6 - 1.8
- 1.8 - 2
- 2.0 - 2.2
- 2.2 - 2.4
- 2.4 - 2.6
- Additional Innundation
- TOPO Contours (1m)

GHD
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Tamworth Regional Council
Barraba Flood Study

Job Number	22-15816
Revision	A
Date	06.02.2012

Climate Change Sensitivity (20%) 1% AEP Flood Event

Figure G.5

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au

493,000 494,000 495,000 496,000 497,000 498,000 499,000 500,000 501,000 502,000 503,000 504,000 505,000 506,000 507,000 508,000 509,000 510,000 511,000 512,000 513,000 514,000 515,000

15,009,000 15,008,000 15,007,000 15,006,000 15,005,000 15,004,000 15,003,000 15,002,000 15,001,000 15,000,000 14,999,000 14,998,000 14,997,000 14,996,000

1:15,000

0 90 180 360 540 720 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

N

Change in Flood Depth (m)

- -0.02 - 0
- 0 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1.0 - 1.2
- 1.2 - 1.4
- 1.4 - 1.6
- 1.6 - 1.8
- 1.8 - 2
- 2.0 - 2.2
- 2.2 - 2.4
- 2.4 - 2.6
- Additional Innundation
- TOPO Contours (1m)

GHD
CLIENTS | PEOPLE | PERFORMANCE

Tamworth Regional Council
Barraba Flood Study

Job Number	22-15816
Revision	A
Date	06.02.2012

Climate Change Sensitivity (30%) 1% AEP Flood Event

Figure G.6

N:\AU\Melbourne\Apps Resources\Local\ESRI\ArcGIS\Libraries_Templates\New_Templates_Rev3\Libraries_Templates\GHD-A3-LANDSCAPE TECH.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au

Appendix H

Flood Planning Map

NOTE:

Flood Planning Area means the land between the “Flood Planning Area Extents” on the Flood Planning Map.

Flood Planning Level means the level of a 1:100 ARI (Average Recurrent Interval) also termed the 1% AEP (Annual Exceedance Probability) flood event plus 0.50m freeboard.

The Flood Planning Area Extent has been determined by abstracting the peak1% AEP flood level plus 0.5m, at 100m to 150m intervals across the entire floodplain, perpendicular to the flow. Thus some anomalies could exist on the edge of the floodplain, when comparing to the 2D flood model results, where localised flood effects could exist.

1:15,000

0 90 180 360 540 720 Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone XX

Legend:

Flood Extent and Depth (m)
- 0.16 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20

- Flood Level Contours (mAHD)
- Flood Planning Area Extents
- TOPO Contours (1m)

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Tamworth Regional Council
Barraba Flood Study

Flood Planning Map
100-Year Flood Event

Job Number	22-15816
Revision	A
Date	09.05.2012

Figure H1

N:\AU\Melbourne\Apps Resources\Local\ESRI\ArcGIS\Libraries_Templates\New_Templates_Rev3\Libraries_Templates\GHD-A3-LANDSCAPE TECH.mxt

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:

230 Harbour Drive Coffs Harbour NSW 2450 Australia T 61 2 6652 5600 F 61 2 6652 5601 E cfsmail@ghd.com.au W www.ghd.com.au

Appendix I

QA Documentation

Baxter Geo Consulting Pty Ltd
Surveying - Development Planning & Co-ordination
ACN: 103 579 335 ABN : 63 323 316 716

2/13 Hill Street
TAMWORTH NSW 2340

please address all correspondence to
PO Box 1402 TAMWORTH NSW 2340

Ph 02 6766 6499
Fax 02 6766 6599
Mob: 0418 401 802

general: okbaxter@baxtergeo.com
writers email: peter@baxtergeo.com

Our Ref: 0487
File Location: Z:\0487 Barrabra Flood Study\Doc\0487-120130 GHD Barraba Quality Doc.docx

Your Ref: Barraba Flood Study

30th January 2012.

