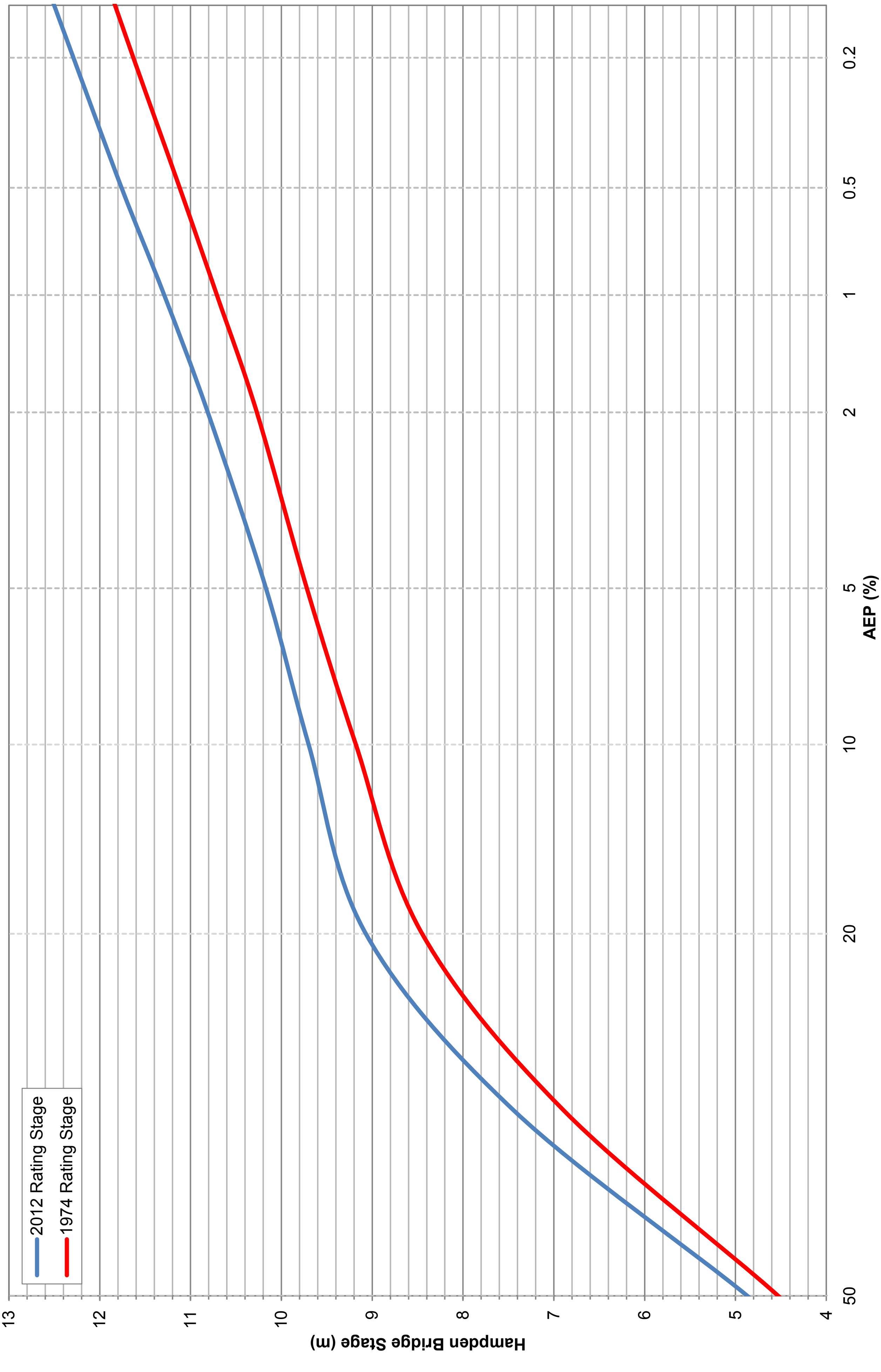
FIGURE 21

WAGGA WAGGA - HAMPDEN BRIDGE GAUGE
STAGE ANNUAL EXCEEDANCE PROBABILITY
2012 VS 1974 RATINGS



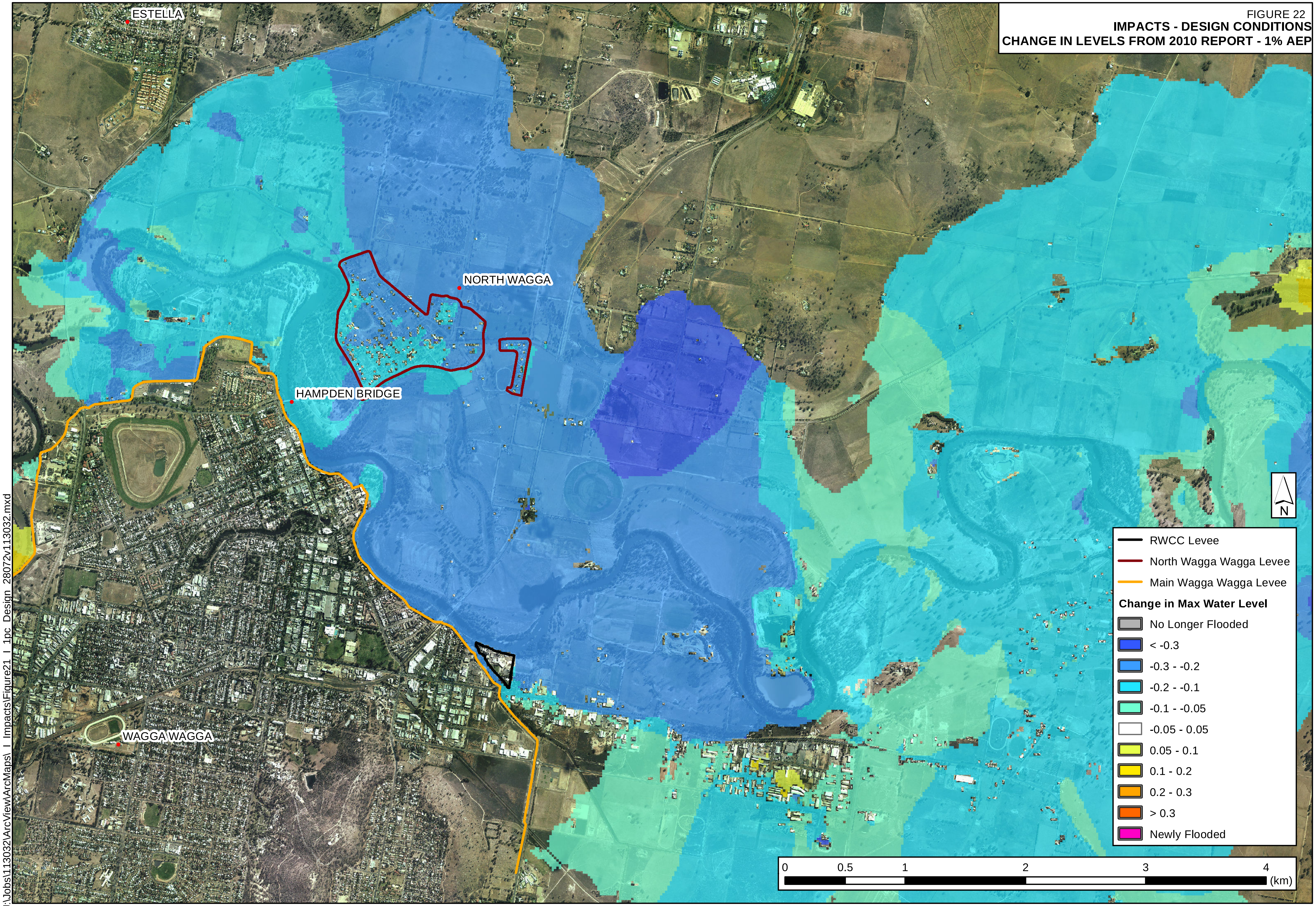


FIGURE 22
IMPACTS - DESIGN CONDITIONS
CHANGE IN LEVELS FROM 2010 REPORT - 1% AEP

