APPENDIX A: FLOOD MODELLING

A1 INTRODUCTION

The flood behaviour around Ballina was investigated in previous studies, with the most recent study being the Ballina Flood Study Update (BFSU) (BMT WBM, 2008). Computer modelling was used in these prior studies to assess the flood behaviour within the study area. These computer models have been updated and reused in this floodplain risk management study. Details of the flood modelling approach and updates are discussed in this Appendix.

A2 HYDROLOGICAL MODELLING

In order to assess the quantity of rainfall and runoff in the catchment, hydrological models of the catchment have been developed. The outputs of the hydrological modelling are used, in turn, as inflows to the hydraulic model.

Hydrological modelling was done previously for the BFSU. The previous hydrological modelling used the XP-RAFTS software. Since a catchment-wide hydrological model was developed using the WBNM software by BMT WBM for the Richmond River Flood Mapping Study (RRFMS) (BMT WBM, 2010) more recently, the WBNM model has been used to supersede the XP-RAFTS modelling. The WBNM model was calibrated to the 2009, 2008 and 1974 historical flood events for the entire Richmond River catchment.

The following assumptions and adjustments to the BFSU hydrological modelling have been adopted for this study in order to be consistent with the Richmond River Flood Study:

- Four different regions have been identified for intensity-frequency-duration (IFD) design rainfall parameters. The regions are summarised below.
    - Alstonville – based on the revised IFD parameters defined during the Ballina Floodplain Management Study (WBM, 1997);
    - Newrybar – based on the maximum IFD parameters within the region;
    - Wardell – based on the maximum IFD parameters within the region; and
    - Tuckean – based on the maximum IFD parameters within the region.
- During the RRFMS, the rainfall intensities derived using the above parameters were cross checked against those listed in the *Northern Rivers Local Government – Handbook of Stormwater Drainage Design (2006)*. The RRFMS rainfall intensities were generally equal to or higher than the design guidelines.
- Zone 1 (from Australian Rainfall and Runoff) temporal patterns have been applied, resulting in higher peak flow rates within the local catchments than used in the BFSU.
- The areal reduction factors (ARFs) used for the previous Ballina flood modelling are now considered overly conservative. The Cooperative Research Centre for Catchment Hydrology (CRCCH) (1996) has derived an empirical method for calculation of ARFs. Higher ARFs are calculated for longer duration and higher frequency events as presented in Table A-1.

Since the CRCCH method also accounts for catchment area, the following criteria have been used:

- For the local catchment storm events (short storm duration), the Lower Richmond River catchment area of 387km^2 has been used; and
- For the broader Richmond River catchment storm events (long storm duration), the entire Richmond River catchment area of 6,900km^2 has been used.

Table A- 1 lists the areal reduction factors used in the WBNM hydrology model.

Table A- 1 Revised Areal Reduction Factors

Event Duration	Areal Reduction Factor for ARI			
	10 year	20 year	50 year	100 year
12 hour	0.81	0.81	0.80	0.80
72 hour	0.86	0.85	0.83	0.82

A3 HYDRAULIC MODELLING

A3.1 Background

Originally, a 1D flood model was developed for the previous floodplain risk management study using software called ESTRY (WBM, 1997). This model was then updated as part of the BFSU by removing much of the 1D floodplain component from the model and replacing the floodplain representation with 2D domains using the TUFLOW modelling software.

The flood model developed for the BFSU was subsequently updated on a regular basis for development assessments. This was done to enable Council to assess the cumulative flood impact of development in the floodplain. The model has been used extensively for this purpose, and is commonly referred to as the integrated flood model. The integrated flood model forms the basis of the flood model that has been developed for this study.

Much of the flood model structure, assumptions and parameters are discussed in detail in the BFSU report. A brief description of the model layout, adjustments made to the model during this study and approved development that is included in the model is discussed below.

A3.2 Model Extent and Schematisation

The model extent covers the lower Richmond River and parts of its major tributaries: Maguire Creek, Emigrant Creek and North Creek. The model extent is illustrated in Figure A-1. Two 2D domains are used: a 40m 2D grid for North Creek, Maguires Creek and the Richmond River areas, and a 10m 2D grid for Ballina Island, West Ballina and Emigrant Creek.

