Mungindi Rural Hotspot Flood Investigation

October 2013

Prepared for NSW Office of Environment & Heritage

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For and on behalf of
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CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Purpose and Intent

Water Technology has been commissioned by the NSW Government Office of Environment & Heritage (NSW OEH) to prepare a 2D Tuflow hydraulic model for the township of Mungindi.

The brief for the study was provided as part of the request for *"quotation for low risk services form for Agreement No: OEH-442-2013 Mungindi Rural Hotspot Investigation"* dated April 2013.

The brief outlined that the objectives of the investigation are to:

- Convert and upgrade the existing Sobek model to Mike Flood (2012) model (subsequently requested by NSW OEH to be changed to a Tuflow model).
- Check calibration for the 1976 & 1996 flood events,
- Ensure that the model is updated to ensure that it is fit for "option modelling" of the adjacent rural levees.

1.2 Study Area

The township of Mungindi is located approximately 500km south-south-west of Brisbane and straddles the Barwon River on the New South Wales and Queensland border. The township has approximately 800 inhabitants and the majority live on the New South Wales side.

Most of the town's residents are protected by two flood levees (one for each side of the river) which were originally constructed over 1977 to 1980 and are designed to withstand flood events up to and exceeding the 100 year ARI Flood event (Lawson and Treloar, 2004). An aerial image of the town showing the Barwon River and town levees is illustrated in Figure 1-1. A view of the northern levee as seen from the Carnarvon Highway is shown in Figure 1-2.

The Barwon River at Mungindi is within the lower part of the Border Rivers Basin and part of an interconnected river network whereby bifurcations and reconnections occur both north (Little Weir River) and south (Boomi River) causing flow around as well as through the centre of the Mungindi township. The catchment area at Mungindi is estimated at 44,100 square kilometres (BoM).

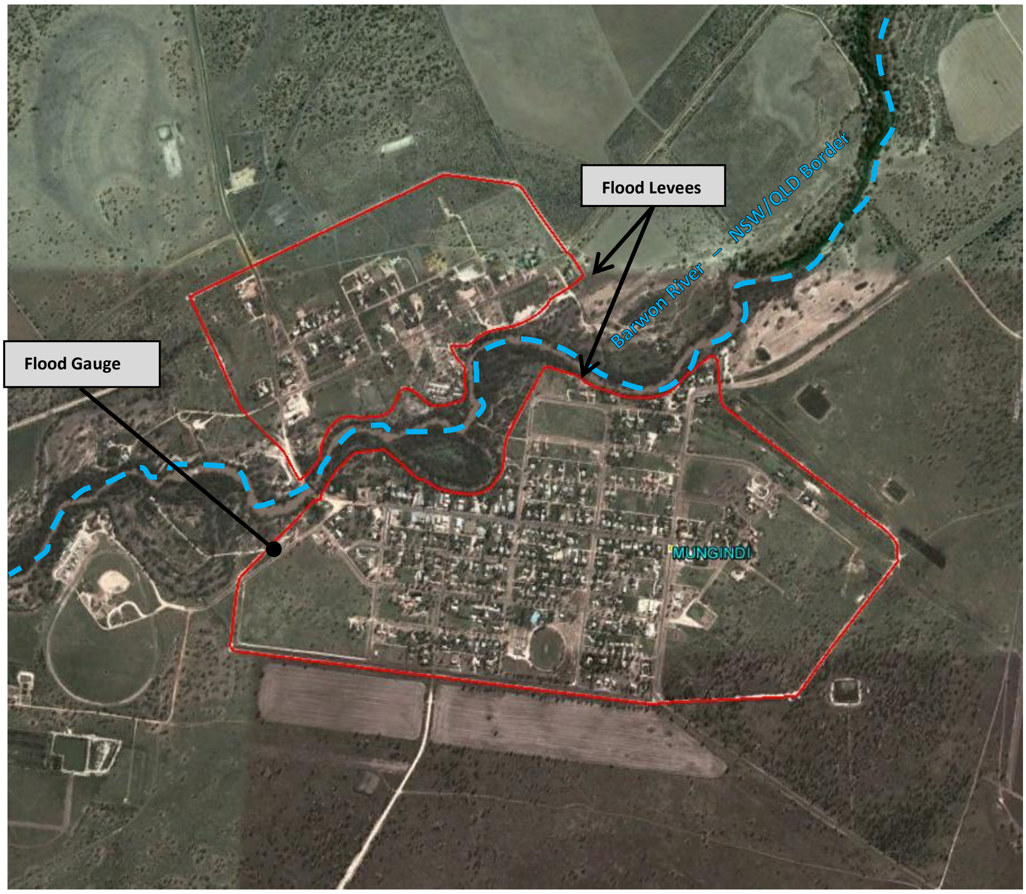

Figure 1-1 Mungindi Townhip and Flood Levee Locations

Figure 1-2 Photo of the levee surrounding the QLD side of Mungindi - View from Carnarvon Hwy (source: Google Earth)

2 STUDY BACKGROUND

2.1 Historical Flood Information

The Barwon River at Mungindi has had a significant history of flooding, with notable events occurring in 1890, 1956, 1976, 1996, 1998, 2011-2012, and 2013. The magnitude of flood events in Mungindi are defined by the level reached at the Mungindi stream gauge (Station Number 416001) located just downstream of the Mungindi Bridge on the Carnavon Highway. It is understood that this gauge was lowered by 0.61m m in 1894 which has caused some confusion with the highest flood on record. WMA (1999) reports that the largest flood on record occurred in 1890 and corrects the previous assumption by L&T (2004) that the event in 1976 was the largest on record. A summary of available flood history is presented in Table 2-1.

