Captains Flat Flood Study

Flood Study Report - Final

W4947

Prepared for
Palerang Council

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Cardno
Shaping the Future

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Foreword

The NSW Government Flood Prone Land Policy is directed towards providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee	Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.
2. Data Collection	The collection of data such as historical flood levels, rainfall records, land use, soil types etc.
3. Overland Flow/ Flood Study	Determines the nature and extent of the floodplain.
4. Overland Flow/ Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
5. Overland Flow/ Floodplain Risk Management Plan	Involves formal adoption by Council of a management plan for the floodplain.
6. Implementation of the Plan	This may involve the construction of flood mitigation works (e.g. culvert amplification) to protect existing or future development. It may also involve the use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The process is iterative, and following the implementation of the plan, it is important that ongoing monitoring and evaluation is undertaken.

This Flood Study has been prepared for Palerang Shire Council by Cardno, and addresses parts 2 and 3 of the Floodplain Management process.

Executive Summary

Palerang Council have commissioned Cardno to undertake a Flood Study for the Captains Flat Township and surrounds.

The study area of Captains Flat is located in the upper reaches of the Molonglo River catchment, near to the rivers headwaters in the Tallaganda State Forest.

The study area lies at the confluence of the Molonglo River with Keatings Collapse and Kerrs creek, and also incorporates a local drainage path, referred to as Town Creek in this report.

This report details the investigations completed as part of the Flood Study, namely:

- Review of available data;
- Collection of additional information;
- Community Consultation;
- Flood modelling; and,
- Preliminary options and risk assessment

Through these investigations the existing flooding behaviour of the Captains Flat Township has been defined for a range of flood events, namely:

- 20% Annual Exceedence Probability (AEP);
- 10% AEP;
- 5% AEP;
- 2% AEP;
- 1% AEP;
- 0.5% AEP and,
- The Probable Maximum Flood (PMF)

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* Figures are located in body of report. Other figures are attached separately.

Glossary

Annual Exceedence Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.

Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the “Standard flood event” of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.

Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Overland Flow	The term overland flow is used interchangeably in this report with “flooding”.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.

Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

* Terminology in this Glossary have been derived or adapted from the NSW Government Floodplain Development Manual, 2005, where available.

Abbreviations

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
ARI	Average Recurrence Intervals
BoM	Bureau of Meteorology
DCP	Development Control Plan
FPL	Flood Planning Levels
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
ha	Hectare
IFD	Intensity Frequency Duration
km	Kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
m	Metre
m^2	Square metre
m^3	Cubic Metre
mAHD	Metres to Australian Height Datum
mm	Millimetre
m/s	Metres per second
NSW	New South Wales
OEH	Office of Environment & Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Service

1 Introduction

This report details the investigations undertaken for the Captains Flat Flood Study.

1.1 Study Context

The Floodplain Management process progresses through 6 steps in an iterative process:

Step 1: Formation of a Floodplain Management Committee

Step 2: Data Collection

Step 3: Overland Flow / Flood Study

Step 4: Overland Flow / Floodplain Risk Management Study

Step 5: Overland Flow / Floodplain Risk Management Plan

Step 6: Implementation of the Overland Flow / Floodplain Risk Management Plan

This report addresses Steps 2 and 3 of the Floodplain Management process.

1.2 Study Objectives

The Flood Study details:

- Review of available data including :
  - Previous flood related reports and studies;
  - Previously constructed hydrologic and hydraulic flood models;
  - Council GIS information;
- Collection of additional survey information;
- Results of the community consultation process;
- The calibration and verification of the hydrological and hydraulic models;
- The existing flood behaviour of the study area for a range of flood events; and,
- A preliminary assessment of flood and risk management options.

2 Catchment Description

The Molonglo River catchment covers an area of approximately 2,000 square kilometres, extending from the Murrumbidgee River to the headwaters of the Molonglo and Queanbeyan Rivers. The land use of the catchment varies considerably, ranging from highly developed areas within Canberra and Queanbeyan, to wetlands, pine forests and rural land.

The study area of Captains Flat is located in the upper reaches of the Molonglo River catchment, near to the rivers headwaters in the Tallaganda State Forest.

The study area and upstream catchment are shown in **Figure 2-1**.

Three tributaries join the Molonglo River in the vicinity of Captains Flat, namely Kerrs Creek, Keatings Collapse, and a local, unnamed creek referred to as Town Creek. The combined catchment area of the Molonglo River and these tributaries upstream of Captains Flat is 45 square kilometres.

The Molonglo River has been dammed immediately upstream of the confluence of Kerrs Creek and Keatings Collapse to form Captains Flat Dam, an 820ML dam which supplies water to Captains Flat.

The key features of the study area are shown in **Figure 2-2**.

The catchment around and upstream of Captains Flat is predominately rural properties and national park areas. The township itself comprises a relatively small part of the catchment, and is made up of medium to low density residential areas with some commercial and industrial properties.

The township has experienced significant historical flooding, with the most severe occurring in December 2010. In this event, over a dozen properties experienced overfloor flooding, some with depths in excess of 1m. Flooding was exacerbated by the blocking of parts of the drainage system.

Downstream of the township, the Molonglo River passes through relatively undeveloped areas comprised of grazing land or open floodplains. Significant development is not encountered along the river until the locality of Carwoola, to the east of Queanbeyan, approximately 30km downstream from Captains Flat.

3 Review of Available Data

3.1 Previous Reports and Studies

A number of previous studies have been conducted concerning the Captains Flat region, and the wider Molonglo River catchment. These studies have been reviewed as part of this assessment and relevant information incorporated.

These previous studies are summarised in **Table 3-1**.

Table 3-1 Summary of Previous Studies and Reports

Study / Report	Description
Captains Flat Dam: Probable Maximum Flood Review Study (NSW Public Works: Hydrology group, 2003)	The study was undertaken to update the 1991 PMF study in light of additional data received, and to incorporate changes in the PMP estimation methodology. As part of the investigation, a RORB model was developed which was calibrated to flood events in 1978, 1998 and 1991. The study found minimal changes compared to the 1991 PMF estimation.
Captains Flat Dam: Further Studies, covering Dambreak Study, Stability Under Earthquake and Stability of Tailings Dumps (NSW Public Works: Dams and Civil, 2004)	The report contains a number of investigations undertaken to inform the development of a Dam Safety Emergency Plan for Captains Flat Dam (see below). The investigations undertaken included a dam break study, earthquake stability assessment, and a review of the failure risks of the adjacent tailings dumps. The dam break study developed a MIKE-11 model downstream of the dam to assess the impacts of failure. The dam was classified as having a “High C” consequence category due to the population at risk and the minimal warning times available. The earthquake investigation undertaken concluded that the dam met the stability requirements for the selected maximum design earthquake, and would remain stable following an earthquake. The adjacent tailings dams were assessed to determine the flooding impacts of their failure, as a result of material entering the dam, and displacing water over the spillway. Flooding risks were found to be minimal, as a result of the low volume of material expected to be displaced during failure, and the low risks of failure due to shallow batters and large benches.

Study / Report	Description
Molonglo River: Rescue Action Plan 2010 (Molonglo Catchment Group, 2010)	Prepared through collaboration with a number of stakeholders including the ACT government, WaterWatch Molonglo Catchment, Murrumbidgee Catchment Management Authority and CIC Australia. The Action Plan was prepared to guide natural resource management within the Molonglo River catchment. The plan does not comment on flooding behaviour, but does note the role of floods in affecting geomorphology and weed dispersion.
Dam Safety Emergency Plan for Captains Flat Dam (NSW Public Works: Dams and Civil, 2011)	The plan details the roles, responsibilities and trigger points for the emergency management of Captains Flat Dam. The plan also details available surveillance, communication, monitoring and warning systems in place at the dam.

3.2 Survey Information

Council provided existing survey data for aspects of the study area. Additional survey was commissioned for the aspects and areas not covered by the existing survey.

3.2.1 Existing Survey

Survey was provided by Council from a number of sources. The following summarises the information received:

- Stormwater survey (Individual A4 forms for each drainage line; prepared November 1981)
- Sewer survey (Drawing Numbers 792142-1A, 1B, 1C, 1D and 79166-2; issued June 1981)
- Foxlow St Drain (Drawing Numbers 06021-2, and 06021-5 to 06021-12; issued December 2008)

3.2.2 Additional Survey

Additional survey was collected for parts of the study area where existing survey did not provide sufficient information or was not available.

The following additional survey was collected:

- Road crest levels throughout the township;
- Detailed cross sections of the Molonglo River and its tributaries;
- Detailed structure of pits, culverts and drainage structures within the study area; and,
- Terrain survey within the 2D model extent

The survey was undertaken by PHL surveyors, and provided to Cardno in November 2012.

3.3 GIS Data

The following Geographic Information System (GIS) data was provided by Council as part of the study:

- Cadastre;
- Aerial image of the study area;
- 5m contours of the catchment area;
- Land-use and Council zoning regions; and,
- Captains Flat catchment extent polygon

3.4 Site Inspection

A site inspection was conducted on 23 March 2012 by Cardno and Council representatives.

3.5 Historic Flood Information

The study area has experienced a number of large flood events, with a significant event occurring in 2010. Other events occurred in 2012, 1991, 1988 and 1978.

A post flood survey was conducted following the 2010 flood event. A survey was made of flood marks on buildings, debris extents and creek top of bank levels, as well as providing photographs of what debris and flood marks remained at the time of survey.

3.6 Historic Rainfall Data

Two pluviograph stations are located within the Captains Flat catchment area, as well as a stream flow gauge on the Molonglo River at Copper Creek. In addition, a number of daily rainfall stations are located in the regions surrounding the catchment. The pluviograph and stream flow stations and gauges are shown in **Figure 3-1**. Details on the gauges are shown in **Table 3-2** and daily rainfall totals for the rainfall stations are shown in **Table 3-3**. All data was sourced from ALS Group, on behalf of ACT Environmental.

Table 3-2 Captains Flat Rainfall and Stream Flow Gauge Information

Station Number	Station Name	Type
570982	Molonglo River at Copper Creek	Pluviograph
570960	Parkers Gap	Pluviograph
570923	Rossi (Sawmill)	Daily
570965	Queanbeyan River at Tinderry (NSW)	Daily
570968	Tinderry Mounts at Simon Creek	Daily
410757	Molonglo River at Copper Creek	Stream flow
41000208	Molonglo River at Kobada	Stream Flow

Table 3-3 Peak Daily Rainfall

Station Number	Total Daily Rainfall (mm to 9am)			
	Dec 2010	June 1991	July 1988	March 1978
570982	-	2.8	0	4.2
570960	0.8	0.21	5.3	13.3
570923	0.6	0.2	2.3	-
570965	0.6	5.07	1.6	14.5
570968	0.8	0.2	1.0	4.6

3.6.2 Previous Modelling

A previous RORB model for the study area was constructed in 1993 to assess the behaviour of Captains Flat dam in the PMF flood event. This model was calibrated to four historical events.

Although the RORB model was not available, the accompanying report which detailed the catchment layout and model parameters, as well as the details of the models calibration, contained sufficient information to allow the new RORB to be built in line with the previous model.

4 Community Consultation

Community consultation is proposed to be undertaken in three key phases over the course of the project:

- Resident Survey;
- Community Forums; and,
- Public Exhibition of Draft Flood Study.

The resident survey and the community forum have been completed and are discussed below. A second public meeting will be held as part of the public exhibition. The final Flood Study will be revised to include the outcomes from this meeting.

4.1 Community Information Brochure / Questionnaire

The first stage of the ongoing community consultation process was undertaken in August 2012. An information brochure and questionnaire were distributed to those property owners within the Captains Flat Township, and a number were also provided for display at the local service station. The brochure and questionnaire are attached in **Appendix A**. The brochure provided an outline of the floodplain risk management process and the objectives of the study. The questionnaire sought information about residents' knowledge and experience of historical flooding events and flood awareness within the community.

The brochure and questionnaire were delivered to approximately 250 property owners within the catchment area. A summary was also advertised in the local newspaper, the Captains Flat Telegraph, informing residents of the study and advising that the survey was being undertaken.

From the distribution, 29 responses were received, representing a return of approximately 12% of direct distribution. An average response rate for these types of surveys is in the order of 10%, and so this represents a reasonable return rate.

A summary of the findings of the resident survey are presented below.

4.1.1 Years at Address

One of the questions in the survey related to the length of time that residents had resided at their current address. The majority of respondents were owner occupiers (81%) with the remainder being tenanted, businesses, or farmland.

Of the 29 respondents, 35% have been at their address for over 10 years. The majority of respondents have lived at their current address for 6 – 10 years. Of the respondents, 86% were living in Captains Flat at the time of the December 2010 flood event.

Figure 4-1 provides an overview of the periods of residency.

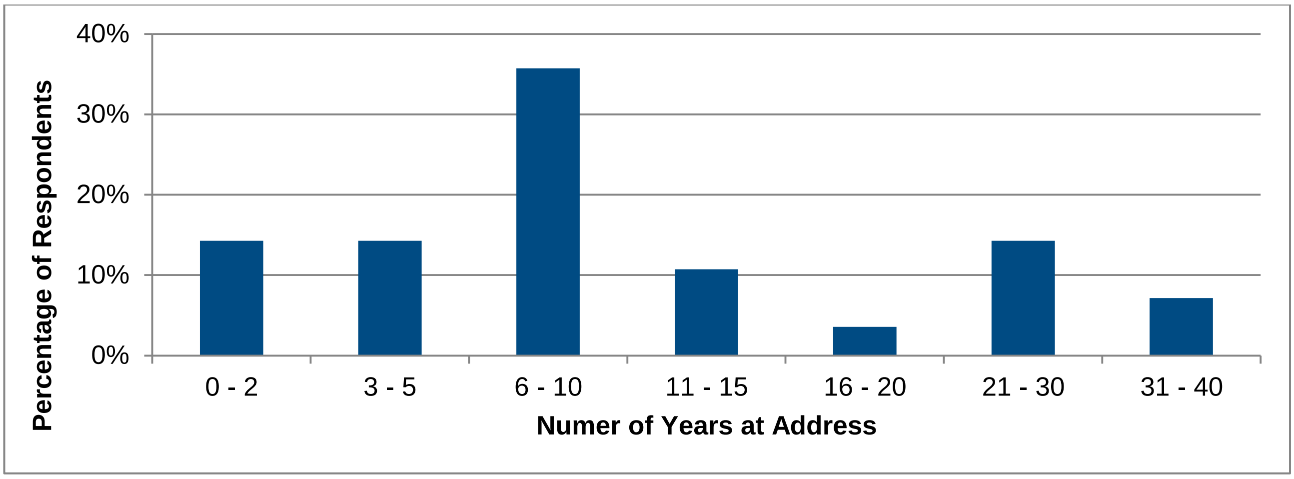


Figure 4-1 Years respondents have spent at current address

4.1.2 Flood Awareness

The questionnaire asked residents how aware they are of flooding within the study area. 76% stated they were aware of flooding in the area, and a further 21% said they had some awareness. Only 3% of respondents said they were not aware.

Given the large flood event in December 2010, and smaller flood events in 2011 and 2012, this level of awareness is reasonable.

4.1.3 Resident Experiences of Flooding

The questionnaire asked residents how they have been affected by flooding. The responses are shown in **Figure 4-2**.

The returned questionnaires showed that 64% of respondents had experienced flooding of their property, with 7% experiencing over flood flooding. This level of flood experience supports the high rate of flood awareness in the study area.

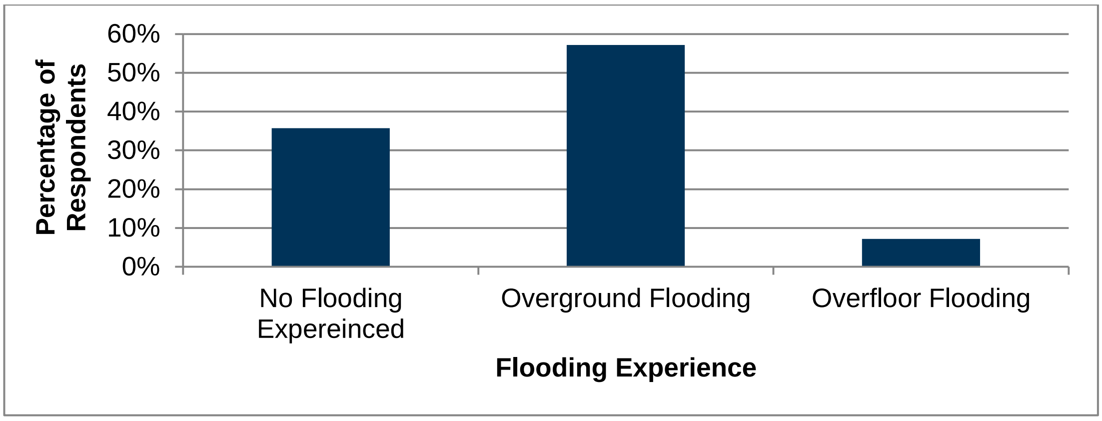


Figure 4-2 Respondent Flooding Experiences

A common concern raised by residents was blockage of drains, culverts and bridges. The majority of respondents had seen culverts and drains blocked during a flood event, generally by more than 50%.

It was also noted by a number of respondents that the Foxlow Street Bridge is affected by blockage. In the December 2010 event, a significant amount of debris was washed down the Molonglo River, which blocked both the creek under the bridge, and the railing along the top of the bridge. Nearby residents attributed property flooding to this blockage.

4.1.4 Community Forums

A community forum was undertaken on 14th March 2013 to present the study to the community and to invite comment on the preliminary results in light of the community's flood experience.

The forum was attended by five community members who were able to provide comment on how the modelling of the December 2010 flood event compared with their experiences and observations. A number of observations were put forward, and these were used as part of the calibration of the hydraulic model (refer **Section 6.2.4**).

A second community forum was held on 24th July 2013 to present the final results of the Captains Flat Flood Study to residents.

The forum was attended by four members of the community, as well as SES and Rural Fire Services (RFS) representatives.

5 Flood Study Modelling

The SOBEK 1D/2D hydraulic model was used to define the flood behaviour in the Captains Flat study area. The hydrological model RORB was used to generate inflow hydrographs while the Direct Rainfall method was adopted for areas within the 2D model domain. Details on the set up of the hydrological and hydraulic models are provided below

5.1 Hydrological Model

5.1.1 Sub – Catchments

The sub-catchment layout used in the RORB model is shown in **Figure 5-1**. These sub-catchments were generally based on those of the previous RORB model, with minor changes made due to the availability of greater terrain resolution, and to better allow the transfer of flows to the 2D hydraulic model.

5.1.2 RORB 'm' Parameter

For this study, an 'm' value of 0.8 was adopted. This value is recommended in AR&R for the estimation of flood events, and was adopted in the previous study. As such, it was fixed in all the RORB models, and was not used in the calibration process.

5.1.3 Captains Flat Dam

Captains Flat Dam was included in the hydrological model. The RORB model has the ability to route flows through the dam using a stage-storage-discharge relationship, as shown in **Table 5-1**.

For the calibration events, it was assumed that the dam was full at the start of the storm. This was based on an assessment of the flows at the Molonglo River gauge during the days before the storm events. In each case, the river flows showed an increase of more than 50% during the days before the storm event compared to the dry period base flows. This suggests that there was rainfall in the catchment before the storm event. It also suggests that as the flows downstream of the dam increased as a result of this rainfall, the dam was full; otherwise the increased flows would have been retained in the dam.

5.1.4 Rainfall and Stream-flow Data

The rainfall volumes applied to the catchments were extracted from the gauges at Parkers Gap and the Molonglo River at Copper Creek (refer **Figure 3-1**). The rainfall volumes for these events are summarised in **Table 5-2** and the temporal patterns are shown in **Figure 5-2** to **Figure 5-5** for the July 1988, June 1991, July 1991 and December 2010 events respectively. Note that the Captains Flat gauge was not operating for the 2010 event.

The downstream flow in the Molonglo River was extracted from the gauge data at Copper Creek. Peak discharges in the river for each historical event are also shown in **Table 5-2**.

Both the June 1991 and July 1991 events show time difference in the initial stages of the storm events, with the Molonglo River gauge showing a delay of 1 – 2 hours behind the Parkers Gap gauge. This suggests that the storm was moving in a northerly direction across the catchment.

Table 5-1 Captains Flat Dam Details

Stage (mAHD)	Storage (m^3)	Discharge (cumecs)
854.27	0	0
855.8	18,000	0
857.32	62,000	0
858.84	130,000	0
864.3	540,000	0
864.35	546,000	0
865.3	634,000	6.7
865.35	638,000	7.3
865.94	692,000	85
866.35	726,000	139
866.49	738,000	168
866.7	756,000	213.4
866.9	770,000	262.6
867	780,000	317
868	856,000	862
869	940,000	1408
870	1,020,000	1953
873	1,240,000	3589.3

Table 5-2 Storm Event Summary

Event	Molonglo River Gauge Total Rainfall Depth (mm)	Parkers Gap Gauge Total Rainfall Depth (mm)	Peak Discharge from study area (cumecs)
July 1988	130.0	134.0	93.1
June 1991	55.9	76.9	35.7
July 1991	90.2	98.3	41.2
December 2010	*No data*	75.8	100.1

Note: Rainfall depths for the 1988 and 1991 events are reported over 50 hours. The 2010 event is reported over 25 hours

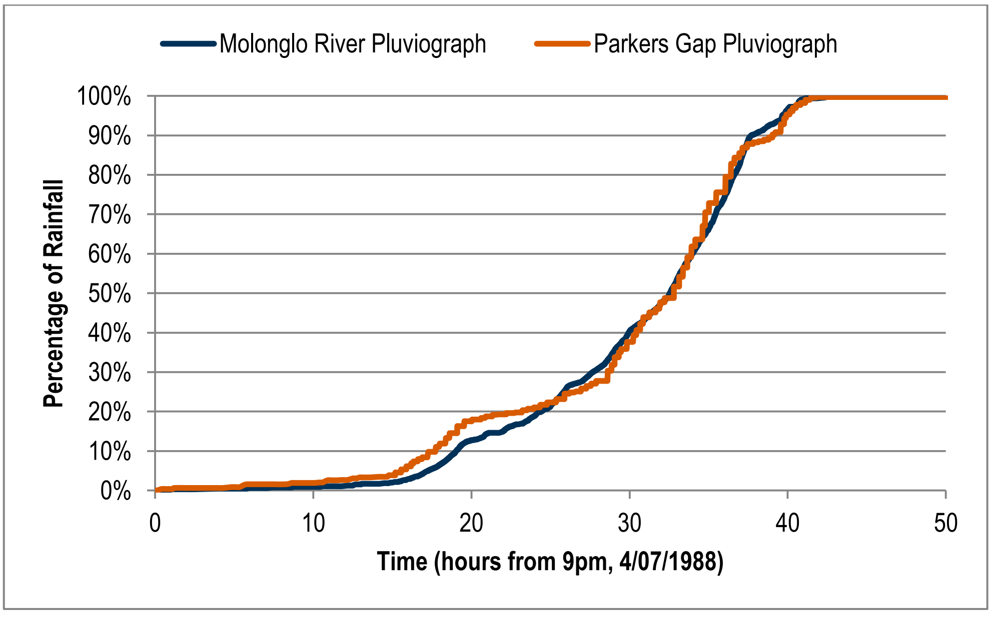


Figure 5-2 July 1988 Cumulative Rainfall

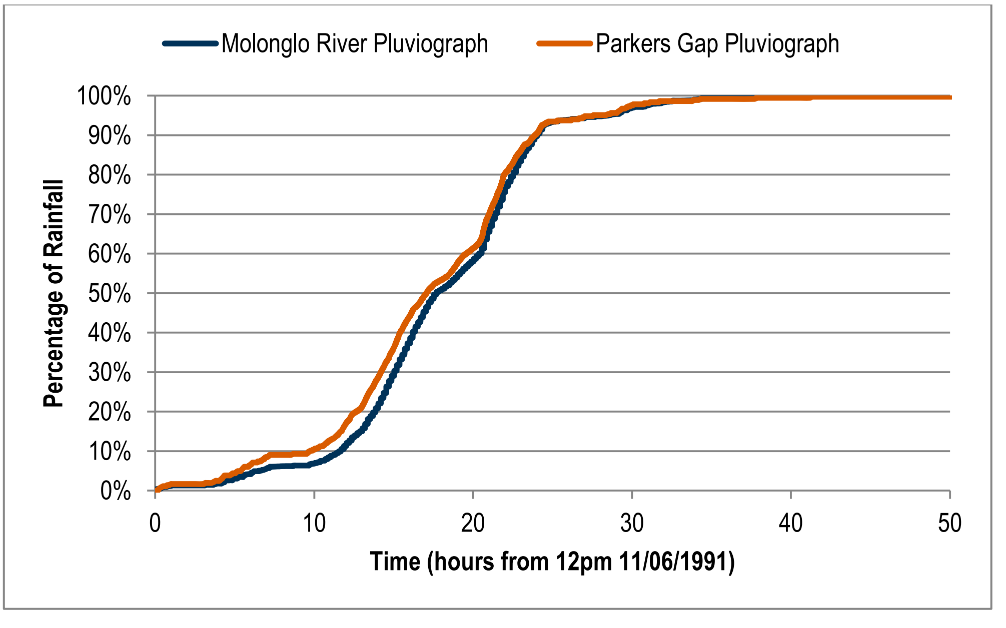


Figure 5-3 June 1991 Cumulative Rainfall

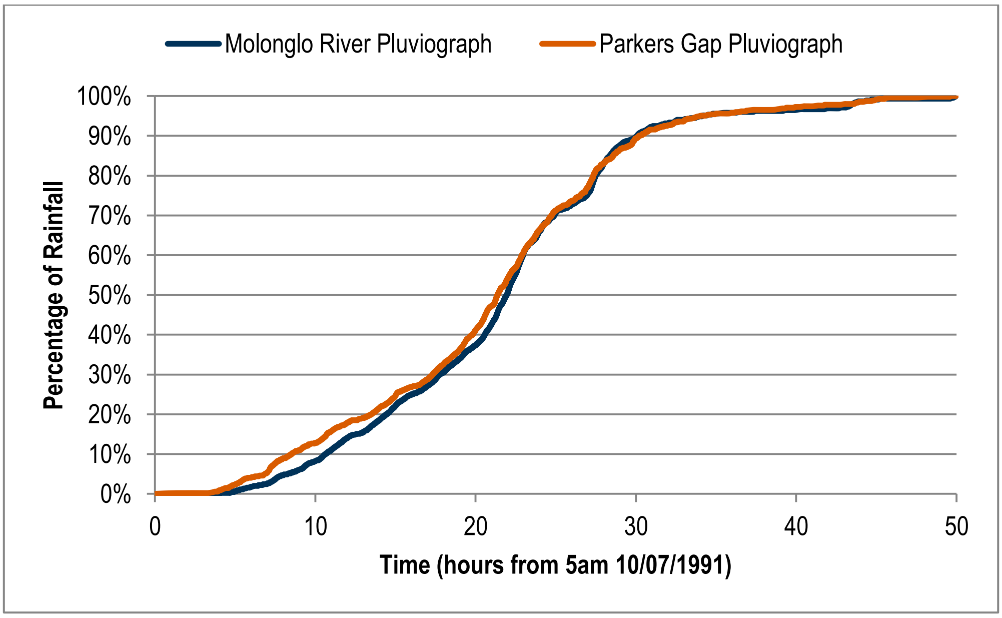


Figure 5-4 **July 1991 Cumulative Rainfall**

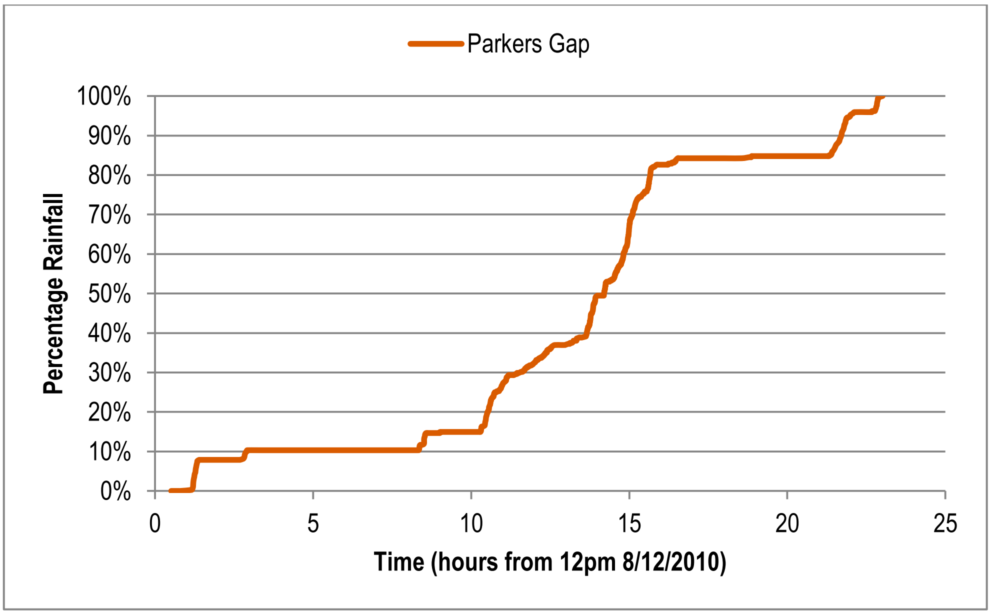


Figure 5-5 **December 2010 Cumulative Rainfall**

5.2 Hydraulic Model Development

5.2.1 2D Terrain

The terrain was developed from the collected survey. A 3m grid was created to cover the study area. The size of this model area is approximately 175ha, represented by approximately 195,000 grid cells. The model terrain is shown in **Figure 5-6**.

5.2.2 1D Elements

Pipe drainage systems and selected open channels were modelled in SOBEK as distinct 1D elements connected to the 2D terrain grid via pits.

The location and size of pipes and culverts were collected as part of the additional survey. Only the trunk drainage system has been modelled in this study.

Kerrs Creek and Town Creek, as well as selected reaches of the Molonglo River, were modelled as distinct 1D elements. This was because the widths of these reaches were generally too small to be accurately represented by the 3m 2D grid. Cross sections were taken from the additional survey. Other creek and river reaches were modelled in the 2D domain.

Figure 5-7 shows the 1D elements in the model.

5.2.3 Roughness

Each 2D model cell has a roughness value applied to model the influence on flow behaviour of a particular land use. The adopted roughness layout, as shown in **Figure 5-8**, was based on aerial photography, site inspections, and survey photographs. A high roughness zone was adopted across the Foxlow Street Bridge. This was to account for the railings, and the debris that gets caught in them that the water must pass through when overtopping the bridge.

The roughness values adopted for each zone are listed in **Table 5-3** below.

Table 5-3 2D Roughness Values

Zone / Landuse	Manning's 'n' roughness value
Urban lots	0.15
Roads	0.015
Open space / light vegetation	0.05
Dense vegetation	0.09
Molonglo River – central channel	0.045
Foxlow Street Bridge	0.2

Each 1D element in the model (pipe, culverts, channels) was also given a roughness parameter. Roughness values were determined from photographs and site inspections. The roughness values adopted for the 1D elements, representing the in-bank area, are listed in **Table 5-4** below.

Table 5-4 1D Roughness Values

1D Element	Manning's 'n' Roughness Value
Concrete pipes and culverts	0.018
Road side swales (Town Creek)	0.03
Molonglo River	0.045
Kerrs Creek	0.06

5.2.4 Inflows

There were two hydrological methods used in this model – one for upstream flows, and one for the 2D domain. The RORB hydrological model (refer Section 2) was used to generate the inflow hydrographs to the study area. There are three inflow locations in the model; Captains Flat Dam, Keatings Collapse and Kerrs Creek.

For the 2D domain, the Direct Rainfall Methodology was adopted. In this procedure rainfall is applied directly to the 2D grid and the resultant flows routed through the model. As such, no separate hydrological model was required for the study area.

A schematisation of the hydrological set up is shown in **Figure 5-9**.

5.2.5 Downstream Boundary

The downstream boundary on the Molonglo River was modelled as a Q-H relationship. This relates a water level in the river to a discharge rate. The relationship was generated from HydroChan, an excel program that creates Q-H relationships for cross sections based on channel roughness and slope using the Manning's formula. The cross section was surveyed at this location as part of the survey works.

The generated relationship is shown below in **Figure 5-10**.

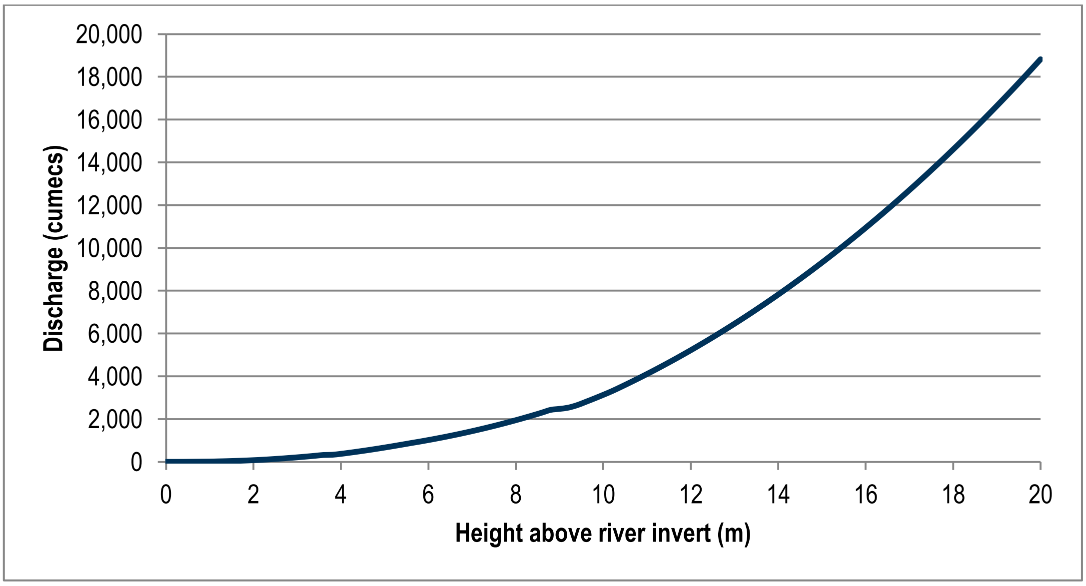


Figure 5-10 Downstream Q-H Relationship

6 Calibration

Calibration of the RORB model was undertaken for three historical events, July 1988, June 1991 and July 1991.

The December 2010 event was not used as there was no flow gauge data available for this event to allow a calibration.

The December 2010 event was instead used to calibrate the hydraulic model, as this event had post flood survey available within the study area. It also served as a means to indirectly verify the hydrological model.

6.1 Hydrological Calibration

Calibration of the RORB model was undertaken for three historical events; July 1988, June 1991 and July 1991. The calibration was undertaken to ensure that the model accurately represents the flooding behaviour of the catchment. The model was calibrated by comparing the recorded gauge flow at the Molonglo River gauge in Captains Flat with the predicted gauge from the hydrological model.