The Richmond River channel is represented using a 1D network from the upstream boundary to Empire Vale on the downstream side of Pimlico Island. Downstream of this point, flow through the river channel is modelled in the 40m 2D domain.

The North Creek, Emigrant Creek and Maguires Creek channels are represented using a 1D network, as well as a number of drains and smaller creeks in the catchment.

The 1D river channel networks, 10m 2D domain and 40m 2D domain are all dynamically linked, thereby enabling flow to transcend across these separate components in real time during the model simulation.

A3.3 Topography

2004 photogrammetry captured for the BFSU covers the 2D domain extents, north of Pimlico Island. For the extension of the 2D domain applied in this study (discussed in Section A3.6) additional topographic data was acquired.

A Digital Elevation Model (DEM) of the Richmond River catchment developed for the RRFMS was available, which was built using a number of data sources. This DEM was used to define the topography in the extension of the 2D domain. The bulk of the topographic data in the extended 2D domain originates from a DEM (based on photogrammetry) created for the Wardell and Cabbage Tree Island Flood Study. Other parts of the DEM in the area covered by the extended 2D domain were based on photogrammetry acquired by the Roads and Traffic Authority (RTA) for the Woodburn to Ballina Pacific Highway Upgrade Project.

A3.4 Model Boundaries

A3.4.1 Upstream Boundaries

There are five upstream boundaries in the flood model. All of these boundaries use flow-time boundary conditions. The flow conditions applied at the North Creek, Emigrant Creek and Maguires Creek upstream boundaries are based on hydrographs developed from the hydrological model. The flow conditions applied at the Tuckean Broadwater and Richmond River upstream boundaries are derived from a synthetic stage-time boundary that was developed during the Ballina Floodplain Management Study (WBM, 1997).

A3.4.2 Intervening Catchment Runoff

Rainfall falling over the sub-catchments within the flood model extent has been applied by using a TUFLOW modelling method that initially inserts the runoff associated with a particular sub-catchment at the lowest cell within that sub-catchment, and subsequently spreads the runoff evenly across all wet cells in the sub-catchment.

A3.4.3 Downstream Boundary

The downstream boundary is located at the outfall of the Richmond River at the Pacific Ocean. Water levels at the downstream boundary are therefore dictated by local tidal conditions. A stage-time boundary has been used, as per the BFSU.

A3.5 Model Roughness Parameters

Land use (surface roughness) definition for the Ballina area remains unchanged from the BFSU. For the extended 2D domain between Broadwater and Pimlico Island, land use is based on that used for the RRFMS, which is based on Council's 2004 aerial photography.

A3.6 Updates Applied to the Flood Model

A number of enhancements to the integrated flood model have been implemented as part of this floodplain risk management study. These include:

- **Extension to southern extent of the 2D domain**
  The southern extent of the 2D domain was originally at Empire Vale near Pimlico Island, and the Richmond River floodplain upstream of the 2D domain extent was represented using 1D elements. These 1D floodplain elements have been removed and the 40m 2D domain has been extended to the upstream boundaries on Richmond River and Tuckean Broadwater.
- **Richmond River bathymetry update**
  Bathymetry for the Richmond River between Broadwater and Pimlico Island has been updated with a survey captured for DECCW's (now Office of Environment and Heritage) estuary program.
- **Change to location of Richmond River upstream boundary**
  The upstream boundary and model extent on the Richmond River has been moved three kilometres further upstream to Rileys Hill. The floodplain at this location is constricted, and is therefore a more appropriate location for the upstream boundary.
- **Change to Richmond River and Tuckean Broadwater upstream boundary type**
  The integrated flood model used head-time upstream boundaries on the Richmond River and Tuckean Broadwater. These boundaries have now been changed to flow-time boundaries. This change has been applied to ensure that the flow through the river systems remains consistent across future model versions.
- **Update to the model inflows**
  The WBNM hydrological modelling results have been applied to the flood model, replacing the XP-RAFTS hydrological inflows that were being used previously.
- **Enable flow through porous rock headwall at Richmond River mouth**
  The northern headwall on the Richmond River mouth blocks water in the Richmond River mouth from entering into the Shaws Bay area. The model was originally set up such that this headwall was impervious. Therefore the model was indicating little flood risk in the Shaws Bay area. However in reality this wall is porous, allowing flood waters to flow into Shaws Bay. The model has been updated by creating some voids in the headwall. The assumptions used for this model adjustment have been informed by the Shaws Bay, East Ballina Estuary Management Plan (Patterson Britton, 2000).