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FIGURE 23

WAGGA WAGGA MAIN TOWN LEVEE
1% AEP FLOOD LEVEL AND SENSITIVITY RESULTS

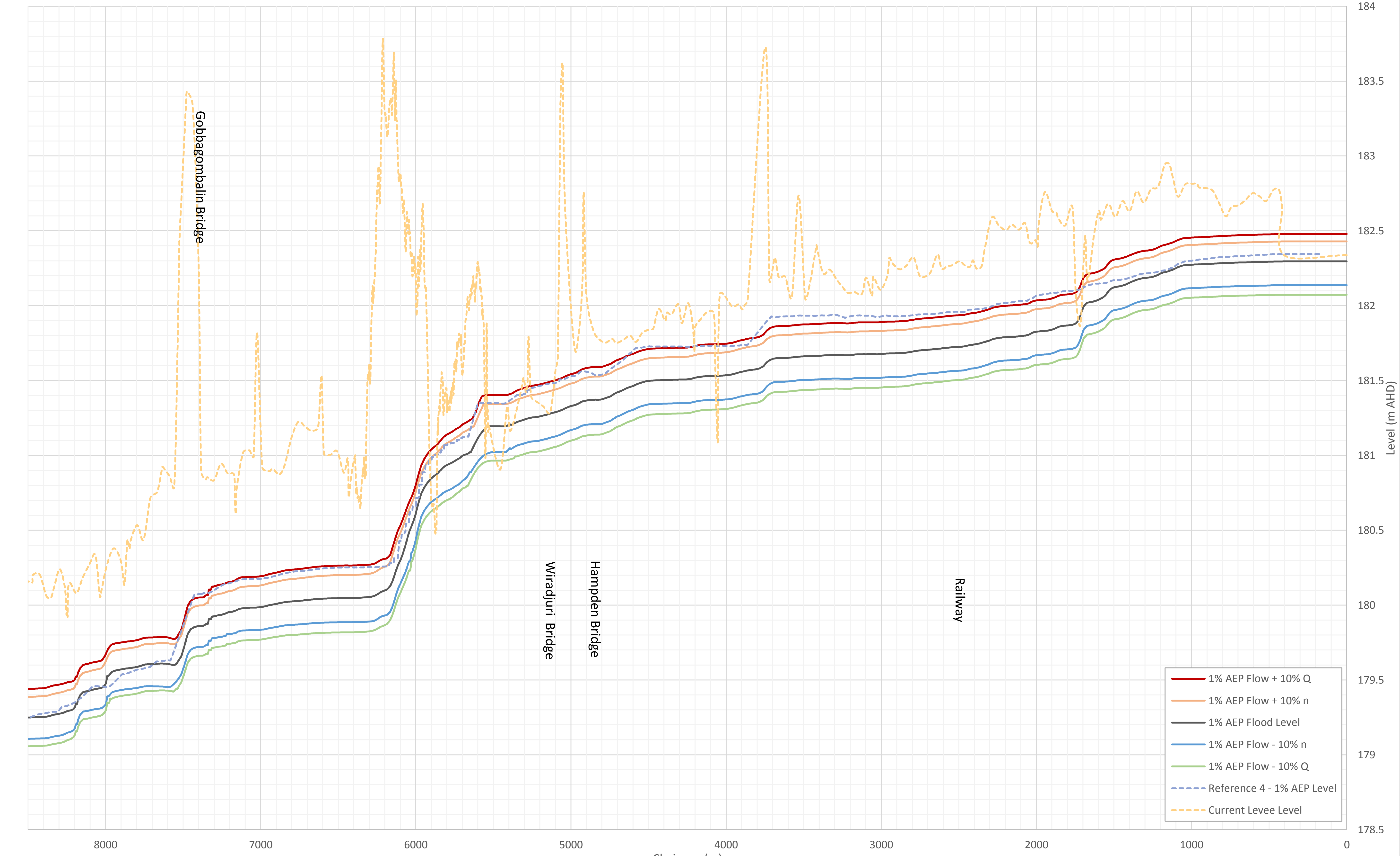

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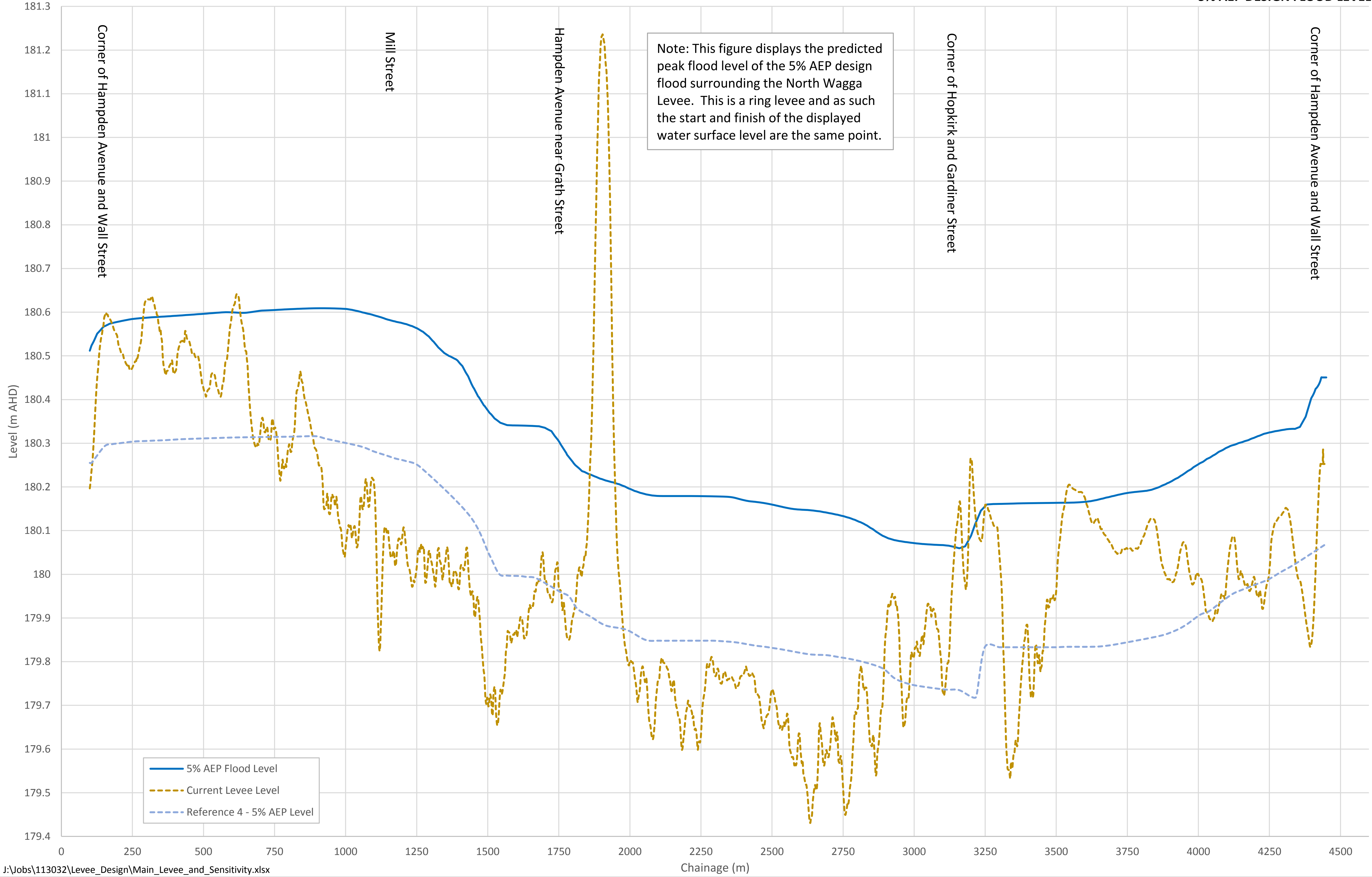
FIGURE 24