A second river gauge was installed at Kobada in 2004, so it was not possible to use this gauge in the calibration. Data from this gauge was used to check the 2010 flows. However, as it is located in the middle of the catchment, it could not be used for a complete calibration (refer **Section 6.2.1**).

The rainfall applied was taken from the pluviograph station data. The rainfall depths for each catchment were linearly interpolated from the Parkers Gap and Molonglo River gauge data based on their relative distance from these gauges.

Calibration in RORB is principally undertaken through varying, within acceptable ranges, the k_c and initial and continuing losses. These parameters were adjusted in order to replicate the observed flow at the downstream gauging station.

The k_c value in RORB influences how quickly rainfall is converted to runoff in a catchment. Lower k_c values describe faster runoff characteristics, resulting in higher peak flows and steeper hydrographs. Conversely, higher k_c values describe a slower catchment response, which typically results in lower peak discharges and flatter hydrographs.

The k_c and initial and continuing losses for each model are summarised in **Table 6-1**, and the results of the calibration models are shown in **Figure 6-1** to **Figure 6-3**.

Table 6-1 RORB Calibration Parameters

Event	k_c	Initial Loss	Continuing Loss
July 1988	7.5	5	2.2
June 1991	7.5	4	2.1
July 1991	7.5	5	2.2

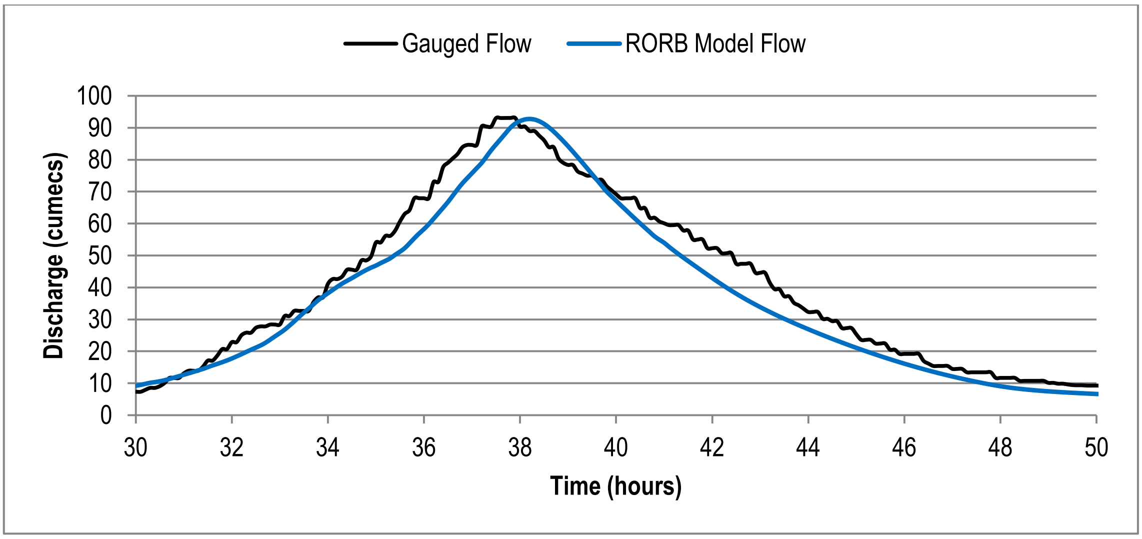


Figure 6-1 July 1988 Calibration

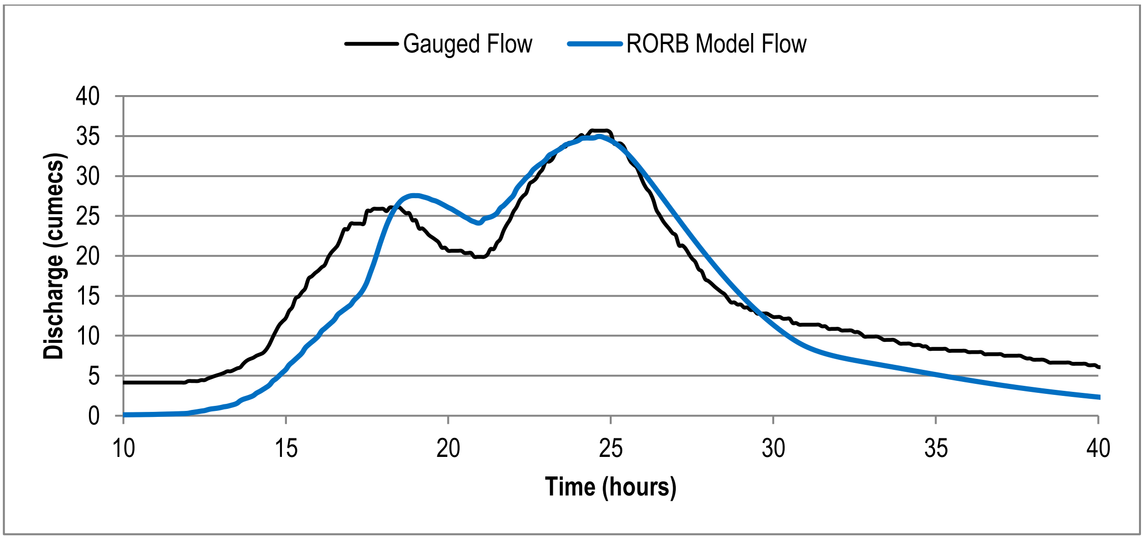


Figure 6-2 June 1991 Calibration

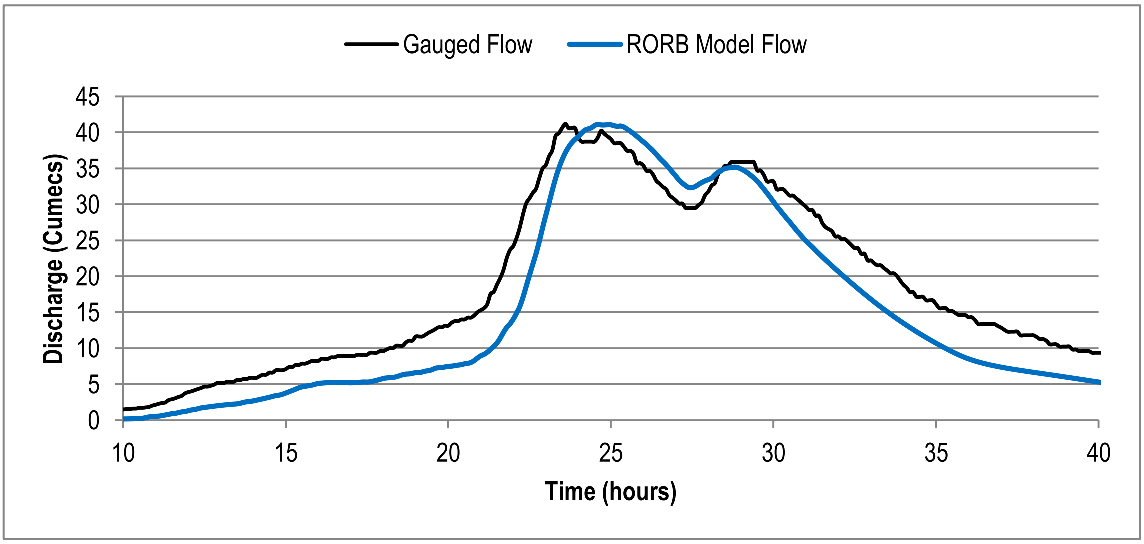


Figure 6-3 July 1991 Calibration

The results show the strongest calibration for the June 1988 event, which is also the largest event. The June and July 1991 events also had reasonable matches. The calibration is also supported by similar k_c and loss parameters for each event, as there is no indication that significant catchment changes occurred between these events which would lead to differences in these values.

From these results, a k_c of 7.5 and losses of 5mm and 2mm for initial and continuing losses respectively were adopted for the design storms.

6.1.2 Flood Frequency Analysis

A flood frequency analysis (FFA) was undertaken on the Molonglo River gauge at Captains Flat. The FFA was undertaken to both assess the reliability of the gauge, and to provide some verification of the generated design flows. The process was undertaken following the methodology from AR&R.

The FFA was completed using gauge data from December 1972 through to August 1997, a period of 25 years, and is shown below in **Figure 6-4**. Statistically, there is a 50% chance of the 1% AEP event occurring within a 70 year period. Given that the recorded period is less than half this, it is unlikely that the gauge data will cover a large range of flood events. The results of the FFA suggest that the largest event within the recorded period was in the order of a 2% AEP event.

The figure shows that all the historical flows are plotted within the 90% confidence limit, suggesting that the gauge recordings are accurate.

The design flows from the hydrological model area also plotted in **Figure 6-4**.

The figure shows that the estimated RORB peak design flows are a close match to the flows estimated from the FFA.

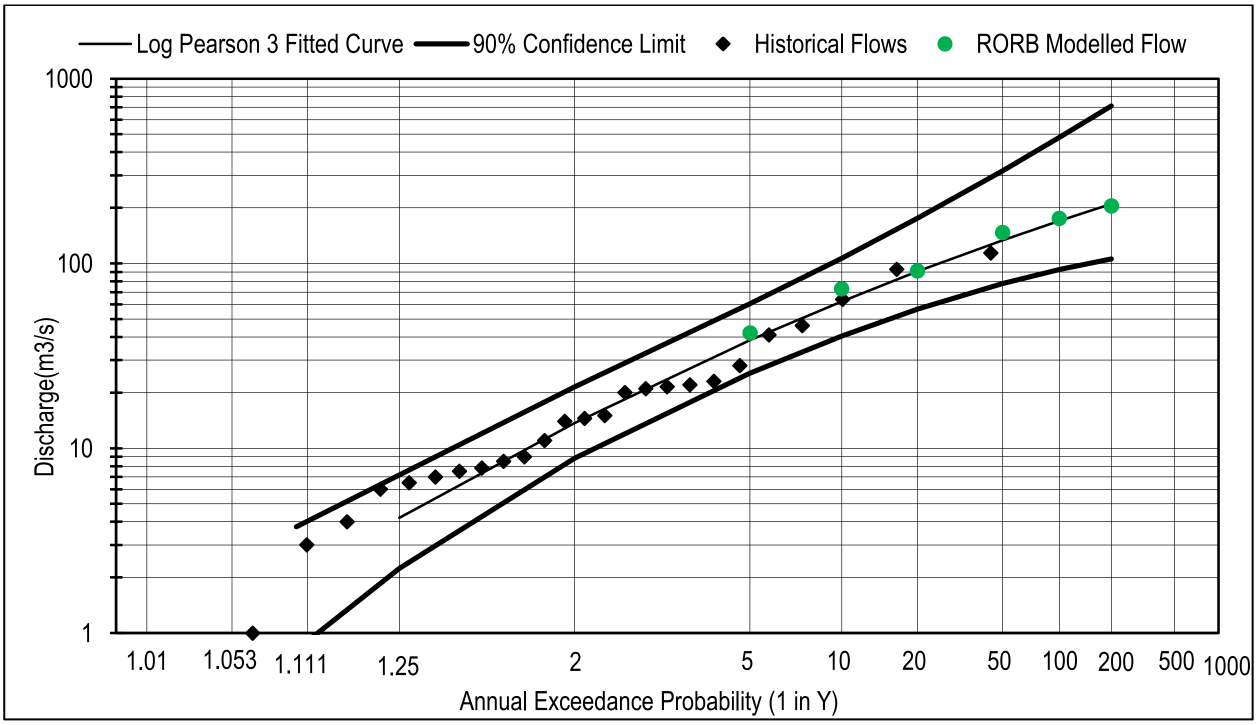


Figure 6-4 Flood Frequency Analysis

6.2 Hydraulic Calibration

The 2010 rainfall event was used to calibrate the hydraulic model. A post flood survey was undertaken within the study area which recorded peak flood heights along the Molonglo River, Keatings Collapse and Kerrs Creek.

The earlier events were not used in the hydraulic model calibration as no detailed flood level information was available for these events.

6.2.1 Hydrological Input

No rainfall data was recorded at the Molonglo River gauge during the 2010 event. In order to assess the storm behaviour in this event the pluviograph stations surrounding the catchment were assessed in order to gain an understanding of how the storm moved through the region. In addition to the Parkers Gap station, two other pluviostations were used. The first, Queanbeyan Rd at Tinderry is located to the west of the catchment area, whilst the second, Sawmill Creek at Rossi, is located to the north east. The rainfall time series from these stations are shown below in **Figure 6-5**.

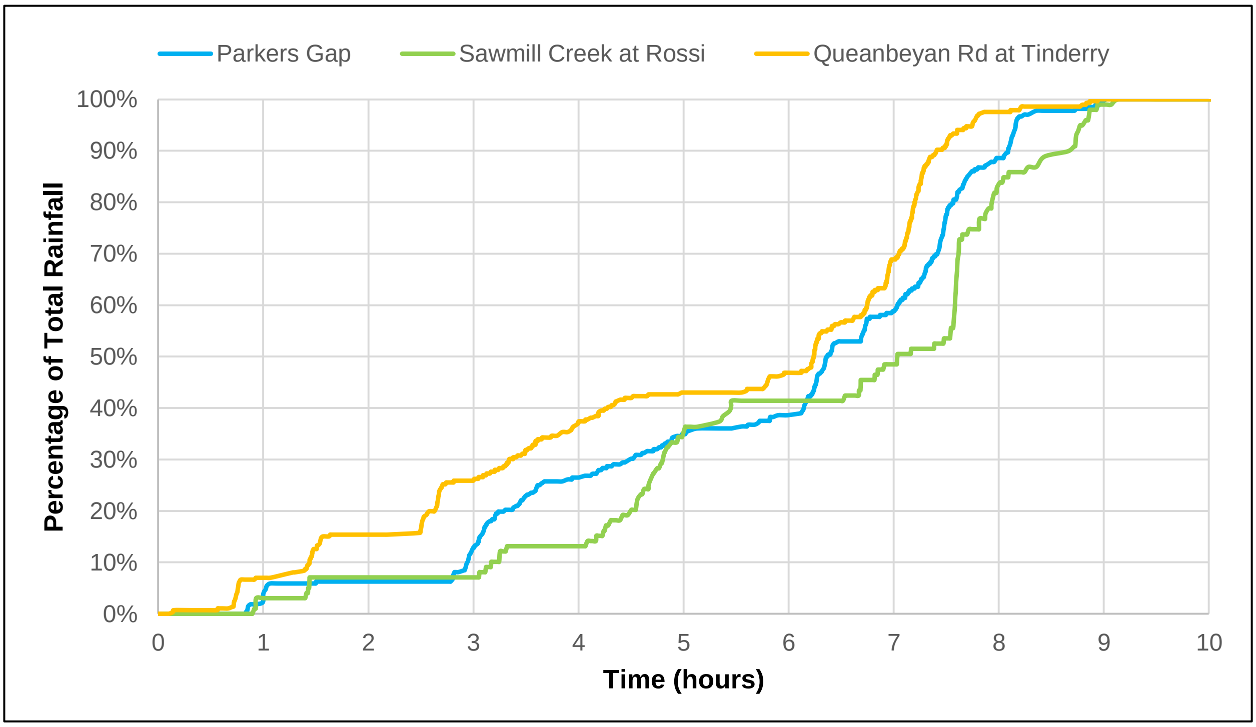


Figure 6-5 December 2010 Cumulative Rainfall Comparison

The pluviograph data shows that the Tinderry gauge experienced rainfall first, followed by Parkers Gap and then Sawmill Creek. This suggests that the storm moved in a roughly north-easterly direction across these gauges. The time the storm took to move across the catchment was approximated by assessing the time difference between each station recording 20%, 50% and 80% of the total rainfall volume. The results are shown below in **Table 6-2**, and show that there is approximately a half hour delay between Tinderry and Parkers Gap, and a 1 hour delay between Tinderry and Sawmill Creek.

Table 6-2 Rainfall delay across the catchment

Pluviograph Location	Time to 20% of total rainfall (hours)	Time to 50% of total rainfall (hours)	Time to 80% of total rainfall (hours)
Queanbeyan Rd at Tinderry	2.6	6.2	7.2
Parkers Gap	3.3	6.4	7.6
Sawmill Creek at Rossi	4.5	7.0	8.0

This behaviour compounded the flooding effects, as rather than the rainfall occurring simultaneously across the catchment, the peak rainfall followed the flood hydrograph through the catchment, resulting in rainfall occurring in time with peak river flows.

This behaviour was modelled by adopting delays in the rainfall hydrographs for the central subcatchments of 0.5 hours, and for 1 hour for the north of the study area. Rainfall intensities were interpolated from the surrounding pluviograph stations.

The hydrological model was run with a k_c of 7.5 and initial and continuing losses of 0mm and 3mm respectively. The initial loss was taken as zero as the storm was preceded by a significant amount of rainfall, 9mm in the preceding 5 hours, which would have resulted in the catchment being saturated prior to the storm event.

As previously noted, it was not possible to calibrate the hydrological model to this event as no flow data was recorded at the Molonglo River gauge. However, a check was made using the Kobada gauge for flow along the Molonglo River. The recorded and predicted flows for the 2010 event at Kobada are shown below in **Figure 6-6**. The figure shows a close match for flows at this location.

The peak inflows are shown in **Table 6-3**. Also included are the other historical events for comparison. The December 2010 event was the largest of the historical events, although it was only slightly larger than the July 1988 event. Both the 1991 events were significantly smaller.

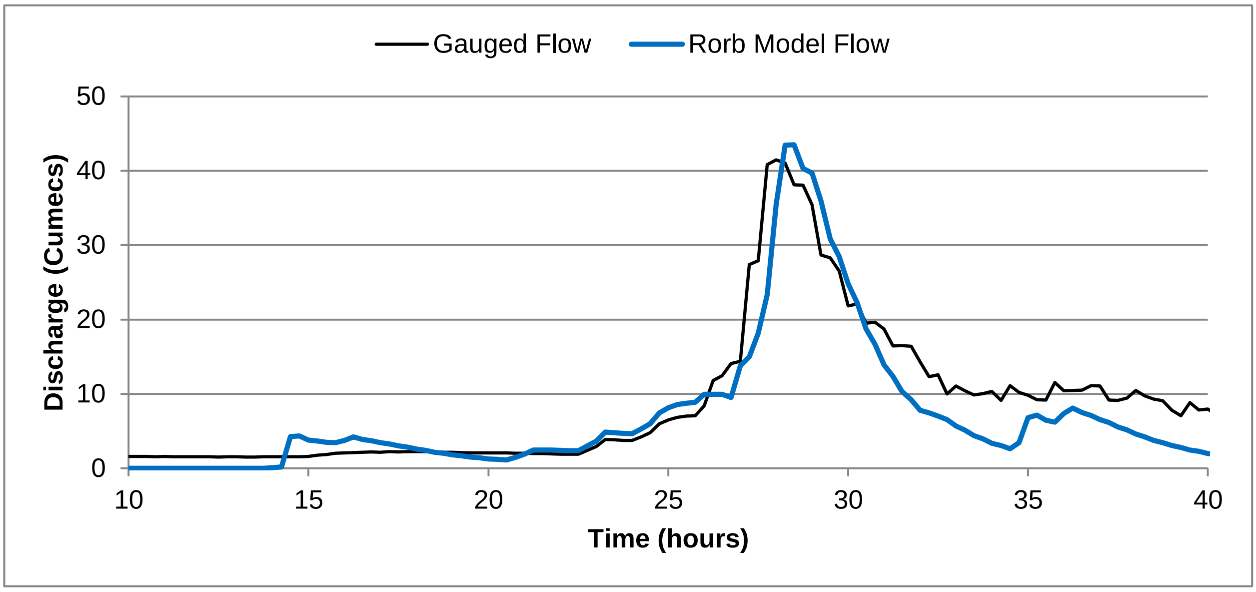


Figure 6-6 December 2010 Flow Comparison at Kobada Gauge

Table 6-3 Peak Inflows from RAFTS Historical Events (cumecs)

Historical Event	Molonglo River	Keatings Collapse	Kerrs Creek
2010 December	79.6	2.6	6.2
1991 July	30.0	2.8	6.9
1991 June	27.5	1.9	4.4
1988 July	75.8	3.7	9.1

6.2.2 Blockages

The key control in the flooding of Captains Flat Township from the Molonglo River was found to be the Foxlow Street Bridge. A range of blockages were assessed ranging from fully open to fully blocked. A summary of the comparison between these models and the post-flood survey is shown below in **Table 6-4**Error! Reference source not found..

Table 6-4 Differences between Model Calibration Results with Varying Assumed Blockages

	No Blockage	50% Blockage	75% Blockage	90% Blockage	100% Blockage
Average Difference	-0.07	-0.05	-0.01	0.02	0.03
Largest Increase	0.10	0.11	0.16	0.24	0.28
Largest Decrease	-0.29	-0.28	-0.17	-0.17	-0.17
50%-ile Difference	-0.04	-0.03	0.00	0.01	0.01
75%-ile Difference	0.01	0.04	0.07	0.09	0.10
90%-ile Difference	0.08	0.08	0.10	0.16	0.20

From this assessment, the closest match was found for the 75% blockage scenario. This was supported by community observations that were gathered during the community meeting, undertaken on the 14th March 2013.

Based on this, the blockage for Foxlow Street Bridge, and the Kerrs Creek pedestrian bridge were assumed to be 75% for the purposes of comparing historical flood levels. However, it is noted that there is some uncertainty with this, and the results should be observed as such.

Small bridges and culverts, such as the Kerrs Creek and Keatings Collapse culverts were given a blockage of 50%. Given the relatively small sizes of these culverts, it is reasonable to expect some blockage due to debris being washed down from the upstream catchment. This was observed by the community during flood events, as reported in the returned community surveys.

6.2.3 Comparison of Hydraulic Model Results to the Post Flood Survey

The results of the 2010 historical event are shown in **Figure 6-7**.

A comparison of the model peak water levels and the post flood survey are shown in **Figure 6-8** for the 75% blockage scenario (refer **Section 6.2.2**), which was found to best match the levels recorded in the post flood survey.

The results show that 65% of the locations are within +/- 0.1m of the surveyed peak levels and 97% are within +/- 0.15m. All the locations are with +/- 0.2m of the post flood survey heights. This level of precision is reasonable, given that there are a number of factors that can affect the calibration, including:

- Accuracy of survey;
- Accuracy of observations;
- Impacts of localised effects like waves and local debris;
- Uncertainty of the level of blockage of structures during the event; and,
- Accuracy of the model.

In order to demonstrate the effect of blockage rates on the calibration, **Figure 6-9** shows the difference to the post flood survey levels and the 50% and 90% blockage scenarios.

6.2.4 Comparison of Hydraulic Model Results to Community Observations

A range of data was collected from the community as part of the community consultation process, both from the returned surveys and the community meeting. This data included comments on the timings, behaviour and extents of the flood behaviour and photographs of the study area after the flood. A comparison between this data and the model results is provided in **Table 6-5** on the following page.

The comparison shows that the model demonstrates the flood behaviour reported by the community.

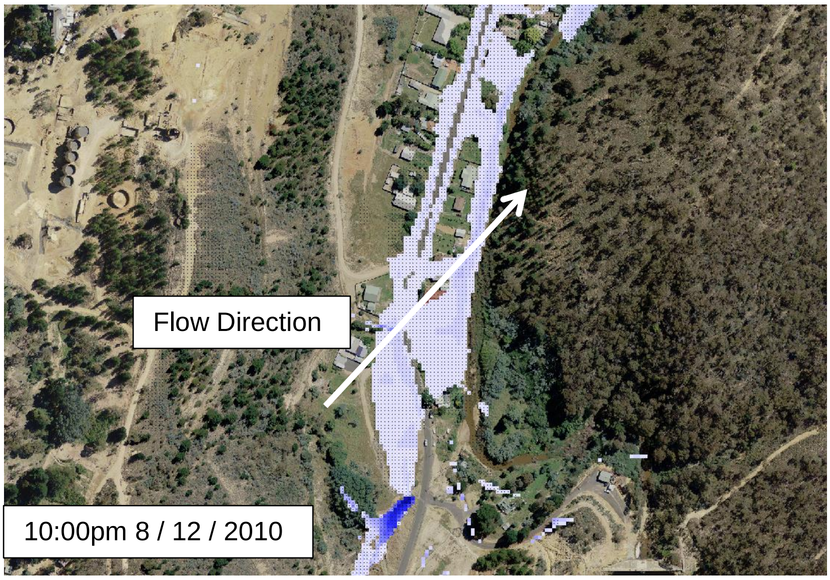
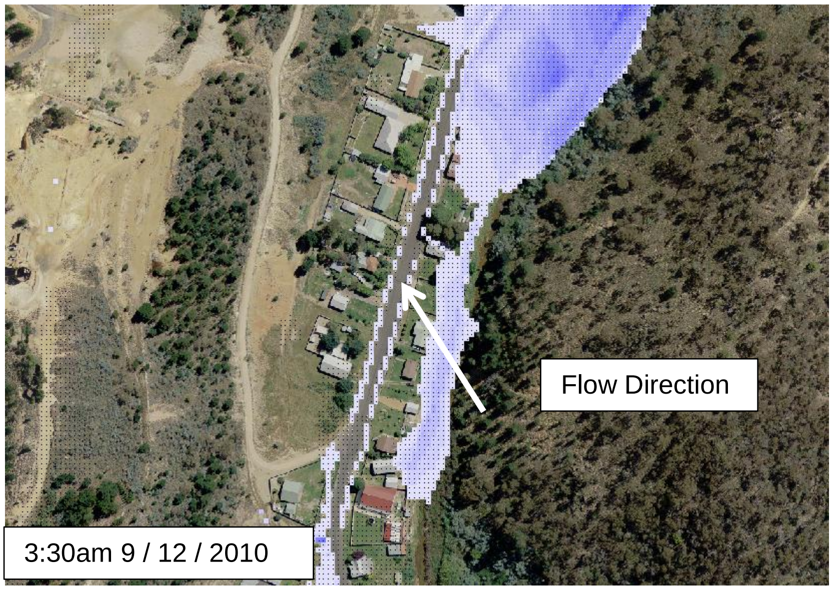
6.3 Calibration Results

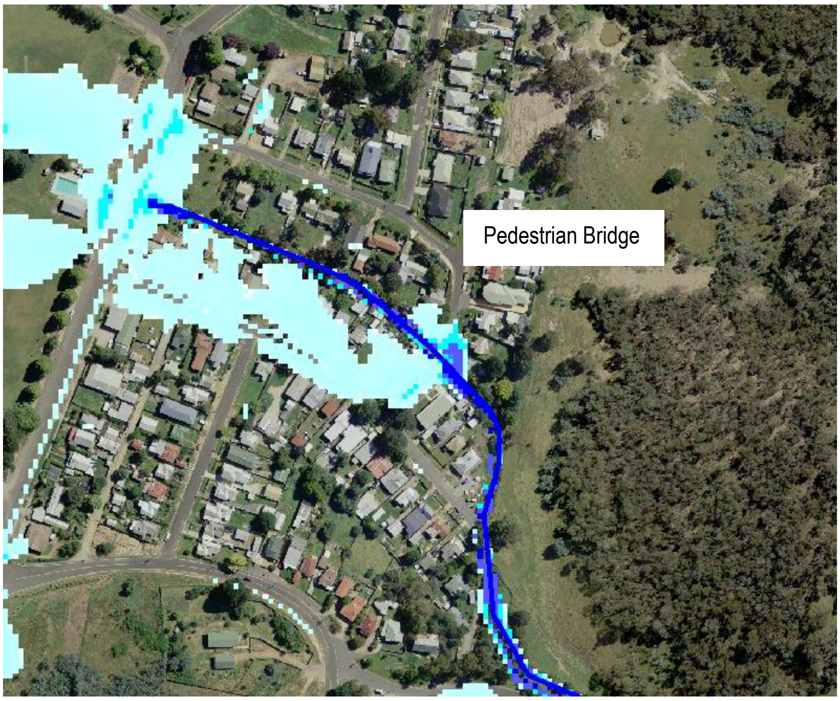
The results of the above assessment show that both the hydrological and hydraulic models have been successfully calibrated; the hydrological model to three historical events, and the hydraulic model to one historical event. As such, the models can be used with confidence in assessing design flood behaviour.

Based on the calibration, the following criteria have been adopted for undertaking the design runs:

- Initial and continuing loss rates of 5mm and 2mm respectively;
- A k_c value of 7.5 and an 'm' value of 0.8 in the hydrological model;
- Two blockage scenarios:
  - All culverts and bridges unblocked; and
  - Culverts and bridges blocked based on the calibration, with a blockage of 75% for the Foxlow Street Bridge and 50% for other structures.

Table 6-5 Comparison of Community Observations and Model Behaviour

Community Comment	Model Behaviour
During the 2010 event, flows from Keatings Collapse crossed Foxlow Street through properties (flowing west to east) before the Molonglo River overtopped its banks and the flow direction reversed. At this time, flow along the western edge of the properties had largely dissipated.	The model replicates this behaviour. Flow from Keatings Collapse crosses Jerangle Road approximately 5.5 hours before flows from the Molonglo River began to inundate properties. Shown below is the initial overtopping from Keatings Collapse flows.  As shown in the image below, when the Molonglo River overtops its banks and inundates adjacent properties, there is only some minor flow in the road reserve on the western side of the properties. 
Flow depth over Foxlow Street bridge was approximately 0.7m around 4:30am	The model shows a flood depth over the bridge of 0.6m occurring at 4:30am, down from a peak of 1m at 12:10am.

Community Comment	Model Behaviour
Flow broke out of Kerrs Creek at the pedestrian bridge and flowed through properties towards Foxlow Street	The model shows this flood behaviour, as indicated in the image below. The flow through this region is dependent on the blockage of the pedestrian bridge. 
Water flowed along Foxlow Street, between Keatings Collapse and the Foxlow Street Bridge, on the western side of adjacent properties	The model replicates this behaviour, as show in the image below. 

7 Existing Case Results

Flood modelling of design storms was undertaken for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events and the PMF event. Each AEP event was run for a series of durations; 0.5hr, 1hr, 1.5hr, 2hr, 3hr, 6hr, 9hr and 12hr storms, and for two blockage scenarios (refer Section 6.3). Further discussion on the effect of drainage and structure blockages is provided in **Section 9**.

An envelope of different durations and blockage rates were taken to determine the peak extent, depth and water level in the study area.

Rainfall was applied directly to the 2D domain, using the Direct Rainfall approach. This approach effectively results in every 2D cell being inundated with some flood depth. In order to create model extents and provide reasonable results, a filter was applied to separate what is catchment runoff and what is flooding.

For the design runs, it was conservatively assumed that the Dam was full at the start of the storm event. An assessment on the impact of dam levels on flood behaviour is discussed in **Section 11.3**.

In this study, flood extents were drawn for depths greater than 0.1m.

Flood extents for the design storms are shown in **Figure 7.1** to **Figure 7.7**.

The peak flood depths for the design storms are shown in **Figure 7.8** to **Figure 7.14**.

8 Existing Flood Hazard & Hydraulic Categories

8.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations (Appendix L; NSW Government, 2005). The Floodplain Development Manual (NSW Government, 2005) defines two categories for provisional hazard – high and low.

The model results were processed using an in-house developed program, which utilises the model results of flood level and velocity to determine hazard. Provisional hazard was prepared for 7 design events, namely PMF, 0.5%, 1%, 2%, 5%, 10%, and 20% AEP. The provisional hazard is based on the envelope of the hazard at each location for each AEP.

Hazard is calculated for each grid cell at each time step based on velocity, depth and velocity x depth, with the highest value giving the hazard rating for the cell.

The provisional hazard is shown in **Figure 8.1** to **Figure 8.7**.

8.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters described above in **Section 8.1**, does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include the:

- Size of the flood
- Effective warning time
- Flood readiness
- Rate of rise of floodwaters
- Duration of flooding
- Ease of evacuation
- Effective flood access
- Type of development in the floodplain

True flood hazard will be assessed as part of the Floodplain Risk Management Study and Plan.

8.3 Hydraulic Categories

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The Floodplain Development Manual (2005) defines flood prone land to be one of the following three hydraulic categories:

- Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.

- Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Floodways were determined for the 1% AEP event by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways are described below (based on Howells et al, 2003).

As a minimum, the floodway was assumed to follow the creekline from bank to bank. In addition, the following depth and velocity criteria were used to define a floodway:

- Velocity x Depth product must be greater than 0.25 m^2/s and velocity must be greater than 0.25 m/s; OR
- Velocity is greater than 1 m/s.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1 m and/or would cause peak discharge anywhere to increase by more than 10%. The criteria were applied to the model results as described below.

Previous analysis of flood storage in 1D cross sections assumed that if the cross-sectional area is reduced such that 10% of the conveyance is lost, the criteria for flood storage would be satisfied To determine the limits of 10% conveyance in a cross-section, the depth was determined at which 10% of the flow was conveyed. This depth, averaged over several cross-sections, was found to be 0.2 m (Howells et al, 2003). Thus the criteria used to determine the flood storage is:

- Depth greater than 0.2m
- Not classified as floodway.

All areas that were not categorised as Floodway or Flood Storage, but still fell within the flood extent, where the depth is greater than 0.1 m, are represented as Flood Fringe.

The hydraulic categories for the design events are shown in **Figure 8.8** to **Figure 8.14**.

9 Sensitivity Analysis

9.1 Model Parameters

A sensitivity analysis was undertaken on the TUFLOW model for the 1% AEP. The analysis was undertaken by:

- Varying the downstream boundary by +/- 20%
- Varying 1D and 2D roughness values by +/- 20%
- Varying the rainfall by +/- 20%

The sensitivity testing showed that a 20% difference in the downstream boundary did not result in any changes to flood levels within the study area. This is likely because the control for flood levels is not the boundary condition but rather the bridge crossing the Molonglo River at Captains Flat Road.

The model was more sensitive to changes in roughness and rainfall intensities. Water level difference plots for changes in roughness are shown in **Figure 9.1** and **Figure 9.2**, and for rainfall intensity in **Figure 9.3** and **Figure 9.4**.

Flows in the Molonglo River were particularly sensitive to changes in rainfall intensities, with changes of +0.3 and -0.3m for increases and decreases in rainfall intensities respectively. Changes to increases and decreases in roughness values resulted in differences of +0.1m and -0.1m respectively.

Other areas of the model, such as Kerrs Creek and Town Creek, were less affected by changes in rainfall and roughness, as show below in **Table 9-1.**

Table 9-1 Average Differences in Rivers and Creeks in Sensitivity Assessment (m)

	Molonglo River	Kerrs Creek	Town Creek
Boundary Increase	0	0	0
Boundary Decrease	0	0	0
Roughness Increase	0.09	0.03	0.02
Roughness Decrease	-0.1	-0.02	-0.02
Rainfall Increase	0.28	0.07	0.03
Rainfall Decrease	-0.3	-0.1	-0.03

9.2 Blockage

As discussed in **Section 6.2.2** the blockage rates adopted within the model, particularly for the Foxlow Street Bridge, have a significant effect on flood behaviour. The reported peak flood depths and levels represent the maximum flood level from an envelope of blocked and unblocked scenarios. The differences between the blocked and unblocked results for the 10% and 1% AEP are shown in **Figure 9.5** and **Figure 9.6** respectively.