A3.7 Development and Infrastructure Included in the Flood Model

The integrated model has been used to quantify the cumulative flood impact of a number of proposed developments. The following proposed development and infrastructure were previously assessed and included in the flood model:

Ballina Shire Council Studies

- West Ballina Master Plan
- Part of the Southern Cross Precinct Master Plan

- North Creek Road
- West Ballina Arterial Road

Roads and Traffic Authority Studies

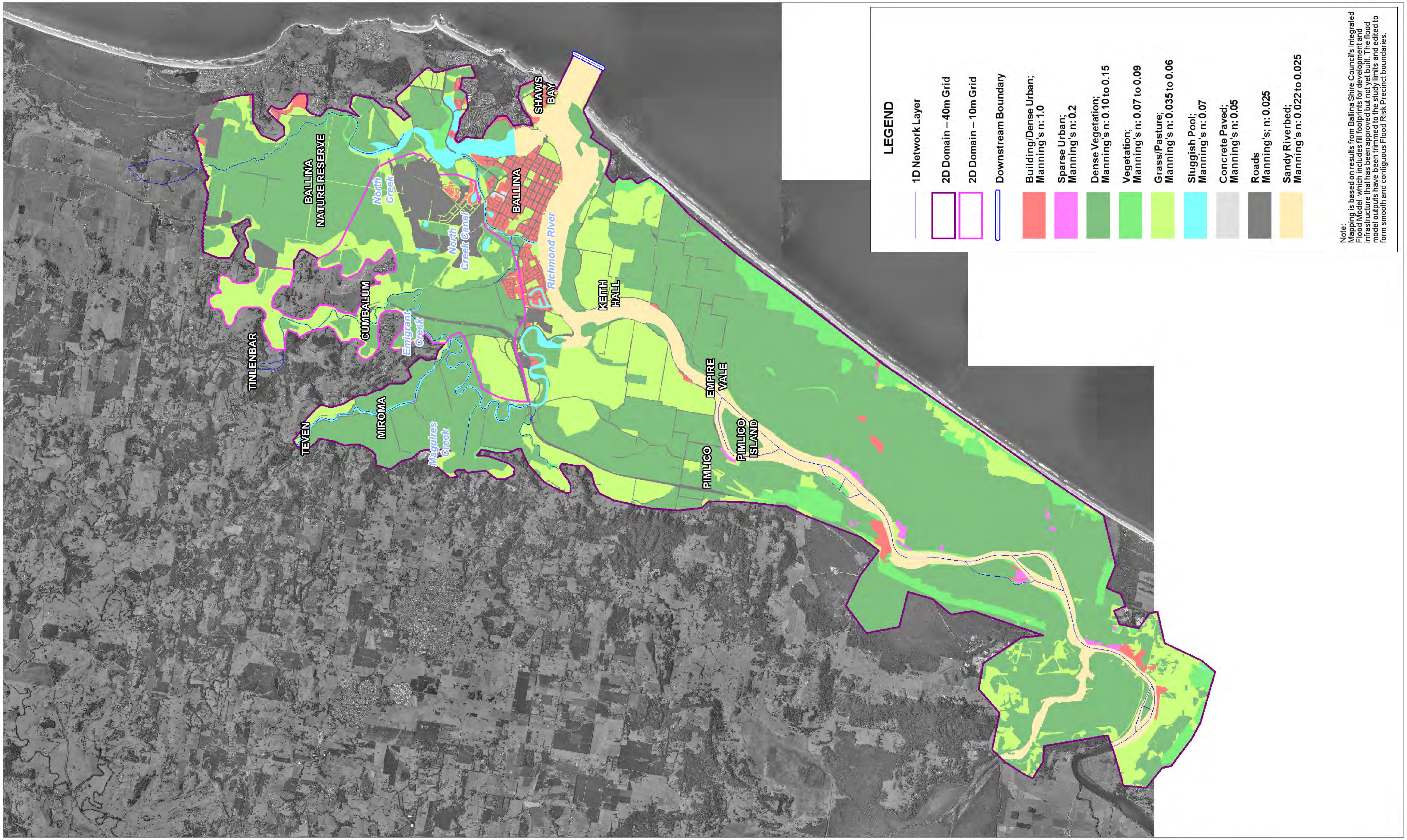
- Ballina Bypass Pacific Highway Upgrade
- Woodburn to Ballina Pacific Highway Upgrade
- Garney Koellner Road Bridge