NORTH WAGGA LEVEE ALIGNMENT

5% AEP DESIGN FLOOD LEVEL



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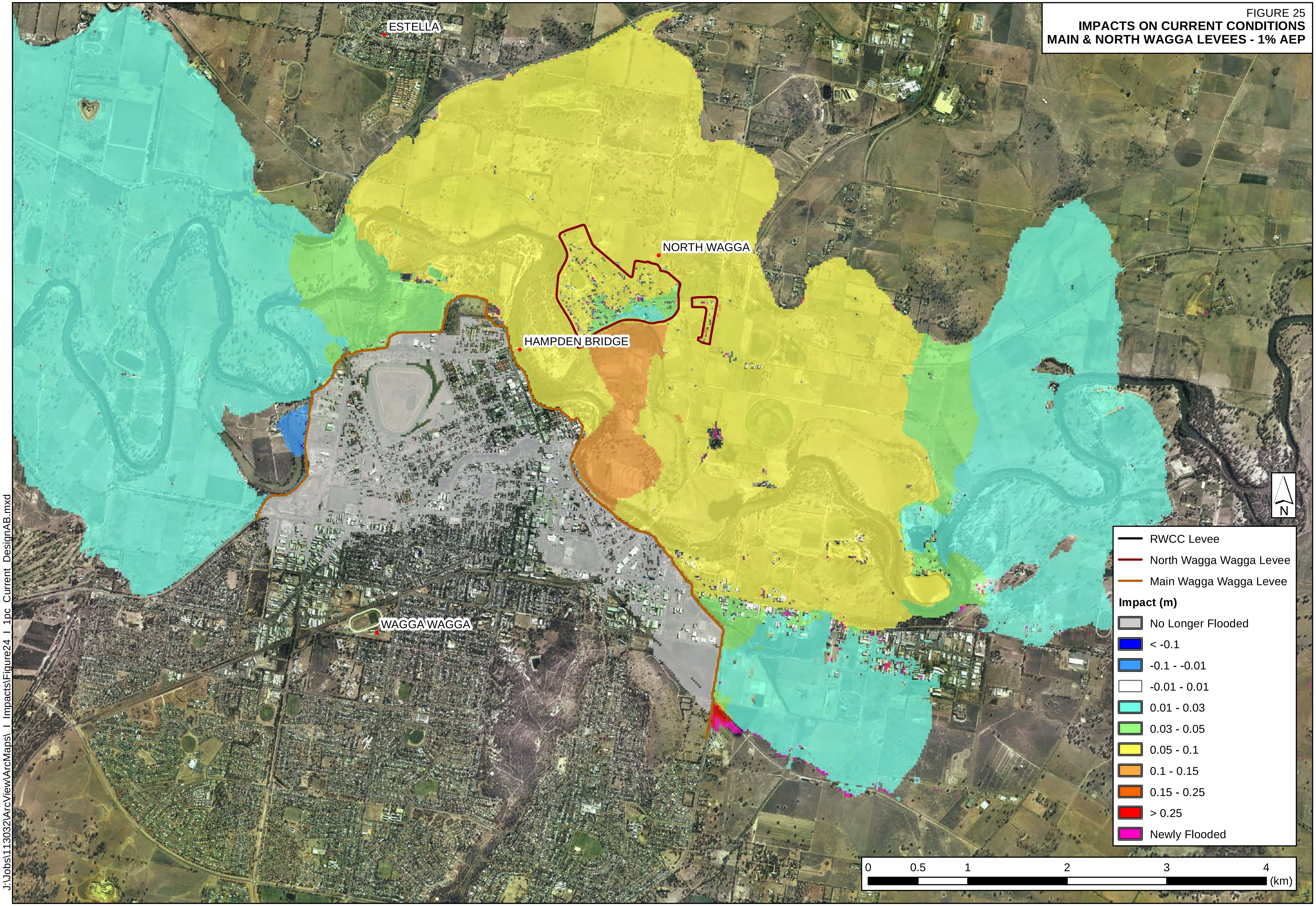

FIGURE 25
IMPACTS ON CURRENT CONDITIONS
MAIN & NORTH WAGGA LEVEES - 1% AEP

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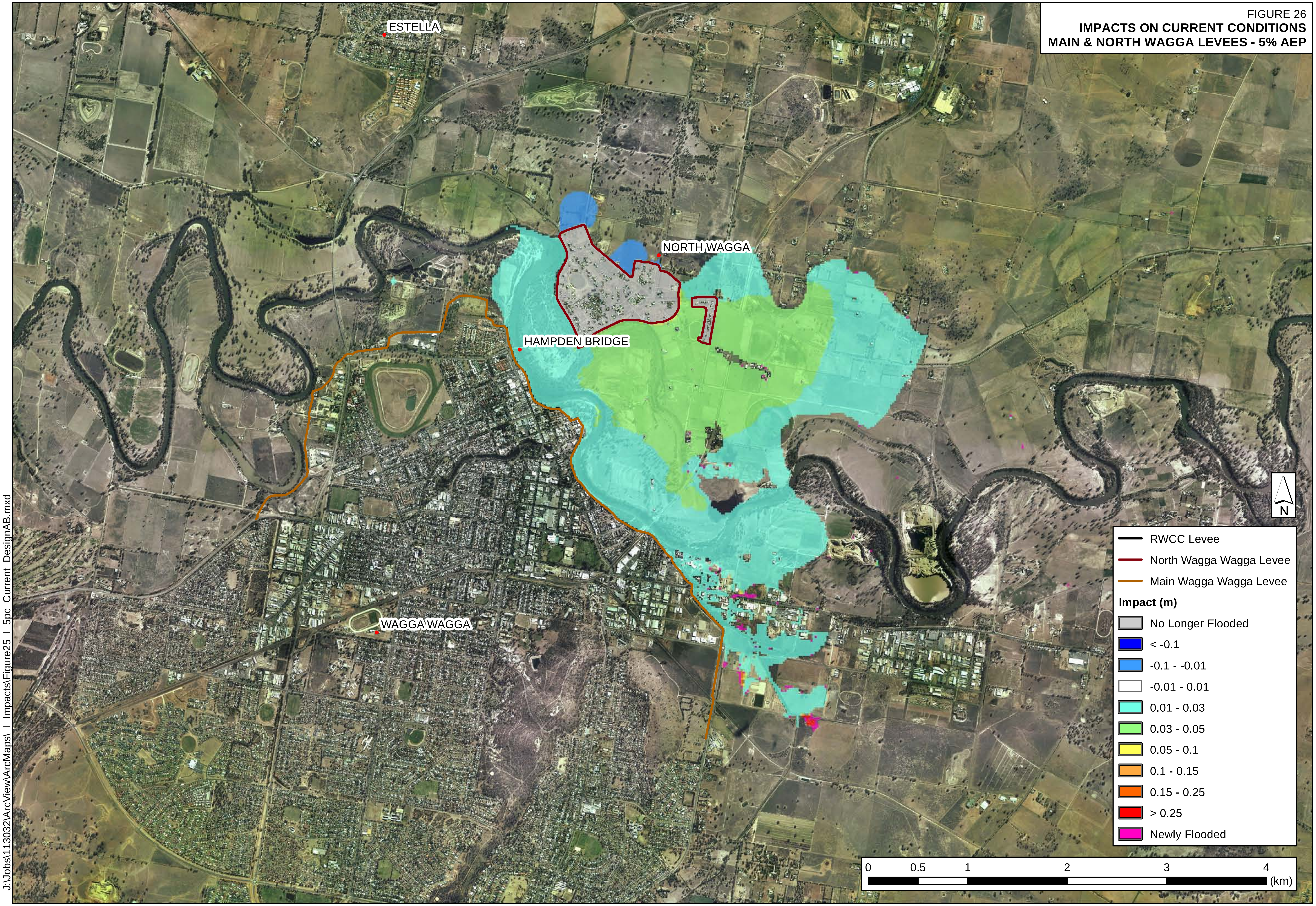

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Appendix A

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils — Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.

Annual Exceedance Probability (AEP) — The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).

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

Average Annual Damage (AAD) — Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.

Average Recurrence Interval (ARI) — The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

caravan and moveable home parks — Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.

catchment — The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

consent authority — The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.

development — Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act).

infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.

new development: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

disaster plan (DISPLAN) A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

discharge The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

ecologically sustainable development (ESD) Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.

effective warning time The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

emergency management A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

flash flooding Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

flood Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

flood awareness Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

flood education Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

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

flood liable land Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).

flood mitigation standard — The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.

floodplain — Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.

floodplain risk management options — The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.

floodplain risk management plan — A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

flood plan (local) — A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.

flood planning area — The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the ‘flood liable land’ concept in the 1986 Manual.

Flood Planning Levels (FPLs) — FPL’s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the ‘standard flood event’ in the 1986 manual.

flood proofing — A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.

flood prone land — Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.

flood readiness — Flood readiness is an ability to react within the effective warning time.

flood risk — Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.

existing flood risk: the risk a community is exposed to as a result of its location on the floodplain.

future flood risk: the risk a community may be exposed to as a result of new development on the floodplain.

continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

flood storage areas — Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.

freeboard Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

habitable room **in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.

in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

hazard A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.

hydraulics Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

hydrology Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

local overland flooding Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

local drainage Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

mainstream flooding Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These

conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical/computer models — The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach — The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding — Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures — Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge — The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) — The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP) The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability A statistical measure of the expected chance of flooding (see AEP).

risk Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

runoff The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

stage Equivalent to ■water level•. Both are measured with reference to a specified datum.

stage hydrograph A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.

survey plan A plan prepared by a registered surveyor.

water surface profile A graph showing the flood stage at any given location along a watercourse at a particular time.

wind fetch The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

Hydrographic & Cadastral Survey Pty Ltd
A.B.N 90 116 658 416

PO Box 171, Figtree, NSW 2525.
Web: *www.hcsurvey.com.au*
Email: *survey@hcsurvey.com.au*

Phone: 1300 796 956 Mob: 0431 209 080 Fax: (02) 4227 2407

1303/2013

03 June 2013

Mr Steve Gray
Level 2
160 Clarence St
Sydney
NSW 2000

HCS116 – REQUEST FOR QUOTATION HYROGRAPHIC AND LAND SURVEY, MURRUMBIDGEE RIVER, WAGGA WAGGA, NSW

Dear Mr Gray,

1. Thank you for the opportunity to provide pricing for the conduct of a hydrographic and land survey at the subject location.