The figures show that the area influenced by blockage of the Foxlow Street Bridge and the Kerrs Creek culvert are similar in both the 10% and 1% AEP events, though the magnitude of the flood level increase is greater in the 1% AEP; 0.25m compared to 0.17m in the 10yr ARI event, upstream of the Foxlow Street Bridge.

10 Discussion on Existing Flooding

10.1 Molonglo River

The Molonglo River is the major flowpath in the study area. It runs through the south western region of the study area, flowing north from Captains Flat Dam, along the eastern side of a number of residential properties. It passes under Foxlow Street, alongside a region of open space, before passing under Captains Flat Road and continuing to the north.

It is a high hazard flow path, due to both depths and velocities, which reach 3.8m and 5m/s in the 1% AEP event.

In events as small as the 20% AEP event, the river breaks its banks on the western side and inundates a number of private lots. The depth and extent of this breakout flow increases for larger events.

The Molonglo River also causes road overtopping, particularly in the vicinity of the Foxlow Street Bridge.

10.2 Keatings Collapse

Keatings Collapse is a steep narrow gully that joins with the Molonglo River via a pipe under Jerangle Road 200m downstream of the Dam. In events larger than the 2% AEP event, flows from Keatings Collapse overtop Jerangle Road due to insufficient capacity of the pipe. This flow proceeds north and east along Foxlow Street before crossing through a number of properties into the Molonglo River.

This overtopping flow is typically less than 0.3m even in large events.

Flow within Keatings Collapse is high hazard; however, the overtopping flows are low hazard. The high hazard regions only affect bushland or open space.

10.3 Kerrs Creek

Kerrs Creek runs from the south east of the study area, through residential areas, before being directed to a piped reach at Foxlow Street, which carries the flow past the swimming pool and discharges into the Molonglo River.

In events larger than the 20% AEP event, the flow overtops Foxlow Street where it transitions to the piped reach.

A portion of the flow breaks out of the creek at the pedestrian bridge at Wilson Road. This flow moves west along Kurrajong Street, crosses Foxlow Street, before draining into the Molonglo River.

The flowpath results in flooding of residential lots between Kurrajong Street and Wattle Avenue. The creek flow and Kurrajong Street flows are high hazard, though all property flooding is low hazard.

10.4 Town Creek

Town Creek is an informal open channel that runs behind properties on the western side of Foxlow Street, north of the Captains Flat Road intersection. The flowpath drains the hills on the east and west of the study area to the Molonglo River. The flowpath inundates a number of properties adjacent to it. However, the flows are shallow and slow moving, and the flowpath is classified as low hazard.

10.5 Flow Timings

Each of the flowpaths responds at a different rate to storm events. Shown below in **Table 10-1** are the times to peak flow in each flowpath from the start of the storm event for the 10% and 1% AEP events.

The table shows that the Town Creek peaks first, due to the fact it only drains the immediate catchment.

Kerrs Creek and Keatings Collapse have relatively small upstream catchment areas compared to the Molonglo River, so these creeks peak 3 to 4 hours before the Molonglo River.

Table 10-1 Time to Peak Flow in the 100yr ARI (hours from start of storm event)

Flowpath	10% AEP	1% AEP
Molonglo River	7	9
Keatings Collapse	6	6
Kerrs Creek	6	5
Town Creek	1	1

10.6 Comparison with 2010 Historical Event

A comparison was undertaken between the design events and the historical 2010 event to assess what recurrence interval the levels in the various flowpaths was representative of.

Different flowpaths have different recurrence intervals associated with them due to the unique behaviour of the historical storm, and the way that it moved through the catchment.

Table 10-2 below shows that levels along the Molonglo River and within Keatings Collapse were equivalent to a 5% AEP event. Kerrs Creek flows however were equivalent to a 2% AEP event.

Table 10-2 Recurrence Interval of Peak Levels from the 2010 Flood Event

Flowpath	2010 Peak Level	Equivalent AEP
Molonglo River (upstream of Foxlow Street)	845.0 mAHD	5%
Keatings Collapse (at pipe inlet)	853.7 mAHD	5%
Kerrs Creek (upstream of pedestrian bridge)	850.1 mAHD	2%
Town Creek (downstream of Foord Street Culverts	855.9 mAHD	20%

10.7 Road Overtopping

Road overtopping occurred in all of the modelled design events. The location at which overtopping first occurred was Foxlow Street, at the beginning of the Kerrs Creek pipe due to flows in Kerrs Creek, although the most significant road overtopping occurred at the Foxlow Street Bridge due to overbank flows from the Molonglo River.

A summary of the road overtopping behaviour for the Molonglo River and Kerrs Creek are shown below in **Table 10-3** and **Table 10-4** respectively, for each design event. Overtopping was said to occur when a flow depth of greater than 0.2m occurred on the road way.

The table shows that, in line with the flow timings above, that the Kerrs Creek flows cause road overtopping 2 – 3 hours before those from the Molonglo River. Road access at Foxlow Street Bridge is lost for 8 to 9 hours in events larger than the 20% AEP event. Overtopping durations at Kerrs Creek are less but still significant; generally 6 to 7 hours.

Table 10-3 Road Overtopping – Foxlow Street (from Molonglo River)

Design Event (AEP)	Time to road overtopping (hours)	Duration of overtopping (hours)	Indicative Peak overtopping depth (m)
20%	6.5	3	0.54
10%	7	8.5	0.64
5%	5.5	7.5	0.77
2%	4.5	8.5	0.90
1%	4	9	1.0
0.5%	4	9	1.1
PMF	0.5	>12	3.6

Table 10-4 Road Overtopping – Foxlow Street (from Kerrs Creek)

Design Event (AEP)	Time to road overtopping (hours)	Duration of overtopping (hours)	Indicative Peak overtopping depth (m)
20%	3.5	8	0.36
10%	5.5	6	0.39
5%	3.5	6.5	0.43
2%	3	6	0.46
1%	2.5	6.5	0.50
0.5%	2	7	0.52
PMF	0.5	>12	1.9

10.8 Property Flooding

A preliminary investigation was undertaken into the timings of property flooding. Summarised below in **Table 10-5** are the times from the start of each design storm when a residential lot first overtops, the time to 0.2m property flooding, and the time to 0.5m property flooding (if applicable).

The table shows that overground property flooding occurs in all design events. Warning times range from 6.5 hours to 0.5 hours depending on the design event. In larger events, significant flood depth on residential lots occurs within 3 to 5 hours.

Due to the timings of the flowpaths, the first location for property flooding is on Kerrs Creek, adjacent to the pedestrian bridge. The deepest property flooding however occurs adjacent to the Foxlow Street Bridge on the Molonglo River.

Table 10-5 Time to Property Inundation

Design Event (AEP)	Time to first property overground flooding (hours)	Time to first 0.2m flood depth on property (hours)	Time to first 0.5m flood depth on property (hours)
20%	4	6.5	-
10%	4	6	8
5%	3.5	4	6
2%	2	3	5
1%	2	3	5
0.5%	1.5	2.5	4.5
PMF	0.2	0.5	1

11 Preliminary Mitigation Assessment

A comprehensive assessment of a range of flooding and risk mitigation options will be undertaken as part of the Floodplain Risk Management Study and Plan. However, as a result of the recent 2010 floods, and subsequent community discussion, some preliminary assessment has been undertaken to assess the viability of some mitigation options. The options assessed were:

- Regrading the Molonglo River to smooth out irregularities between the Dam and the Captains Flat Road bridge;
- Vegetation management and debris removal within the Molonglo River to reduce impediments to flow; and,
- An assessment into the impact of pre-flood levels in Captains Flat Dam on flood behaviour, and whether the dam can be used to reduce flooding downstream.

11.1 Molonglo River Regrading

The hydraulic model was revised to remove local high points within the Molonglo River, and to provide a generally constant fall from the Dam to the Captains Flat Road Bridge. A longsection showing the difference between the existing case and the option case is shown below in **Figure 11-1**.

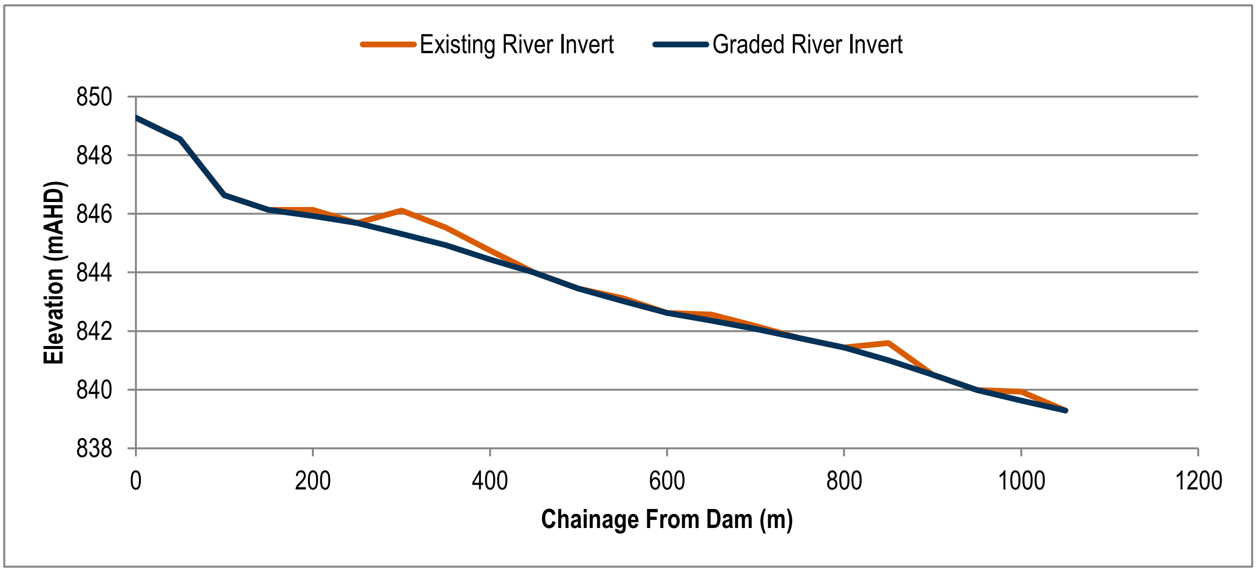


Figure 11-1 Molonglo River Longsection

The impact of regrading the Molonglo River on the 10% and 1% AEP peak flood levels are shown in **Figure 11-2** and **Figure 11-3** respectively.

Water level reductions occurred downstream of Keatings Collapse, and extend to approximately 100m upstream of the Foxlow Street Bridge. Localised decreases of 0.03m occurred immediately downstream of the Foxlow Street Bridge for approximately 20m, but the option did not result in any changes further downstream.

For each event, the regrading resulted in typical flood level reductions on adjacent properties of 0.02 – 0.05m in both events. Higher increases occurred upstream of 0.08m and 0.1m in the 10% and 1% AEP events respectively.

There were some localised increases in the 1% AEP event of 0.01 – 0.02m. These occurred immediately after the two main lowering locations, at chainages 350m and 850m. The minor increases are likely due to an increased volume passing downstream due to the increased channel efficiency.

11.2 Molonglo River Vegetation Management and Debris Clearing

The roughness parameters for 1D and 2D elements representing the Molonglo River were adjusted to represent clearing of the Molonglo River from the Dam to the Captains Flat Road Bridge. Manning's roughness values were lowered from the existing 0.045 to 0.035 to represent a cleared river. The reduction was applied to the Molonglo River from the Dam to the Captains Flat Road Bridge.

The impact of clearing the Molonglo River on the 10% and 1% AEP peak flood levels are shown in **Figure 11-4** and **Figure 11-5** respectively.

The 10% AEP result is similar to the regrading option, with reductions of 0.02 – 0.05m occurring across properties adjacent to the Molonglo River.

The reductions in the 1% AEP event were more wide spread than the regrading option, extending from the confluence of Keatings Collapse to approximately 200m downstream of the Foxlow Street Bridge. Flood level reductions were of a similar magnitude to the 10% AEP event; 0.02 – 0.05m.

Both AEP events had localised flood level increases immediately upstream of the Foxlow Street Bridge of 0.03m.

11.3 Impact of Captains Flat Dam Levels on Flood Behaviour

The hydrological and hydraulic models were both run for the 10% and 1% AEP events with Captains Flat Dam empty to assess the Dam's effect on flood behaviour.

In both events, having the dam empty at the start of the flood event did not result in any difference to the peak flood levels. This was likely because the dam was filled in both events prior to the arrival of the flood peak. This can be seen in the Captains Flat Dam outflow hydrographs from the hydrological model shown below in **Figure 11-6**.

The hydrographs show that the dam is filled in 5 hours in the 10% AEP event and in 3.5 hours in the 1% AEP event, which results in the dam being filled 3 hours before the peak in the 10% AEP event and 3.5 hours before the peak in the 1% AEP event.

Because of this, the dam has no impact on peak flood levels or extents.

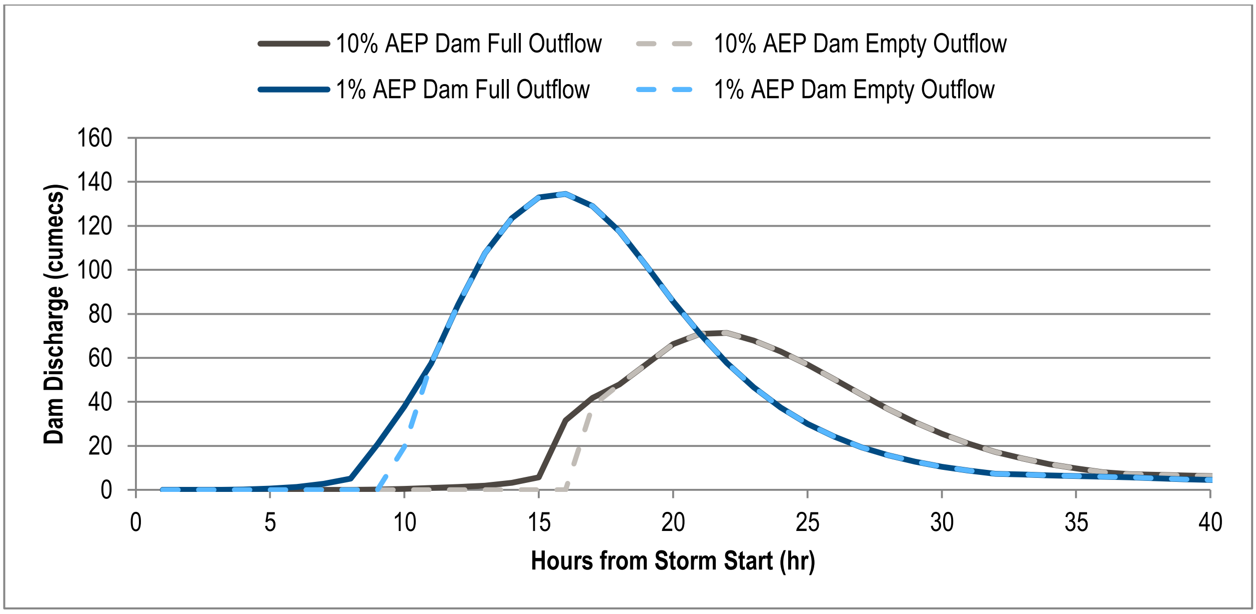


Figure 11-6 Captains Flat Dam Discharge Hydrograph Comparison

12 Conclusions

Flood modelling has been undertaken for the Captains Flat Township in order to describe the existing flood behaviour, as part of the NSW Floodplain Management Process.

Hydrological modelling was undertaken in RORB, and calibrated to three historical events.

Hydraulic modelling was undertaken in SOBEK and was calibrated to a recent historical flood from December 2010 for which post-flood survey had been collected.

The calibrated hydrologic and hydraulic models were used to asses a range of design events, namely:

- 20% Annual Exceedence Probability (AEP);
- 10% AEP;
- 5% AEP;
- 2% AEP;
- 1% AEP;
- 0.5% AEP and,
- The Probable Maximum Flood (PMF)

Each event was run for a range of durations ranging from the 30min event up to the 24 hour event in order to determine critical durations for the study area. Peak water levels, depth and velocities, as well as provisional flood hazards and hydraulic categories were determined for each AEP event.

Preliminary assessments were undertaken on road and property flooding in order to provide initial flood intelligence to Council and the SES prior to the comprehensive Floodplain Risk Management Study being undertaken.

The community have raised some options that they would like investigated as flood mitigation strategies. Three of these, clearing of the Molonglo River, regrading of the Molonglo River, and utilising Captains Flat Dam as a flood control structure, were assessed for the 10% AEP and 1% AEP to provide some early indication of their feasibility.

Both the clearing and regrading options reduced levels upstream of the Foxlow Street Bridge in both the 10% and 1% AEP events. Analysis of Captains Flat Dam showed it was not effective at controlling flood waters, even if empty at the start of the storm, as floodwaters filled the dam 3 hours before the peak of the flood event, so there was no change in peak flood levels or extents.

13 Qualifications

This report has been prepared by Cardno for Palerang City Council and as such should not be used by a third party without proper reference.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The report relies on the accuracy of the survey data and pit and pipe date provided by Council.

Study results should not be used for purposes other than those for which they were prepared.

Flood Study Report - Final

FIGURES

Shaping the Future

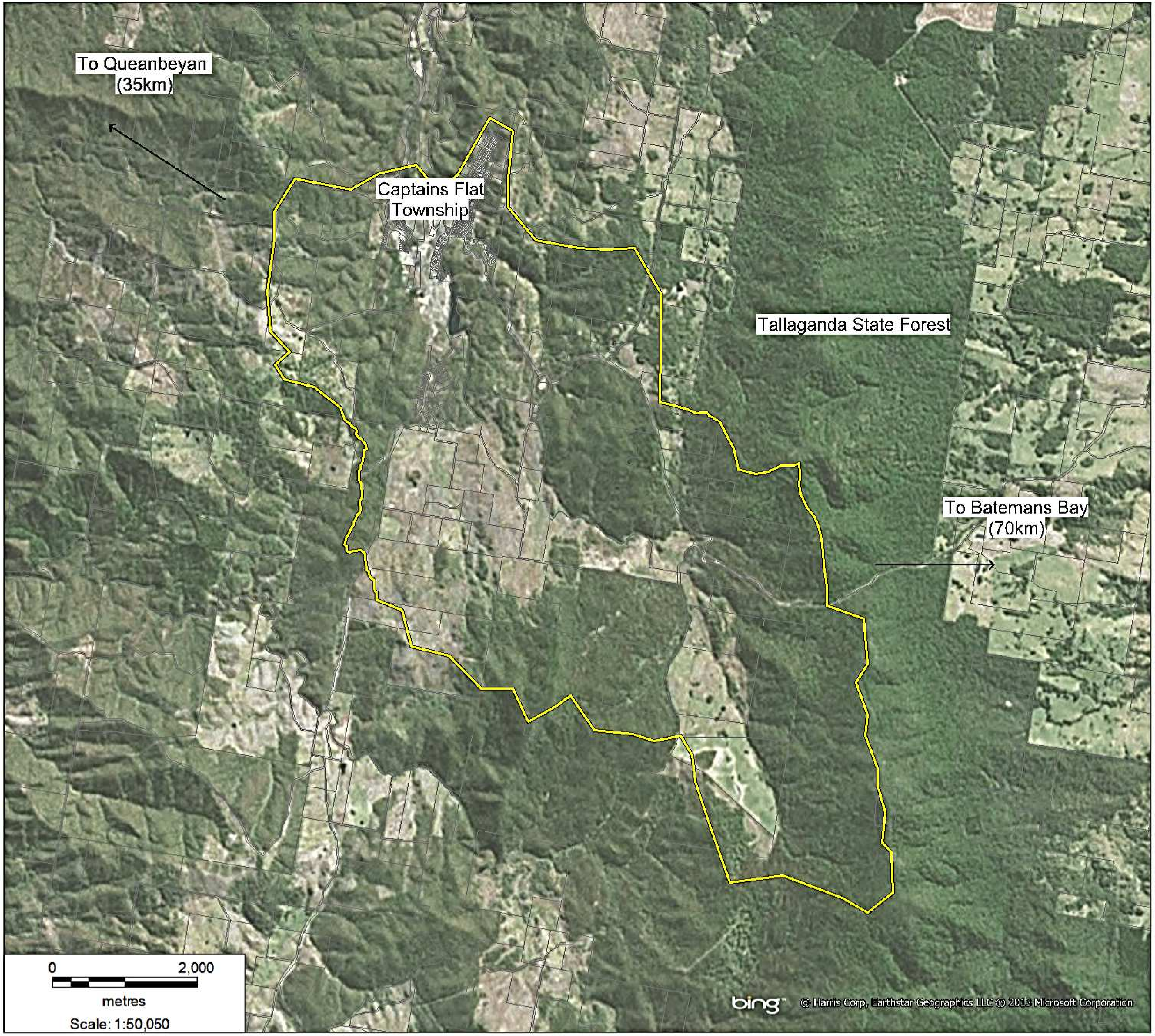


FIGURE 2-1

CATCHMENT AREA

CAPTAINS FLAT
FLOOD STUDY

Cadastre

Catchment Area

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 7 November 2012
Coordinate System: Zone 56/1 ISG

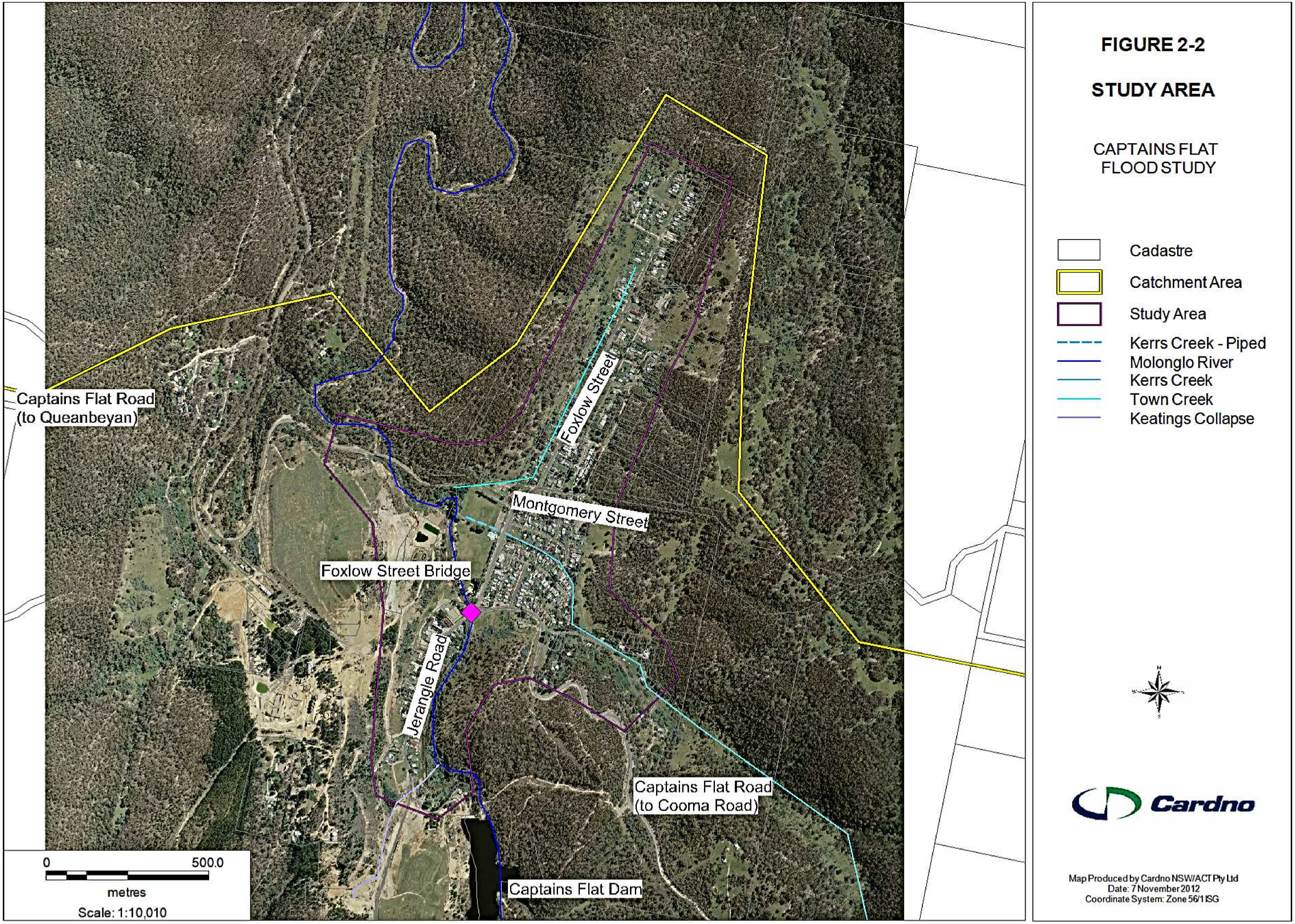


FIGURE 2-2

STUDY AREA

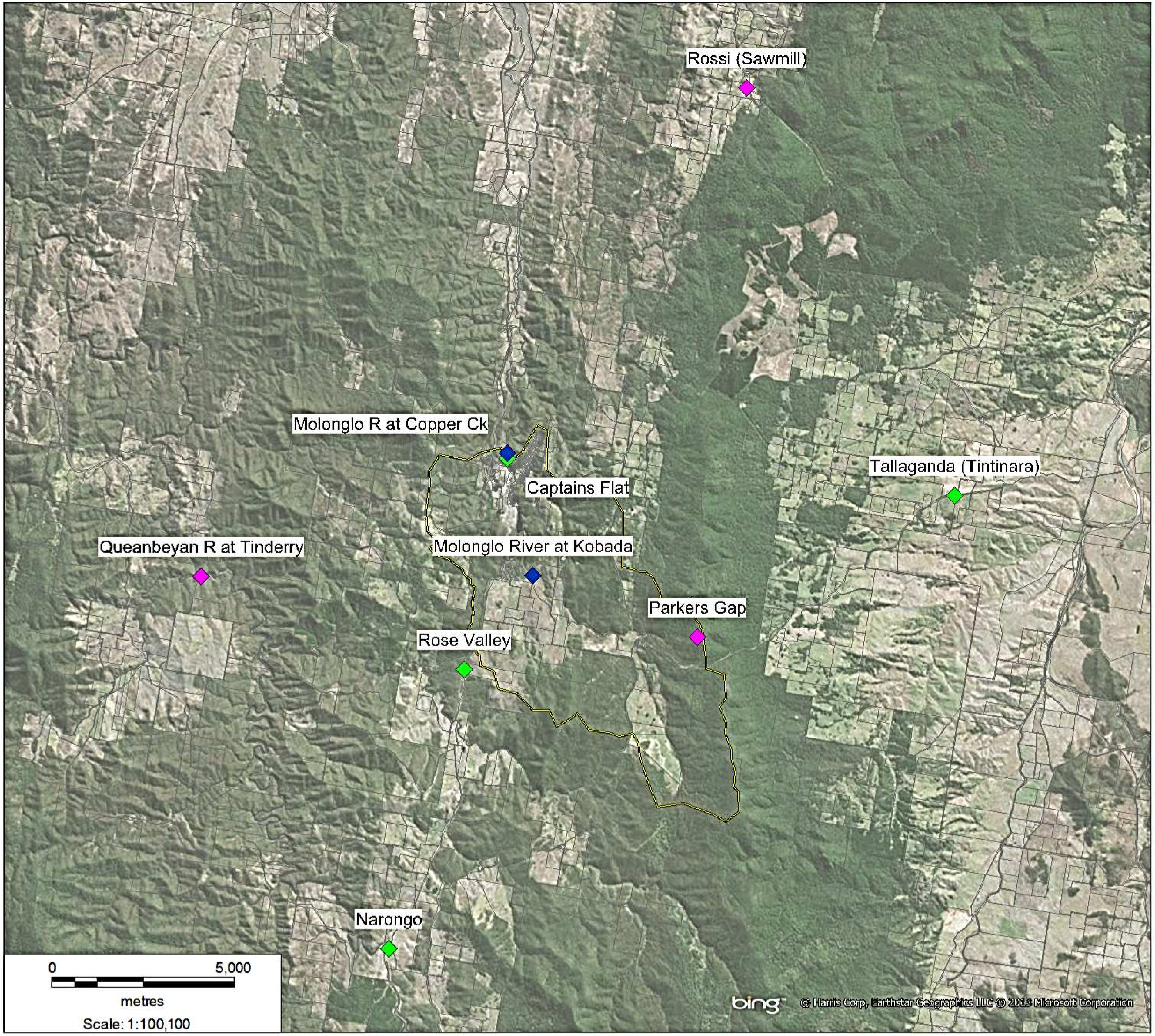


Figure 3-1

Gauge Locations

CAPTAINS FLAT
FLOOD STUDY

Cadastre
Catchment Area
Daily Rainfall
Pluviograph
River Flow

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

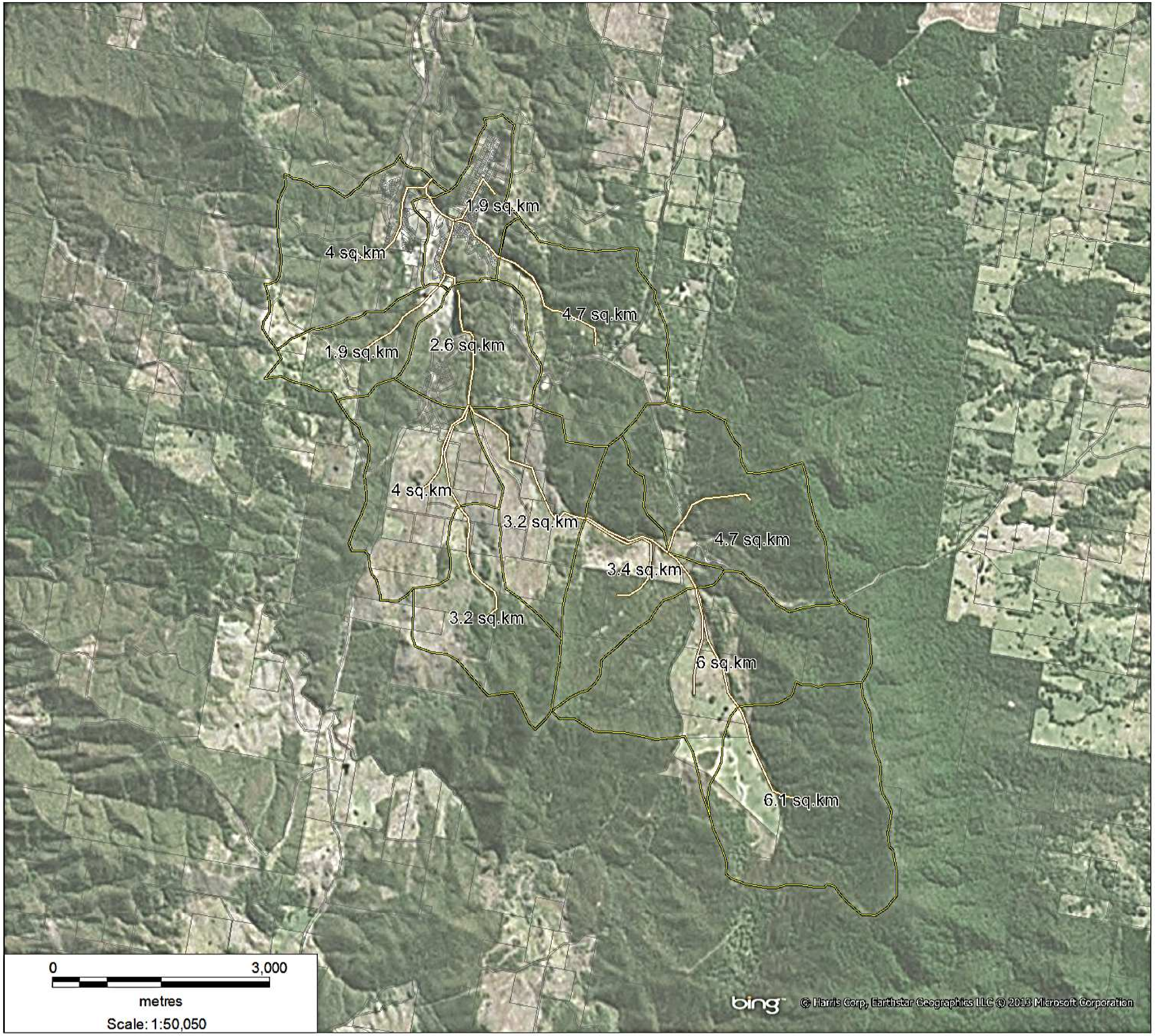


Figure 5-1

RORB Subcatchments

CAPTAINS FLAT
FLOOD STUDY

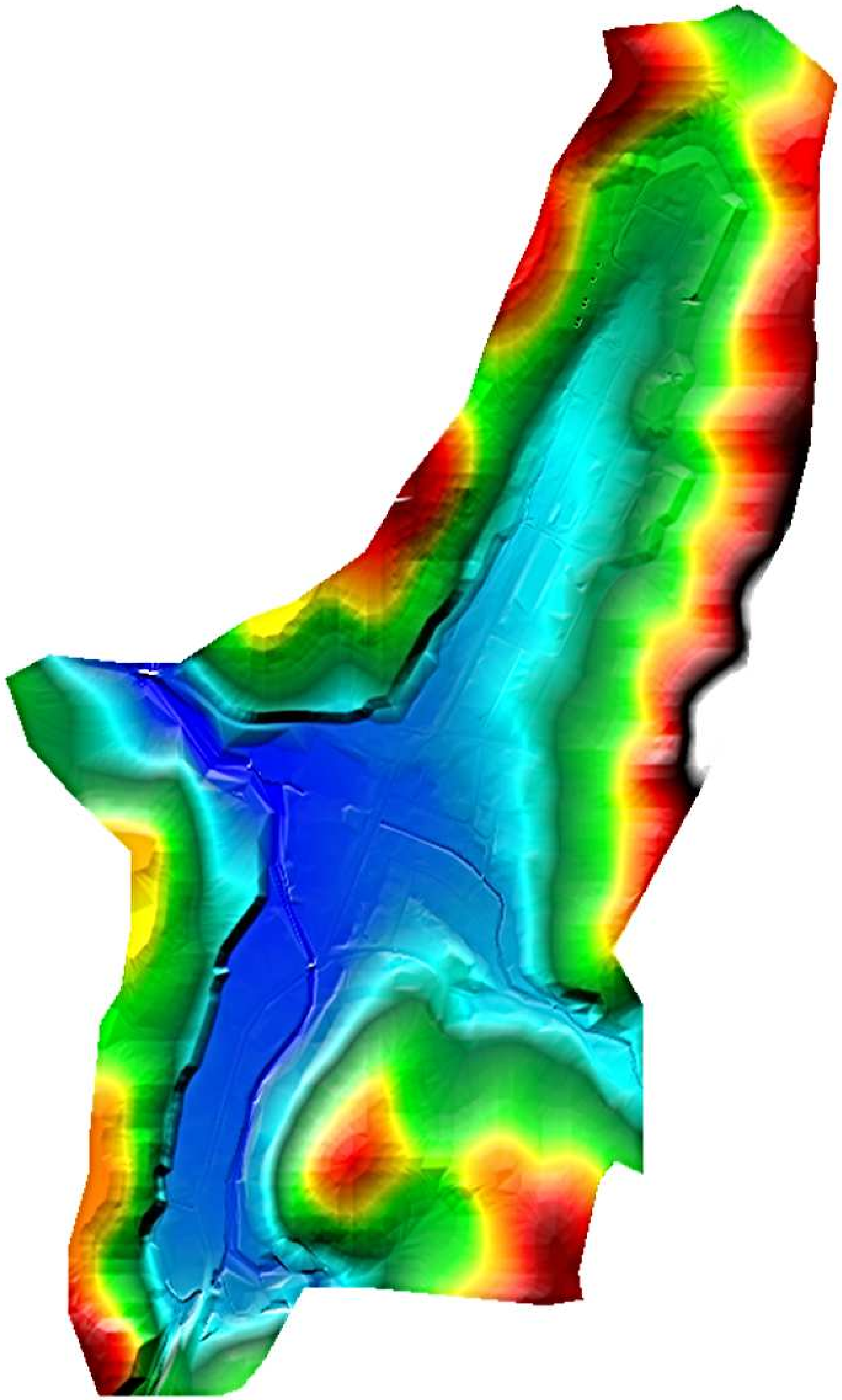
Cadastre

RORB Subcatchments (with Area in sq.km)