The General Manager
Tamworth Regional Council
P.O. Box 555
TAMWORTH NSW 2340

Dear Sir,

Re: Quality Control Barraba Flood Study – Joint Venture Aerometrex, Baxter Geo & GHD

Survey Control

Establish Survey Control

A SCIMS search was undertaken on 8th September 2011 to locate reliable Survey Control in the town of Barraba. PM148166 being of Class A Order 1 Horizontal and Class B Order 2 Vertical was chosen as the control station for all survey work.

A GNSS base station and eccentric check station were established on the SCIMS co-ordinates and the primary control measured using two rovers, each set at different heights on a range pole with bi-pod. This methodology provides an independent check on heights. Measurements were made to SSM 13083 (Class A Order 1 Horizontal – Class LC Order L3 Vertical), PM 71470 (Class A Order 1 Horizontal – Class B Order 2 Vertical). There was good agreement with the SCIMS data base and our initial calibration survey.

Mean Observation					SCIMS						
	Easting	Northing	AHD		Easting	Northing	AHD		dE	dN	dH
PM-148166	270060.875	6635342.415	525.459		270060.875	6635342.415	525.459				
SSM-13083	270578.763	6634989.485	490.710		270578.77	6634989.483	490.702		0.004	-0.002	-0.008
PM-71470	271302.173	6636690.589	491.473		271302.19	6636690.605	491.495		0.019	0.016	0.022

The largest difference shown at PM 71470 is over a distance of 1832.59m and represents an accuracy of 1:73,777 in distance and height.

Eccentric Control Station

The co-ordinates of the eccentric control station were documented and on each subsequent survey a check measurement was taken to the eccentric station at the beginning and end of each day. The check co-ordinates were compared to establish no errors were made in setting up the base station each day and that the base station had not been disturbed or tampered with during the days observations.

Establish Photo Control
Aerometrex required photo control points to be established in six areas. An RTK survey was undertaken with two rovers set at different heights. A minimum of two control points (each determined by observations using two rovers) were taken in each of the six areas. This gave a redundancy of 100% for Aerometrex.

Establish Quality Control
During the control survey a GNSS rover was fixed to the top of the car and random measurements at an approximate interval of 50m spacing.

Control Data was forwarded to Aerometrex for processing.

Processed Photogrammetric Data
Aerometrex supplied digital data which was read into AutoCAD Civil 3D. The data was processed and a Digital Terrain Model created.

Checking and Quality Control
The random heights were placed in the model and a data set of heights on the DTM for those points calculated. A total of 229 points were analysed. Of these points 171 points agreed to better than 0.15m. A further 33 points were in the range 0.16m to 0.25m and 16 points were in the range 0.26 to 0.35m. The remaining 9 points were analysed visually to determine why larger difference were calculated. It is our conclusion the larger differences are due to the location of the check points being inappropriate, eg on the crown of a dirt road etc.

It is our opinion the data supplied by Aerometrex and the subsequent DTM is superior to what could be achieved by conventional ground survey. The anomalies mentioned above are not considered significant in the overall accuracy of the DTM for the purpose calculating water levels over a large area. A large number of points with a lower accuracy (X, Y, Z) and breaklines lines will provide a more superior DTM than a low number with highly accurate points (X, Y, Z). It is our opinion the aerial photography and the subsequent DTM are suitable for the purpose.

Supply of data to GHD
The electronic data was supplied by FTP to GHD.

Floor Level Survey
A data set containing the 1:100 and PMF flood lines was provided to Baxter Geo by GHD. This data was loaded into the model and a series of field sheets produced to identify the floor levels required to be measured.

Floor levels were determined using GNSS and a laser level. The system was checked prior to field survey to ensure accuracy. The initial check showed what we believe to be a collimation error in the laser level. A new laser level was obtained and a further field check undertaken to confirm accuracy. This check proved satisfactory and the field survey was then undertaken using the previous GNSS control station and the eccentric control station. During the course of the floor level survey, measurements were taken to known points and the values of the GNSS / laser level survey compared. All results showed good agreement. We are of the opinion our levels determined by this method are good to 0.05m or better.