Your investment (**inclusive of GST**) is detailed below:

a. Conduct hydrographic single beam echo sounder survey for general bathymetry of Murrumbidgee River as per survey brief L130513. [redacted]

b. Land survey (*Five of the specified 15 hydrographic cross-sections will require a land component of survey which will be compared by WMAwater, to floodplain data obtained by ALS. In each case (i.e. for the five cross-sections) the land based part of the cross-section will extend at most 200 m from either bank.*) [redacted]

c. Office processing in addition to initial requirements $[redacted]

Notes:

i. Land survey – Locations unknown. Left and right bank to consider different access arrangements.
ii. Land survey – Agree on location of sections as soon as possible to allow surveyors time to establish land owners consent of access.
iii. Echo sounder validation – several means of validation may be utilised depending upon water depth and river conditions: Lead line, secchi disc, measured pole.
iv. Limitations to echo sounder proximity to left and right of bank are may occur and is dependent upon water depth, overhead vegetation and submerged hazards.

2. **Hydrographic Certification.** You may confirm certification currency at the following internet link: http://www.sssi.org.au/details/commission/4/cat/425.html

3. **Payment Terms.** Our payment terms are as per Annex A.

4. **Acceptance of Quotation**. Acceptance of this quotation constitutes acceptance of stated conditions and payment terms.

5. To accept this quotation and engage the services of Hydrographic & Cadastral Survey Pty Ltd please complete Annex A and return via email.

6. Hydrographic & Cadastral Survey hope that you find this information suitable for your requirements. Should you have any queries please do not hesitate to contact the undersigned.

Yours sincerely,

Richard Cullen
Surveying & Spatial Science Institute Certified Professional - Hydrography (Level 1)

Annex:
A. Agreement to Engage the Services of Hydrographic & Cadastral Survey Pty Ltd

ANNEX A TO
1303/2013
DATED 03 Jun 13

AGREEMENT TO ENGAGE THE SERVICES OF HYDROGRAPHIC & CADASTRAL SURVEY PTY LTD

Project Number: HCS116

Client: (Block Letters Please)	WMAwater – Steve Gray
Postal Address:	**Level 2, 160 Clarence St**
	Sydney, NSW 2000
Phone:	**02 9299 2855** **Mobile:** 0413 631 447
Fax:	**Email:** gray@wmawater.com.au
Preferred Method of Contact:	☑ Phone ☑ Mobile ☐ Fax ☑ Email ☐ SMS
Please invoice to:	**WMAwater** Pty Ltd.

Job Address: *Murrumbidgee River, Wagga Wagga, NSW*

Scope of work: Hydrographic and land survey to the specification outlined in quotation and survey brief L130513.

Payment Terms: Payment by cash, cheque or EFT, will be required ***prior*** to delivery of plans and digital files. Our invoice will be sent on completion of the survey. On receipt of full payment, hard copy plans and reports will be forwarded by post and digital files will be forwarded by email.

Investment:

1. Conduct hydrographic single beam echo sounder survey for general bathymetry of Murrumbidgee River as per survey brief L130513. [redacted]

2. Land survey (*Five of the specified 15 hydrographic cross-sections will require a land component of survey which will be compared by WMAwater, to floodplain data obtained by ALS. In each case (i.e. for the five cross-sections) the land based part of the cross-section will extend at most 200 m from either bank.*) [redacted]

3. Office processing in addition to initial requirements [redacted]

Note: All fees include G.S.T.
Quotation valid for 90 days
Hydrographic & Cadastral Survey Pty Ltd

Cancellation Policy:

In the event of a completed agreement being cancelled by the client the client agrees to pay Hydrographic & Cadastral Survey Pty Ltd a fee based on the proportion of the work completed at the time of cancellation. The fee in the event of cancellation would be based on [redacted] per hour of fieldwork and [redacted] per hour of office-based calculations. Plans or documents ordered from government agencies for the purpose of carrying out the survey prior to cancellation will be charged at cost plus 50%. The cancellation fee shall not be more that the total cost quoted above.

Confirmation:

To secure commencement of work as stated in this agreement and associated quotation please complete this agreement, sign below and return in .pdf or .jpg form via email.

I Steve Gray of WMAwater Pty Ltd
(Please use Block Letters)

agree to all terms and conditions outlined above and hereby instruct Hydrographic & Cadastral Survey Pty Ltd to commence the work indicated above and more fully outlined in the supplied quotation dated 03 June 2013.

June 4th – 2013.

(Signed) *(Date)*

Appendix C

APPENDIX C: PRE AND POST DAMS FFA

Exceedance probabilities of the pre and post Burrinjuck Dam events are displayed in Figure C1. The Pre-Dam series contained a total of 71 years (1838 – 1909), 41 of which the peak flood level was known and the rest were assumed to be smaller than the minor flood level (7.3 m, 700 m^3/s). The post dam series was a continuous record composed of 103 years of record (1910 – 2012). It should be noted that the rating used to determine flows has not been changed to account for vegetation variance, only to account for the levees (i.e. as per 2004). It can be seen that the 1% AEP flow estimate for pre-dam conditions is 9,200 m^3/s, 3,100 m^3/s higher than the 6,100 m^3/s estimated for post dam conditions.

However, upon further analysis it was noted that the two data sets are not independent (t-test). The difference between the two calculated probability distributions is not statistically significant and therefore nothing can be said about the variance in probability for pre and post dam design events. Furthermore, a concern with the pre and post FFA analysis is that the flows are estimated by RUBICON from the 2004 study. These flows tend to be exaggerated as the 2004 work did not assume higher levels of roughness for 19th Century events (see Section 4.3.2.1). This then further exaggerate the difference between the pre and post FFA.

Accordingly, the historical event based analysis was used in preference to the pre and post dam FFA to determine the likely impact of upstream dams on design flows at Wagga Wagga (see Section 4.3.2.3).