RORB Reaches

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG



0 500.0

metres

Scale: 1:10,010

Figure 5-6

Terrain Elevation

CAPTAINS FLAT
FLOOD STUDY

Elevation (mAHD)

850
860
870
880
890
900
910
920
930
940
950

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Coordinate System: Zone 55/1ISG

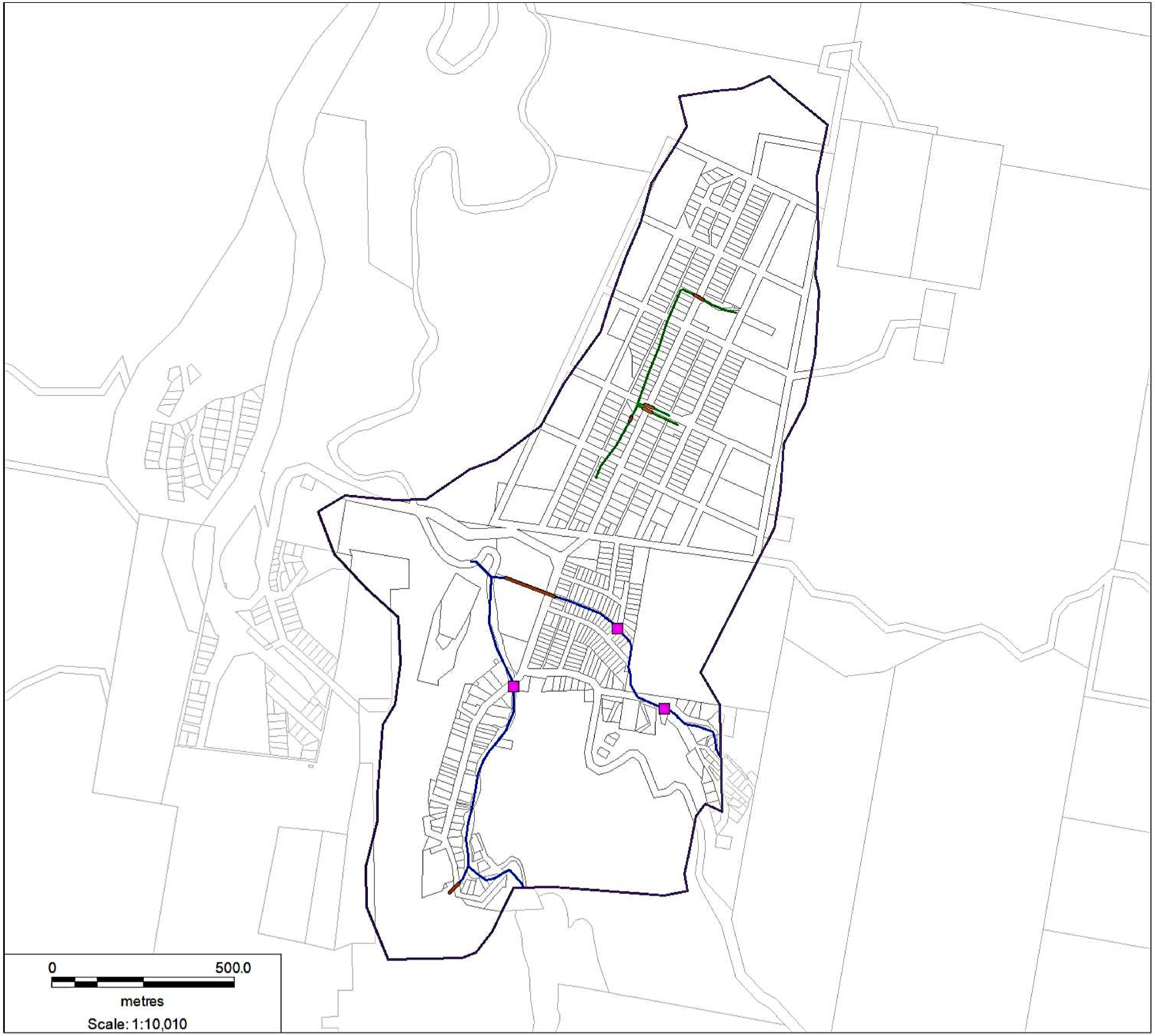

Figure 5-7

1D Elements

CAPTAINS FLAT
FLOOD STUDY

Cadastre
Study Area
Bridge
Creek
Swale Drain
Pipe / Culvert

Map Produced by Cardno NSW/ACT Pty Ltd
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Coordinate System: Zone 55/1 ISG

Figure 5-8

Roughness Zones

CAPTAINS FLAT
FLOOD STUDY

Study Area

Mannings 'n'

Urban Lots	(0.15)
Roads	(0.015)
Bush / Brush	(0.09)
Open Space	(0.05)
Waterways	(0.045)
Bridge	(0.20)

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Coordinate System: Zone 55/1 ISG

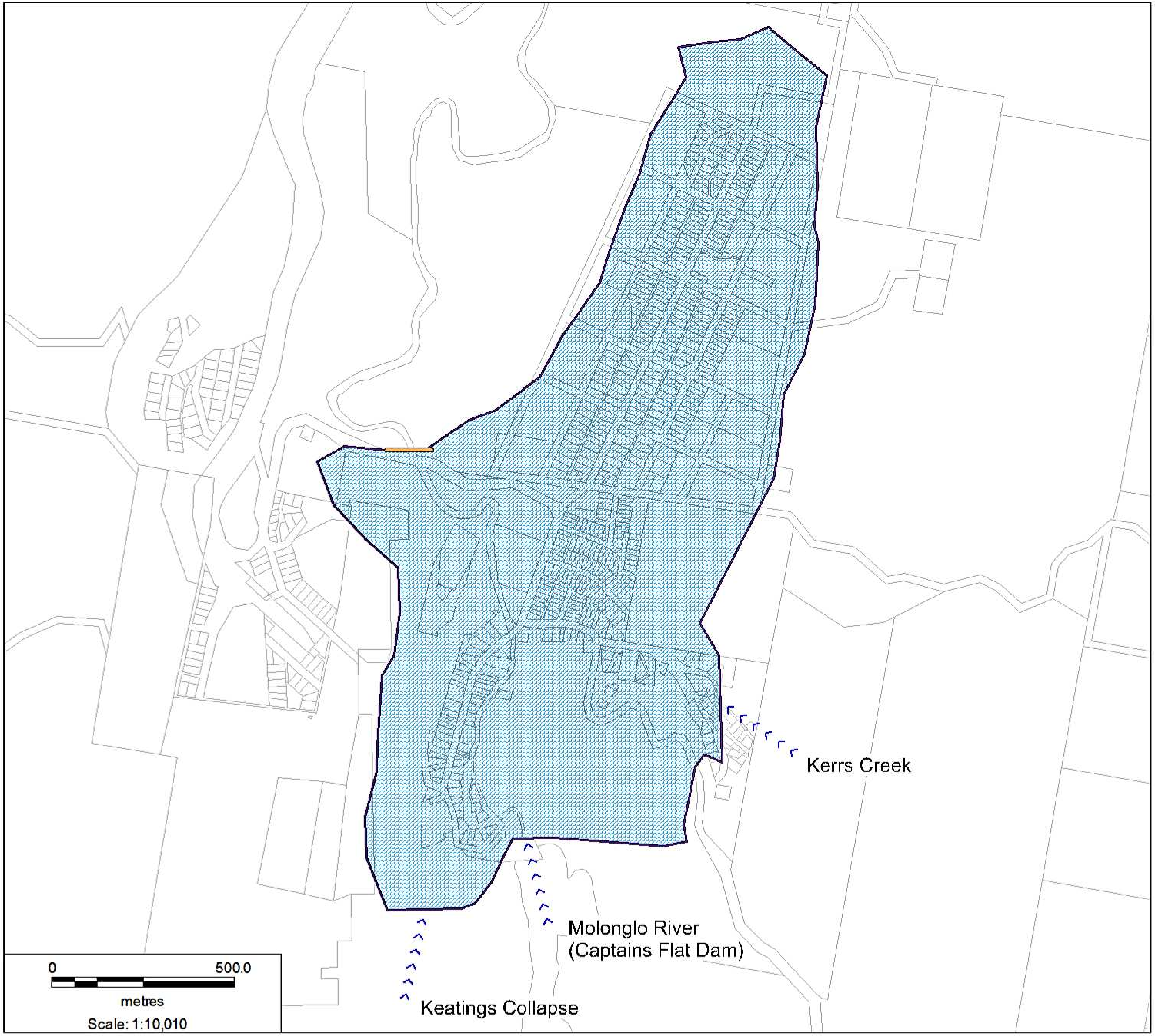

Figure 5-9

Hydrology Schematisation

CAPTAINS FLAT
FLOOD STUDY

Cadastre

Study Area

Rainfall On Grid

Hydrological Inflow

Downstream Boundary

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Date: 15 April 2013
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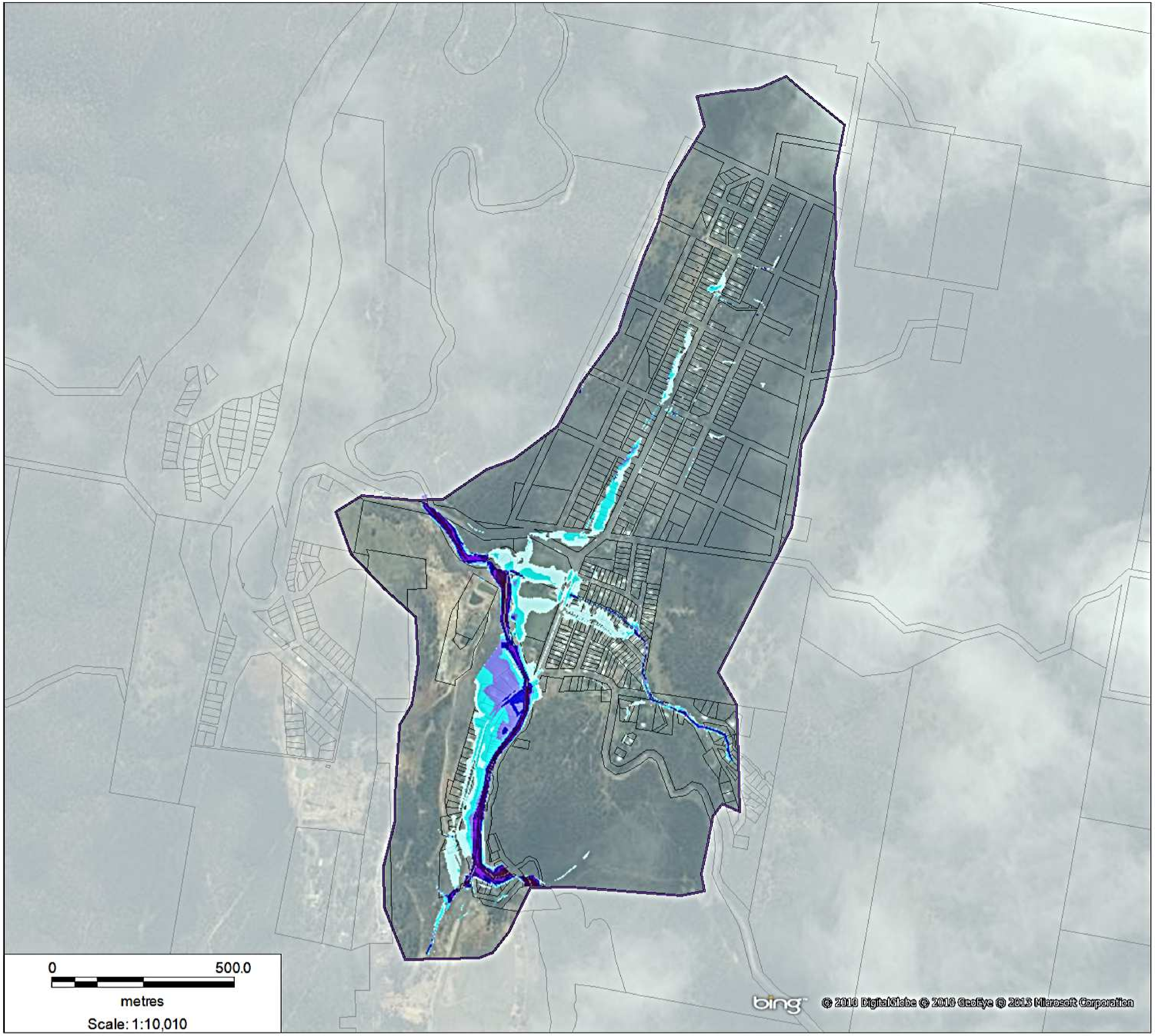


Figure 6-7

December 2010 Hydraulic Model Results

CAPTAINS FLAT
FLOOD STUDY

Study Area

Depth (metres)

0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
2.00 - 3.00
> 3.00

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

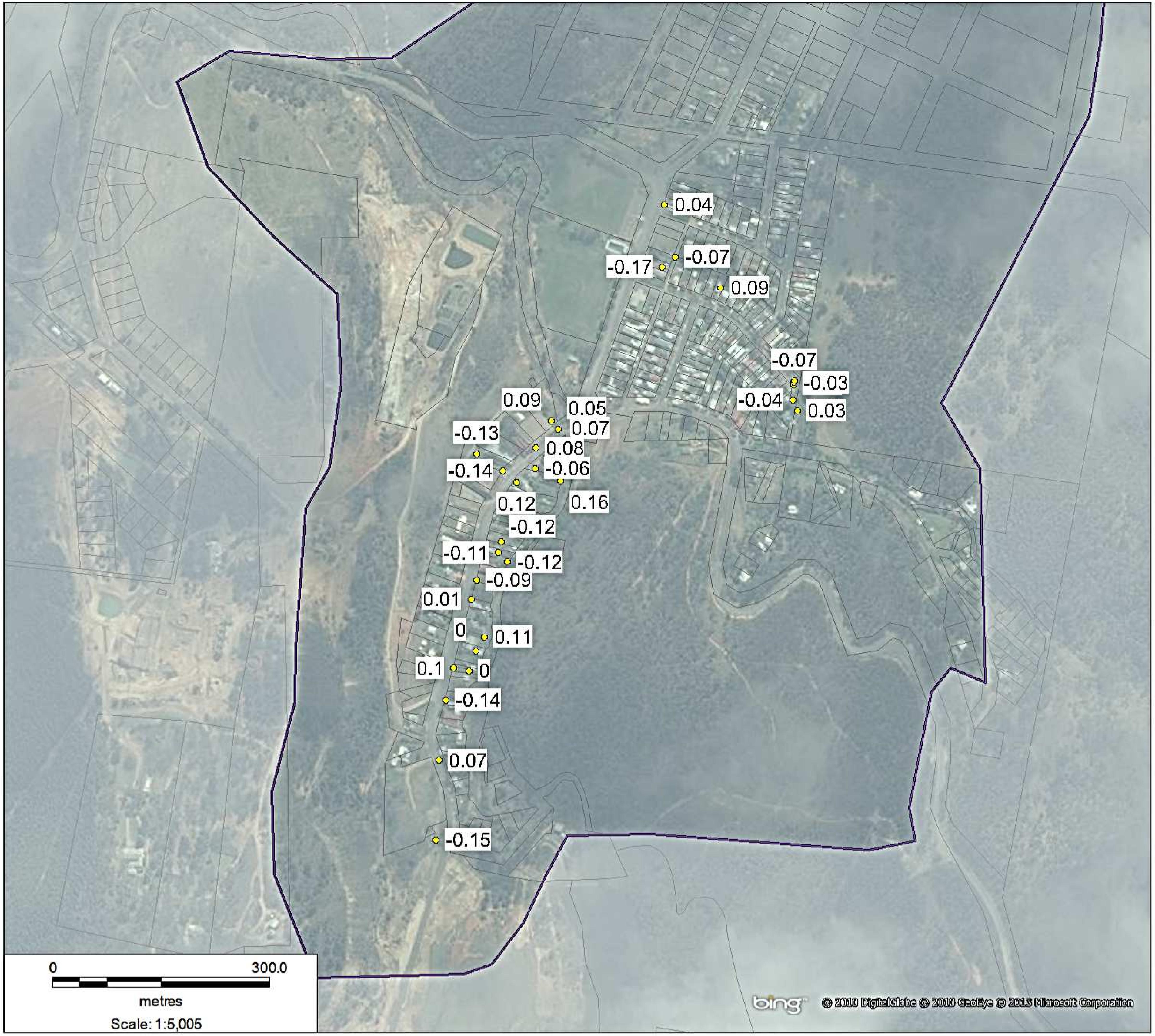


Figure 6-8

Hydraulic Model Calibration

CAPTAINS FLAT FLOOD STUDY

Cadastre

Study Area

Difference (m)

Note: Differences shown are the SOBEK level minus the post flood survey level

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

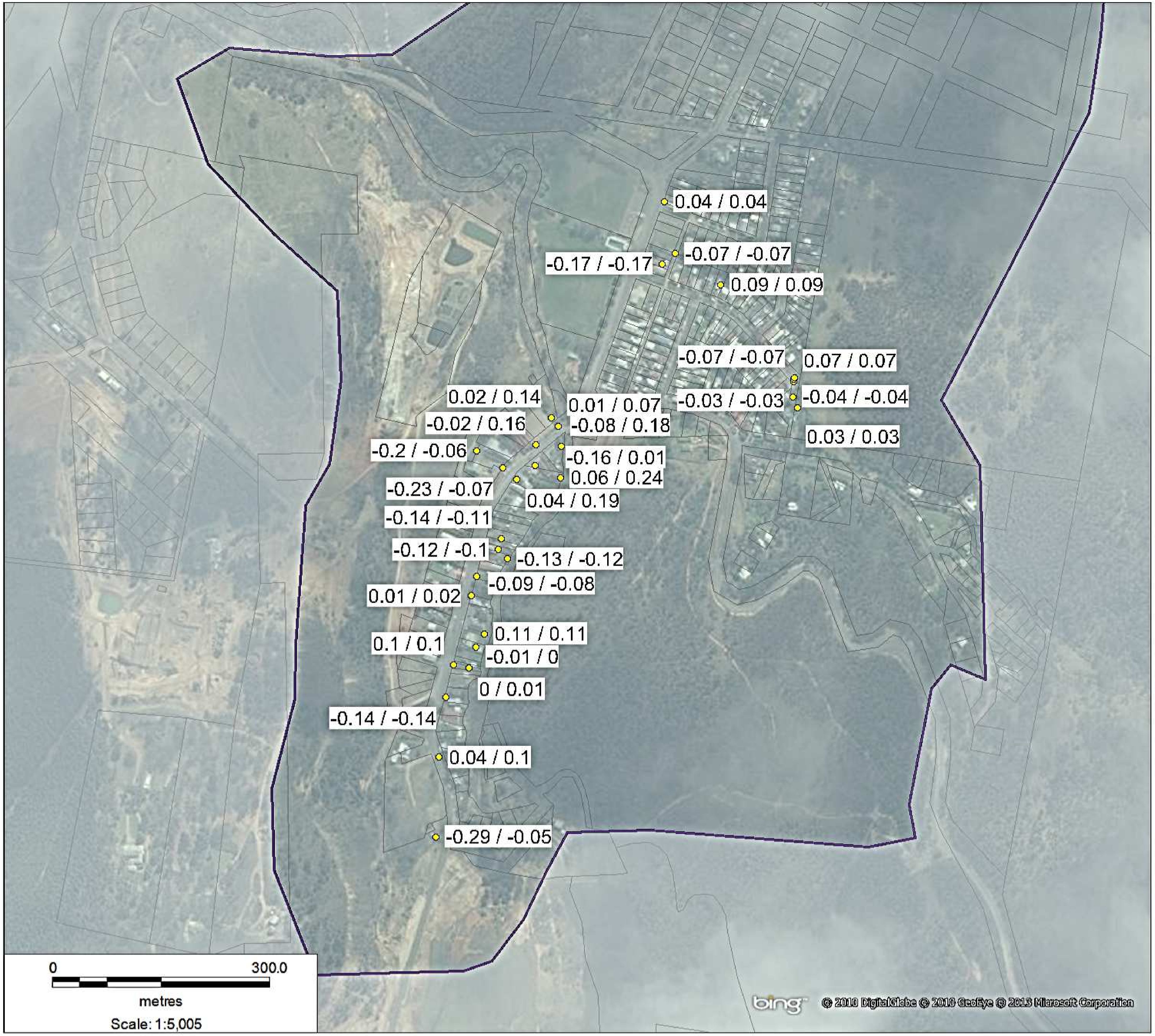


Figure 6-9

Effect of Blockage on Model Calibration

CAPTAINS FLAT
FLOOD STUDY

Cadastre

Study Area

Difference (m) (50 / 90 Percent blocked)