The greatest source of uncertainty in determining the floor levels is picking a point on the outside of the building that is representative of the floor level inside. Our instruction was to determine the floor levels within +/- 0.1m. We are of the opinion that this criteria has been satisfactorily met.

Each measurement with the laser level was measured in metres and inches. Each value was entered into the data recorder. The observed inches were converted to metres on a handheld calculator and compared to the reading in metres entered into the data recorder before the data was stored. This methodology provided quality control in the field.

The GNSS and level observations were downloaded and converted to an Excel spreadsheet. The processed data was then read into the Civil 3D model and a visual check made against the aerial photography. This was then checked against a data file of Manilla showing the cadastral layout and street numbers supplied by Tamworth Regional Council. A number of amendments to the addressing collected in the field were required to be made to be consistent with Council's data set.

The processed floor levels were exported to an Excel spreadsheet and this was supplied to GHD as a Excel spreadsheet and a pdf print of the file.

Personnel

All surveys were undertaken by the undersigned with the assistance of Dan Whale who is a competent field assistant and a qualified town planner.

Yours faithfully

Peter J Baxter *B.Surv M.I.S(NSW) S.S.S.I.*
Registered Surveyor / Licensed Strata Managing Agent
for Baxter Geo Consulting Pty. Ltd.

GHD JFlow QA Documentation

2215816 TRC - Barraba Flood Study (T074/2011) James McPherson Rainer Berg 93,237 Active 28/02/2012
- DELIVERABLE: Calculations - Barraba RORB model check : Completed on 15/05/2012
  - REVIEW: Online Review - Michelle S Kan : Completed on 01/03/2012
    - CHECKSHEET: Calculations - Michelle S Kan : Completed on 01/03/2012
- DELIVERABLE: Calculations - Barraba Tuflow Model Check : Completed on 15/05/2012
  - REVIEW: Online Review - Michelle S Kan : Completed on 01/03/2012
    - CHECKSHEET: Calculations - Michelle S Kan : Completed on 01/03/2012
- DELIVERABLE: Reports - Barraba Flood Study Report : Due on 01/03/2012
  - REVIEW: Authorised Person to Sign - Rainer Berg : Completed on 15/05/2012
  - REVIEW: Authorised Person to Sign - Rainer Berg : Completed on 15/05/2012
- JOB REVIEW: 15% Job Review : Completed on 31/08/2011 by Rainer Berg
  - CHECKSHEET: 15% Job Review - by Rainer Berg due 09/09/2011 - completed on 31/08/2011
- Risk: Not meeting completion date of 28 Feb 2012 - Complete
- Risk: Package to include three studies. Will need high level of support and success will depend on availability of key personnel. - Complete
- Risk: Project Environmental Impact - Complete
- Risk: Survey information incompatability - Complete
- SUBCONSULTANT: Aerometrex Pty Ltd - PI Current; PL Current; Registration None
- SUBCONSULTANT: Baxter Geo Consulting Pty Ltd - PI Current; PL Current; Registration None

2215815 TRC - Manilla Flood Study (T073/2011) James McPherson Rainer Berg 98,807 Active 28/02/2012
- DELIVERABLE: Calculations - Catchment Delineation : Completed on 15/05/2012
  - REVIEW: Signed Check to be Kept on File - Samuel L Douglas : Completed on 29/02/2012
- DELIVERABLE: Calculations - RORB model Check : Completed on 15/05/2012
  - REVIEW: Online Review - Michelle S Kan : Completed on 01/03/2012
    - CHECKSHEET: Calculations - Michelle S Kan : Completed on 01/03/2012
- DELIVERABLE: Calculations - tuflow model : Completed on 15/05/2012
  - REVIEW: Online Review - Michelle S Kan : Completed on 01/03/2012
    - CHECKSHEET: Calculations - Michelle S Kan : Completed on 01/03/2012
- DELIVERABLE: Reports - Flood Study Report : Due on 01/03/2012
  - REVIEW: Authorised Person to Sign - Rainer Berg : Completed on 15/05/2012
  - REVIEW: Authorised Person to Sign - Rainer Berg : Completed on 15/05/2012
- JOB REVIEW: 15% Job Review : Completed on 31/08/2011 by Rainer Berg
  - CHECKSHEET: 15% Job Review - by Rainer Berg due 09/09/2011 - completed on 31/08/2011
- JOB REVIEW: Project Review Group (PRG) Review : Completed on 15/05/2012 by Rainer Berg
- Risk: Environmental impact - Complete
- Risk: Not meeting completion date of 28 Feb 2012 - Complete
- Risk: Survey information incompatability - Complete
- SUBCONSULTANT: Aerometrex Pty Ltd - PI Current; PL Current; Registration None
- SUBCONSULTANT: Baxter Geo Consulting Pty Ltd - PI Current; PL Current; Registration None