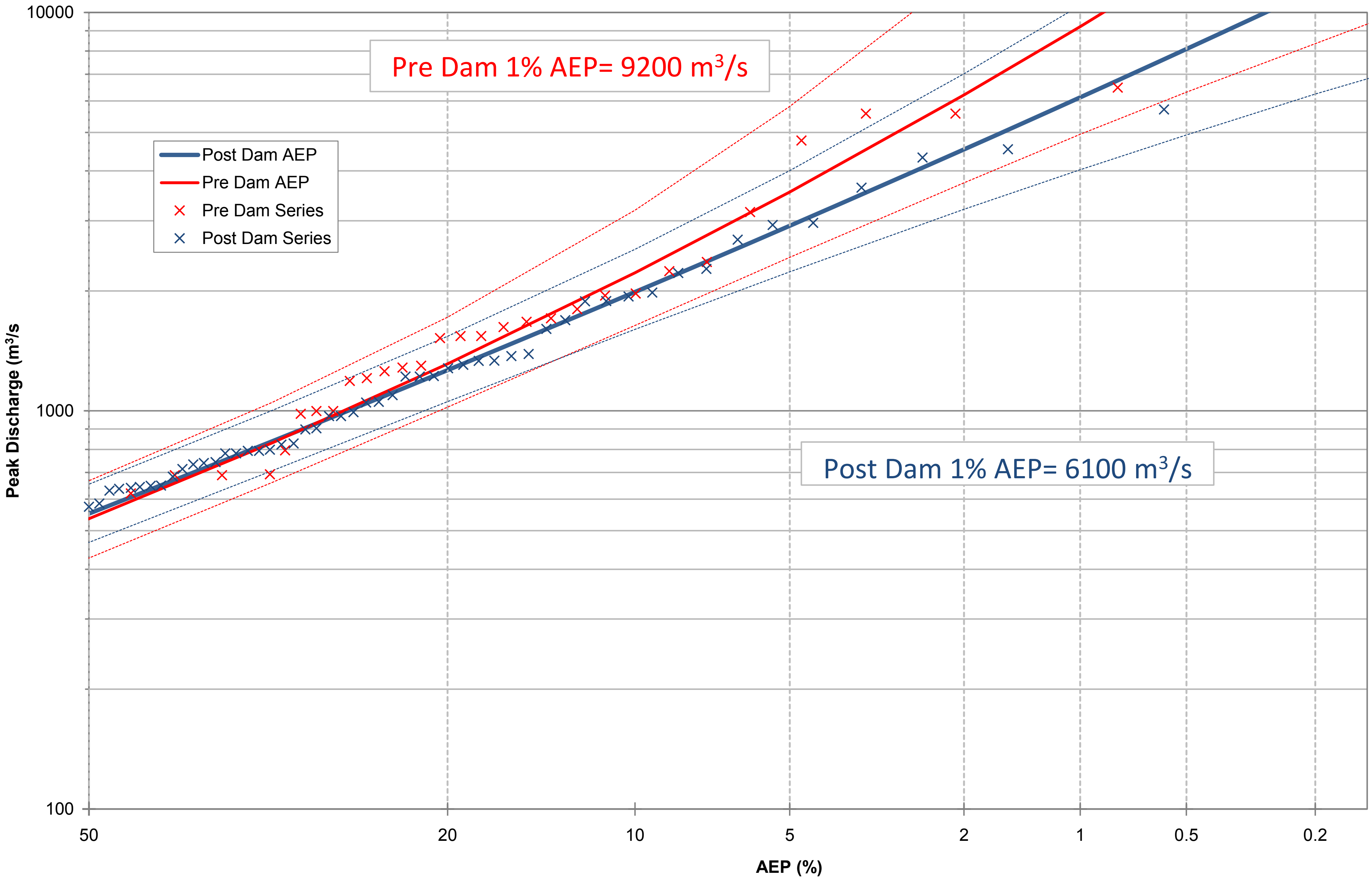


FIGURE C1

WAGGA WAGGA - 2004 STUDY PRE AND POST BURRINJUCK DAM
PRE DAM (1834 - 1909) 41 RECORDED EVENTS AND 35 EVENTS LOWER THAN THE MINOR FLOOD LEVEL (700m³/s)
POST DAM 103 YEARS OF CONTINUOUS RECORD (1910 - 2012)
LP3 ANALYSIS - BAYESIAN

Appendix D

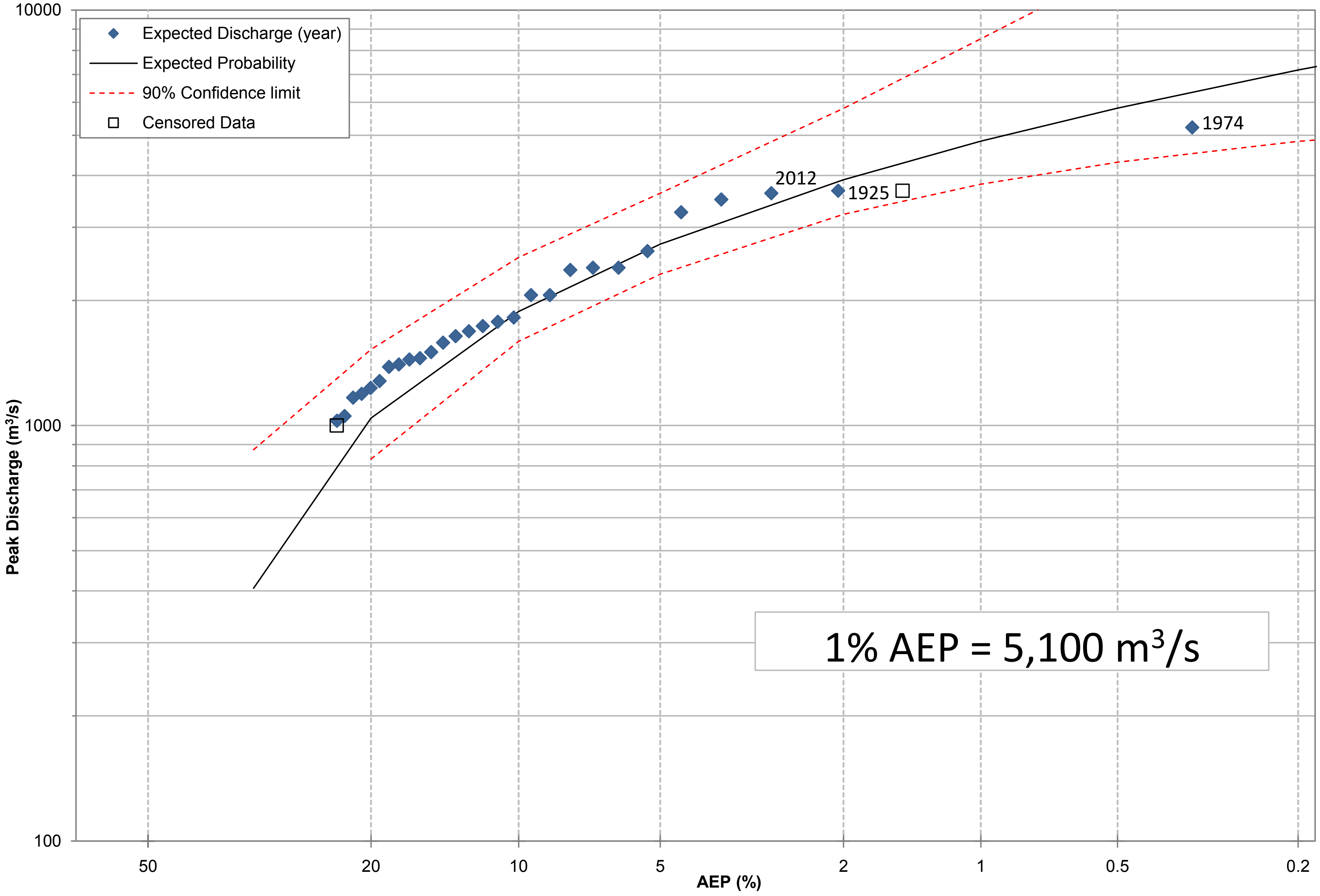


FIGURE D1
WAGGA WAGGA - MODEL DERIVED RATINGS
1853, 1870 EVENTS LARGER THAN THE 1925 EVENT WITH 52 YEARS BELOW THRESHOLD
TRUNCATED SERIES (93 Events < 1000 m³/s)
GEV ANALYSIS - BAYESIAN