Note: Differences shown are the SOBEK level minus the post flood survey level

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

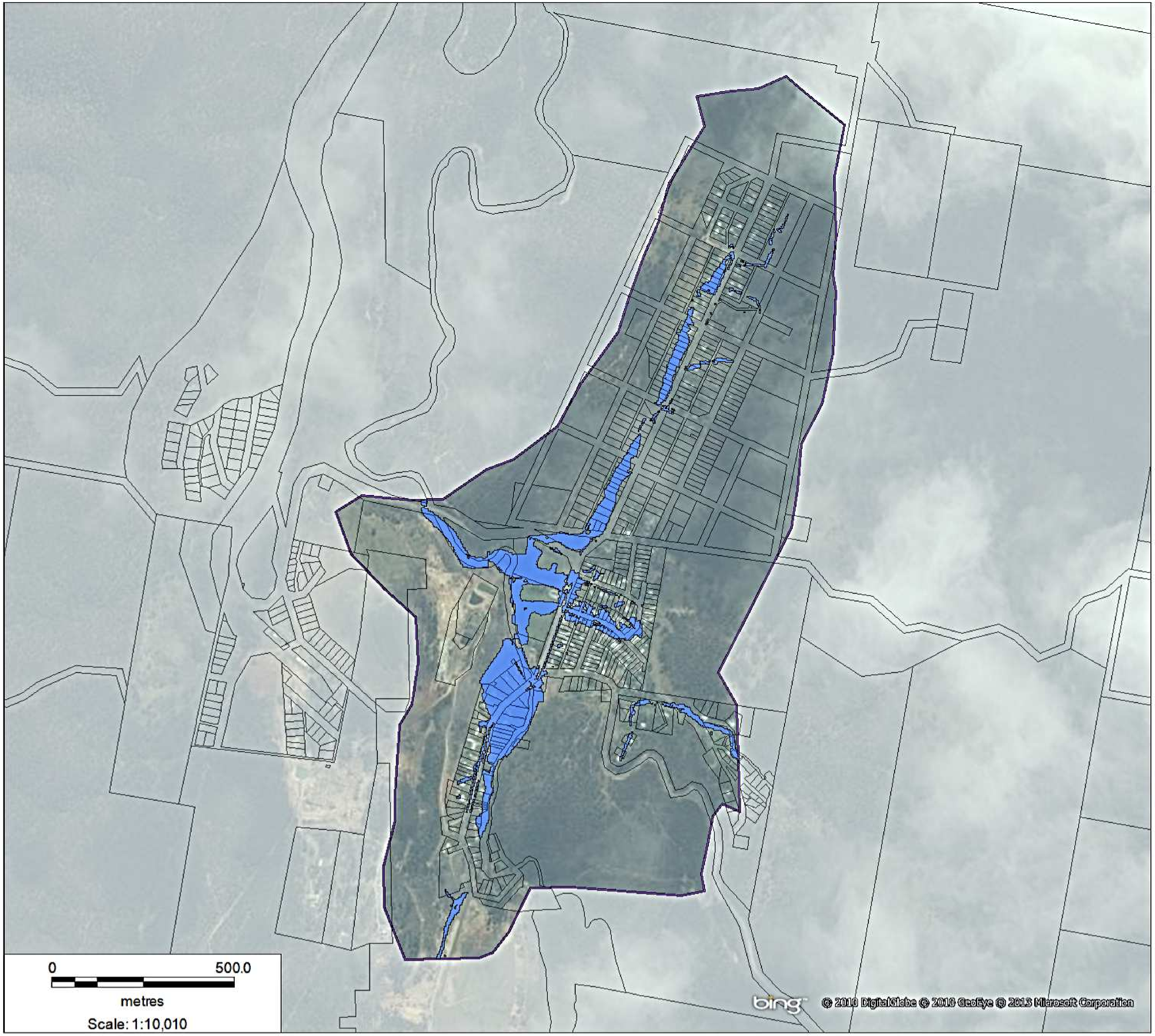


Figure 7-1

20% AEP
Flood Extent

CAPTAINS FLAT
FLOOD STUDY

Study Area
Flood Extent

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

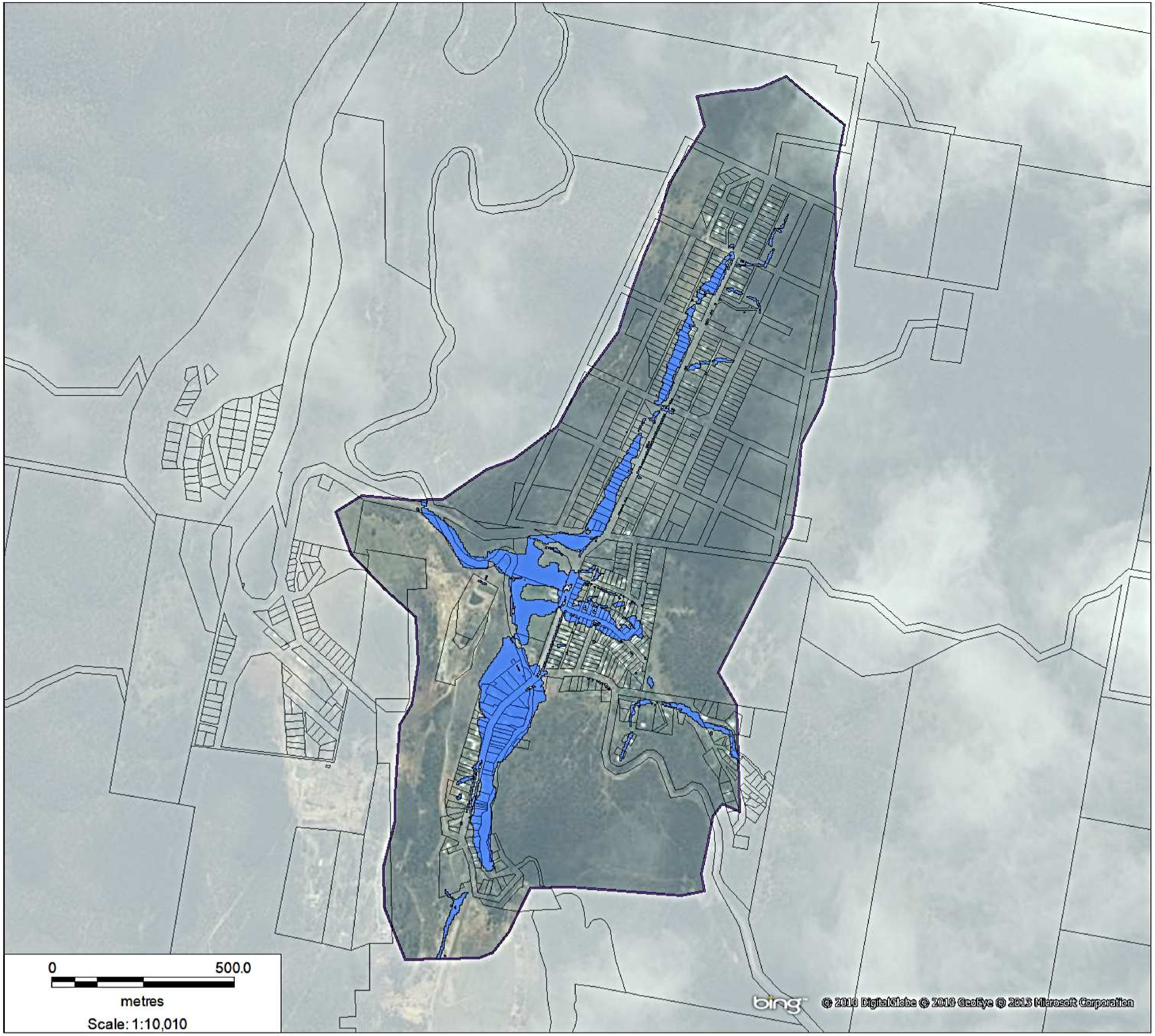


Figure 7-2

10% AEP Flood Extent

CAPTAINS FLAT FLOOD STUDY

Study Area

Flood Extent

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

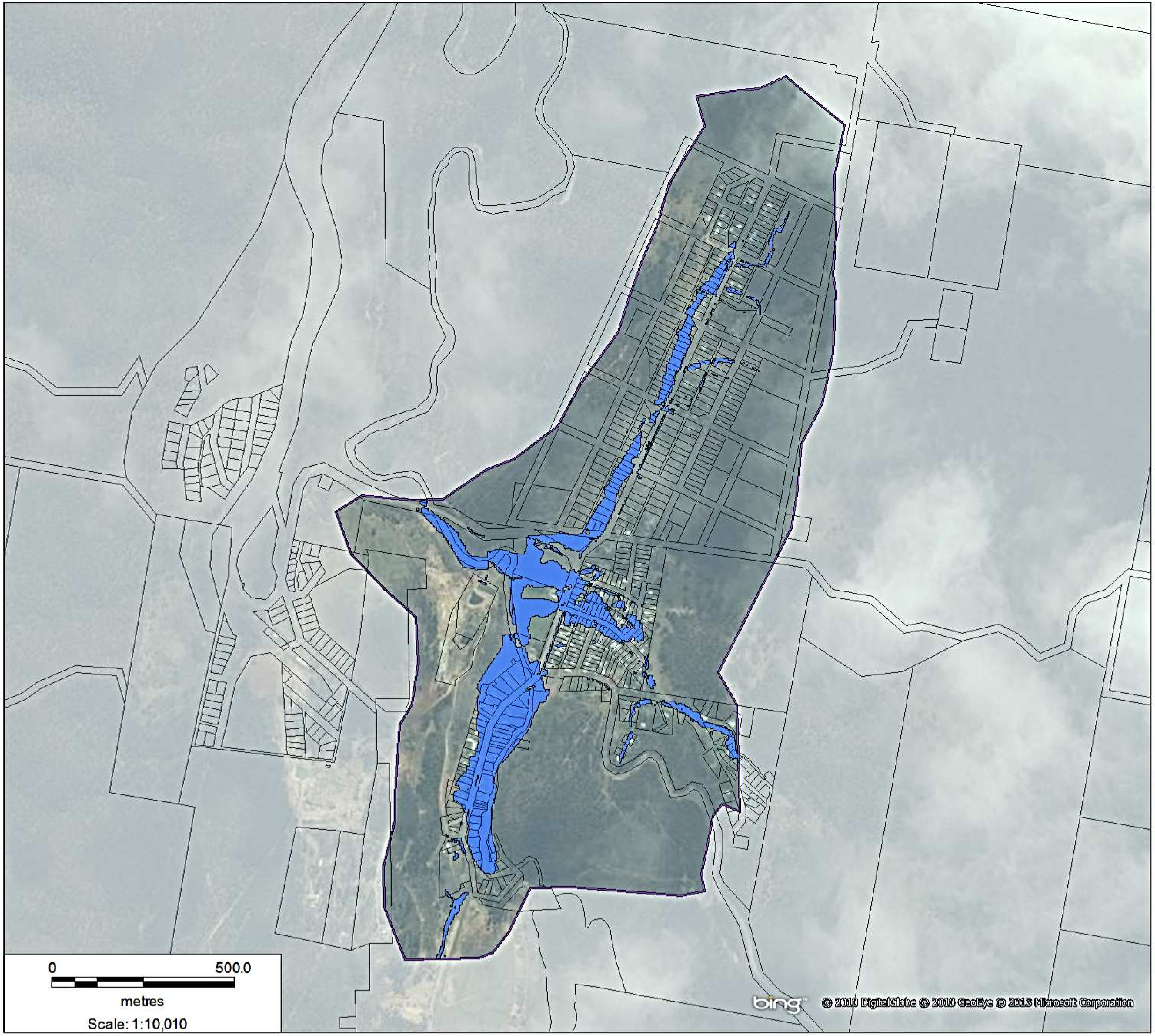


Figure 7-3

5% AEP Flood Extent

CAPTAINS FLAT FLOOD STUDY

Study Area

Flood Extent

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

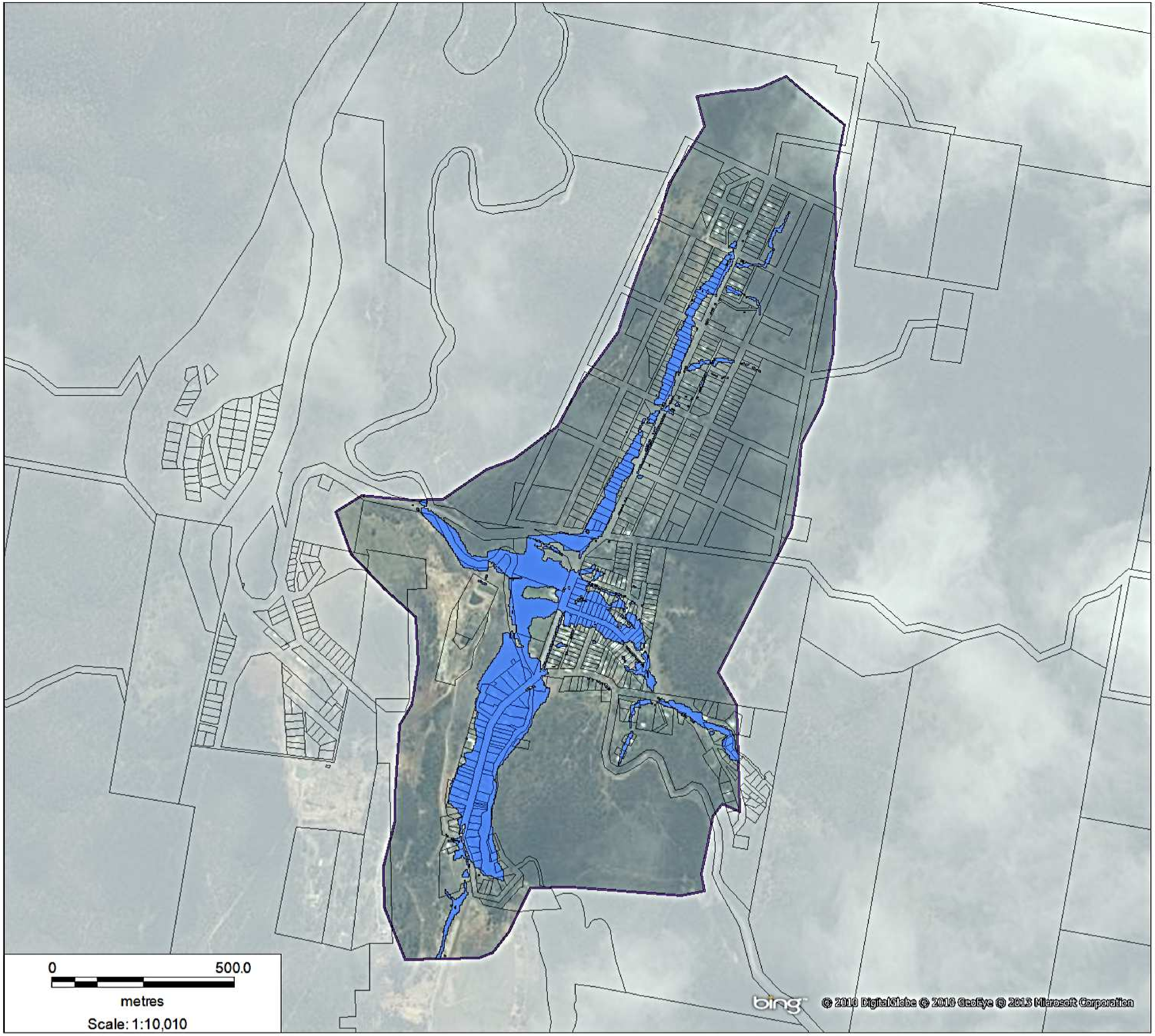


Figure 7-4

2% AEP
Peak Extent

CAPTAINS FLAT
FLOOD STUDY

Study Area

Flood Extent

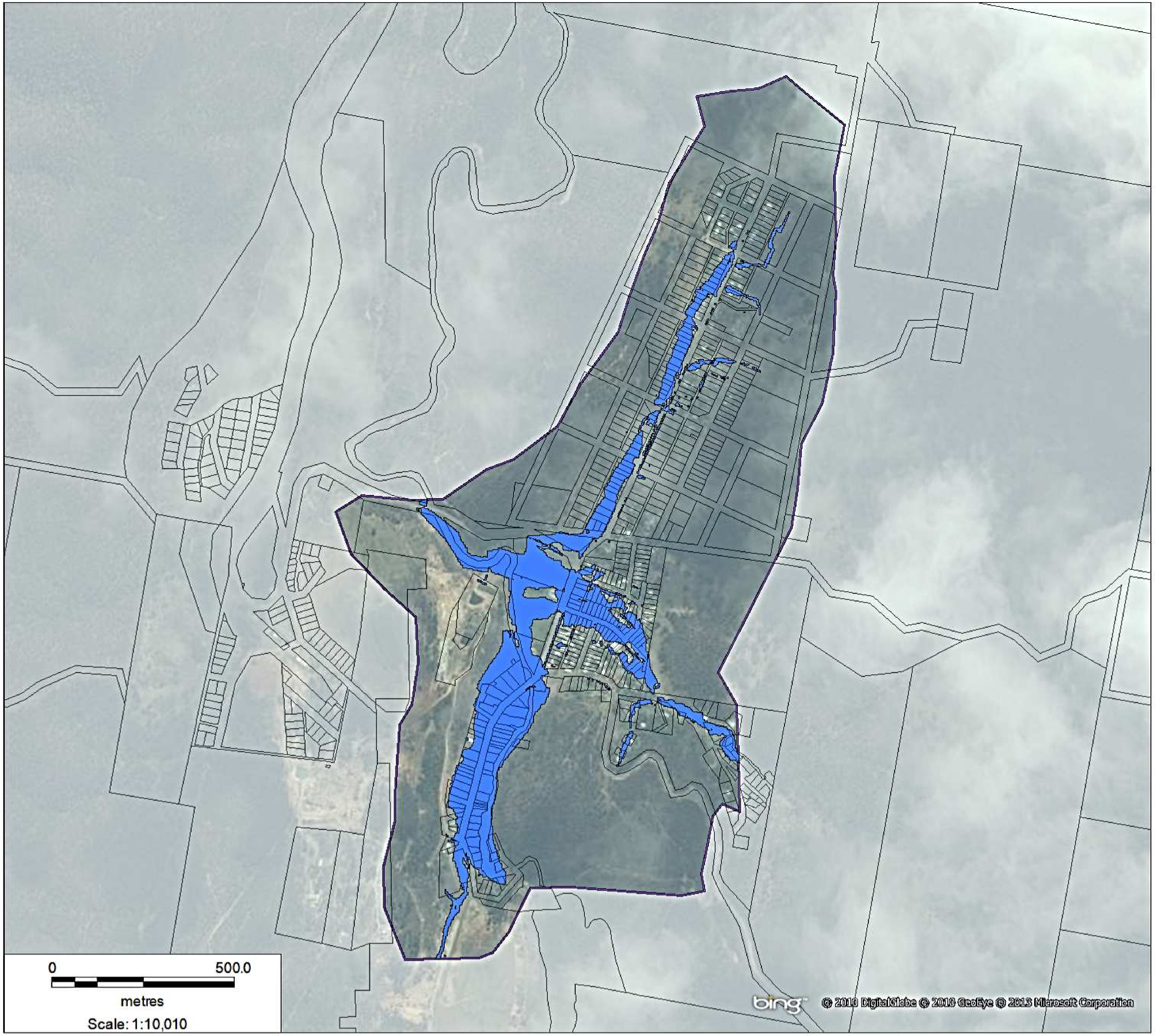
Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

Figure 7-5

1% AEP Flood Extent

CAPTAINS FLAT FLOOD STUDY



Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

Figure 7-6

0.5% AEP Flood Extent

CAPTAINS FLAT FLOOD STUDY

Study Area

Flood Extent

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

Figure 7-7

PMF
Flood Extent

CAPTAINS FLAT
FLOOD STUDY

Study Area
Flood Extent

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

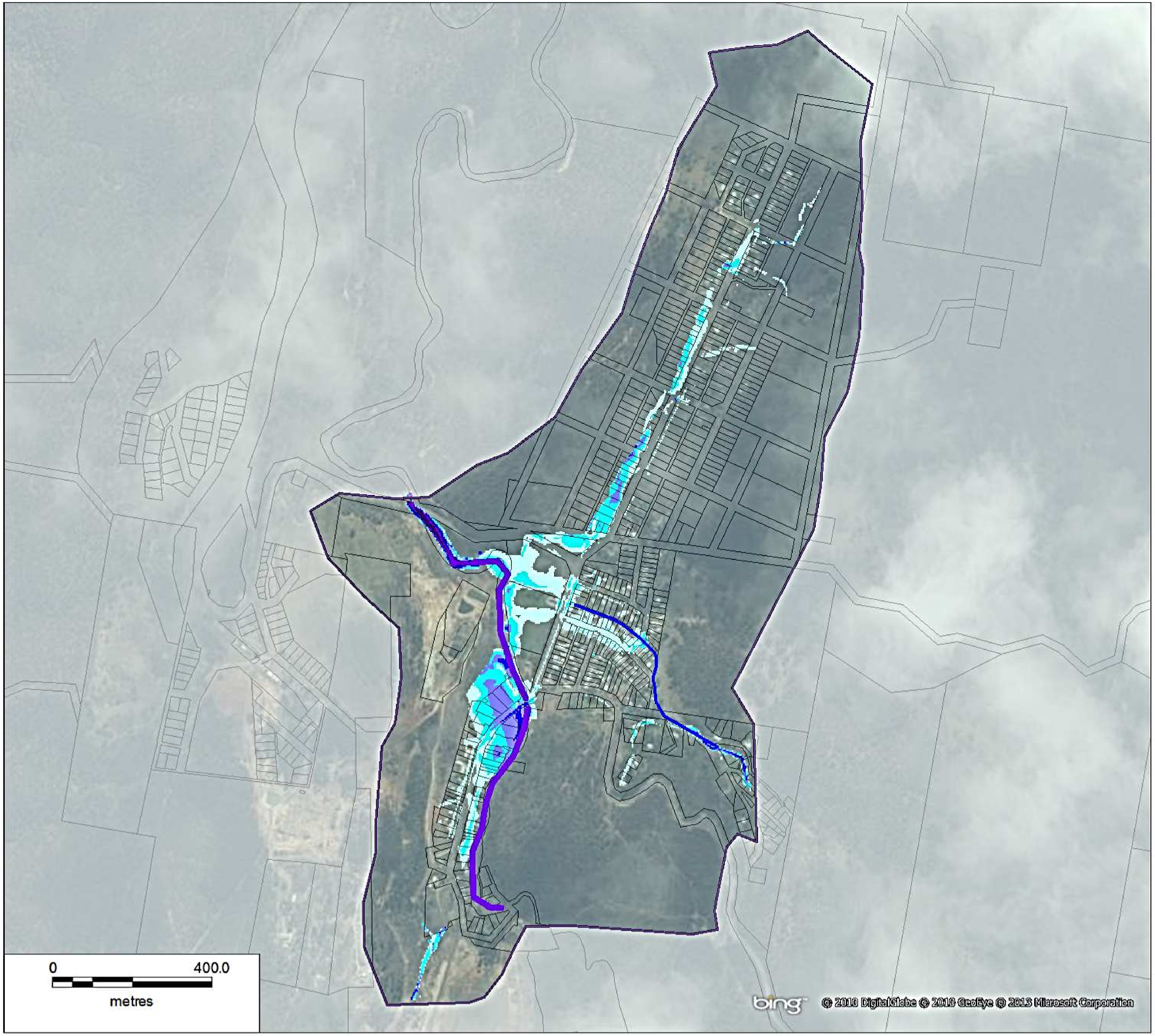


Figure 7-8

20% AEP
Peak Flood Depths

CAPTAINS FLAT
FLOOD STUDY

Study Area

Depth (metres)

0.10 - 0.25

0.25 - 0.50

0.50 - 0.75

0.75 - 1.00

1.00 - 1.50

1.50 - 2.00

2.00 - 3.00

> 3.00

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

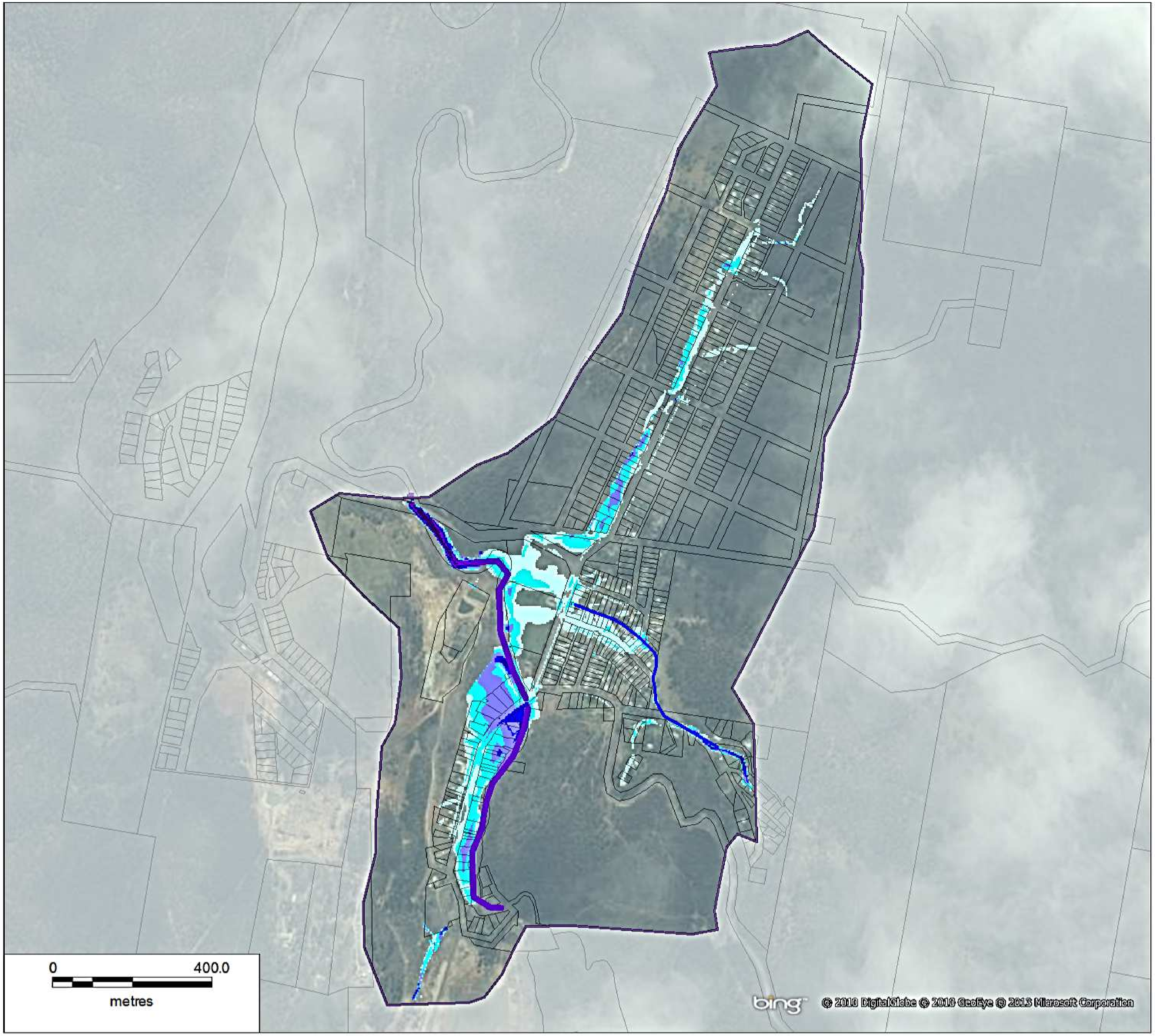


Figure 7-9

10% AEP Peak Flood Depths

CAPTAINS FLAT FLOOD STUDY

Study Area

Depth (metres)

- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

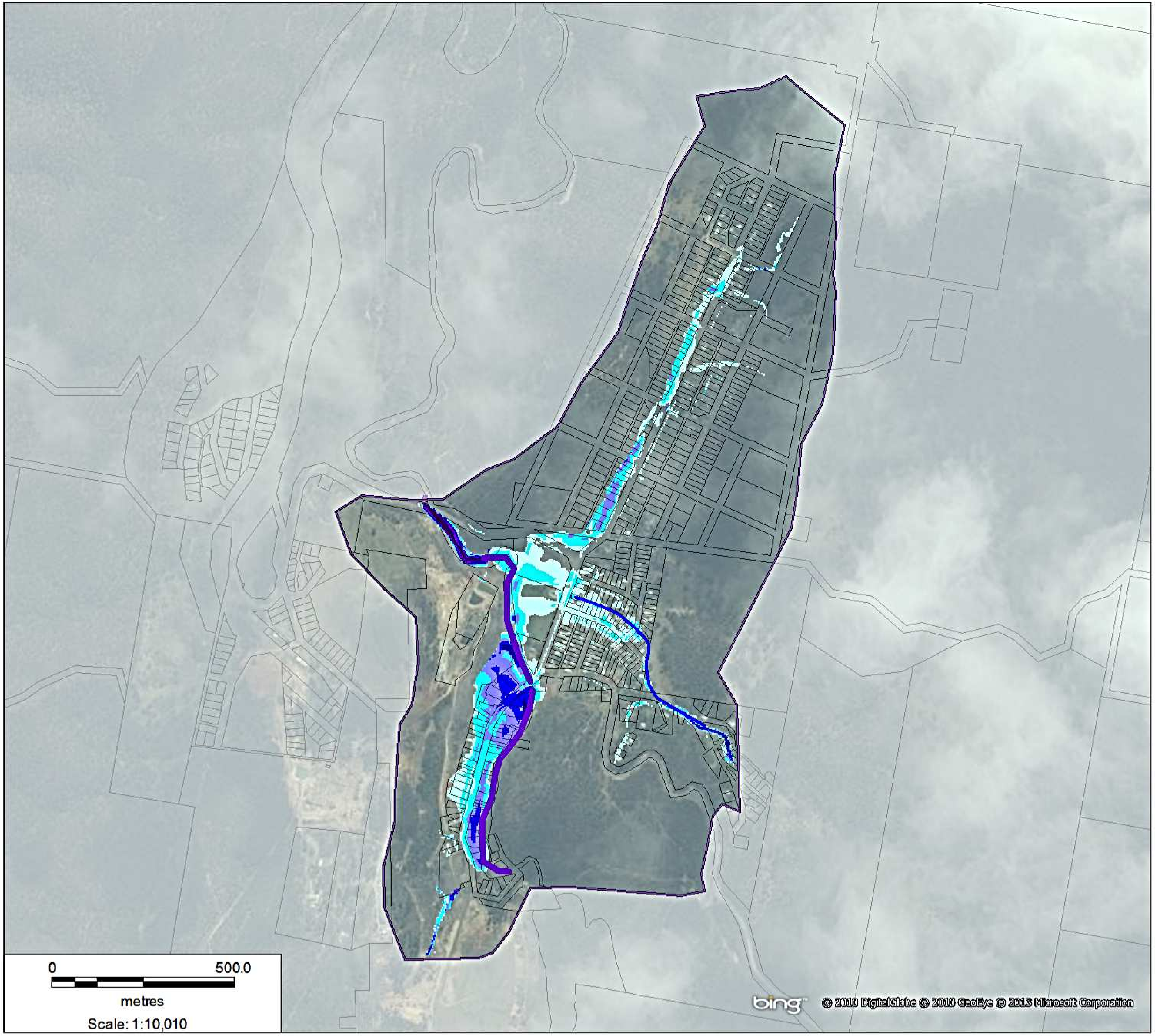


Figure 7-10

5% AEP
Peak Flood Depths

CAPTAINS FLAT
FLOOD STUDY

Study Area

Depth (metres)

0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
2.00 - 3.00
> 3.00

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

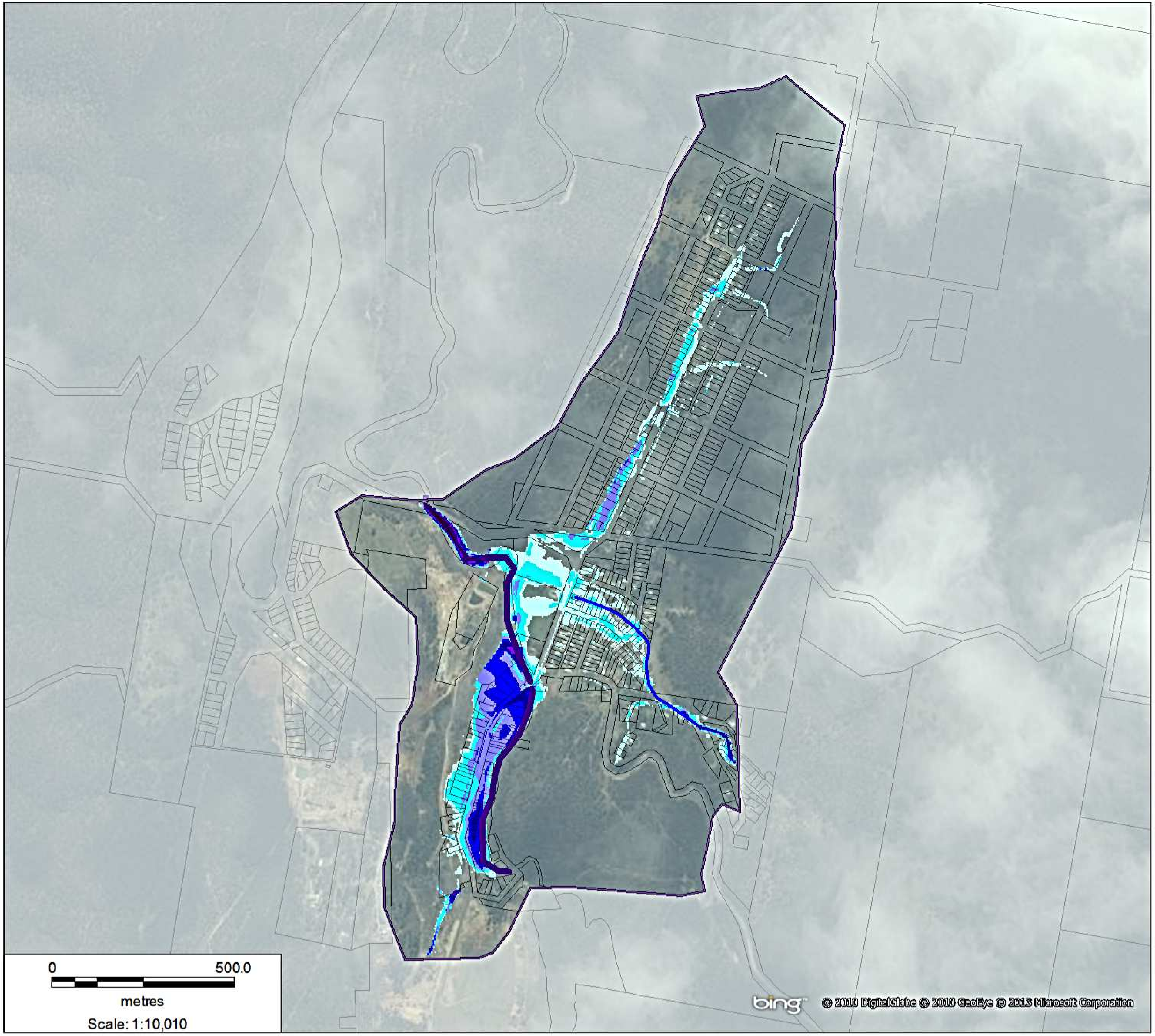


Figure 7-11

2% AEP
Peak Flood Depths

CAPTAINS FLAT
FLOOD STUDY

Study Area

Depth (metres)

- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

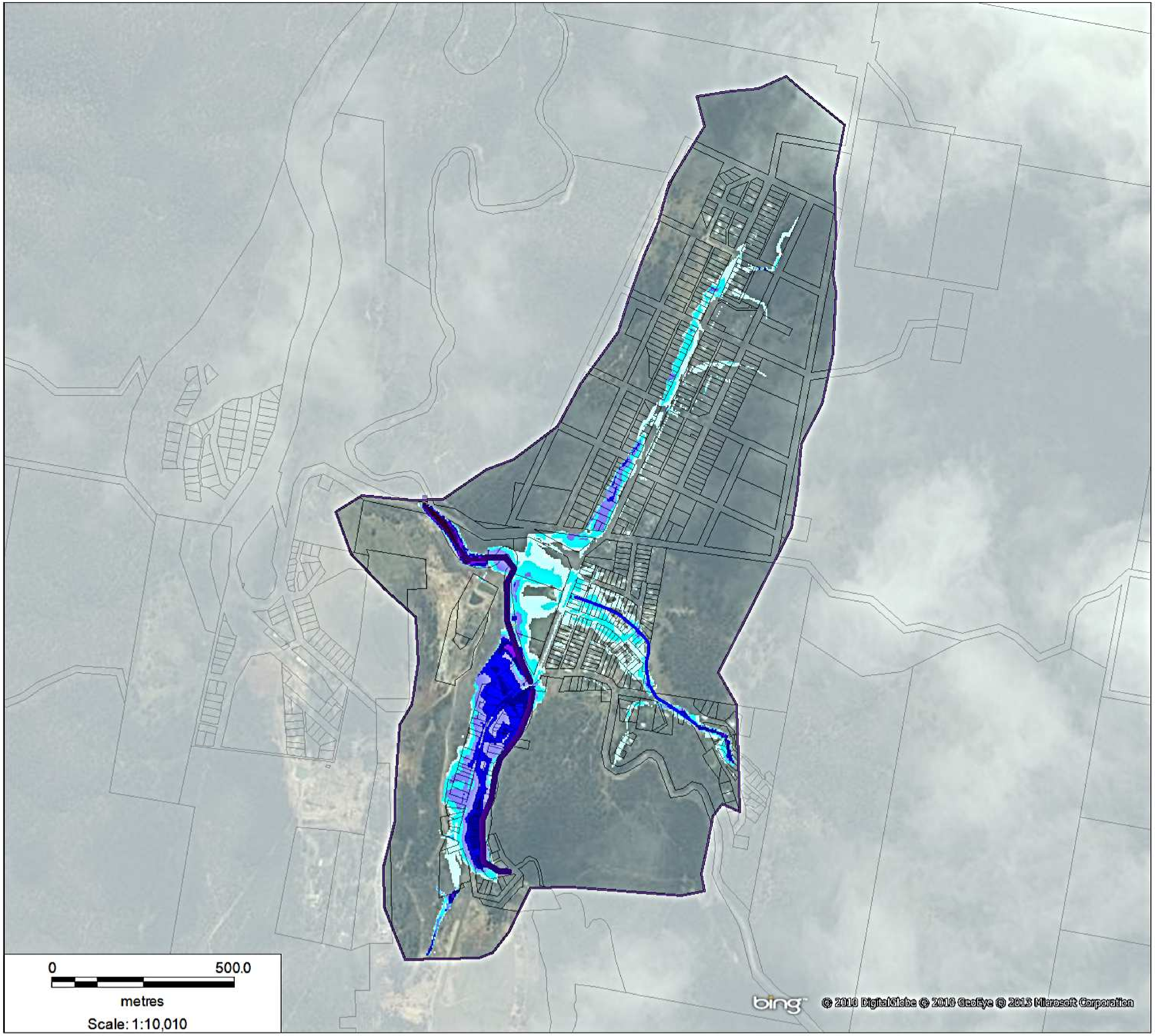


Figure 7-12

1% AEP
Peak Flood Depths

CAPTAINS FLAT
FLOOD STUDY

Study Area

Depth (metres)

- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

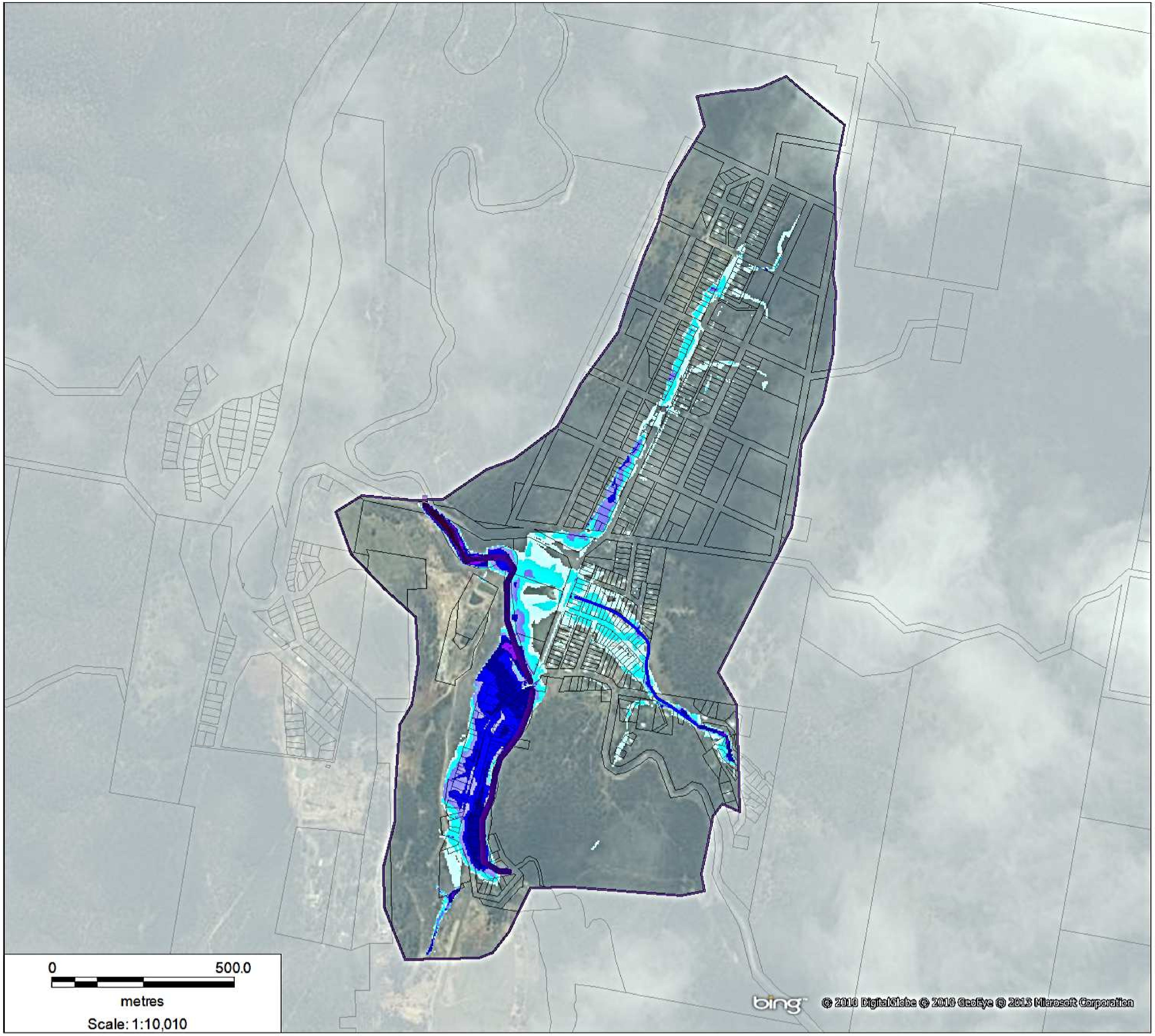


Figure 7-13

0.5% AEP
Peak Flood Depths

CAPTAINS FLAT
FLOOD STUDY

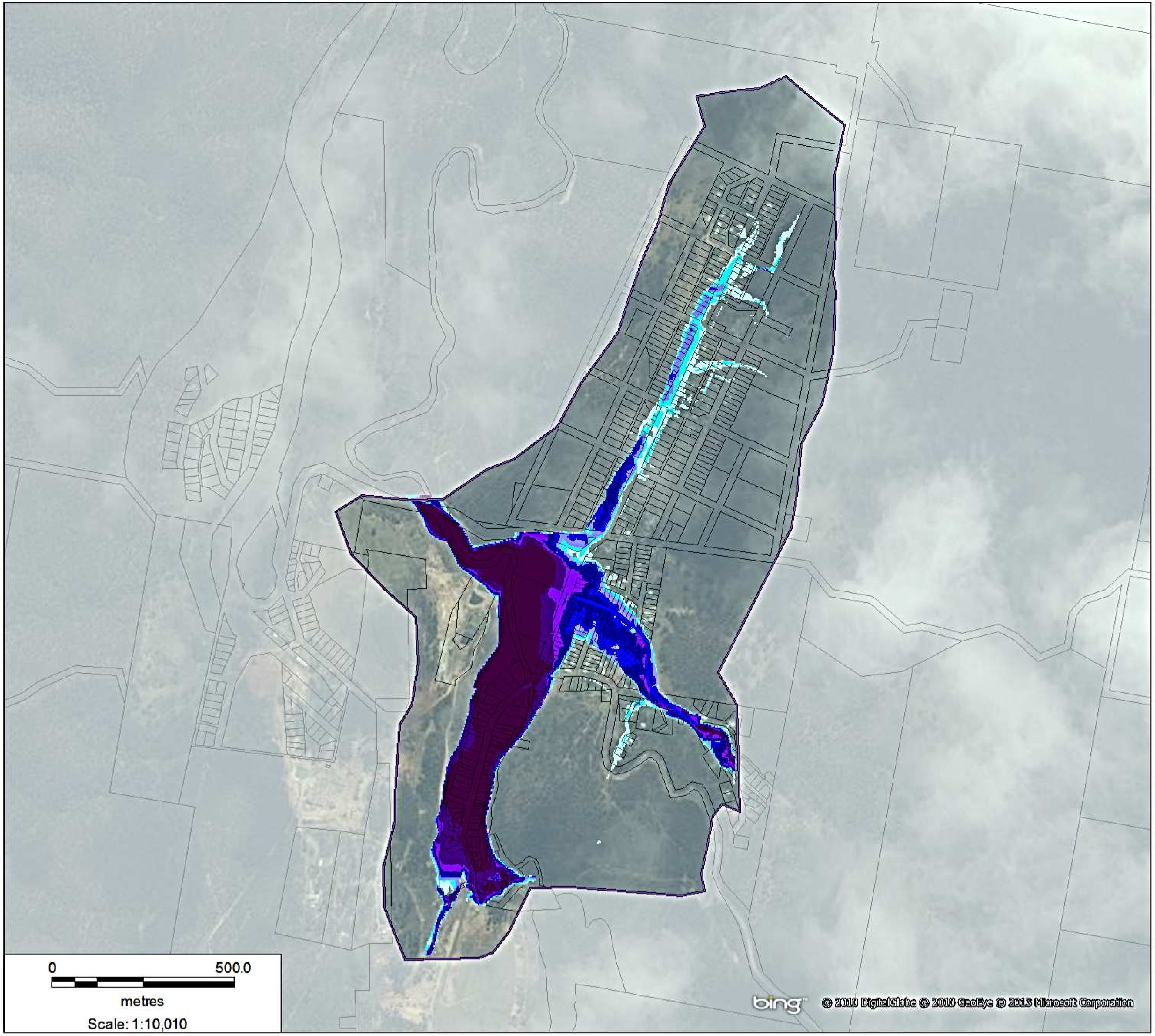


Figure 7-14

PMF
Peak Flood Depths

CAPTAINS FLAT
FLOOD STUDY

Study Area

Depth (metres)