aerometrex.
ABN 94 153 103 925
Digital Mapping Specialists
www.aerometrex.com.au

Adelaide Office: 413 Magill Road, St. Morris SA 5068
Contact: Todd Dunow – Senior Account Manager
T: (08) 8361 3111 Mobile: 0419 712 897
E: todd.dunow@aerometrex.com.au

Project Reference: A3177 Barraba

15 May 2012

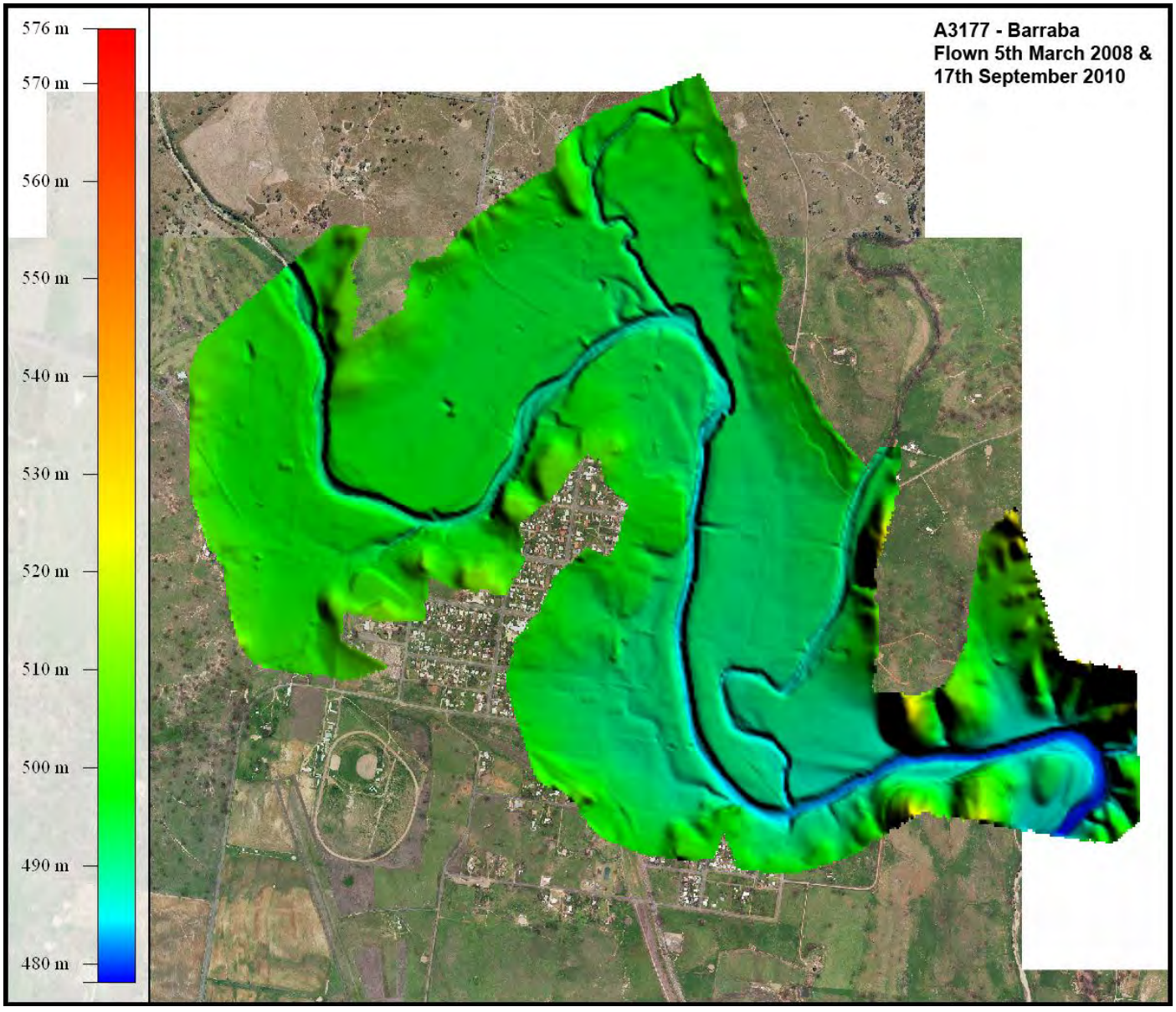
Dr. Rainer Berg
GHD
230 Harbour Drive
Coffs Harbour NSW 2450