Appendix E

FIGURE E1

LEVEE FAILURE LOCATIONS

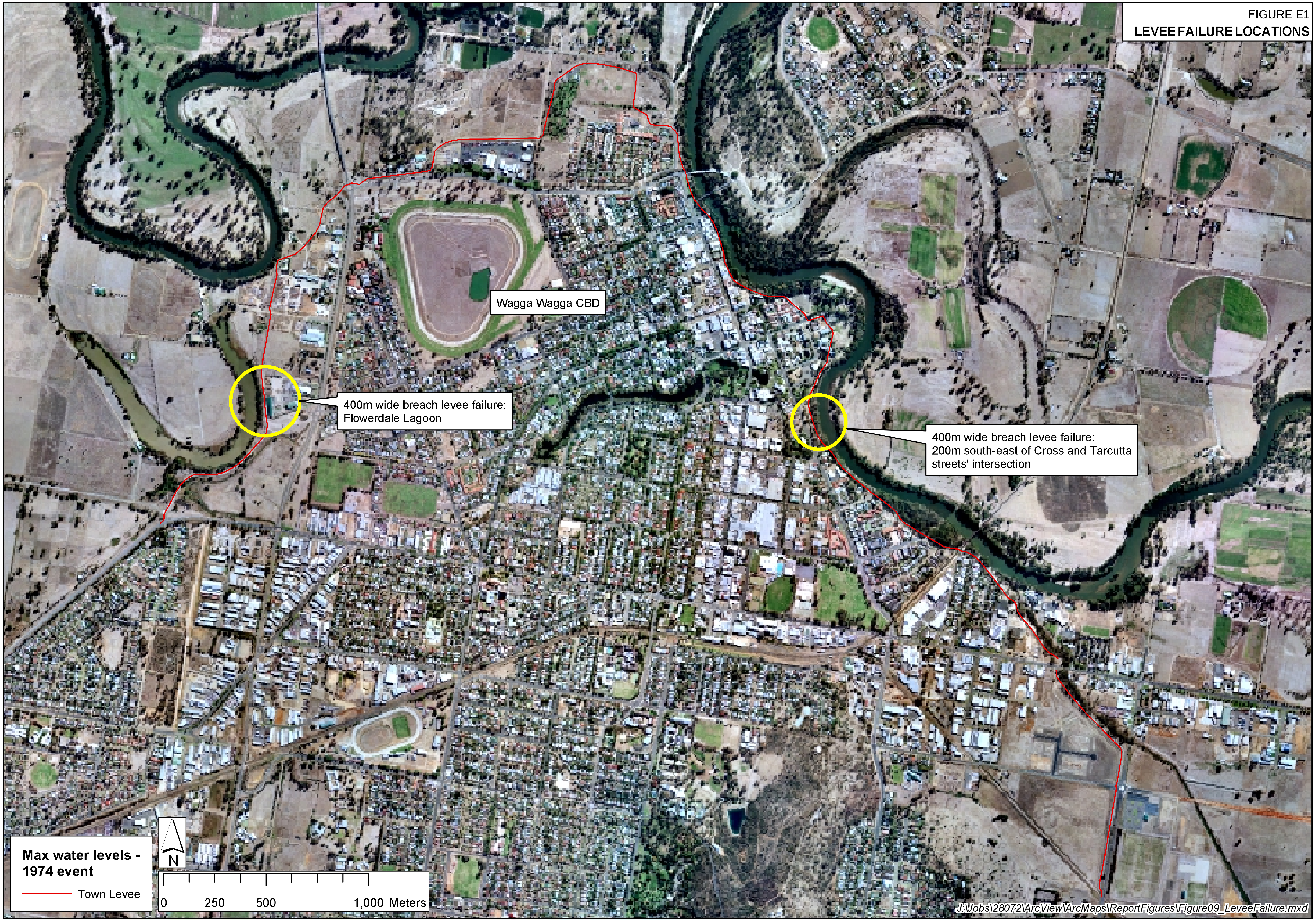


FIGURE E2
LEVEE FAILURE CROSS SECTION

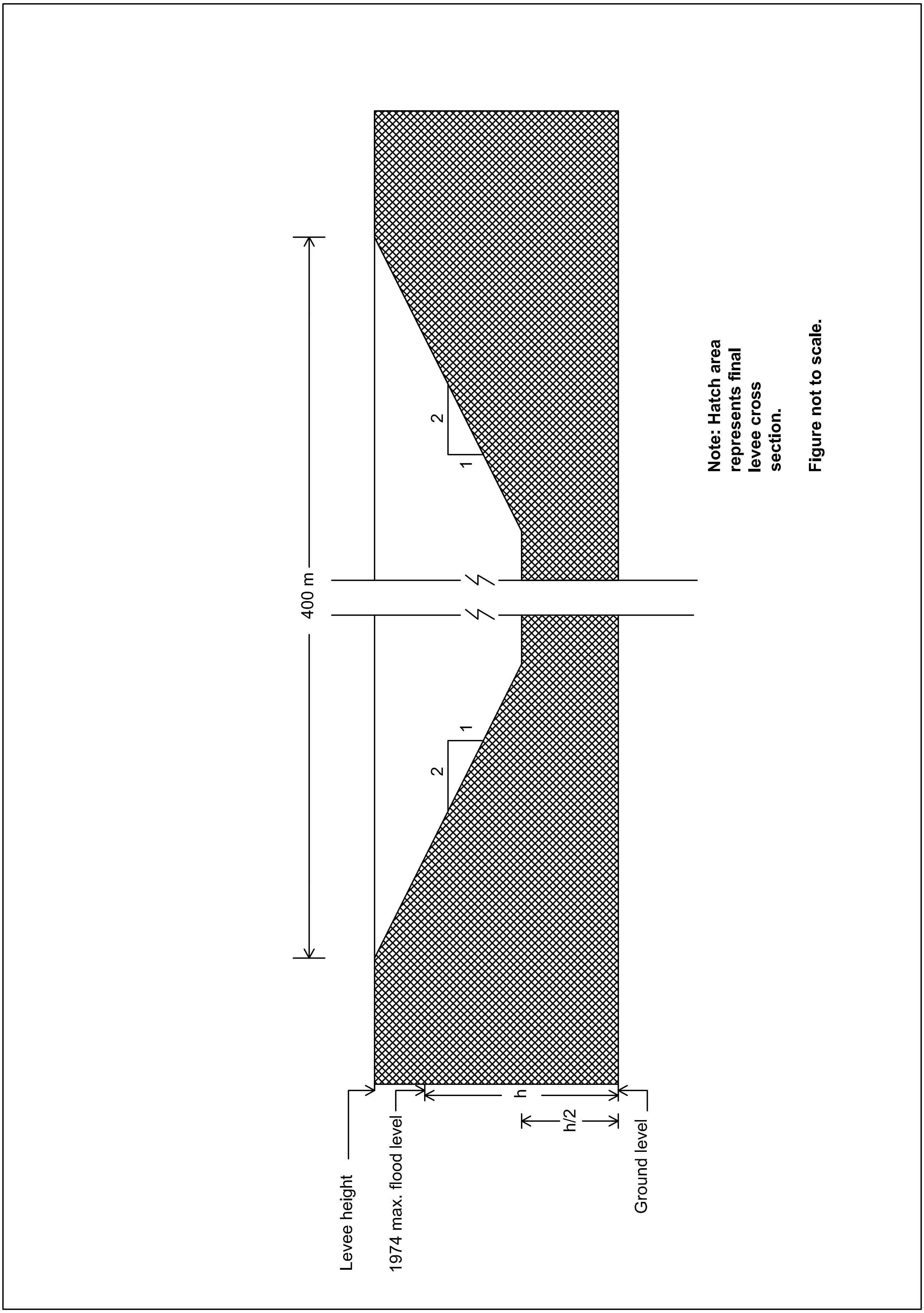
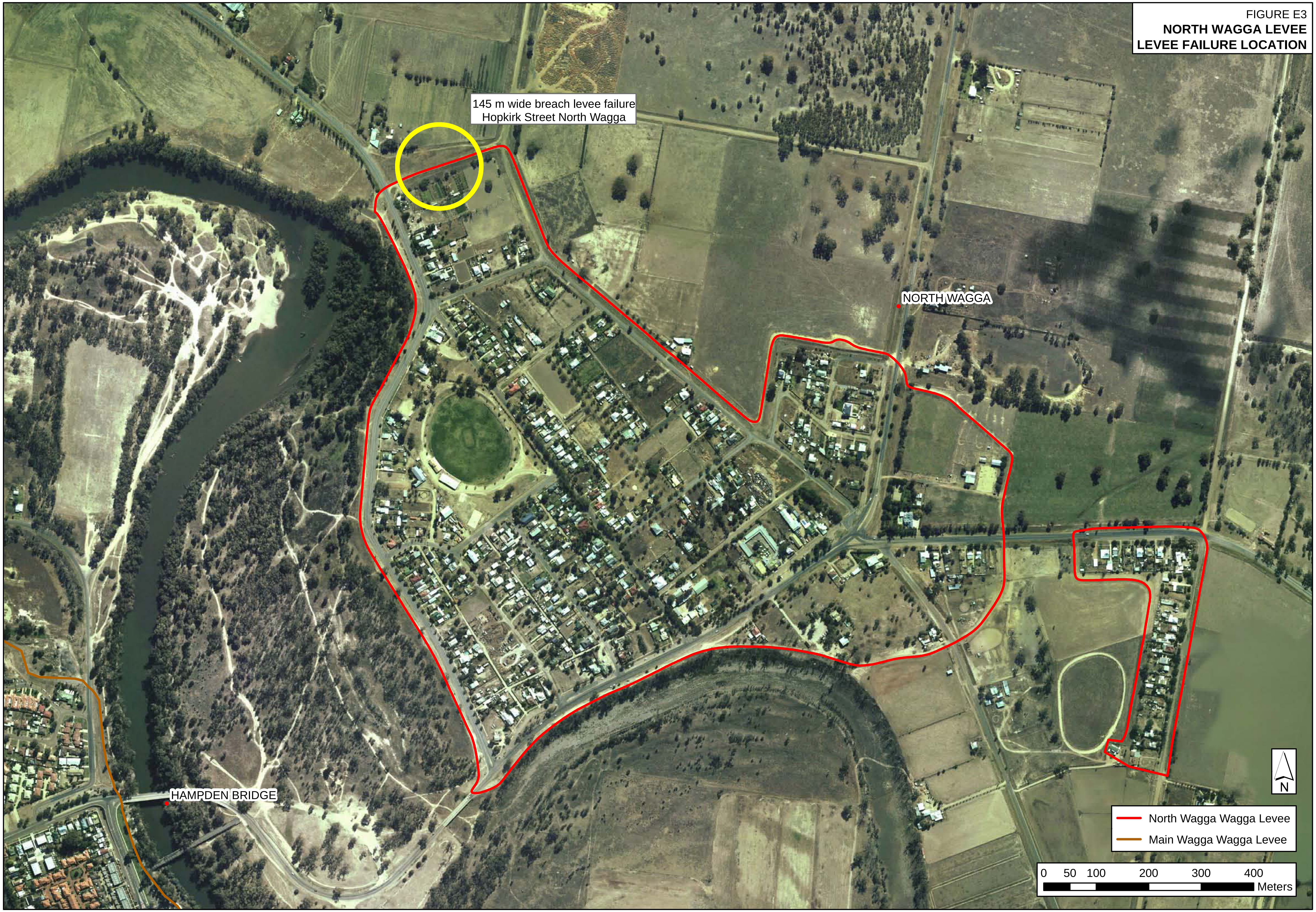


FIGURE E3
NORTH WAGGA LEVEE
LEVEE FAILURE LOCATION



Appendix F

APPENDIX F: PUBLIC EXHIBITION

The Wagga Wagga Detailed Flood Model Revision Draft Final Report was placed on exhibition for 28 days for public comment. As part of the public exhibition process the draft report was promoted via FloodFutures, the community engagement platform for Council's floodplain management activities and projects.