0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
2.00 - 3.00
> 3.00

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

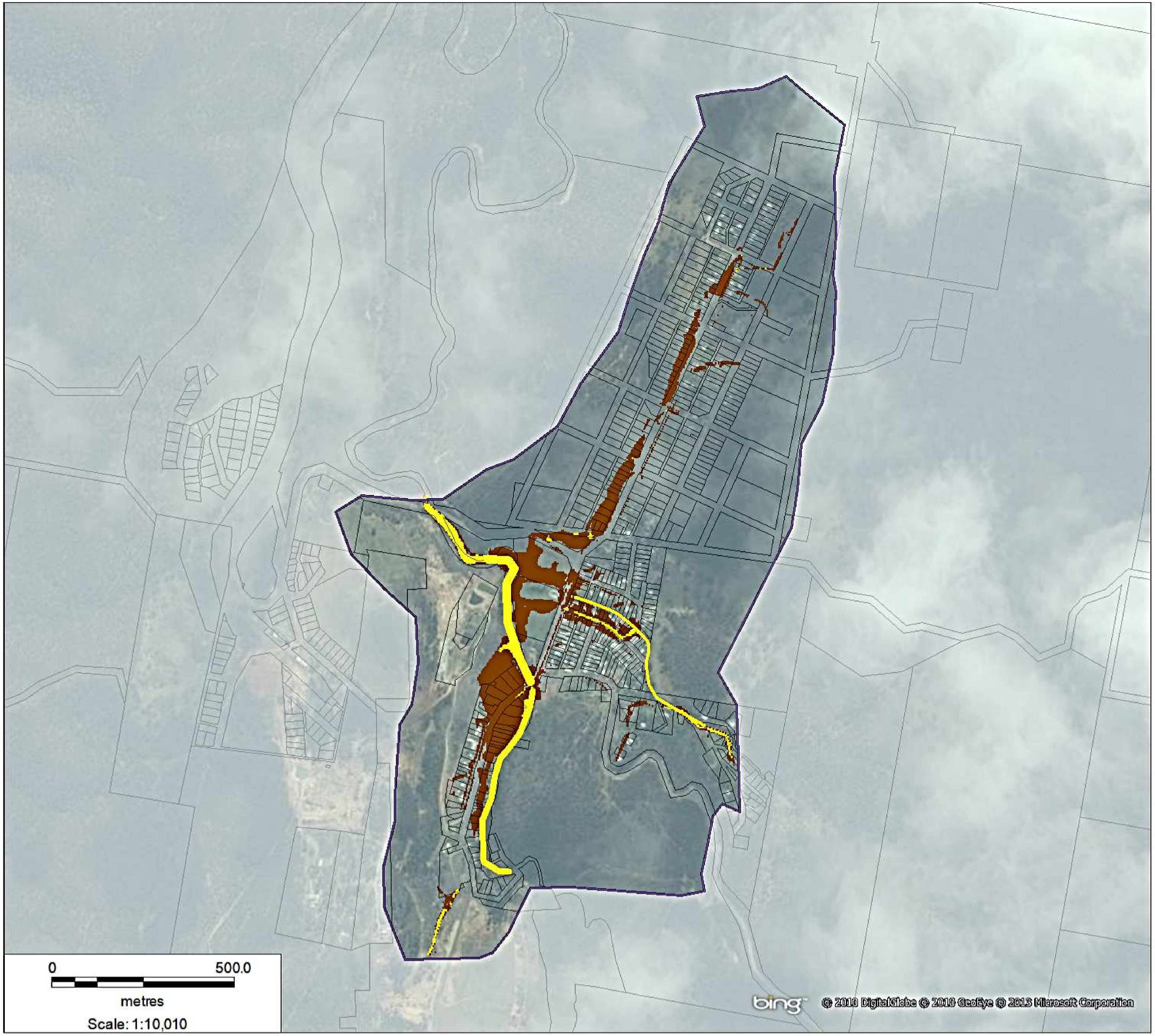


Figure 8-1

20% AEP Provisional Hazard

CAPTAINS FLAT FLOOD STUDY

Study Area

Provisional Hazard

Low

High

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

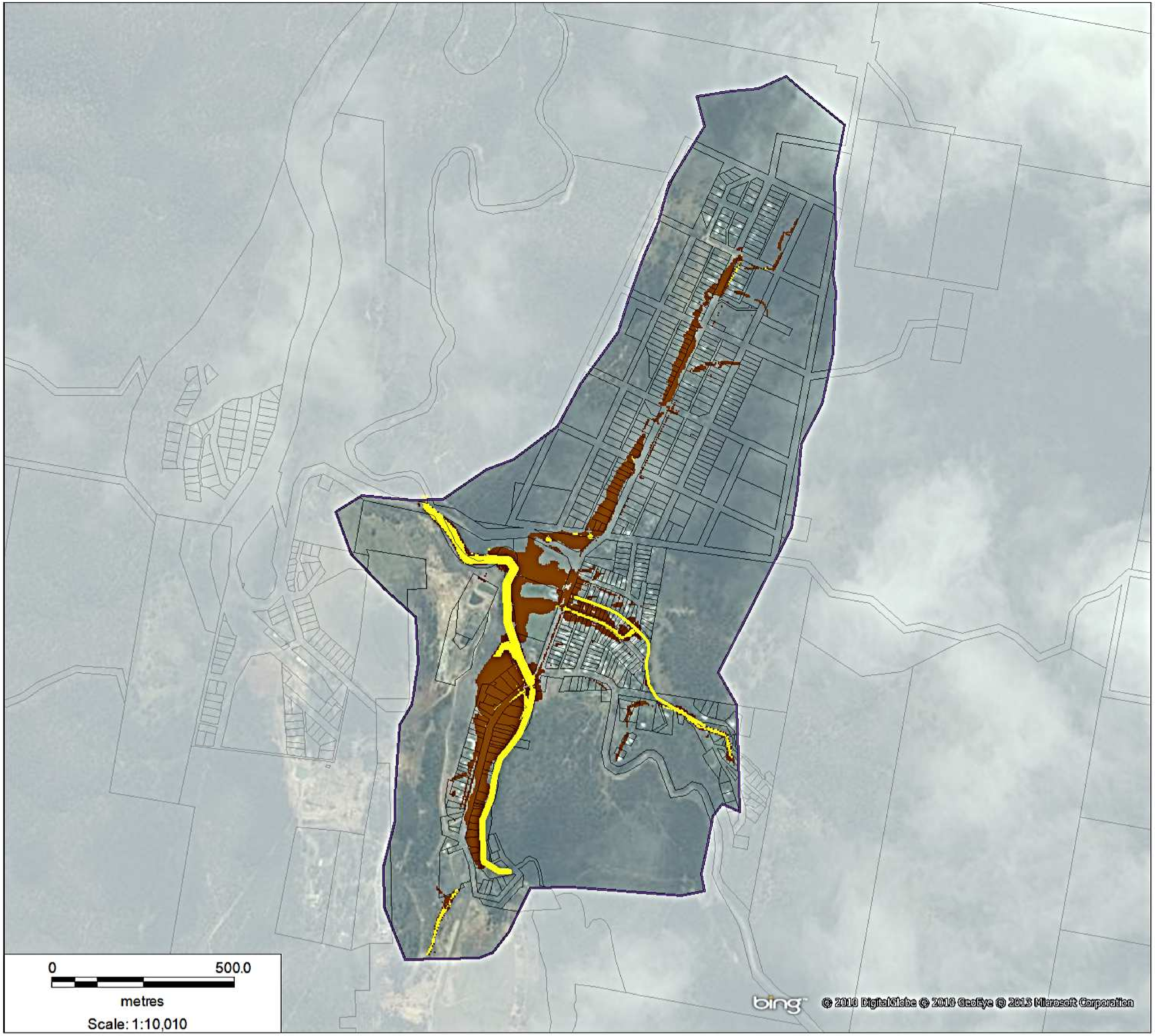


Figure 8-2

10% AEP Provisional Hazard

CAPTAINS FLAT FLOOD STUDY

Study Area

Provisional Hazard

Low

High

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

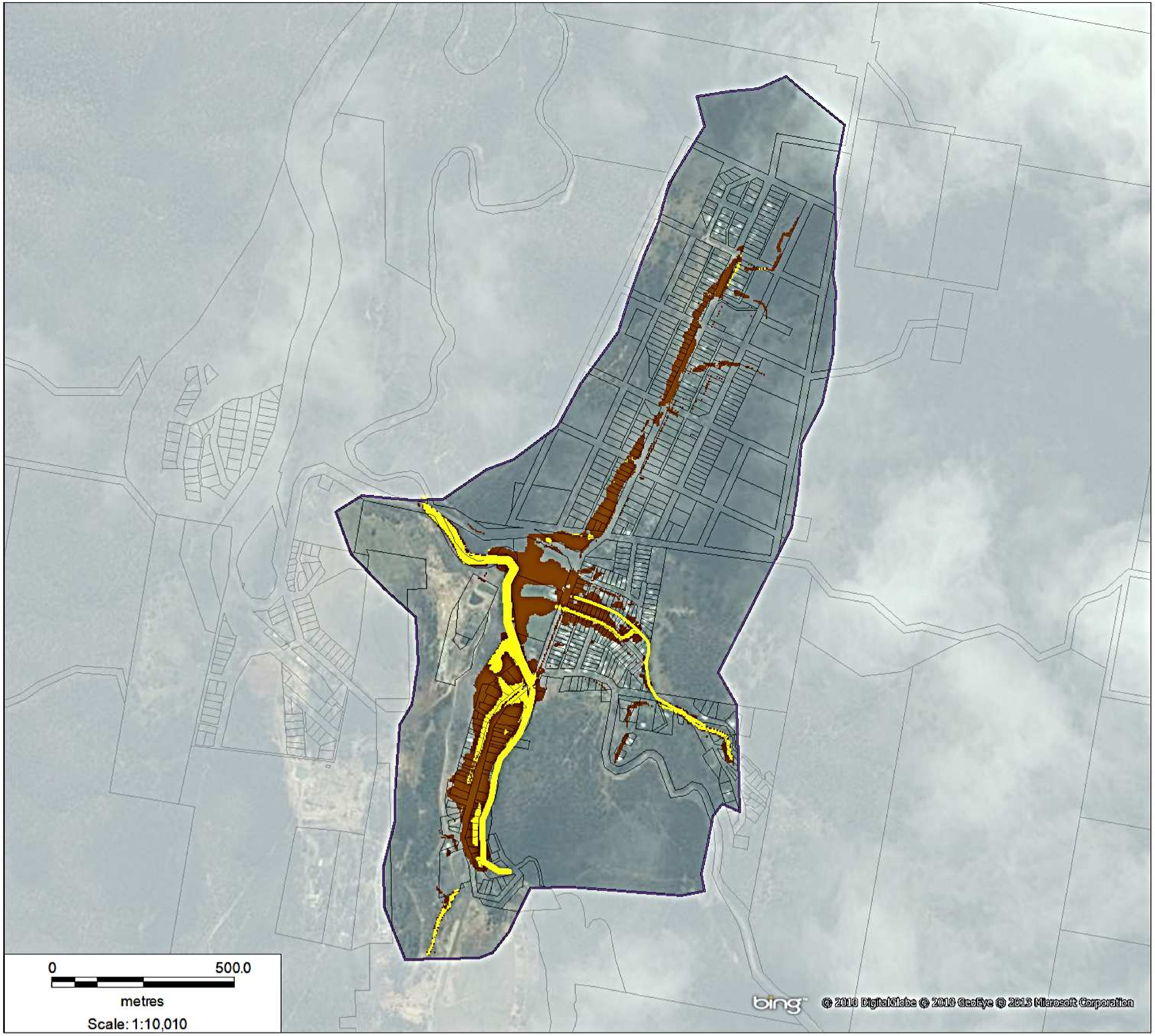


Figure 8-3

5% AEP
Provisional Hazard

CAPTAINS FLAT
FLOOD STUDY

Study Area

Provisional Hazard

Low

High

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

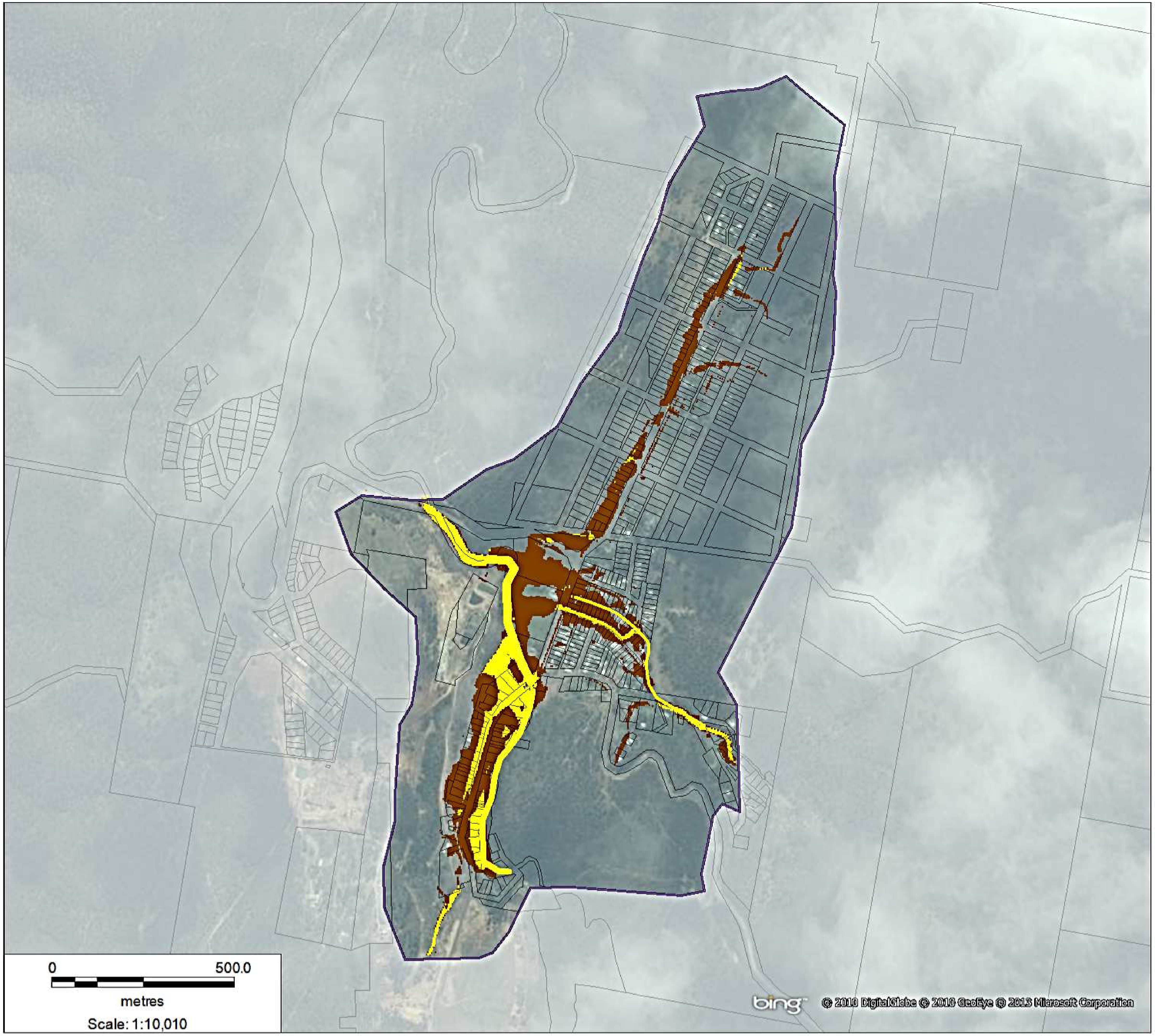


Figure 8-4

2% AEP Provisional Hazard

CAPTAINS FLAT FLOOD STUDY

Study Area

Provisional Hazard

Low

High

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

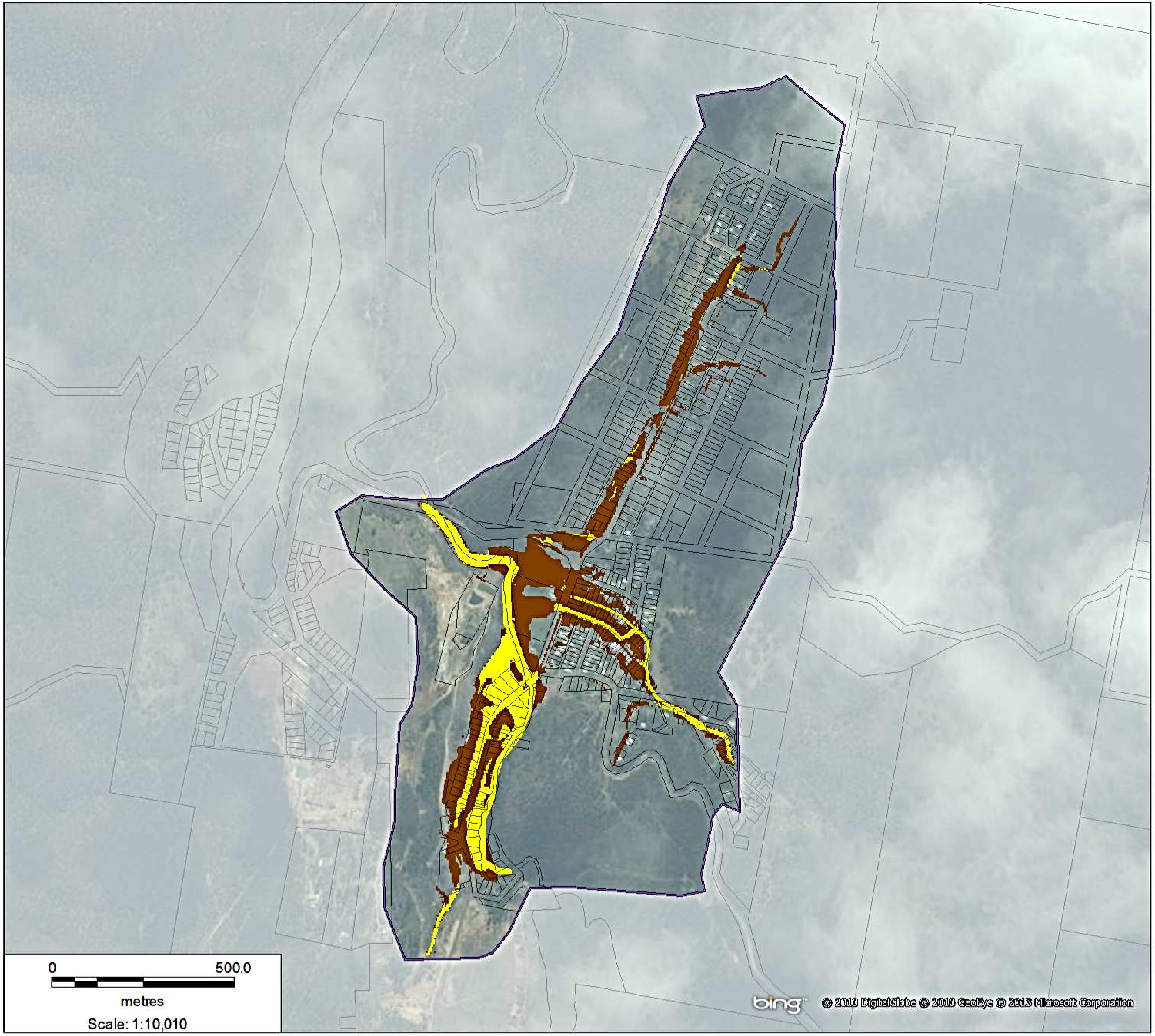


Figure 8-5

1% AEP Provisional Hazard

CAPTAINS FLAT FLOOD STUDY

Study Area

Provisional Hazard

Low

High

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

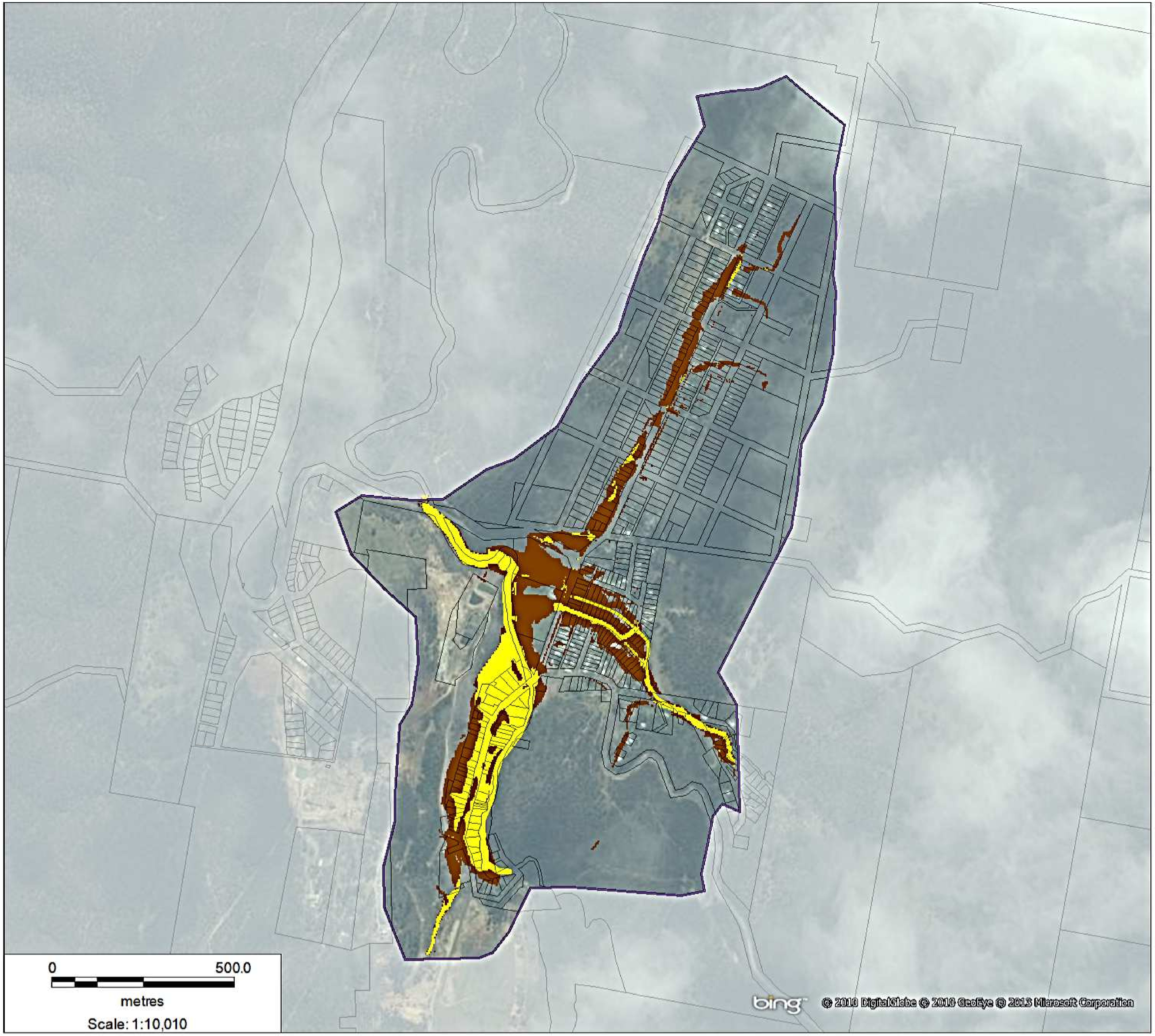


Figure 8-6

0.5% AEP
Provisional Hazard

CAPTAINS FLAT
FLOOD STUDY

Study Area

Provisional Hazard

Low

High

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

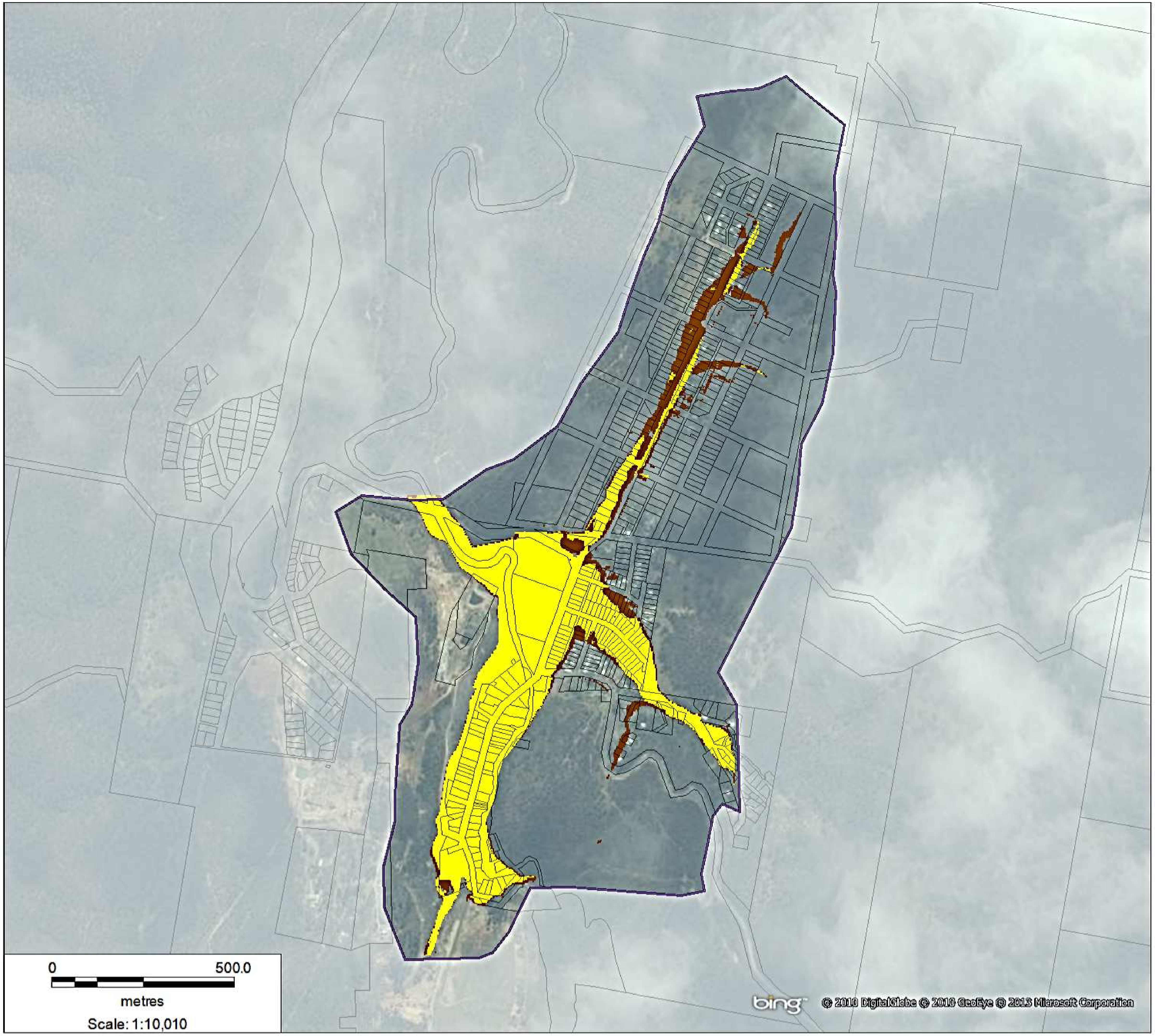


Figure 8-7

PMF
Provisional Hazard

CAPTAINS FLAT
FLOOD STUDY

Study Area

Provisional Hazard

Low

High

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

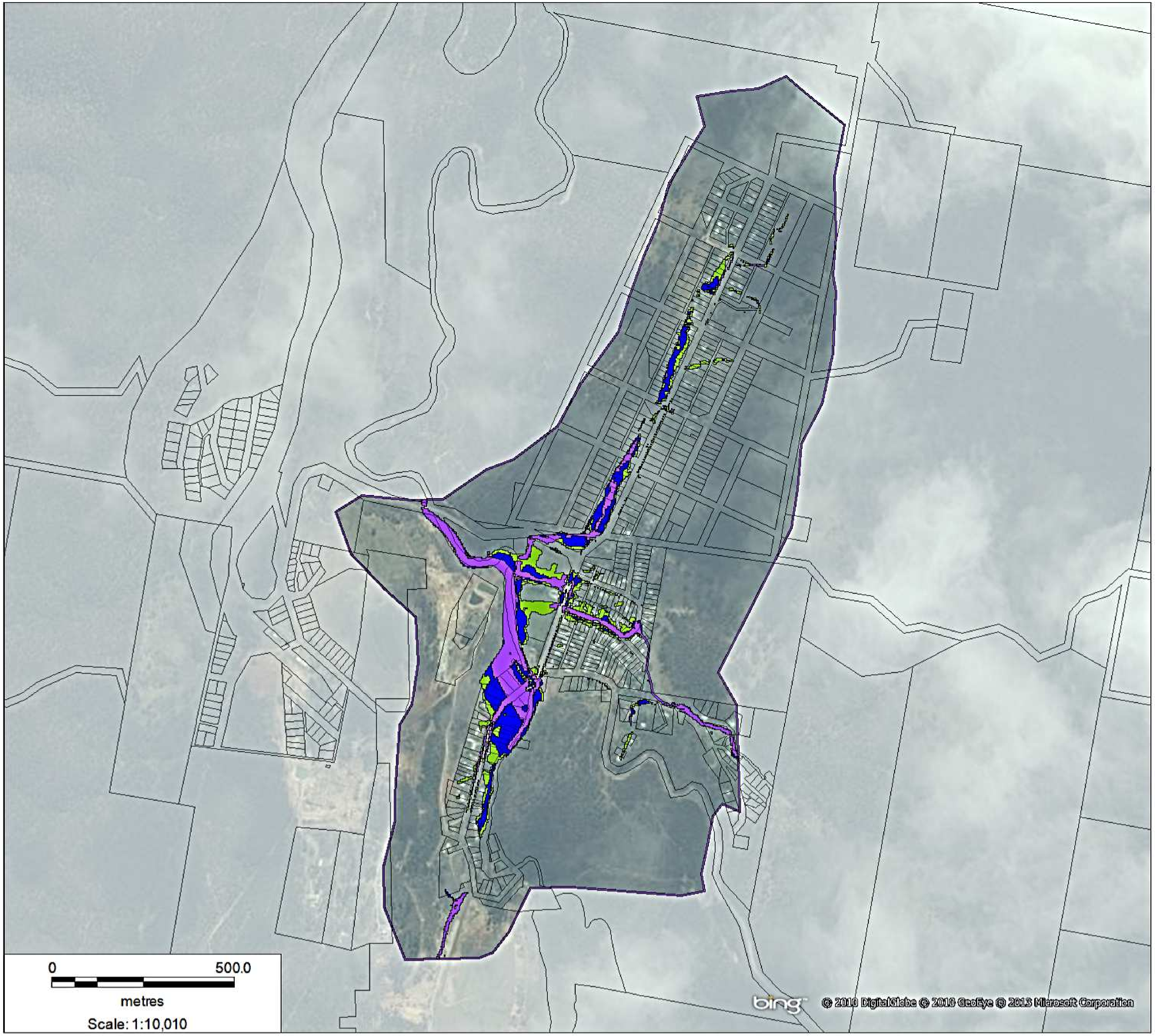


Figure 8-8

20% AEP
Hydraulic Categories

CAPTAINS FLAT
FLOOD STUDY

Study Area
Floodway
Flood Storage
Flood Fringe

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

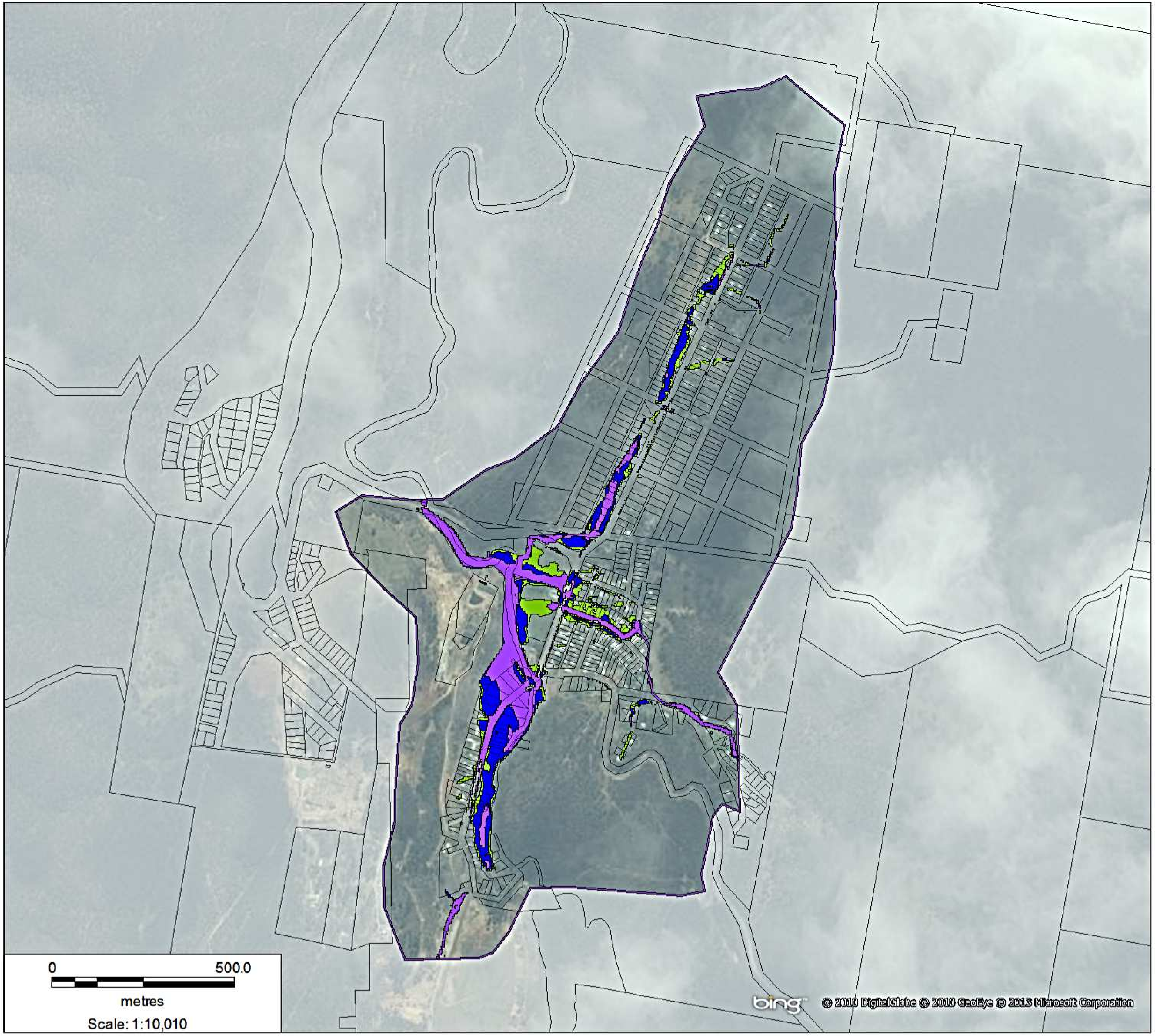


Figure 8-9

10% AEP
Hydraulic Categories

CAPTAINS FLAT
FLOOD STUDY

- Study Area
- Floodway
- Flood Storage
- Flood Fringe

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

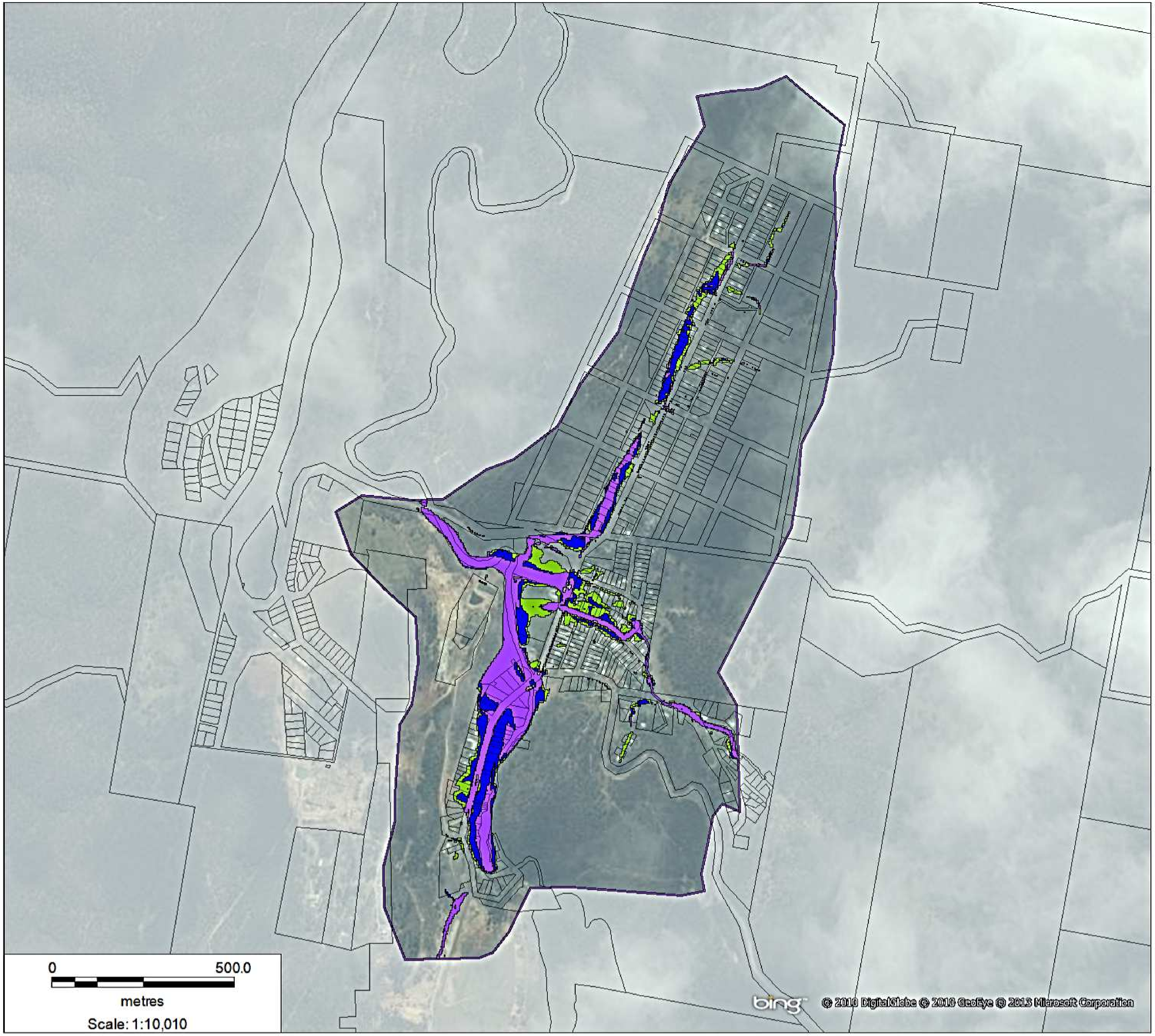


Figure 8-10

5% AEP
Hydraulic Categories

CAPTAINS FLAT
FLOOD STUDY

Study Area
Floodway
Flood Storage
Flood Fringe

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

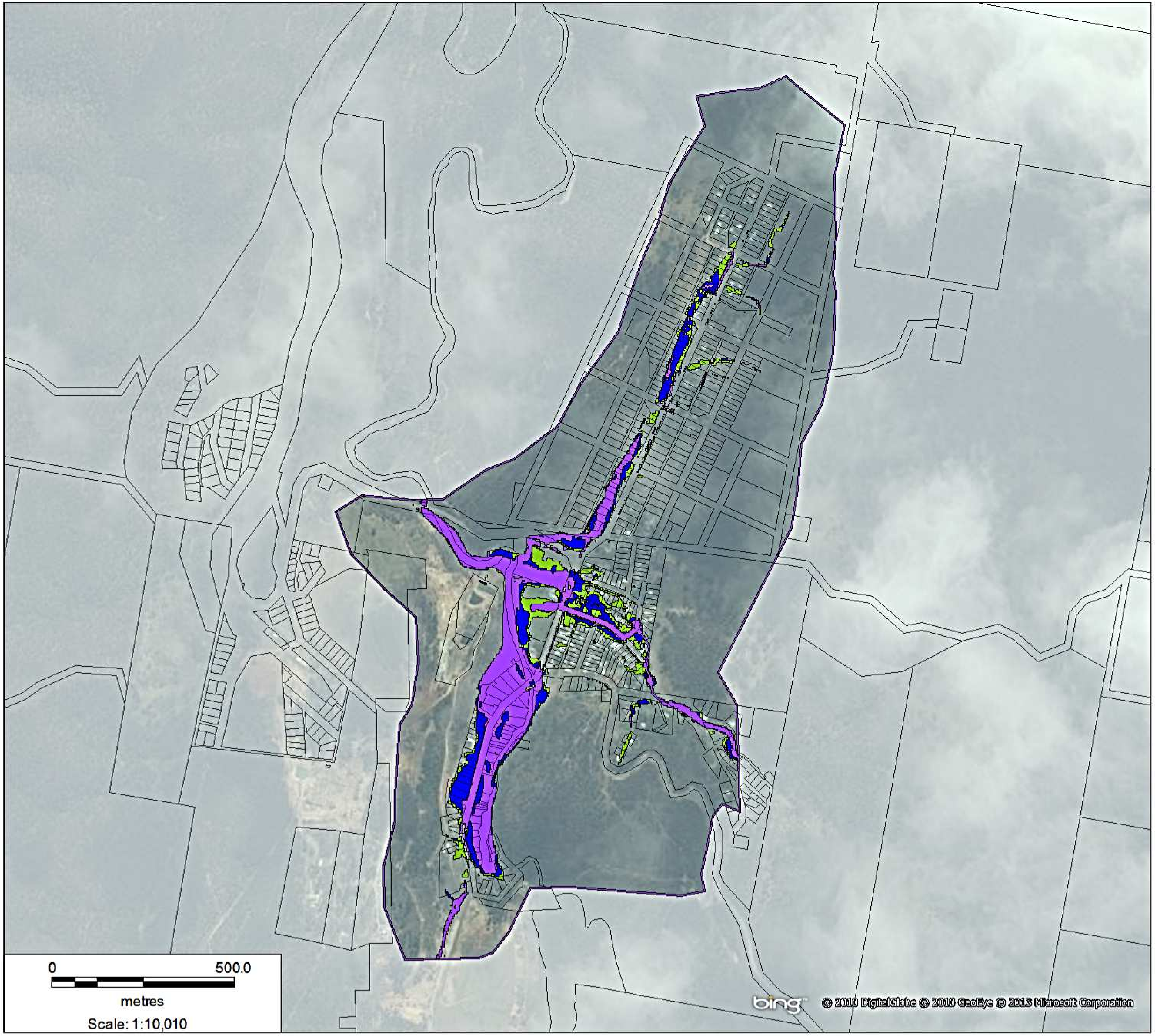


Figure 8-11

2% AEP
Hydraulic Categories

CAPTAINS FLAT
FLOOD STUDY

	Study Area
	Floodway
	Flood Storage
	Flood Fringe

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

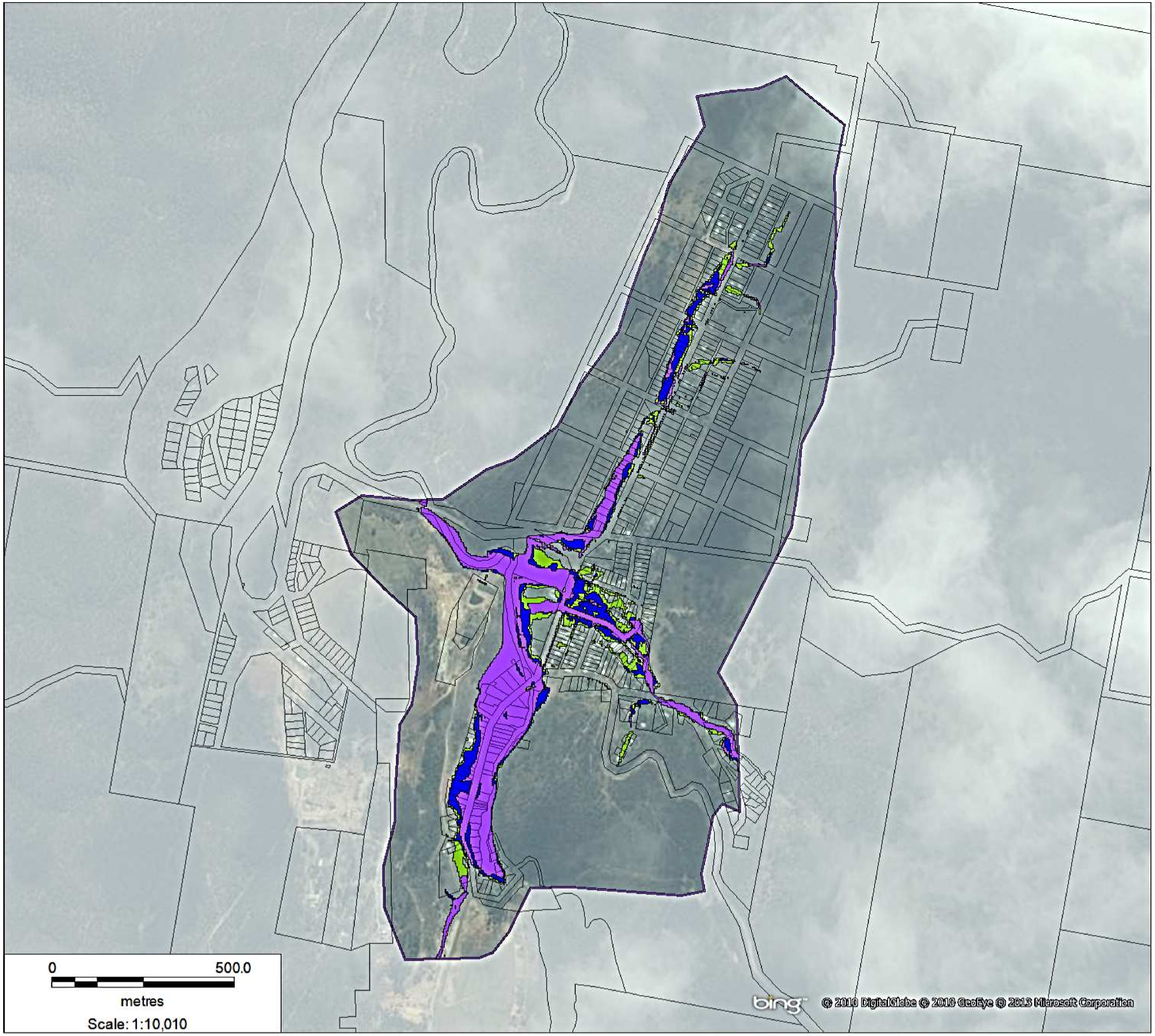


Figure 8-12

1% AEP
Hydraulic Categories

CAPTAINS FLAT
FLOOD STUDY

Study Area
Floodway
Flood Storage
Flood Fringe

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

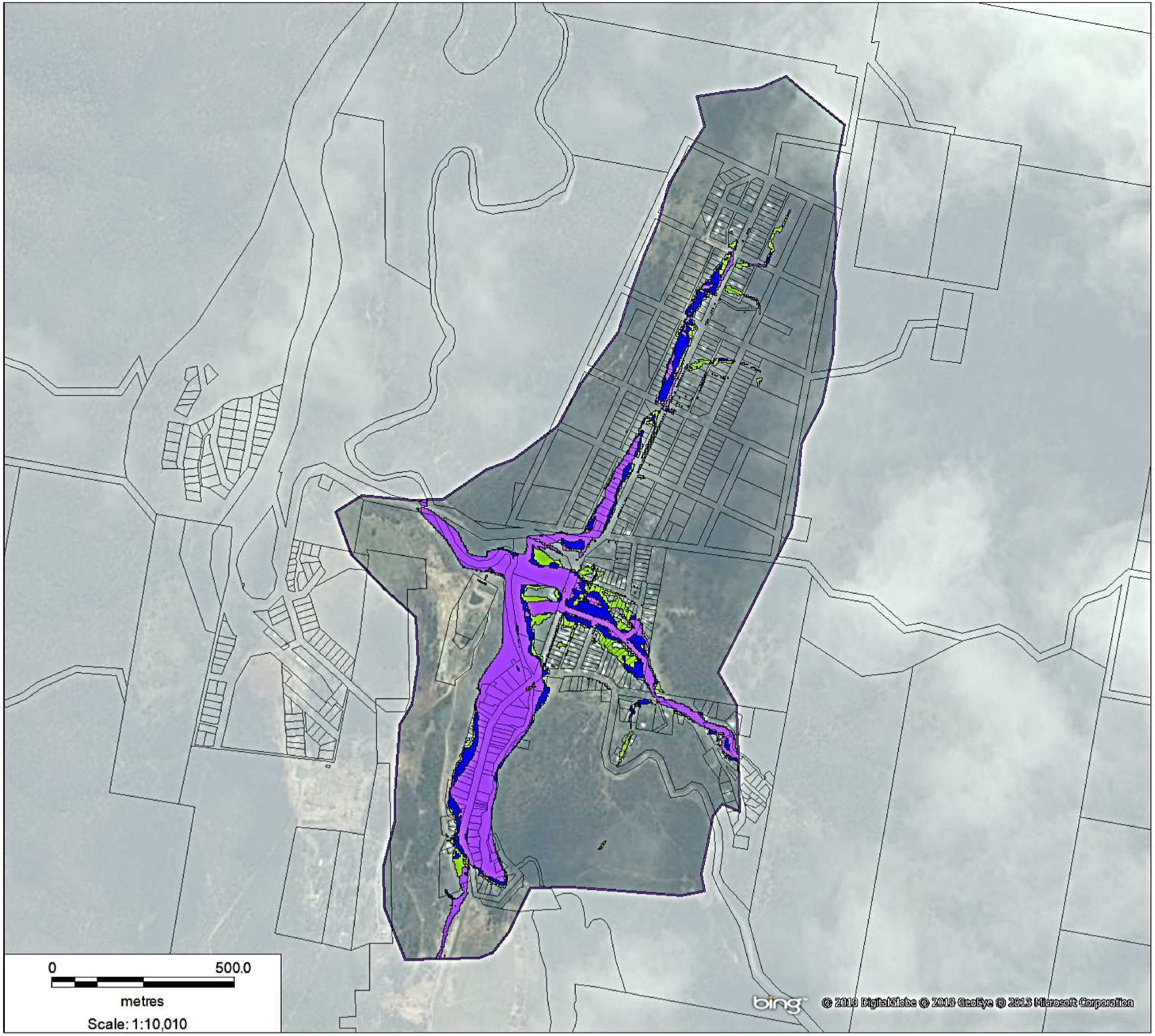


Figure 8-13

0.5% AEP
Hydraulic Categories

CAPTAINS FLAT
FLOOD STUDY

- Study Area
- Floodway
- Flood Storage
- Flood Fringe

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

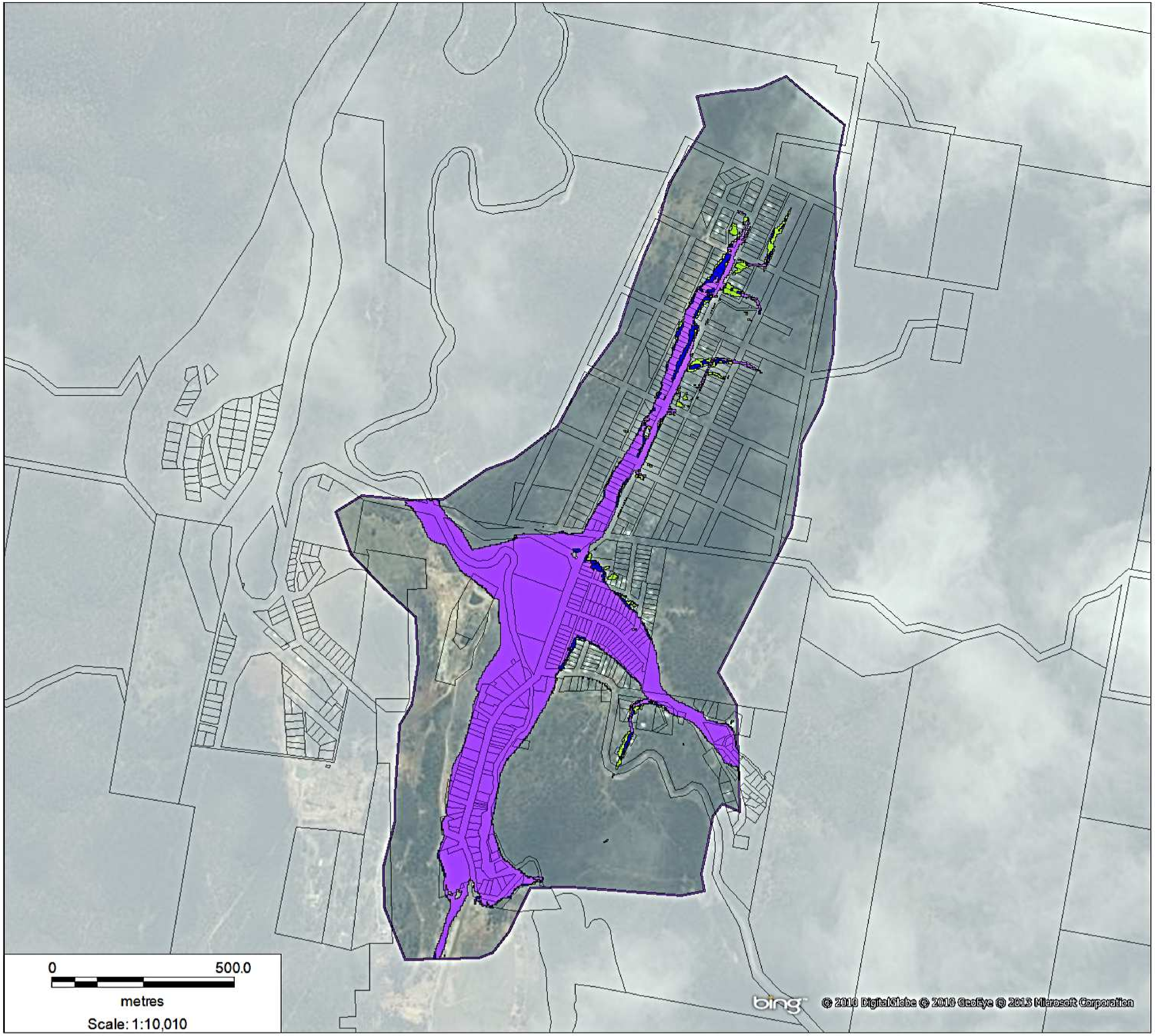


Figure 8-14

PMF Hydraulic Categories

CAPTAINS FLAT FLOOD STUDY

Study Area
Floodway
Flood Storage
Flood Fringe

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

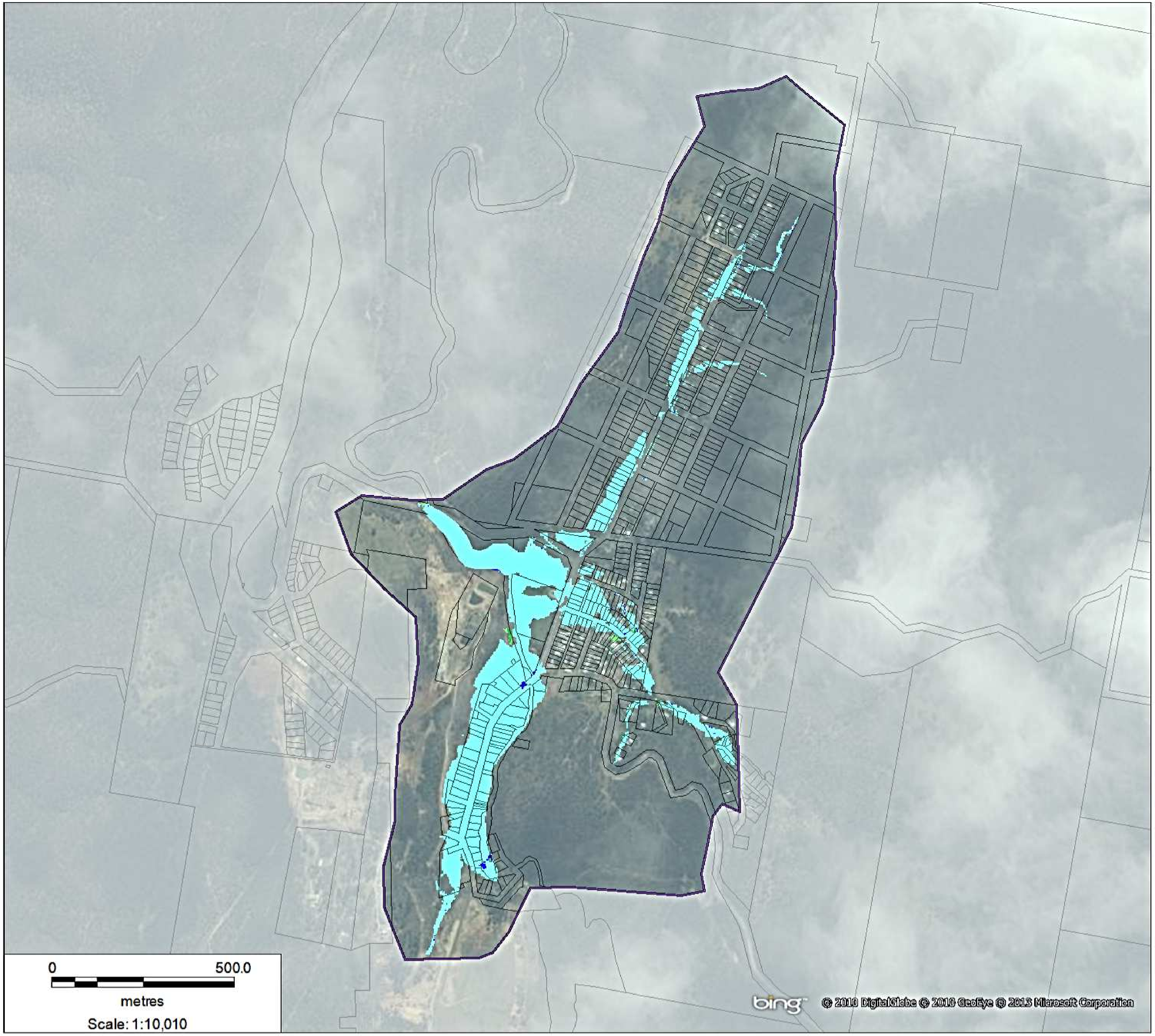


Figure 9-1

1% AEP Sensitivity Roughness +20%

CAPTAINS FLAT FLOOD STUDY

Study Area

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

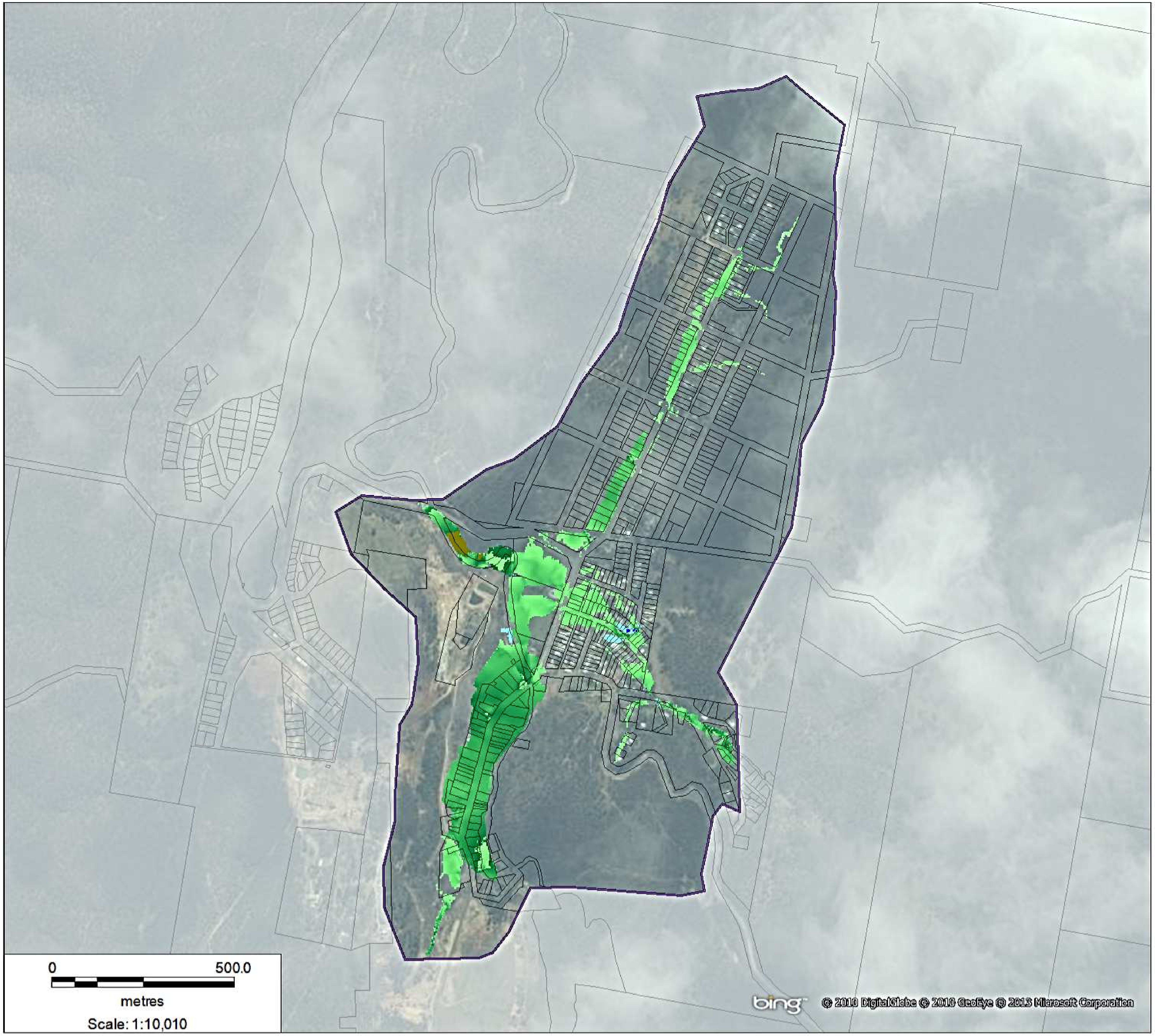


Figure 9-2

1% AEP Sensitivity Roughness -20%

CAPTAINS FLAT FLOOD STUDY

Study Area

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

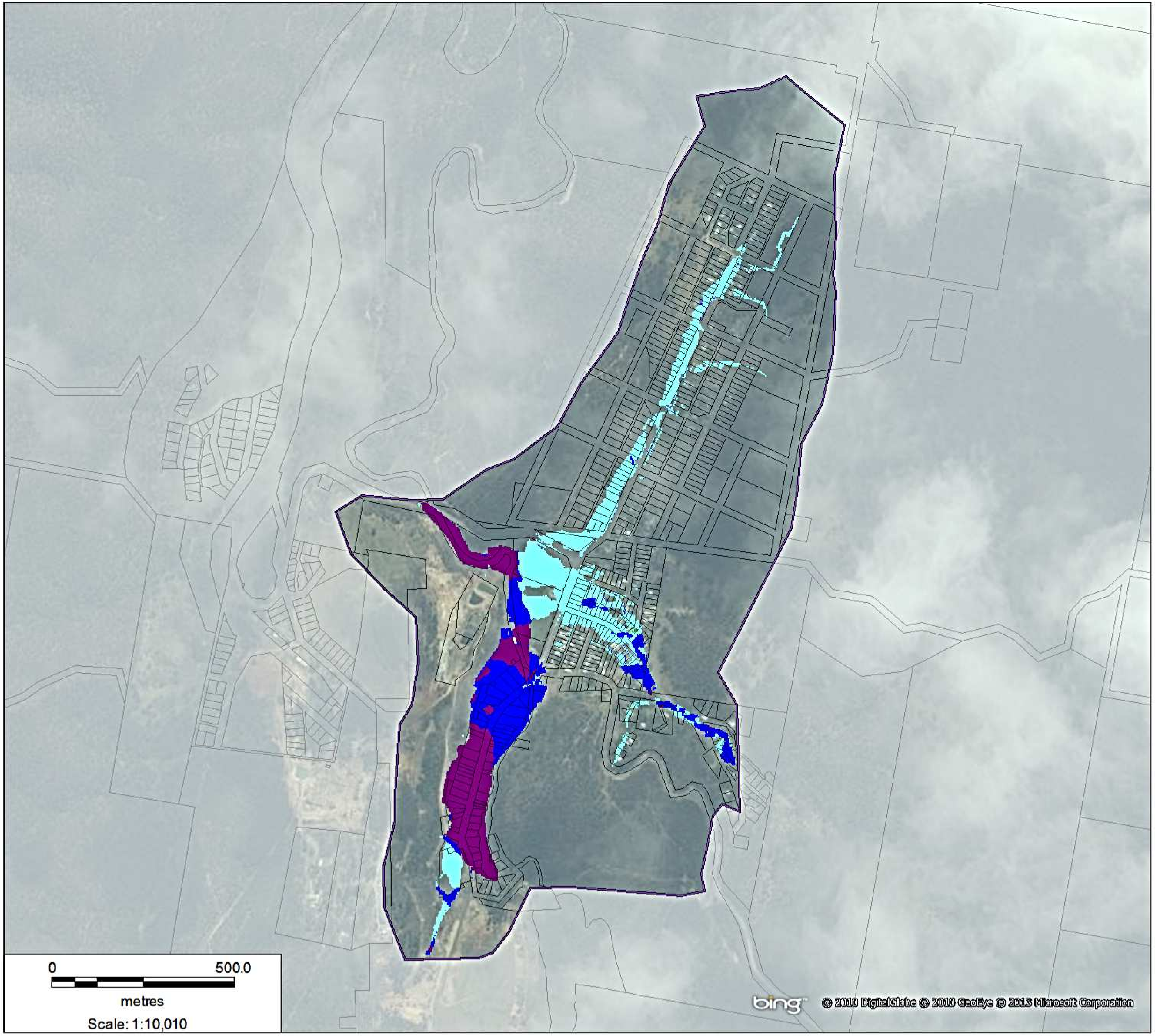


Figure 9-3

1% AEP Sensitivity Rainfall +20%

CAPTAINS FLAT FLOOD STUDY

Study Area

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

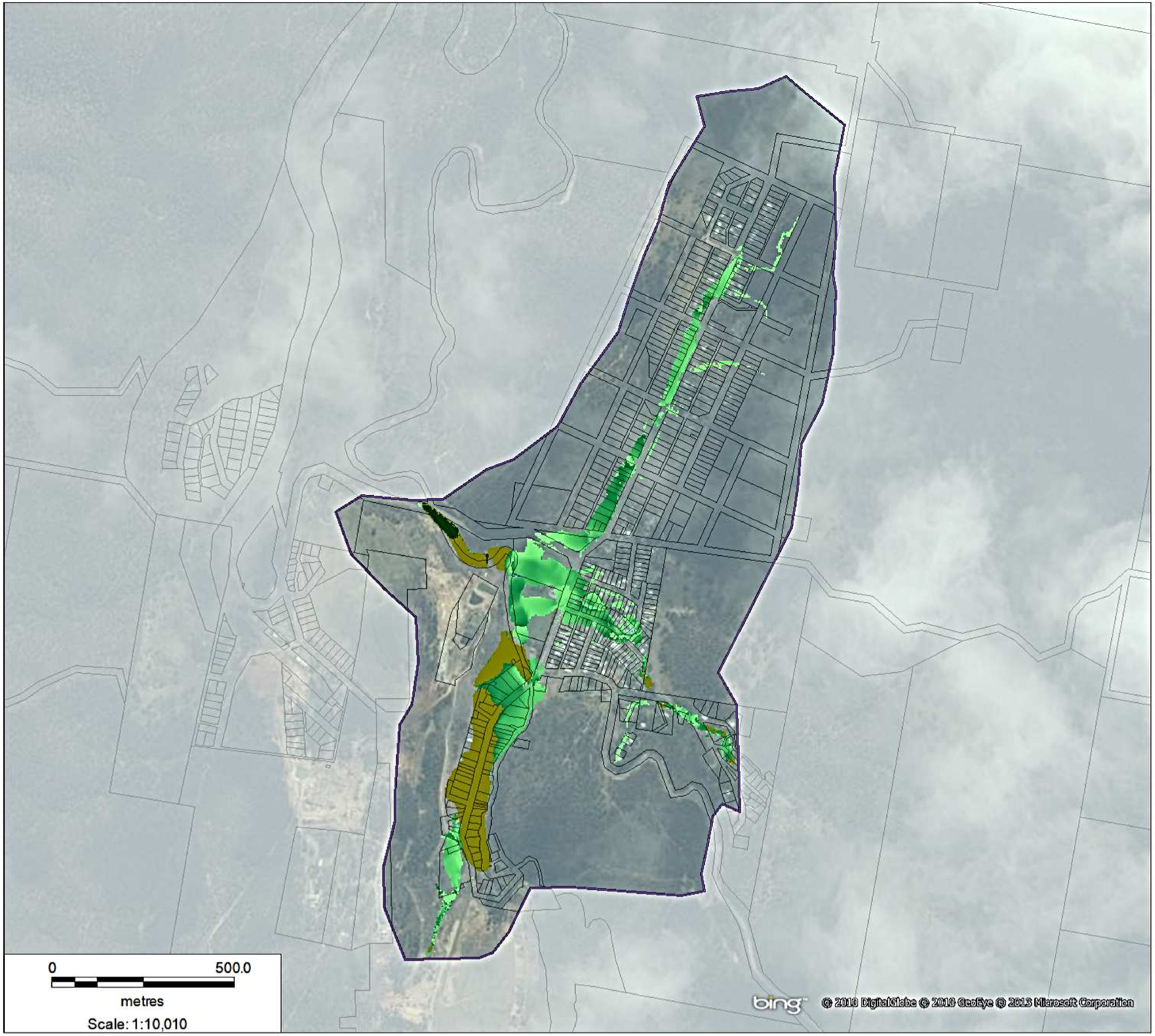


Figure 9-4

1% AEP Sensitivity Rainfall -20%

CAPTAINS FLAT FLOOD STUDY

Study Area

Peak Water Level Difference

metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1 ISG

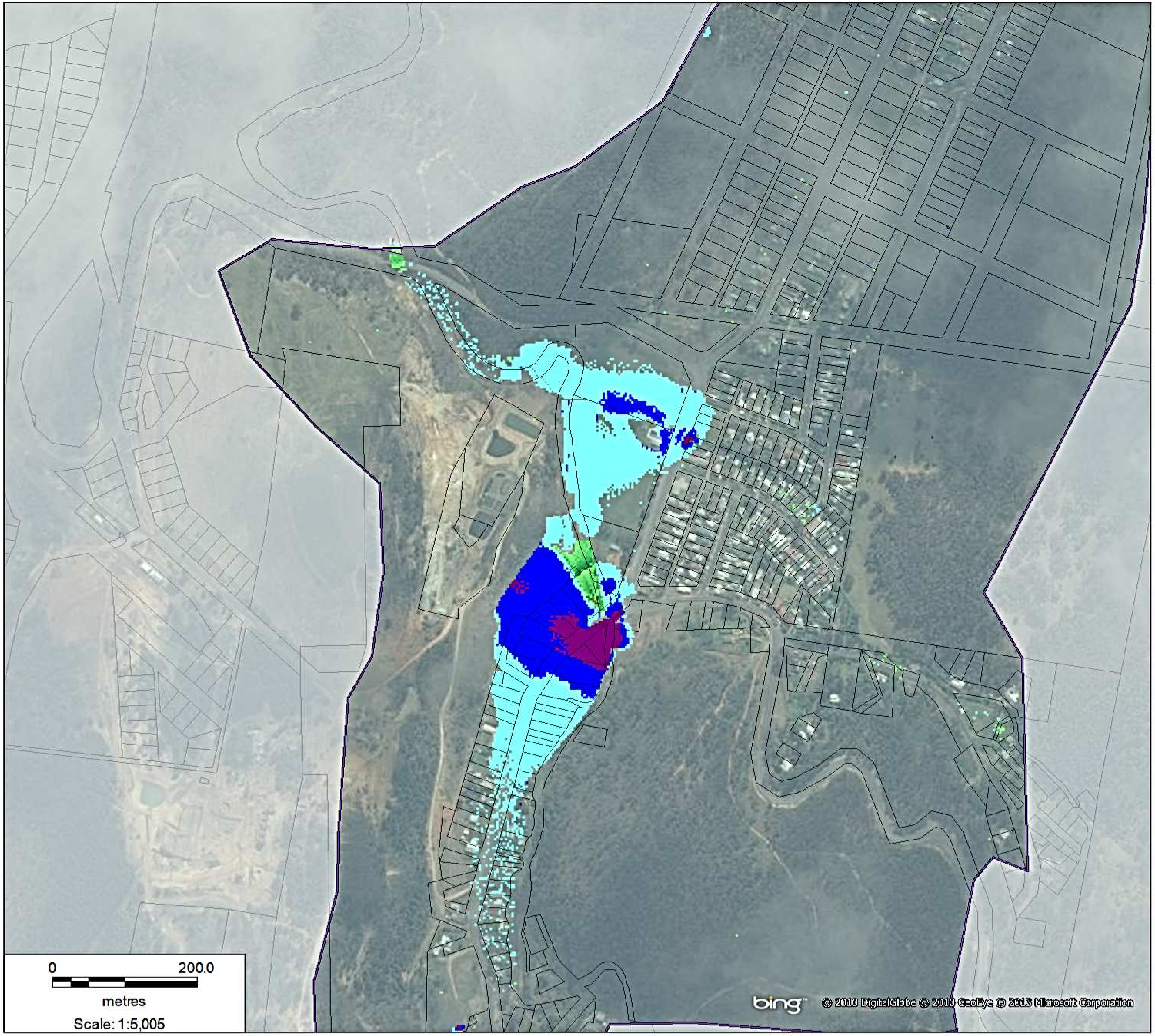


Figure 9-5

Sensitivity 10% AEP Blockage

CAPTAINS FLAT FLOOD STUDY

Study Area

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

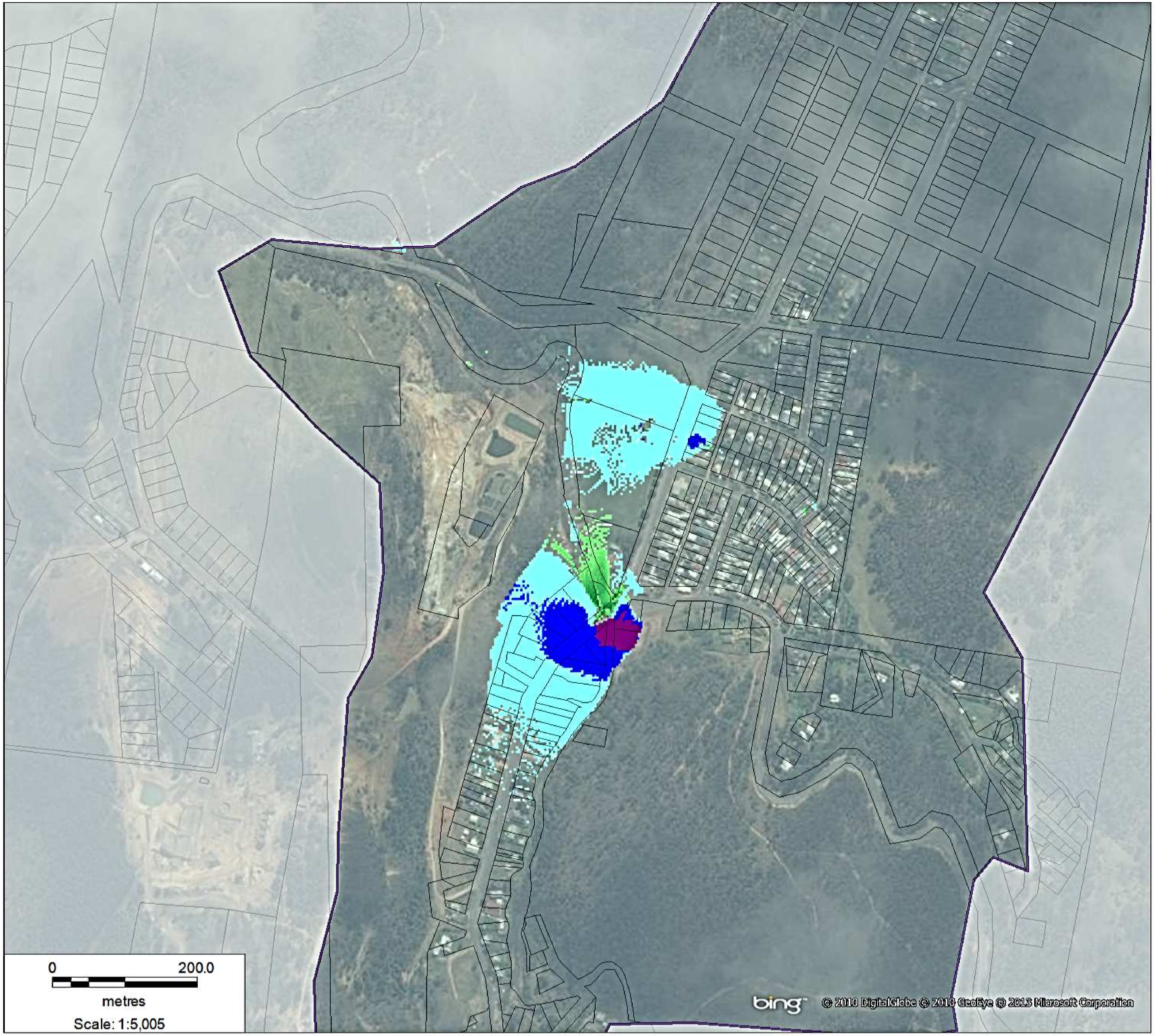


Figure 9-6

Sensitivity
1% AEP
Blockage

CAPTAINS FLAT
FLOOD STUDY

Study Area

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

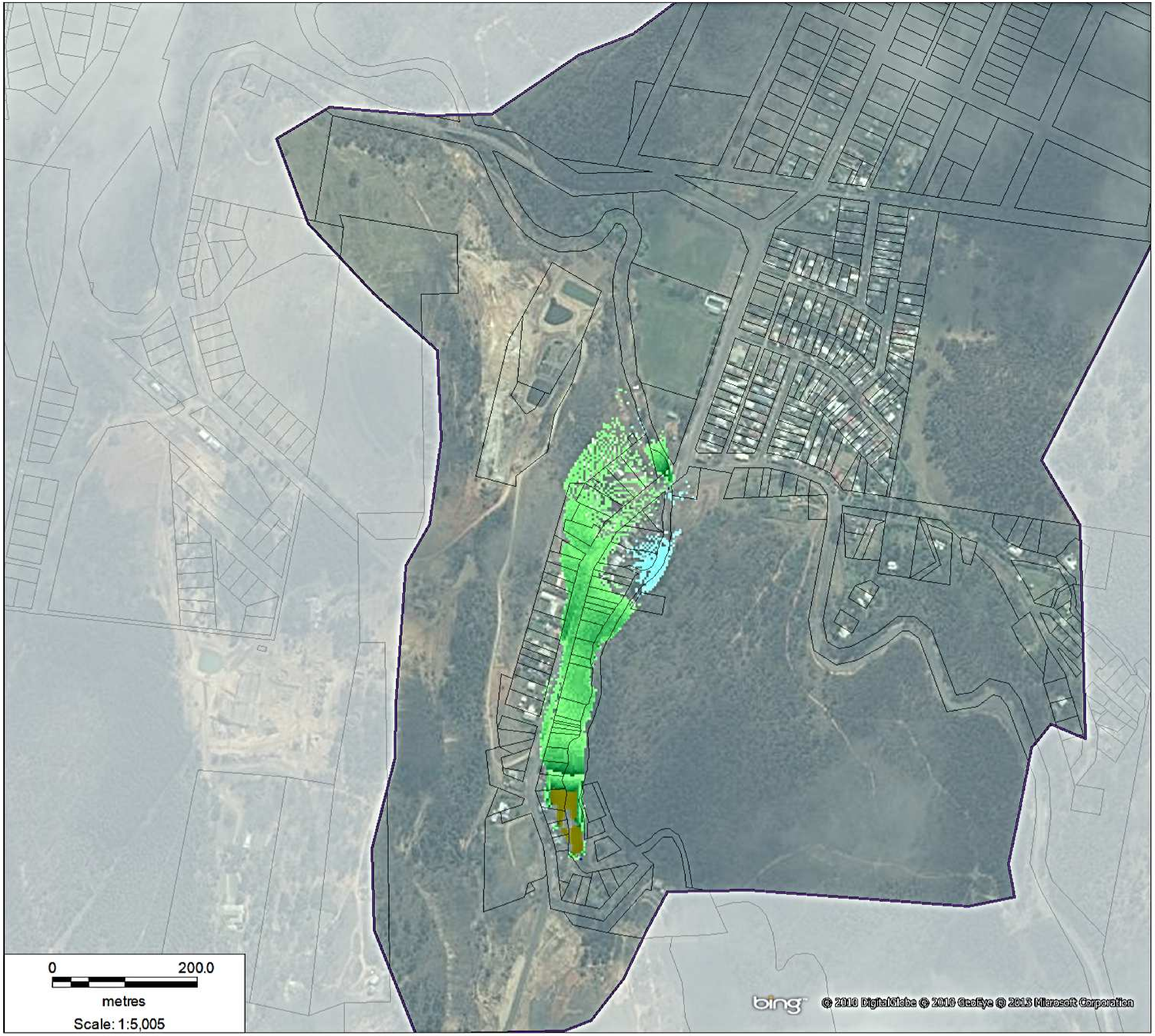


Figure 11-2

Option Assessment
10% AEP
Molonglo River Regrading

CAPTAINS FLAT
FLOOD STUDY

Study Area

Peak Water Level Difference

metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

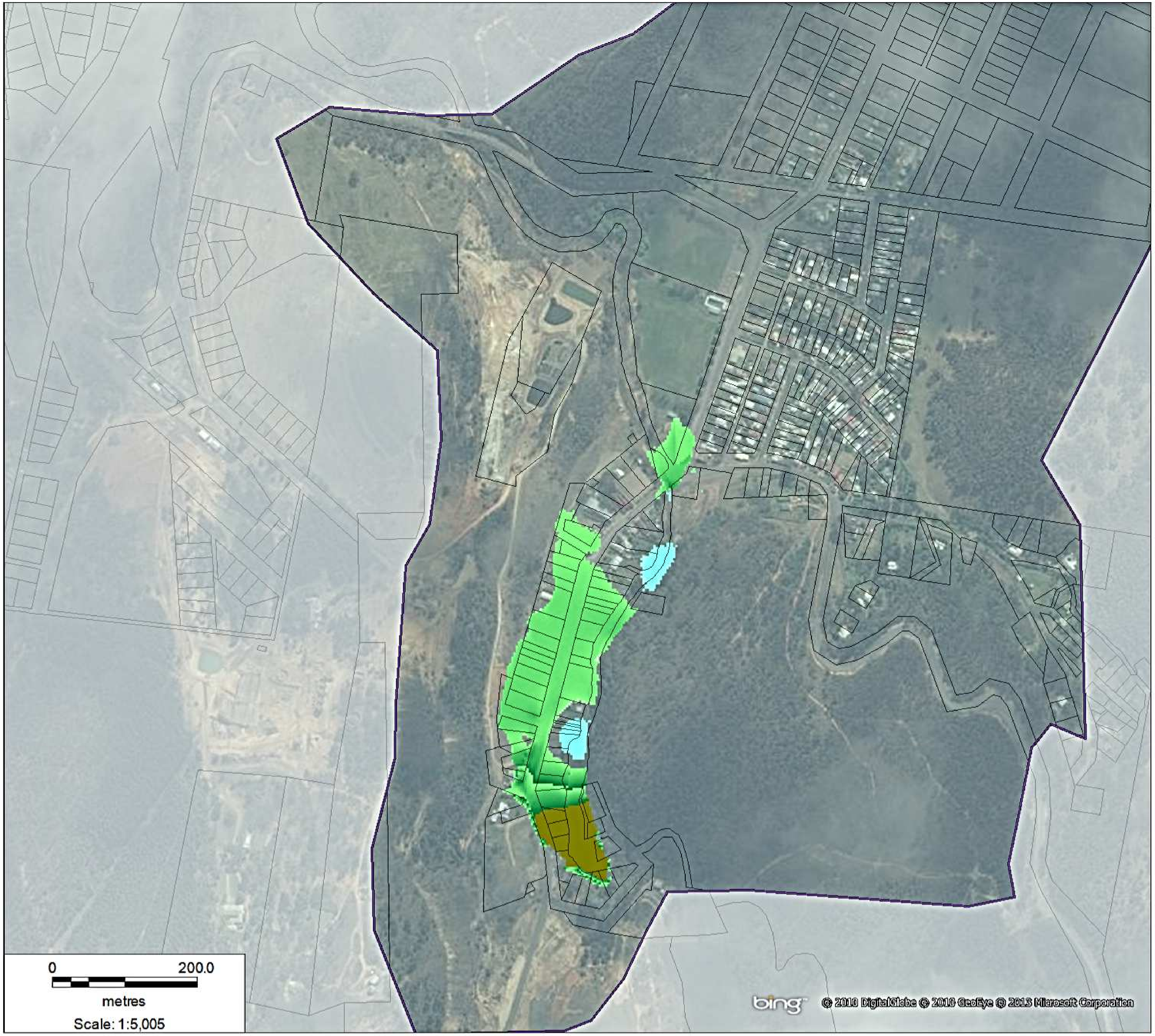


Figure 11-3

Option Assessment
1% AEP
Molonglo River Regrading

CAPTAINS FLAT
FLOOD STUDY

Study Area

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