Residential/commercial development

- Natuna
- Ferngrove (previously called Riveroaks)
- Ballina Waterways
- Ballina Heights
- Cumbalum Precinct B
- Barrets
- Dr Stewarts
- Various Tevan Road filling

Note that while an assessment has been undertaken for a proposed development (highway service centre) at Lot DP238009, this development is not included in the model as the development had not been approved at inception of this study. The western portion of the site has since been approved.

Since the developments listed above have been included in the flood model, the model does not represent the catchment's current conditions. It is estimated that the development will be built over the next few years, and that that the model therefore relates to catchment conditions expected by approximately 2020.



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Flood Model Schematisation

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A-1

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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A4 DESIGN FLOOD EVENTS

The study area is prone to three sources of flooding, namely: Richmond River, local catchment (i.e. tributaries of the Richmond River) and ocean storm flooding. In reality, a variety of combinations of these flood sources can occur. However, for the purpose of developing hypothetical design flood events the flood study (BMT WBM, 2008) defined three separate design flood scenarios which are dominated by a particular flood source. These are:

Scenario A – Richmond River dominated event;

Scenario B – Local catchment dominated event; and

Scenario C – Ocean storm surge dominated event.

These three scenarios have been modelled independently for the 20, 50, 100, and 500 year Annual Recurrence Interval (ARI) flood events. For small flood events (i.e. 5 and 10 year ARI), it is assumed that there is no flood source dominance, and each flood source is applied concurrently (Scenario D).

The Probable Maximum Flood (PMF) is a hypothetical flood, or combination of floods, which represents a theoretical 'worst case' scenario. The PMF design floods were developed using a 10,000 year ARI flow in the Richmond River and 500 year ARI ocean storm levels at the downstream boundary. For local catchment flows, the Probable Maximum Precipitation (PMP) storm has been determined and applied to the flood model considering three different storm centres:

Scenario E – PMP storm centred on Maguires Creek catchment;

Scenario F – PMP storm centred on Emigrant Creek catchment; and

Scenario G – PMP storm centred on North Creek catchment.

In summary, the 5, 10, 20, 50, 100, 500 year ARI and PMF events have been simulated using the flood model. For a given return period flood event, the flood model results for each scenario have been amalgamated by selecting the most severe flood condition at each location, thus generating the 'worst case' flood conditions.

Table A- 2 Design Flood Event Scenarios

	Scenario	Richmond River Level (ARI)	Local catchment storm (ARI and storm duration)	Ocean Storm Surge(ARI)
PMF	E	10,000 year	PMP[1] (centred on Maguires Ck catchment)	500 year
	F	10,000 year	PMP[1] (centred on Emigrant Ck catchment)	500 year
	G	10,000 year	PMP[1] (centred on North Ck catchment)	500 year
500 year ARI	A	500 year	500 year (72 hours)	10 year
	B	100 year	500 year (12 hours)	10 year
	C	100 year	100 year (12 hours)	500 year
100 year ARI	A	100 year	100 year (72 hours)	10 year
	B	10 year	100 year (12 hours)	10 year
	C	10 year	10 year (12 hours)	100 year
50 year ARI	A	50 year	50 year (72 hours)	10 year
	B	10 year	50 year (12 hours)	10 year
	C	10 year	10 year (12 hours)	50 year
20 year ARI	A	20 year	20 year (72 hours)	10 year
	B	10 year	20 year (12 hours)	10 year
	C	10 year	10 year (12 hours)	20 year
10 year ARI	D	10 year	10 year (12 hours)	10 year
5 year ARI	D	5 year	5 year (12 hours)	5 year

Notes: 1. PMP = Probable Maximum Precipitation is the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of year.