Table 2-1 Summary of Available Flood History

Date	Source	Comments / Notes
1890	Book: *Flood Country; An Environmental History of the Murray-Darling Basin*	"…the Mungindi District where of my knowledge, 400,000 sheep drowned within 100 000 miles.." WMA (1999) reports a corrected gauge level of 8.23 m.
February 1956	BoM QLD Flood History	"The repeated flood rains have maintained very high levels in the Balonne and Barwon rivers for the whole month and towns are still isolated."
October 1970	BoM QLD Flood History	"…minor flooding between Goondiwindi and Mungindi."
February 1976	BoM QLD Flood History	"Record flood levels and near record flood levels were recorded in many streams between Warwick and Mungindi." Recorded Gauge level of 7.99 m.
August 1984	BoM QLD Flood History	"Major flooding in the Macintyre River reached a peak at Mungindi on the 10th."
January 1996	Lawson and Treloar (2004)	Recorded gauge level of 160.83 m AHD
September 1998	BoM QLD Flood History	"The Barwon River at Mungindi peaked at major flood level on the 6th. Moderate to major flood levels were maintained in the Kanowna to Mungindi area until the end of the month." Recorded gauge level of 160.86 m AHD (L&T 2004)
February 2013	http://www.abc.net.au/news/2013-02-07/barwon-river-peaks-in-mungindi/4507336	"The Bureau of Meteorology's National Flood Desk has predicted a major flood peak (at Mungindi) of around 7.8 metres."

2.2 Previous Studies and Investigations

This report has drawn upon several reports and investigations which are described further in the following sections.

2.2.1 Flood Study for Mungindi, Lawson & Treloar 2004

A flood study was completed of Mungindi for Moree Plains Shire Council by Lawson and Treloar Pty Ltd in 2004 as part of the NSW Flood Prone Land Policy.

This study extracted historic flood flows from a previous 1D Mike11 Model developed by Lawson & Treloar for the Border Rivers floodplain for hydraulic model calibration purposes. Design flows for the 20%, 10% and 1% AEP flood events were estimated using flood frequency analysis at the Mungindi stream gauge (Station Number 416001). An estimate of the Probable Maximum Precipitation (PMP) event was also modelled as 3 times the 1% AEP flow. This technique was used due to uncertainty created by the limited model extents.

The flood events of January 1996 and September 1998 was used for the hydraulic model calibration purposes however the study also noted that, whilst the February 1976 event was the largest on record, it occurred prior to the Mungindi Levee being constructed around the township and therefore was not used in the calibration.

Peak flows estimated in L&T (2004) are listed in Table 2-2 below:

Table 2-2 Barwon River Peak Discharges Estimated at the Mungindi Stream Gauge (L&T 2004)

Event Type	Flood Event	Peak Discharge (m^3/s)
Historic	1976	1816
	1996	638
	1998	724
Design	20% AEP	191
	10% AEP	307
	1%	1204

The hydraulic analysis utilised a SOBEK 2D model for the Mungindi township and greater floodplain area. The model had an overall grid resolution of 30 m grid with a nested 10 m grid around the township itself. Two topographic cases were prepared, one for the historic events and one for the design events. The latter case incorporated an extension to the township levee and one small farm levee on the Queensland side.

Predicted peak flood levels estimated from the model are provided in Table 2-3.

Table 2-3 Barwon River Peak Levels Estimated at the Mungindi Stream Gauge (L&T 2004)

Event Type	Flood Event	Peak Level (m^3/s)
Historic	1996	161.02
	1998	161.07
Design	20% AEP	160.55
	10% AEP	160.79
	1%	161.45

2.2.2 Mungindi Levee Flood Analysis, Webb, McKeown & Associates Pty Ltd, 2009, prepared for Moree Plains Shire Council

This report was prepared to investigate a sound level of flood protection to the Mungindi township though a rehabilitation of the existing levee system around the southern section of town (within the Moree Plains Shire Council LGA).

The purpose of the flood analysis was to assess the performance of the existing flood level system and identify levee works required to achieve the preferred level of flood protection.

A summary of relevant information from this report is provided below:

- The study undertook a revised Flood Frequency Analysis (FFA) which identified differences to the previous L&T (2004) study due to an apparent gauge lowering in 1894 (i.e. after the 1890 flood). This affected the ranking of floods and determined that the 1890 flood was higher than the 1976 flood which is converse to that reported by L&T.
- It was nominated for the study that the level of flood protection to be provided by any upgraded levee is to be the 1% AEP flood plus 1 m.
- The available data for the study included photogrammetry and some field survey of the area around the Mungindi township. There were discrepancies observed on comparison of this data and additional field survey was required to adjust the photogrammetry data to the available field survey.
- The gauging data shows that the rating at Mungindi overs flows in Little Weir River and Gravelling Creek as well as Barwon River. Some of these areas were outside of the flood model extent and therefore FFA estimates were factored downwards for the model boundary inflows.
- A revised set of historic and design peak flood flows at the gauge were reported and these are listed in Table 2-4. The table also lists the peak modelled discharge which takes into account the modelled width being smaller than the gauge rating curve width. The modelled flows varied from 65 to 75% of the gauge flows. Further explanation is provided in Section 5.3.2.1 of WMA (2009).