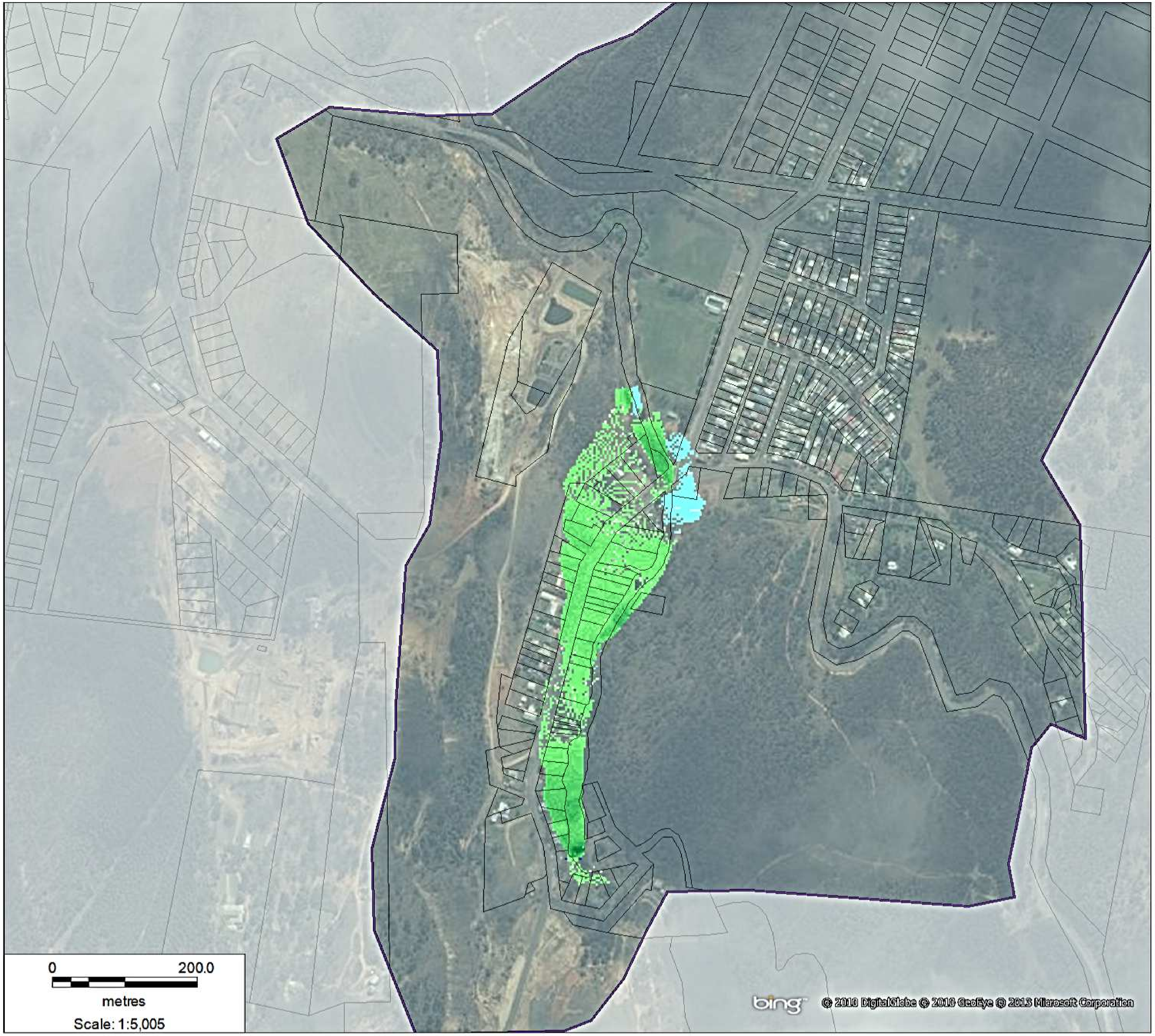


Figure 11-4

Option Assessment
10% AEP
Molonglo River Clearing

CAPTAINS FLAT
FLOOD STUDY

Study Area

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

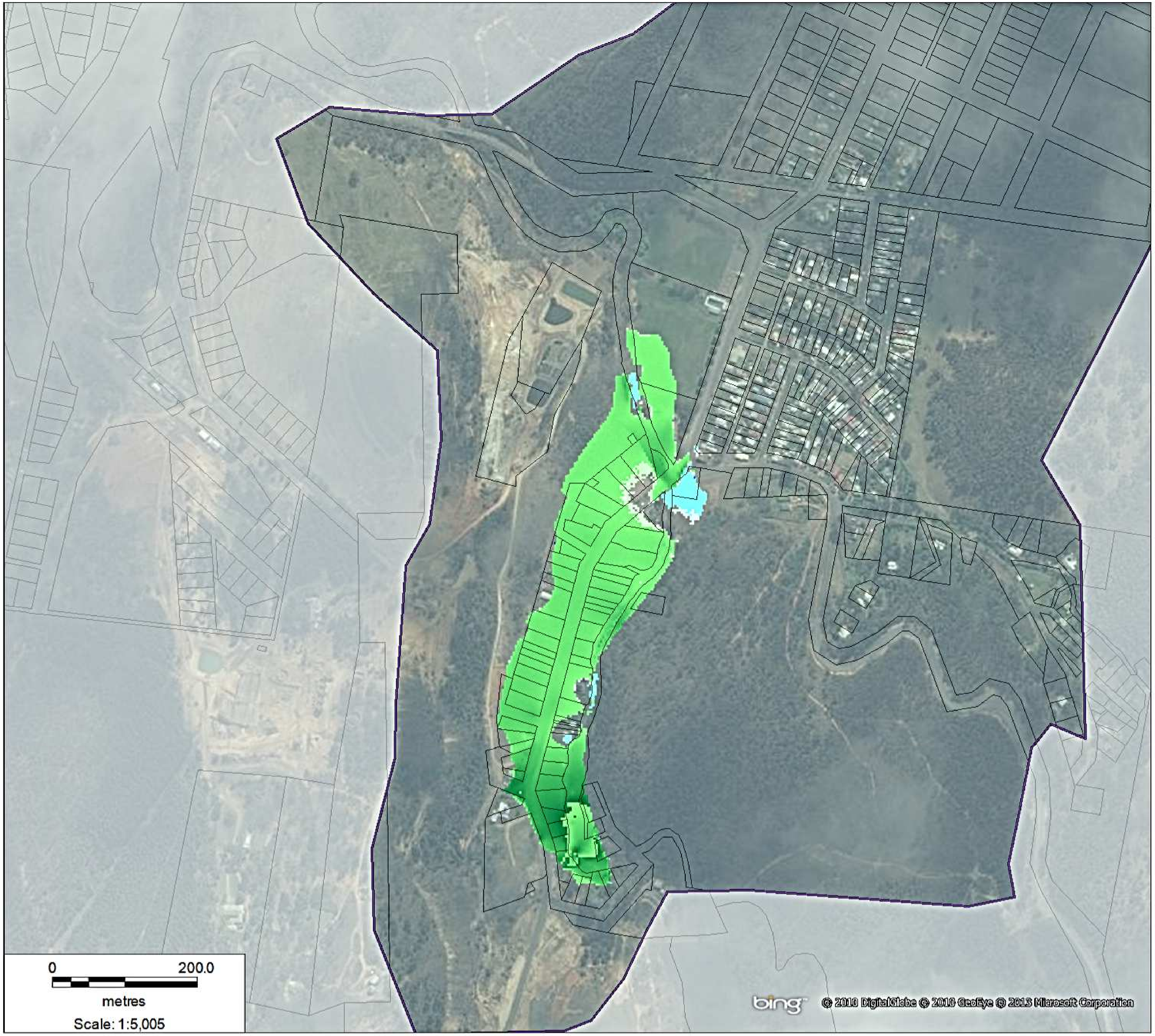


Figure 11-5

Option Assessment
1% AEP
Molonglo River Clearing

CAPTAINS FLAT
FLOOD STUDY

Study Area

Peak Water Level Difference

metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 15 April 2013
Coordinate System: Zone 55/1ISG

Flood Study Report - Final

APPENDIX A
COMMUNITY BROCHURE AND QUESTIONNAIRE

Cardno
Shaping the Future

Action

The purpose of this brochure is to inform you about the Flood Study that is being prepared for Captains Flat, and invite you to contribute information to the study. Your responses to the questionnaire included will help us collect historical flood data.

Residents and business owner's local knowledge and personal experience of flooding in this area are an invaluable source of data. We are specifically interested in any historical records which residents and businesses owner might hold such as photographs, videos, flood marks or observations. This information will help Council make a more informed, effective and economical decision on potential future floodplain management options.

Committee

A Floodplain Risk Management Committee has been established, made up of a number of government representatives of relevant authorities as well as community members. The Committee will oversee the floodplain management process, as shown in the flowchart spanning the inside pages of this brochure, and contribute to revisions and review.

Exhibition

The Draft Flood study is scheduled to be completed in January 2012. The community is invited to view and comment on the draft study when it is available on exhibition. The exhibition period will be advertised and residents notified when the Draft Flood Study is on exhibition.

Please fill out the accompanying questionnaire and return it in the reply paid envelope. If you have any further questions or would like further details, please find contact details below.

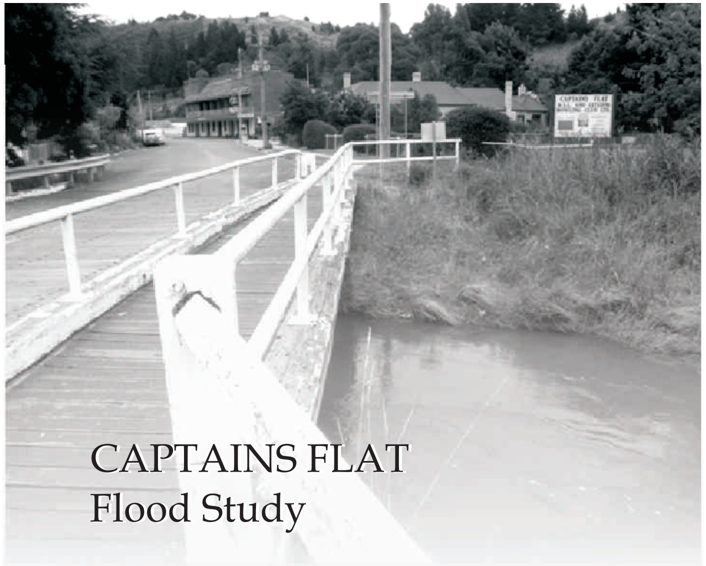
Contact Us

PALERANG COUNCIL

NAME
Palerang Shire Council
P: (02) 4429 3145
F: (02) 4422 1816
E: NAME@email

Cardno Shaping the Future

Rhys Thomson
Cardno
Level 9, 203 Pacific Highway
St Leonards NSW 2065
P: (02) 9496 7700
F: (02) 9499 3902
E: ryhs.thomson@cardno.com.au



CAPTAINS FLAT
Flood Study

Information Brochure

Palerang Shire Council has engaged Cardno to assist with the preparation of the Captains Flat Flood Study.

The Flood Study aims to help Council better understand the flooding in your area to help make informed decisions on how to manage flood risks in the future.

This brochure provides an introduction to the Flood Study and informs you of its objectives.

Your feedback on the accompanying questionnaire will play an important role in the project.

prepared for PALERANG COUNCIL | prepared by Cardno Shaping the Future

Formation of a Committee | Data Collection | Flood Study | Floodplain Risk Management Study | Floodplain Risk Management Plan | Implementation of Plan

Objectives

The objectives of the Captains Flat Flood Study are to:

• Investigate historical flooding in Captains Flat,

• Develop a computer model of flooding processes that can be used to predict the magnitude and extent of future floods, and

• Provide Council with the necessary information to make effective and economically viable flood decisions options in the future.

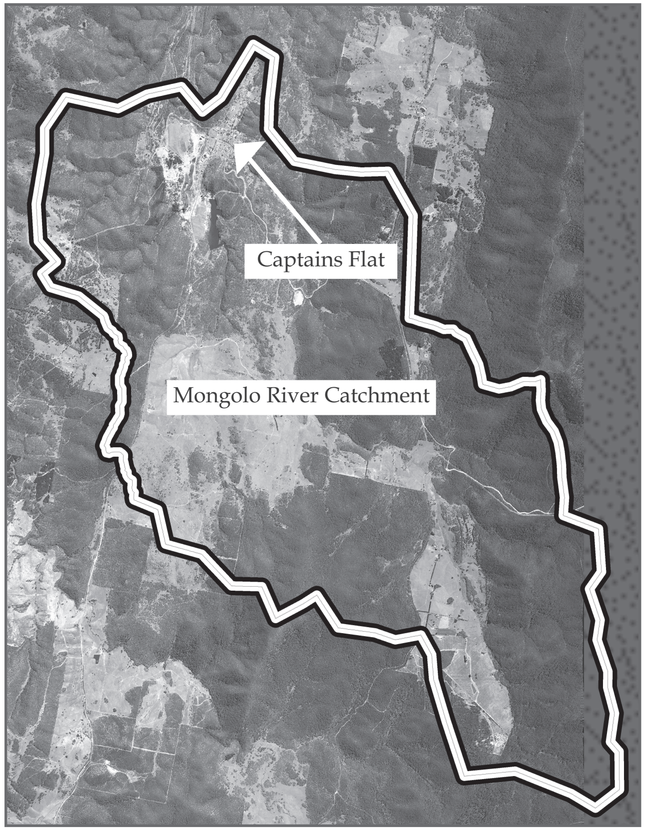
The Flood Study

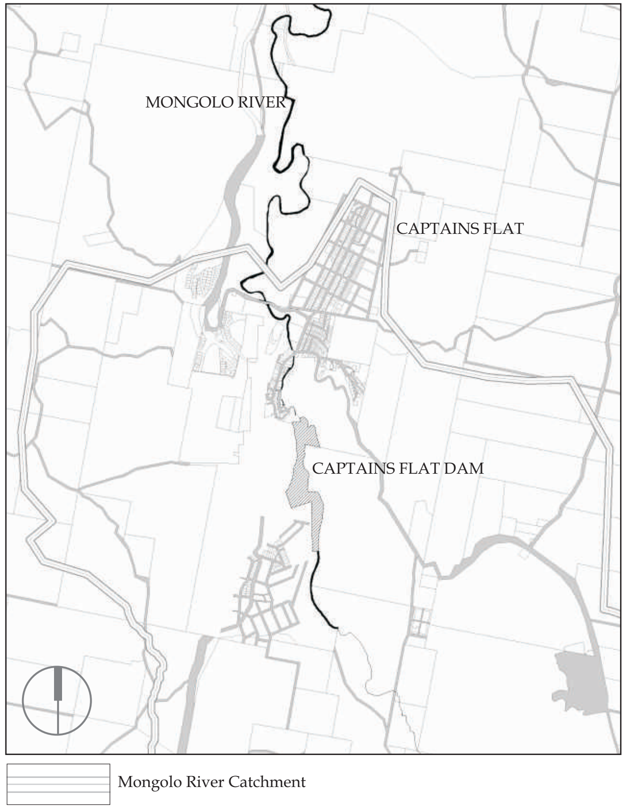
The Captains Flat Flood Study will be based on historical data, and includes computer to simulate flooding in your area. This information will help future planning of flood management options in Captains Flat.

The Flood Study is part of a staged floodplain management process, as shown the figure above, spanning this brochure. Following the Flood Study, a Floodplain Risk Management Study and Plan will be prepared where specific management options to mitigate the risk of flooding will be prepared.

Study Area

Captains Flat is located south east of Canberra and is located in the north of the Mongolo River Catchment, as shown in the figure below. Mongolo River runs by the township and also feeds the town's water supply, the Captains Flat Dam, south of the township. The Dam was constructed in 1939, and was upgraded in the early 1990s.





Existing Flooding Issues

Captains Flat can be prone to flooding. In the past, flooding has caused damage to property and infrastructure damage and has isolated residents.