Dear Rainer,

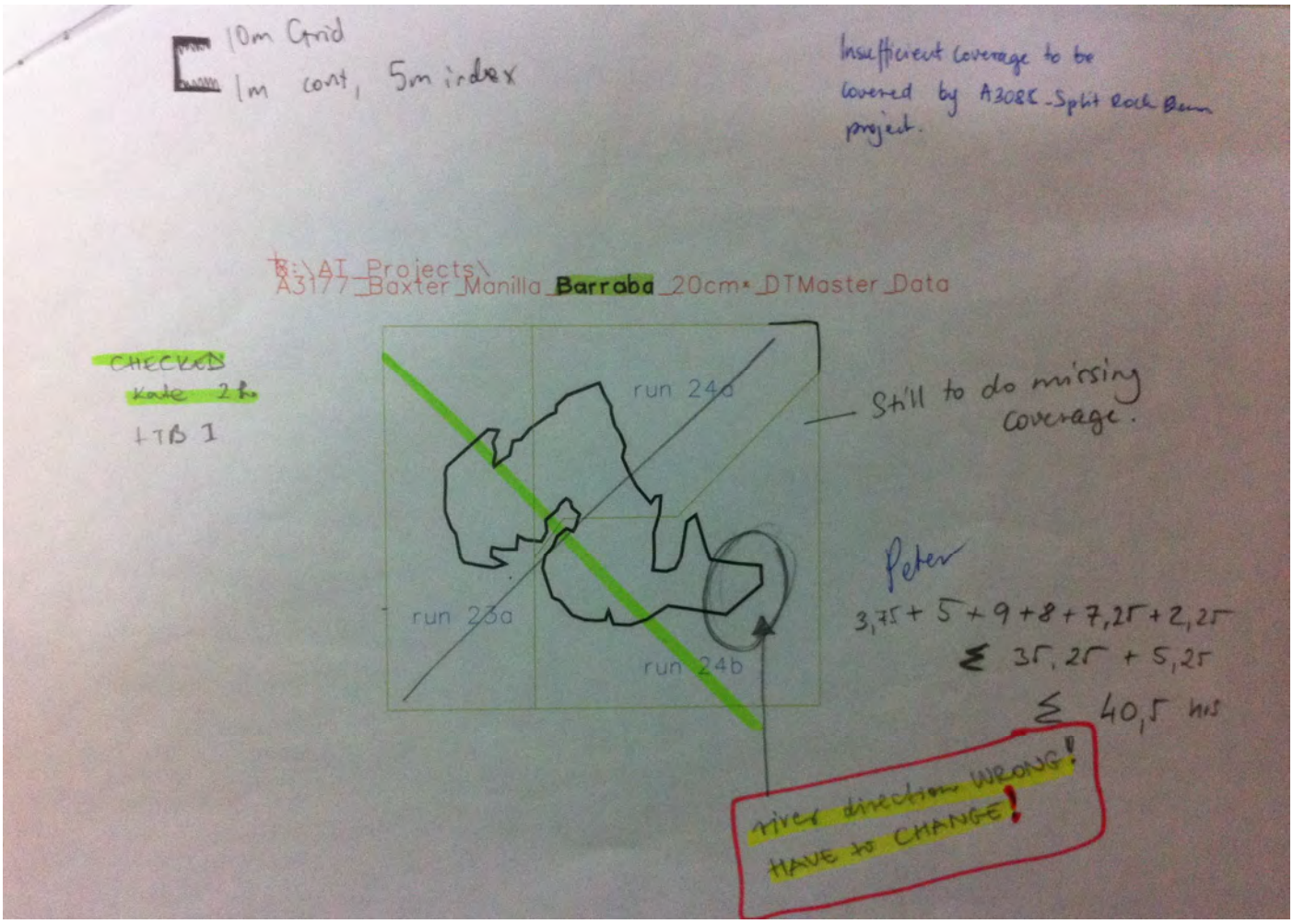
Please find below survey specifications, accuracy statements & the quality control check sheets for the aerial survey Aerometrex conducted over the township of Barraba in October 2011.