Table 2-4 Barwon River Peak Flows Estimated at the Mungindi Stream Gauge (WMA 2009)

Event Type	Flood Event	Peak Discharge (m^3/s)	Peak Modelled Discharge (m^3/s)
Historic	1890	3385	N/A
	1976	2248	1455
	1998	724	530
	1996	638	428
Design	5% AEP	720	525
	2% AEP	1360	910
	1% AEP	2190	1420

- Webb, McKeown & Associates developed a single 10 m grid SOBEK 2D model of a similar study area to that of L&T's previous model and used steady state flow boundary conditions and a rating curve for the downstream boundary.
- Several historic and design model scenarios were run. Historic events included the 1890, 1976, 1996 and 1998 events however there were issues in knowing the extent of levees in 1976 therefore all

town and rural levees were removed for this event. Design events included the %%, 2%, 1%, 2x1% and 3x1% AEP events and scenarios included cases with and without levees and with raised levees.

- A revised set of design peak flood levels at the gauge were reported and these are listed in Table 2-5.

Table 2-5 Barwon River Peak Levels Estimated at the Mungindi Stream Gauge (WMA 2009)

Event Type	Flood Event	Peak Discharge (m^3/s)
Design	5% AEP	160.96
	2% AEP	161.32
	1% AEP	161.72
	0.5% AEP	162.48
	3 x 1% AEP	163.04

- The existing NSW town levee would remain intact during a 1% AEP flood event.
- The 1976 event was recorded at 160.95 m AHD at the town gauge and was estimated to be approximately a 5% AEP.
- The 1996 event was estimated to be of 9% AEP in magnitude.

2.2.3 Floodplain Risk Management Study, Coffey Geotechnics 2012

This study relied upon WMA (2009) therefore only limited additional information was of relevance. This includes:

- The levee was constructed in 1977 and was since flooded in 1996 and 1998 however neither events overtopped the levee or resulted in any instability of the levee or river banks.
- The levee crest varies in elevation from 161.8 m AHD to 162.75 m AHD.
- The height of the levee above the natural floodplain ranges from 1.6 m to 3.5 m. It has been increased since the original construction took place.
- Mungindi has two flood gates which allow water to be drained through the levee. These floodgates are kept open during the majority of the year and are closed with the onset of a large flood.
- The levee provides no freeboard in some sections above the 1% AEP flood event, thus the levee will be overtopped by flood events that exceed a peak flood level of 161.72 m AHD or a lower flood combined with levee failure, wave action or other combined event.
- The 1% AEP design flood level of 161.72 m AHD has been set as the recommended flood planning level.
- Other recommendations included:
    - a more detailed study to capture all levees
    - The existing levee be raised to a level of the 1% AEP plus 1 m.
    - Development controls on floor levels and zonings
    - Establishment of an additional flood gauge; and
    - Improvement of community preparation and post event response.

2.2.4 Mungindi Flood Investigation – Levee Failure, Cardno, 19 Febuary 2013, prepared for Moree Plains Shire Council

This was a very brief report with the purpose of investigating the predicted flood levels in the event of levee failure.

It is understood the model used was that developed by Lawson & Treloar in 2004 but updated to a new version of SOBEK (version 2.12.04). It was noted that there were no differences in flood level between this model and the previous 2004 model.

The levee failture was represented by complete removal of the levee and run for the 1% AEP flood event as established by L&T 2004.

Maps of peak water levels, depths and velocities were provided.

3 HYDRAULIC ANALYSIS

3.1 Model Software

The hydraulic model prepared for this study has been developed using a two dimensional TUFLOW model as requested by NSW OEH. A TUFLOW 2D model is well suited to the complicated flow dynamics of the study area.

3.2 Model Layout and Boundaries

The hydraulic model developed for this study covers an area of approximately 11km x 7km and has utilised a model grid of 6 metres. This grid size is finer than the 30m/10 m nested grid developed by L&T (2004) and the 10 single grid of the study area developed by WMA (2009). Computationally, this new grid size translates to a model size in excess of 2.1 million points. The model extent was set to be similar to the previous WMA (2009) Sobek model extent with the inflow approximately 6km upstream of the Mungindi Bridge on the Carnarvon Highway and the outflow boundary approximately 7.3km downstream of the bridge. The model extent is presented on Figure 3-1.

Hydrologic analysis was not required as part of the brief and the inflows from WMA (2009) were adopted. Similarly to previous models, WMA (2009) and L&T (2004), a steady state inflow boundary was used which is deemed to be acceptable as typical floods in Mungindi last from days to weeks and therefore storage and hydrograph shape will have little effect on the results. An example of this is during the September 1998 flood event, where the water remained above the major flood category for over 2 weeks. The outflow boundary was set as a discharge-water level relationship which was also taken from the WMA (2009) flood study.

3.3 Model Topography

The model topography for the hydraulic model was based on 1m LiDAR sourced from the Queensland Department of Natural Resources and Mines (DRNM) with relatively small areas missing in the dataset supplemented with the topography used in the WMA (2009) 10m grid model. Due to the nature of LiDAR and its inability to penetrate water, the invert of the River was also extracted from the WMA (2009) Sobek model. The invert of the channel in the WMA (2009) Sobek model topography was typically around 3m lower than the LiDAR data.