Two public meetings occurred to discuss the outcomes of the updated modelling with the community in North Wagga Wagga (21 May 2014) and Gumly Gumly (28 May 2014). Furthermore, a video of the presentation has been made available on the FloodFutures website.

During the public exhibition period (19 May – 16 June 2014) 1,226 people visited FloodFutures with 228 document downloads and 30 plays of the Revised Flood Model presentation.

The 28 day exhibition period has concluded and Council received three submissions to the report.

WMAwater assisted Council in providing input to the responses to the submissions as per the following table and this advice has been reviewed by the Office of Environment and Heritage who are of the opinion that the responses adequately cover the issues raised in the submissions.

The submissions are also contained in this section, however names have been removed for privacy reasons.

Issue	Response
Submission One	
a. Will study area be expanded from current study area of Oura to Malebo Gap?	Council Officers will assess the need to expand the study area for the updated flood modelling.
b. Can the report show where native vegetation is planned for removal in conjunction with levee upgrade?	The impacts on native vegetation resulting from the levee upgrade project will be assessed in detail as part of the detailed investigation and design phase for the project.
Submission Two	
a. Notes that 2012 levels being relatively higher than 1974 levels may be related to debris.	Council agrees. Certainly some difference between the events is due to blockages that occurred in 2012 due to debris.
b. Notes filling and development in Copland Street area and wonders at impact of this on flood levels.	These impacts have been examined via modelling and are very slight. Increased imperviousness in the Copland Street area is not going to impact on Murrumbidgee River flood levels as Wagga local runoff does not tend to interact with peak River runoff.
c. Concerned that report is setting a path for removal of riparian vegetation. Emphasises that whilst there may be some impact on flood behaviour of riparian vegetation, there are many advantages in other ways.	Council Officers will work together with all stakeholders in developing a management plan for the control of vegetation on the floodplain that balances biodiversity with the flow of floodwaters.
Submission Three	
a. Page 1, Para 2. "…substantial modelling errors that have produced misleading interpretations of the final results."	The letter raises several issues which are discussed below. None of the issues undermine the levels produced by the report for the Main City and North Wagga levees.
b. Page 2, Para 1. Issue of 1974 event and a drainage ditch to east of North Wagga are discussed	The fit issue with the 1974 modelling was widespread not localised. The drainage ditch mentioned is a localised feature which was well under water at the flood peak and would have had little to no impact on flood behaviour at the peak.

Issue	Response
c. Page 2, Para 2. Respondent unable to test veracity of report conclusions re: cross-sections and changing River shape	The report states that there is not enough data to decide one way or another if bathymetry changes in River are significant. Certainly available evidence (11 cross-sections, see Figure 5 - 8) does indicate little has changed in River shape for ~ 12 years (since RTA survey). Note WMAwater do have the location of RTA survey cross-sections.
d. Page 2, Para 3 – Removal and replacement of Railway Bridge	Minor change and highly localised. Overall a trivial impact on overall flood behaviour as there is little to no interaction with the deck
e. Page 2, Para 4. Movement (translocation) of sand as a result of flood events in 2010 and 2012 and impacts on bathymetry and hence modelling work (including roughness estimation).	Highly probable some change occurred or some sand was moved around in events. Impact likely to be quite small. 15,000 m^3 of material for example is very little in context of flow volume moving down the river of ~ 3,000 GL or 3 x $10e^9$ m^3 of water
f. Page 3, Para 2 and 3 (refers Page 18, Section 3.3). Discrepancy between Table 5 and Page 18, Section 3.3 final paragraph. 'n' is a qualitative value.	WMAwater have not been able to find a discrepancy between Section 3.3 and Table 5. Mannings 'n' roughness is estimated and then calibrated. Selecting the right 'n' value can be a subjective process. Selection of 'n' is strongly based on Engineer experience, calibration and by reference to texts such as Chow 1959.
g. Page 3, Para 4 (refers Page 19, 4th para, 2nd sentence). Suggestion that roughness values observed after 2012 event are not indicative or pre-event roughness values.	Roughness values indicate density of vegetation, which generally would not have changed significantly pre/post event. The match between post event vegetation density and pre-event vegetation density is good enough that any discrepancy is a minor issue. Also note that photos used to inform roughness (starting point) and that values may be adjusted based on model calibration/validation work.

Issue	Response
h. Page 3, Para 5 and 6 (refers Pages 19-21). Major errors in landuse map used in modelling work (comparing aerials Fig 9 and 10 to Figures 11 and 12). Also Willows along the River have been removed and roughness values don't reflect this.	Land use mapping is approximate only. WMAwater are confident that in aggregate the land use map is at a suitable resolution in order to define required design flood levels to inform the levee design work. In regard to removal of Willows etc. again it may be that the respondent seeks a level of detail in the modelling work that is not appropriate to the model work goal/project scope.
i. Page 3, last para. Approximate nature of observations of Wagga floodplain vegetation.	WMAwater agree, however indicatively it appeared that broad trends could be described with regard to clearing work between the time of white settlement and now. Also we agree that indications are that at the time of white settlement the Wagga floodplain was not uniform but had open treeless areas as well as treed areas.
j. Page 4, Para 2 (refers to Page 27, 4th Para). Was East St included in modelling?	Yes
k. Page 4, comments under "CH6. Hydraulic Model Results"	Comments noted.
l. Page 4, comments under "Executive Summary". No justification for saying vegetation had an impact on flood levels. Others are comment.	Disagree re: impact of vegetation. There is perhaps a lack of data to rule out bathymetry changes but overall the aerial pictures and comparison plus the models known sensitivity to such changes (that is we know vegetation increases lead to roughness increases and we know roughness increases make a River less efficient) make conclusions strong. To some degree perhaps the respondent does not appreciate that other mechanisms suggested for 1974 event mismatches are not adequate to explain the widespread discrepancies and that vegetation is main cause.

Submission 1

16 June 2014

The General Manager
Wagga Wagga City Council
P.O Box 20, Wagga Wagga, NSW 2650

Dear Sir,

Re: Revised Detailed Flood Modelling on Exhibition

Thank you for the opportunity to provide comment on the Revised Detailed Flood Modelling report dated March 2014.

would like to make the following general comments:

1. It appears that the report only looks at the river corridor from Oura to Malebo Gap. Is there future scope to look at surrounding impacting catchments as well?
2. The report does not identify exactly where the increases to the Wagga Wagga levee bank will be required. A detailed report showing the areas where native vegetation is planned to be removed to maintain and increase the levee bank would be beneficial in providing detailed comments.

Native Vegetation Removal

Please be aware that clearing of native vegetation may require assessment and approval as required under the Native Vegetation Act 2003 and Native Vegetation Regulations 2013. Please contac or emai for further advice regarding native vegetation clearing approval.

Please do not hesitate to contac should you wish to discuss these comments or to arrange a meeting regarding how Riverina LLS may be able to assist.

Submission 2

The General Manager
Wagga Wagga Cit Council
PO Box 20

Dear Sir

Re: Comments on the Wagga Wagga Detailed Flood Model Revision

I have read the *Wagga Wagga Detailed Flood Model Revision* report and wish to comment on the report. I understand that the present review was in response to a significant flood event in 2012. As the levee banks are in need of repair, it is a timely review to assess the adequacy of the levee banks for future significant flood events.

My understanding of the main concern expressed in the report was the elevated height of the flood in 2012 compared to the expected level based on historic events, especially the 1974 flood. The conclusion of the study as that the water was being obstructed in some manner. Through modelling the increased height was suggested to be due to increased roughness on the floodplain. This roughness was attributed to increased vegetation on the floodplain since 1974. However, the report said that the 1974 flood waters came mainly from Burrinjuck dam, not the tributaries and had very little debris. This differed from the 2012 flood which had a large amount of debris with major inputs from the local tributaries like Tarcutta and Kyeamba Creeks. Both of these factors may have contributed to the higher than expected levels in the 2012 flood.

Page 17 of the report states that flood behaviour can change due to changes in the river and/or floodplain. The report indicates that changes have occurred on the floodplain around Wagga Wagga such as levee banks and increased road height (Sturt Highway), but nothing was started about the increase building development on the floodplain, notably along Copeland Street. This area has had large amounts of fill dumped there to elevate it above flood level as historically it flooded during floods at Wagga Wagga. Surely moving the amount of water that use to flow onto this area back toward the river and levee banks would have some influence on the flood height. Additionally there is more water running off the Copeland Street area from the large expanses of hard surfaces now present (buildings, driveways, parking areas and roads). There are also developments of other large areas of hard surfaces since 1974. These are found in new residential areas surrounding urban Wagga Wagga.