Survey Reference: A3177 Barraba / Baxter.

Overview:

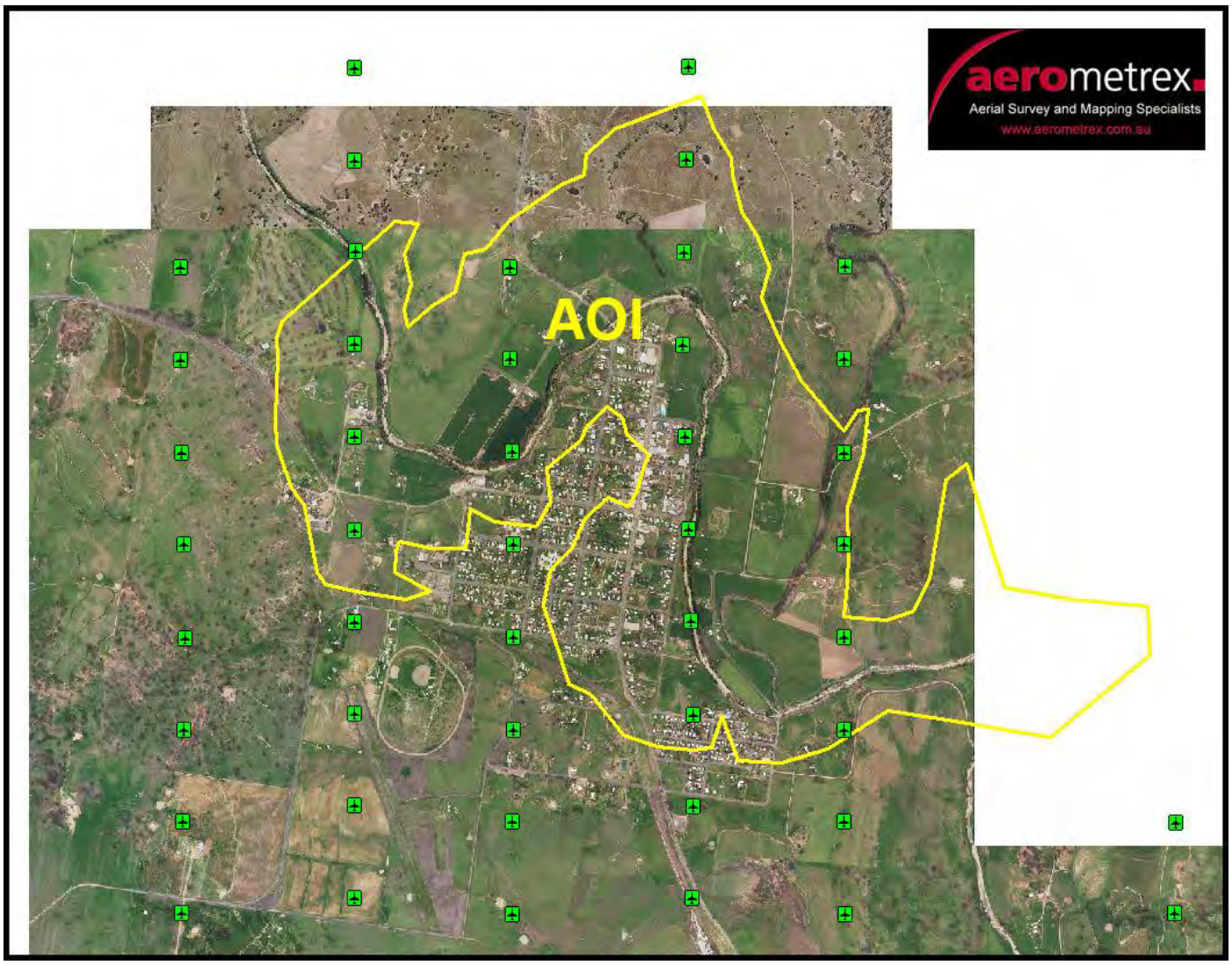


Quality Control Sheet:



Survey Details:

Flown – 5th March 2008 & 17th September 2010
Plane – Conquest VH-VEW & Shrike VH-VJU
Capture Height – Approx. 9500 Feet
Number of Runs – 5
Number of Frames - 44
Direction of Runs – North / South
Ground Sample Distance – 20cm
Forward frame overlap: 70%
Side frame overlap: 30%



Sensor Details:

Sensor – Vexcel Ultracam D, Large Format Mapping Camera – UCD-SU-1-0047
Focal Length: 105.200mm
Image Extent: (-33.75, -51.75)mm (33.75, 51.75)mm
Image Format: 7500 pixels (width) x 11500 pixels (height)
Pixel Size: 9.000 micron x 9.000 micron
PPA: X_ppa = -0.000 mm , Y_ppa = 0.180 mm
Please refer to included document “Calib-Report_0047_V10_short.pdf”

The sensor used in this survey was fully calibrated in Dec 2006.

Flight Report:

AEROmetrex Pty Ltd
ABN 19 438 552 201
Mapping Specialists
Web: www.aerometrex.com.au

AIR PHOTOGRAPHY REPORT

Times in UTC

Camera Type - Vexcel UltraCam		Calibrated FL - 105.2mm					Date - 05MAR08A			Possible Images - 1337