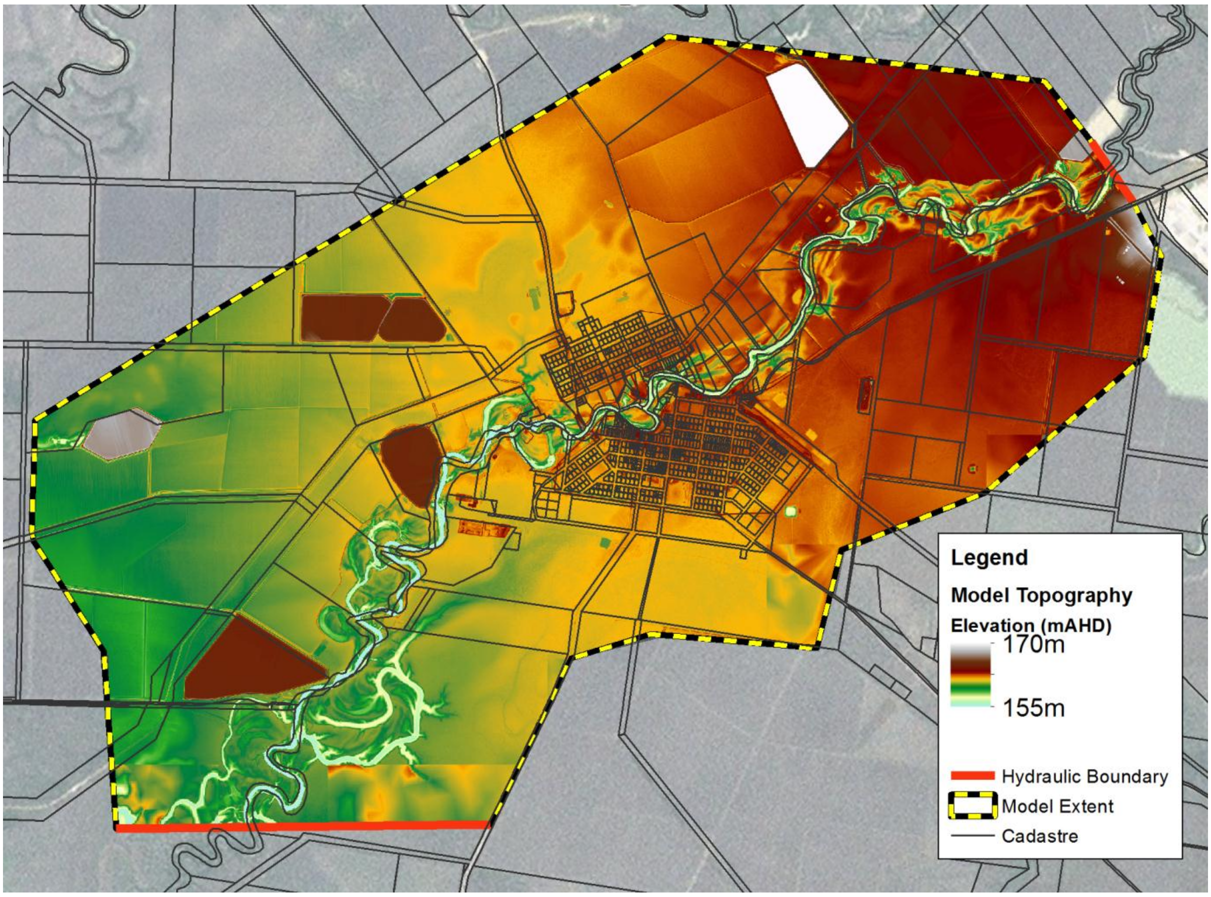

Figure 3-1 Hydraulic Model Layout

3.4 Model Roughness

Model roughness in the form of Manning's 'n' roughness coefficients were taken from the most recent WMA (2009) Sobek model, with minor modifications made during the calibration process. Table 3-1 provides a summary of the roughness zones applied in the hydraulic model together with the roughness value assigned to each of the zones. A map showing the spatial variation of roughness as applied in the model is also presented in Figure 3-2.

Table 3-1 Manning's "n" Roughness

Roughness Type / Description	Manning's "n" Roughness
Roads (including verge and traffic lanes)	0.03
Water Course	0.045
Floodplain	0.07