Flood waters can rise from Mongolo River. Council is currently trying to understand the extent of flooding in Captains Flat and the interactions between rising waters of the Mongolo River and dam management of Captains Flat Dam, located South of the township as shown in the figure above.

If you have any further comments that relate to the Captains Flat Floodplain Risk Management Study and Plan, please express them in the space below. Please feel free to attach additional pages if necessary.

....

Thank you for providing the above information. Please remember to put the pages back in the reply paid envelope by DATE. A representative from Cardno may contact you the near future to discuss your response.

YOUR PERSONAL INFORMATION WILL REMAIN CONFIDENTIAL

If you have any queries, please contact:

NAME
Palerang Council
P: (02) 0000 000
F: (02) 0000 000
E: NAME@palerang.nsw.gov.au

Rhys Thomson
Cardno
P: (02) 9496 7700
F: (02) 9499 3902
E: rhys.thomson@cardno.com.au

June 2012

Captains Flat Flood Study

Local Resident/Land Owner Survey

*Note: information supplied will remain completely confidential.

Q1. Could you please provide us with the following details? We may wish to contact you to discuss some of the information you have provided us.

Name: ....
Address: ....
Daytime Ph: ....
Email: ....

Q2. Is your property (please tick)?

☐ Owner occupied ☐ Occupied by a tenant
☐ A business ☐ Farmland

Q3. How long have you lived, worked and/or owned your property at Captains Flat?

..............Years ....Months

Q5. How aware are you of flooding from streets or channels in the catchment? (please tick)

☐ Aware
☐ Some knowledge
☐ Not Aware

prepared for PALERANG COUNCIL prepared by Cardno Shaping the Future

Our team appreciates the diverse effects of flooding – from its dynamic shaping of the environment through to its potential negative social and economic impact. With this knowledge we analyse and develop comprehensive plans.

Q 5. Have you ever experienced flooding working/living in Captains Flat?

☐ Yes, I have experienced flooding in Captains Flat.

If yes, please fill our the table below.

Yes, I have experienced flooding	Date	Location and Description
☐ Yes, my daily routine was affected e.g. it was difficult to get to work		....
☐ Yes, my safety was threatened		....
☐ Yes, access to my property affected e.g. roads were flooded.		....
☐ Yes, my business was unable to operate.		....
☐ Yes, I had to move my livestock; my livestock was threatened by flooding		....
☐ Other, please specify		....

☐ No, I haven't experienced a flood

Q6. Has your residential/commercial property been flooded because of uncontrolled floodwater/stormwater?

Yes, my property has been affected	Date	Location and Description
☐ Frontyard and backyard		....
☐ Garage or shed		....
☐ Residential: below floor level		....
☐ Residential: above floor level		....
☐ Commercial (e.g. shop): below floor level		....
☐ Commercial (e.g. shop): above floor level		....
☐ My farming property was flooded		....

☐ No, I haven't experienced a flood

Q7. Have you seen flooding in other locations around Captains Flat?

☐ Yes, I have seen flooding in other locations other than my property.

If yes, please fill out the table below. If possible, please indicate where the flooding occurred on the map provided in this questionnaire

Type of Location	Date	Address and Description
Residential		....
Commercial		....
Rural		....
Roads or footpaths		....
Parks or other open spaces		....
Other, please specify		....

☐ No, I have not seen floods in other areas

Q8. Have you noticed any culverts or drains blocked during a

☐ Yes, I have seen culverts or drains blocked during a flood.

If yes, please specify roughly how much the culvert or drain was blocked (please tick)

☐ less than 10% ☐ 10% ☐ 25% ☐ 50% ☐ 75%

☐ more than 75%

If yes, what was blocking the culvert or drain? Please specify.....................................

Q9. Do you have any material showing past floods in Captains Flat? For example: photos, videos or watermarks on walls.

☐ Yes. Please specify ....

☐ No, I don't have any material. Please go to Q11.

Q10. Would you be willing to share your material with us for the purposes of this study?

☐ Yes, I would be willing to share my material.

☐ No, I would not like to share my material.

Q11. Are you interested in participating in the Floodplain Risk Management Committee?

☐ Yes, I would like to participate in the Floodplain Risk Management Committee.

☐ No, I would not like to participate.

If yes, a member of Palerang Council will contact you via the details you have provided in this questionnaire.