Capture Time Interval 3.9s		GPS Base Station Tamworth ARP					Pilot - George Scott			Navigator - John Murphy
Max Aircraft Speed 220kts		Data Download Time -					Aircraft Registration - VH-VEW			Aircraft Time - 042200 - 050203
JOB NO.	PROJECT	GSD	AMSL(ft)	RUN No.	DIRECTION	START_SU	START_Wpt	END_SU	END_Wpt	Comments
A2705	Tamworth	20	9635	26	181	78935	010	78944	001	OK
				25	001	78945	001	78985	041	OK
				24	181	78986	041	79026	001	OK
			9730	1	091	79027	001	79096	070	OK
				2	271	79097	070	79166	001	OK
				3	091	79167	001	79236	070	OK
				4	271	79237	070	79306	001	OK
				5	091	79307	001	79376	070	OK
				6	271	79377	070	79446	001	OK
				7	091	79437	001	79516	070	OK
			9665	8	271	79517	070	79586	001	OK
				9	091	79587	001	79656	070	OK
				10	271	79657	070	79726	001	OK
				11	091	79727	001	79796	070	OK
				12	271	79797	070	79866	001	OK
			9305	22	001	79867	001	79878	012	OK
				23	181	79879	012	79890	001	OK
			8815	19	181	79891	014	79904	001	OK
				20	001	79905	001	79918	014	OK
				21	181	79919	014	79932	001	OK

aerometrex.
Digital Mapping Specialists
Part of the Aerometrex Group

AIR PHOTOGRAPHY REPORT

All Times in UTC (DTG)