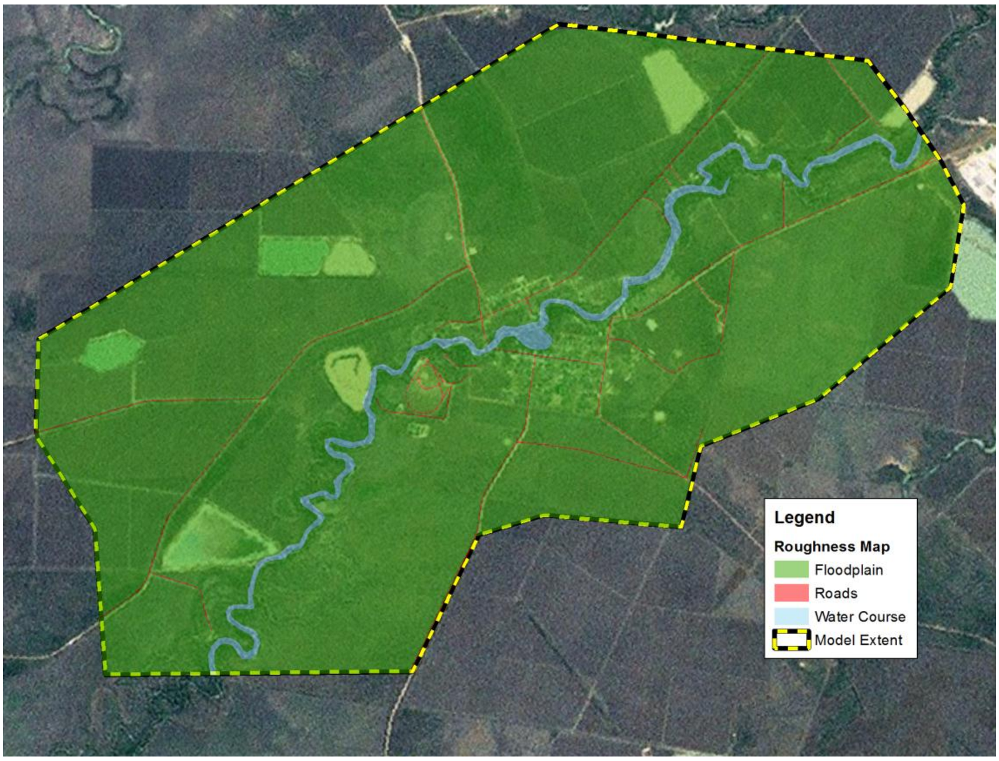

Figure 3-2 Hydraulic Roughness Map

3.5 Hydraulic Structures

There are three structures along the Barwon River in the vicinity of Mungindi, these are:

a) The Mungindi Bridge crossing of the Carnarvon Highway over the Barwon River
b) A pedestrian bridge approximately 700m upstream of the bridge
c) A sheet pile weir located 480m downstream of the bridge.

L&T (2004) and WMA (2009) did not report of any of these structures nor were made any details available or included in any of the models. As the hydraulic model was to replicate the Sobek model from the previous 2009 study, there were no structures entered. This is unlikely to affect the calibration significantly because the gauge is downstream of the Mungindi bridge however if the Mungindi Bridge causes significant afflux then levels for a distance upstream may be higher than those modelled. It is understood that the Mungindi Bridge has recently been upgraded and therefore plans should be obtained for the purposes of including the bridge in the model.

3.6 Hydraulic Model Calibration and Verification

The hydraulic model has been calibrated against the 1996, 1998 and 1976 historical events. Additionally, we have undertaken model calibration of the 100 Year ARI event as additional task to compare the model against previously reported levels for this larger flood event.

3.6.1 Historical Calibration

The calibration model data was based on the previous calibration done for the 2009 flood study. Discharge and peak water elevations were taken from WMA (2009) and checked against online information from the Waterinfo.nsw website run by NSW state government. Recorded discharge, level and modelled level for the calibration events are shown in Table 3-2.

A water depth map of flooding during the historical events and the location of the gauge is illustrated in Appendix A.

3.6.2 100 Year ARI Model Verification

The model was also checked against the 1% Annual Exceedence Probability model that was completed as part of WMA (2009). The 1% AEP flow was estimated by WMA (2009) to be 1,420 m^3/s for the extents of the model domain.

A water depth map of flooding during the historical events and the location of the gauge is illustrated in Appendix A.

3.6.3 Model Results

Table 3-2 below shows the calibration and verification results.

Table 3-2 Model Results

Event Type	Event	Peak Discharge (m^3/s)	Modelled Discharge (m^3/s)	Recorded Water Level (m AHD)	Modelled Water Level (m AHD)	Difference (m)
Historic Calibration	1976	2248	1455	160.95	161.09	+0.14
	1996	638	428	160.83	160.83	0.00
	1998	724	530	160.86	161.92	+0.06
Verification	1% AEP	2190	1420	161.72	161.36	-0.36

The recommended planning level for 1% is 161.72 from the Coffey Study (2013) and it is noted that the current model falls below this level (at 161.36 m AHD). These is possibly due to the large variations in topographic levels between the two studies.

4 CONCLUSIONS AND RECOMMENDATIONS

Water Technology has been commissioned by the NSW Government Office of Environment & Heritage to develop a 2D Tuflow hydraulic model for the township of Mungindi. The model will replace the existing 2D Sobek model developed as part of the 2009 study conducted by WMA. The hydraulic model is being developed with the aim of ultimately being used to inform future development and planning within the Mungindi area, including future flood mitigation option planning, land use planning and disaster management planning.

The model utilised existing hydrologic data from the previous flood study from 2009 (WMA) to estimate inflows for the historic and design events. The topographic data was updated to new LiDAR data which was flown in 2011.

The hydraulic model has been calibrated using hydrologic flows and boundary conditions estimated in the 2009 WMA report. WMA used a proportion of the rated flows based on the fact that the model width did not encapsulate the entire rated flow width. The Tuflow model was constructed with a similar model width and therefore these proportioned flows were also used in the Tuflow model as well as the same height-flow relationship at the downstream boundary. Due to the nature of floods in Mungindi typically lasting relatively long periods, for example the 1998 flood event caused the water level to exceed the major flood level for over 2 weeks, the use of a steady state model was considered appropriate. As with the 2009 Sobek model, hydraulic structures including culverts, bridges and weirs have not been included in the model. It is noted that there was a footbridge, a new road bridge and a weir located along the Barwon River within Mungindi.

Some calibration issues were identified in the area to the south of Mungindi, where the extents of inundation in the Tuflow model did not match the inundation extent observed in the previous studies. Our investigation into the reasons for the differences lead to two of the possible contributors:

- The topographic differences between the models were relatively large with areas being greater than one metre above and below the previous WMA (2009) model which was based on photogrammetry. These topographic differences were significant in areas where breakouts would occur from the Barwon River and flow toward the southern side of the town.
- Lack of culvert details, particularly along Mungindi-Goondiwindi Road which may have hampered the flow across the levee caused by the road crest.