The report concluded after modelling river and floodplain profiles over time with flood events that increased riparian vegetation since 1974 (roughness) was the main contributor to the elevated 2012 flood height. This alarms me especially in the context of a past report that suggested having a 300m wide cleared “maintenance zone”. Natural systems are very unpredictable and highly variable therefore models should be used only as a guide in decision making. There is no comment on the importance of riparian vegetation, which I realise was not part of the brief. Riparian vegetation plays an important role in stabilising riverbanks and floodplains. Riparian vegetation is regard internationally as important in controlling erosion along rivers and creeks. China has started an extensive revegetating program to reduce the probability of massive landslides like those they had in 2012. Wetlands are being reinstated along the Mississippi River in the USA as a way of controlling erosion in floods. A local example is the need to rock wall the riverbank near the Tourist Information Centre because of the eroding banks that have been destabilised from lack of riparian vegetation. To be effective riparian vegetation has to be more than one strip of trees because water wets river bank soil several meters from the water's edge.

Big roots from mature riparian native trees are also valuable habitat for native fauna. Research has shown that platypuses are more abundant in areas with mature native trees that have large tree roots deep in river banks. These roots provide stable areas to make their burrows in. Native fish also use large tree roots in water for shelter and feeding amongst. These are but a few of the benefits for retaining riparian vegetation along the Murrumbidgee floodplain. The present analysis should be seen as only one part of the picture to consider before any drastic action is taken to reduce the roughness of the floodplain by removing trees.

Yours Sincerely

Submission 3

The General Manager
Wagga Wagga City Council
P.O. Box 20
Wagga Wagga NSW 2650

Dear Mr Pinyon,

Submission: Wagga Wagga Detailed Flood Model Revision – March 2014

I am a rate payer to Wagga Wagga City Council and have a keen interest in the welfare of the city residents.

I have carefully read the above flood study prepared by WMA Water which is currently on public exhibition. Although the report sounds good there are some substantial modelling errors that have produced misleading interpretations of the final results. Accordingly I have outlined these errors in my attached submission on this flood report.

Should Council staff wish to discuss my comments further then I can be contacted at the above address or by telephone on

Yours sincerely,

Submission on:

Wagga Wagga Detailed Flood Model Revision

Prepared by WMAWater – March 2014

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Ch. 2. Available Data

Page 9, Table 2. There is an interesting story relating to the gauge height of the 1974 flood. As the flood was developing the engineer in charge of the flood management had observers stationed at different places along the river to Gundagai and also at various points on the Tarcutta and Kyeamba Creeks. These observers were stationed at established sites that had been used in previous flood events. At frequent intervals these observers telephoned to the engineer in Wagga the flood heights at their respective observation points. From these observations the engineer was calculating the expected river height at the gauge in Wagga. However, the flood peak of 10.741m was about 1ft (0.3m) higher than the expected height from the observations. When the flood waters had receded the engineer wanted to know the reason for the flood being higher than anticipated. The cause was attributed to a long drainage ditch east of North Wagga that directed water towards the main levee rather than allowing water to follow its natural path to the north of North Wagga. This observation may contribute to the problems of fitting the model to the 1974 flood height (see Section 2.4.1.2, Page 12).

Ch. 3. Change in Stage/Discharge Relationship at Wagga

Page 17, Section 3.2, 1st Paragraph. The locations of the cross sections obtained from the RTA survey are not stated in the document nor shown in any Figure in this report. Without this information it is impossible to judge the veracity of these conclusions.

Page 17, Last Paragraph. In 2007 the railway bridge was replaced by the current structure. The removal of the old bridge and its piers and the construction of the new bridge probably altered the river cross section and thalweg at this location.

Page 18, 4th Paragraph. Relevant to this section are the facts that during the 2010 and 2012 floods large volumes of sand were translocated through the river channel. For example, after the 2010 an extremely large quantity of sand was deposited in the channel between "the rocks" and the railway bridge. A visual assessment of this reach suggests that during the 2012 flood perhaps 10,000m^3 to 15,000m^3 of sand from this reach had been shifted downstream. This translocation of sand could generate a dynamic blockage with consequential impacts on the gauged river heights and in-channel flows through the urban area. These impacts would not necessarily be detected at the ADCP gauging site upstream of Gobbagombalin Bridge (Image 1). Potentially this sand translocation could distort the roughness values assigned to the deep channel area and to the channel banks (Table 7).

Page 18, Section 3.3. The roughness values for the Murrumbidgee River shown the final paragraph do not resemble the roughness values shown in Table 5, page 21. For example, the roughness value for vegetation, n4=0.025-0.05 (mid value) but in Table 5 vegetation is assigned a value of 0.1. The authors do not explain this discrepancy or the other discrepancies shown in Table 5.

It is noted that the formula for the "*n*" is aggregated from the addition of different elements. In turn, these elements are subjectively ranked against qualitative assessments. The resultant value of "*n*" is a qualitative value.

Page 19, 4th Paragraph, 2nd Sentence. The significance of this sentence is that the photographs and assessment of "*n*" values for the channel banks were taken **after** the flood event which is the subject of this modelling study. Consequently, the roughness values obtained are not measures of the roughness at the time the flood started. Therefore the roughness values used in this modelling study may have little relevance to the roughness that was operative during the flood event. The conclusion is that no element in the modelling study can be identified as having a greater impact on the flood behaviour than any other element considered in the modelling.

Pages 19 – 21. When one examines the aerial images shown in Figures 9 and 10, it is apparent that there are some major errors in the land use and roughness maps shown in Figures 11 and 12. Examples are evident in the areas of Medium Density Trees where there has been little change in tree density between 1971 and 2012 but the 2012 map shows that a change has occurred.

Related to the preceding comment is the fact that between 2006 and 2011 there was extensive clearing of willows along the banks of the Murrumbidgee River through the urban area. The total area cleared was 17ha along 6.5km of river bank and included Orange Tree Reserve. Most of the willows cleared were beside the water's edge or even fallen into the river. It would be difficult to ascertain the impact of these removed willows on the roughness value assigned to the riparian vegetation in the flood modelling, particularly when working from aerial photographs as stated on page 20. However, an independent hydrologist, who has seen this willow removal work, has commented that the roughness value for the riparian vegetation through these river reaches should be about 0.03 and not 0.1 as shown in Table 5.

Ch. 4. Hydrology

Page 26, 3rd Paragraph. When giving citations and quotations to early European descriptions of the vegetation it is essential to recognise that these are qualitative descriptions and not objective data. I do not know of any data from which one can estimate tree density in the Wagga Wagga region during the nineteenth century. I know of contracts written for tree clearing in the late 1800s at sites that can be identified on modern maps. Even though these contracts have all the details of the clearing process and the payment method there are no details of the tree densities. There is much circumstantial evidence that suggests that the tree cover was not uniform in density at the time of European settlement and there were more open grassy areas, even along the river, than is indicated by subjective descriptions.

Page 27, 4th Paragraph. The report does not mention whether or not the impact of the levee around East Street was included in these runs of the model. The levee around East Street is more or less perpendicular to the flow of flood waters and I would expect that this levee would have a substantial impact of flood water levels.

Ch. 6. Hydraulic Model Results

Page 39, Section 6.2. To aid clarity to the report this heading needs to include the words: **— December 2010 Flood**. Without this qualifying phrase it is difficult for a reader to understand the context of the entire section.

Page 45, Section 6.4.6. The results discussed in this section are potentially confounded by the effects of the drainage ditch referred to in comments above regarding Table 2.

Page 47, Section 6.7. The levee around East Street is not mentioned in this section.

Page 48, Section 6.10.1, 1st Paragraph. The information in this paragraph should be added to the **Executive Summary** on page ix to add clarity to the interpretation of the model's accuracy.

Executive Summary

Page viii, 1st Paragraph, 6th Line. Correct 1970 to 1870.

2nd Paragraph, 1st Sentence. Given the errors noted above with regard to the assessments of roughness values and the errors in the mapped land use changes (Figure 12), especially for vegetation, there is no justification to support the statement that vegetation had a measureable impact on flood levels in Wagga.

Page ix, 8th paragraph. These summary results need to be qualified by the appropriate AEP level, i.e. 1% or 5%. Also, it is significant to note that the flow rate has a greater impact on flood peak height than the impact from roughness.

It would be of interest to readers to know the effects on flood peak of the interactions of flow and roughness, i.e. 10% flow increase **and** 10% roughness decrease; 10% flow decrease **and** 10% roughness increase; and the impacts when both factors are increased by 10% and both are decreased by 10%.

In conclusion I consider that the errors in the model associated with roughness values and land use changes render the model outcomes inaccurate with regard to the relative importance of flood plain elements to the observed flood peak heights. The model results are inadequate to draw conclusions with regard to the relative impacts from physical elements on the flood plain.