System Times	17:02:05 to 17:07:50
GPS Session No	03:0011A10.260
Antenna Height	1.310m
Possible Images	1784
Navigator	Nicholas Rusk
Aircraft Time	17:02:37 to 17:06:17

Camera - Vexcel UltraCam UCD47		Calibrated FL - 105.2mm					Date	17-Sep-10			
Capture Time Interval	2 - 6 sec	GPS Base Station		AMX 011 - Tamworth Airport			Pilot	Andre Van Ginkel			
Max Aircraft Speed	186kts	Data Download Time			17:01:50 to 17:08:05		Aircraft Registration		VH-YJU		
JOB NO.	PROJECT	GSD	AMSL(ft)	RUN No.	DIRECTION	START SU	START Wpt	END SU	END Wpt	Comments	Sun Angle
A3025	Tamworth	20cm	10125	+001	340	83401	001	83446	046	ok	53
			10225	-002	160	83447	046	83492	001	ok	52
			9800	-003	299	83493	037	83529	001	ok	51
				+004	119	83530	001	83566	037	ok	50
A3025	Tamworth	10cm	5210	-025	001	83567	027	83593	001	ok	49
				+024	181	83594	001	83620	027	ok	48
			5635	-023	001	83621	060	83680	001	ok	47
			5800	+022	181	83681	001	83740	060	ok	46
			5600	-021	001	83741	060	83800	001	ok	45
			5470	+020	181	83801	001	83860	060	ok	44
			5305	-019	001	83861	060	83920	001	ok	43
			5240	+018	181	83921	001	83980	060	ok	42
			5075	-017	001	83981	060	84040	001	ok	41
	Tamworth	20cm	9470	-008	001	84041	059	84041	059	broke run - 1 frame taken - problem with drift	39
				-008	001	84042	059	84100	001	ok	38
				+009	181	84101	001	84159	059	ok	37
				-010	001	84160	059	84219	001	ok	34
				+011	181	84220	001	84271	053	ok	32
				-012	001	84272	053	84324	001	ok	30
				+013	181	84325	001	84377	053	ok	29
				-014	001	84378	053	84430	001	ok	27
				+015	181	84431	001	84483	053	ok	25
				-016	001	84484	053	84536	001	ok	24

Survey Accuracy:

The table below defines the accuracy Aerometrex is able to quote and obtain from this survey. The highest quality equipment combined with hundreds of surveys of experience allows Aerometrex to confidently quote these accuracies. Having two surveys over the same area allowed the ideal cross check.

Aerometrex has considerable resources and time over the past 10 years in research and development proving its ability to conform to specified accuracies.

Accuracy	20cm pixel resolution
Horizontal (Point) Horizontal (Ortho)	+/- 0.20m RMSE +/- 0.40m RMSE
Vertical (With BGC ground survey inputs)	+/- 0.17m (68% c.i., 1σ) +/- 0.34m (95% c.i., 2σ)

The above vertical accuracies were obtained by incorporating ground control supplied by Baxter Geo Consulting.

Supplied data details:

10m spacing gridded DTM with breaklines.
10m spacing gridded DTM with breaklines converted to breakpoints every 1m.
1m Contours in dxf format.
4 DTM Points around the base of all buildings.

Please do not hesitate to contact me if any more information is required.

Yours sincerely,

Todd Dunow
Senior Account Manager
Aerometrex Pty Ltd.

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
EARLYDRAFT	S Douglas/R Berg	R Berg		R Berg		17/01/2012
DRAFT	S Douglas/R Berg	R Berg		R Berg		07/02/2012
FINAL DRAFT	S Douglas/R Berg	R Berg		R Berg		27/02/2012
FINAL	S Douglas/R Berg	R Berg		R Berg		25/04/2012