However, the following is also of note:

- The 1976 modelled calibration event was 0.14m above the recorded historic level. This was considered to be acceptable, as the topography was based on the 2011 LiDAR with the removal of levees, which may not have replicated the conditions as they were at the time.
- The 1996 modelled calibration event matched the level at the gauge to two decimal places.
- The 1998 Calibration was 0.06m above the recorded historic level.
- The 1% AEP modelled verification result was 0.36m lower than that modelled by WMA in in the 2009 study. The main factor contributing to this is thought to be the major differences in the topography.

The detailed 2D Tuflow model was found to calibrate well to all three historic events at the Mungindi flood level gauge (Gauge #416001). The calibrated Tuflow model was considered to be representative of flooding in the Mungindi area. Possible improvements in the calibration accuracy would be the inclusion if possible of other recorded flood heights to compare to the recorded gauge level, and also the inclusion of hydraulic structures within the model.

5 REFERENCES

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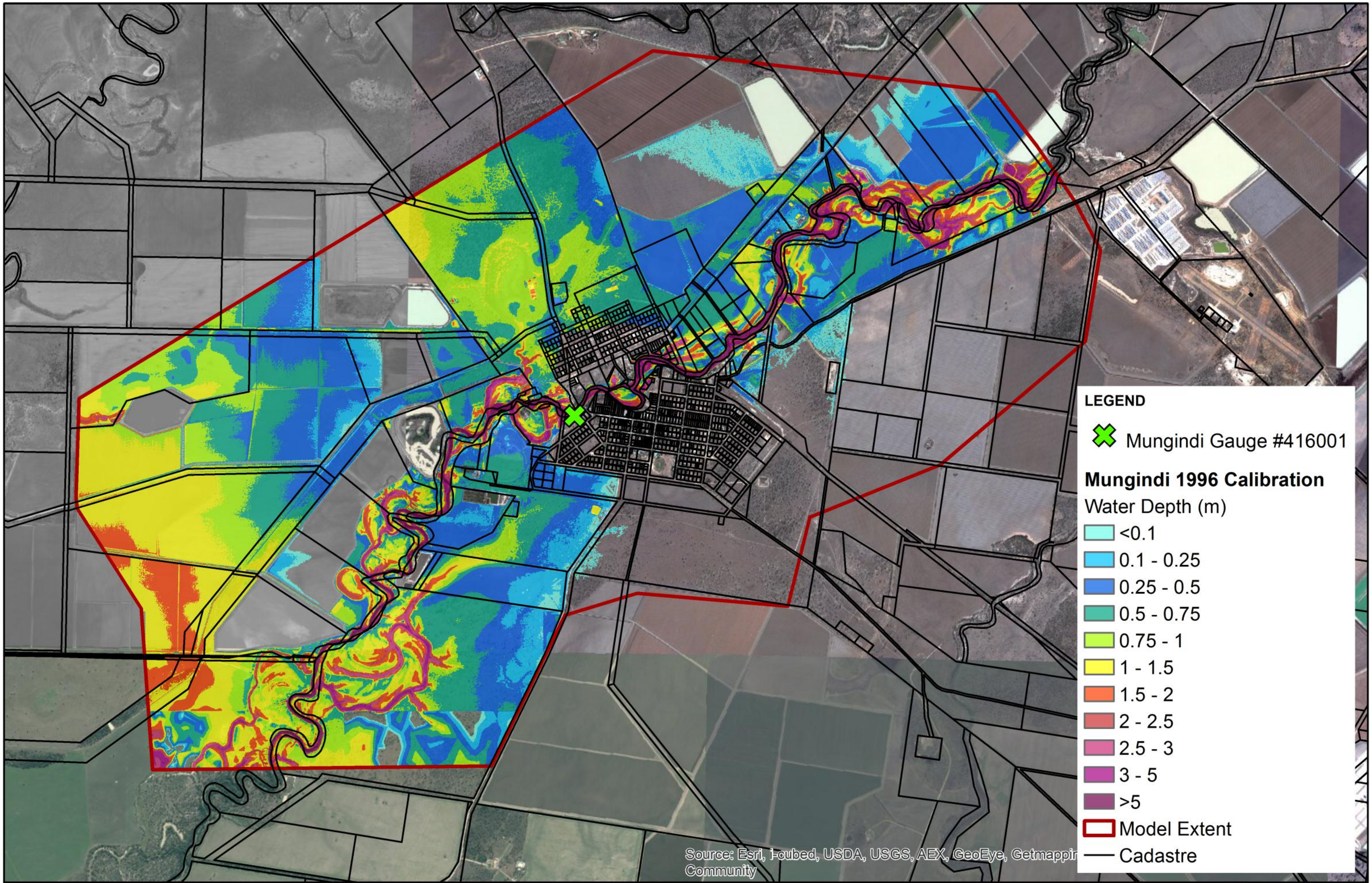
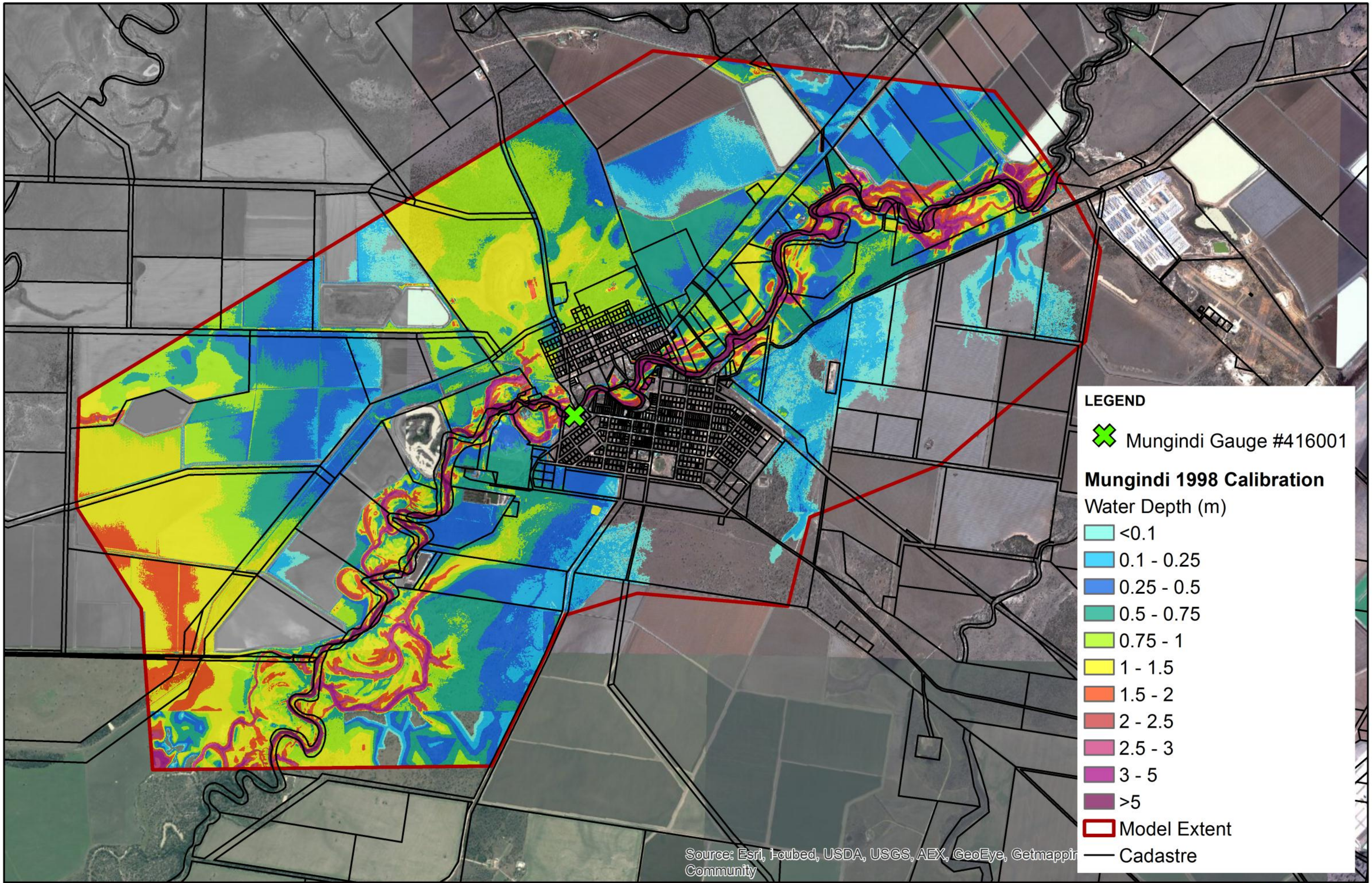
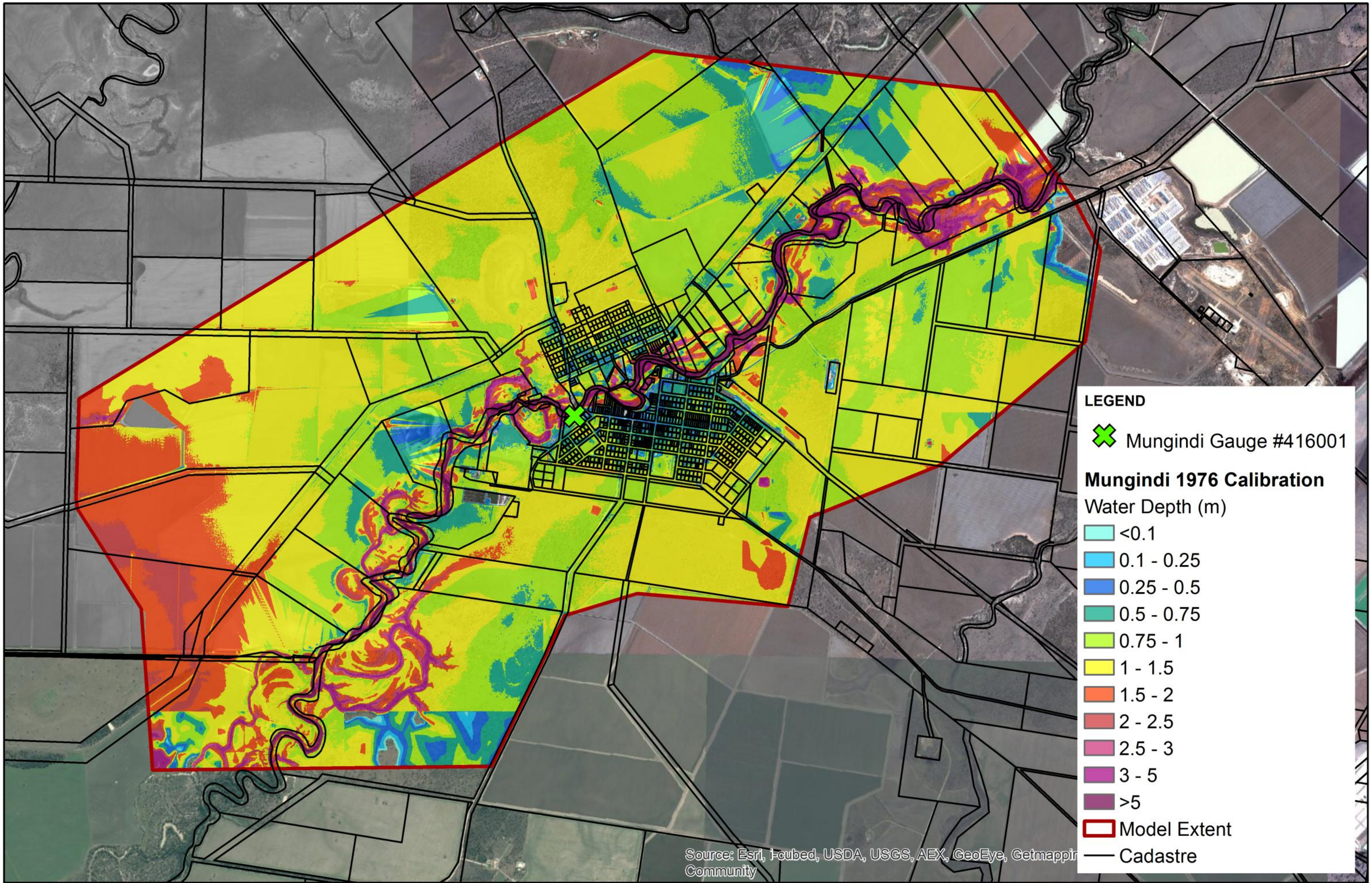
APPENDIX A
Calibration Results



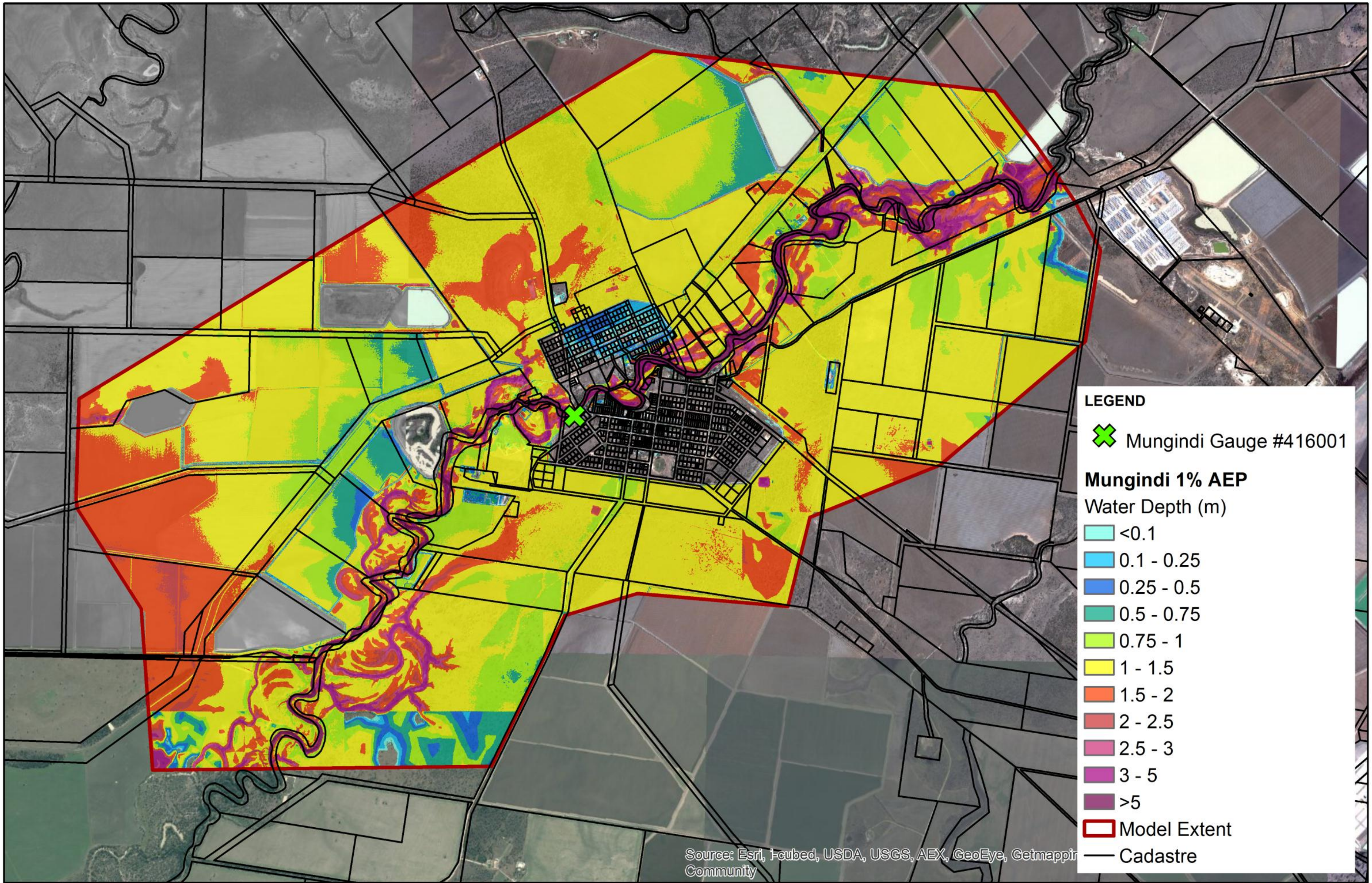
A1 - 1996 Calibration



A2 - 1998 Calibration



A3 - 1976 Calibration



A4 - Mungindi 1% AEP