A5 MAPPING THE MODEL RESULTS

The flood model computes a number of hydraulic characteristics through the modelled extent, such as flood level, flood depth, flow velocity and the depth velocity product (used to assess flood hazard). These are captured in the flood model's results files. TUFLOW's results files are output in a format that is compatible with software called SMS (Surface-water Modeling System, developed by the US Army Corps of Engineers). The SMS file format stores the model results at the 2D domain's computational grid cell corners rather than at the grid centre. Thus the resolution of TUFLOW results is generally half the resolution of the 2D domain's computational grid size, i.e. 20m for the flood model used in this study.

Each design event comprises the three sources of flooding described in Section A4. Therefore, to generate maps of the flood model results for each design event, the maximum result from each of the three source events have been overlayed and the maximums extracted. This provided a maximum envelope of peak flood levels, depths, velocity and depth velocity product across the model area.

Figure 2-1 in Section 2 of the body of this report shows the dominance of the different sources of flooding for the 100 year ARI flood event. Richmond River flooding tends to be dominant across the Richmond River floodplain to Ballina Island, across the lower Emigrant Creek floodplain and across the North Creek catchment. Local catchment flooding is the dominant source of flooding in upper Emigrant and Maguires Creeks, whilst the area covering Ballina Island to the ocean, experiences worst flooding from elevated ocean levels.

APPENDIX B: DERIVATION OF DEMOGRAPHIC AND PROPERTY DATABASE

B1 PURPOSE

A property and demographic dataset has been developed for use in the flood damage estimation and the evacuation capability assessment. This dataset combined a large amount of information about individual properties, including floor level, building type and number of residents. Importantly, the database spatially distributes the property information, enabling identification of flood effects on individual properties and residents.

B2 PROPERTY DATABASE

The property database is derived from 1979 survey information, supplemented with additional survey commissioned for this study. This additional survey was required in areas which were developed or modified during the last 30 years.

The following methodology has been applied to generate the property database:

1 The existing 1979 survey data has been reviewed to determine which properties required updated survey. Properties which appeared to have been rebuilt or have modified floor levels have been removed from the 1979 dataset. The survey review has been based on aerial photography, cadastral data and ground inspection. Approximately 1,090 residential and 170 commercial/ industrial properties remained in the 1979 survey dataset at the end of this process.

2 Residential, commercial and industrial properties not covered by the revised 1979 survey dataset have been identified. This process focussed on identifying those properties that are within or near the floodplain, i.e. properties on high ground have not been included. Floor levels and building data for these properties have been surveyed by Landsurv (Tweeds Head Office) in 2009. In total 2,340 residential properties and 380 commercial/industrial properties were surveyed. The 1979 and 2009 surveys have been merged into one residential floor level survey and one commercial/industrial floor level survey.

3 A small number of isolated properties were not included in the original or supplementary survey. Details of these developments have been estimated using aerial photogrammetry data, cadastre data and Google imagery.

4 The number of units within properties surveyed in 1979 has been estimated from cadastre type, property type, Google imagery and ground inspection where necessary.

5 The building areas of commercial properties have been determined based on the cadastre parcel sizes and, for large buildings, digitised from aerial photos.

It is noted that flood damages assessments are typically combined for commercial and industrial properties. For simplicity, both types of properties and damages are referred to as *commercial* herein, but in all cases refer to *commercial and industrial*.

In total, approximately 3,770 residential and 550 commercial properties have been identified within the study area and incorporated into the dataset.

Additional assumptions used to derive the property data set and associated parameters are listed in Table B-1 to Table B-3.

B3 DEMOGRAPHIC DATABASE

Population data has been used to estimate the number of people requiring evacuation and the number of vehicles which will be used to evacuate. This information has been combined with the property database to determine which properties are predicted to be flood affected.

Due to the uncertainty regarding the size of the impending flood event at the time of flood prediction, it is necessary to evacuate the entire population at risk of flood inundation or isolation in a PMF.

Information regarding population and vehicles has been derived from the 2006 census (Australian Bureau of Statistics 2010), as this is the most recent data available.

B4 FUTURE DEVELOPMENT AND POPULATION

The flood model includes assessed development that is yet to be built. Therefore the future development has been accounted for in the property database and projected population estimates included in the demographic database. This has been implemented by developing an additional dataset consisting of only the unbuilt assessed development to supplement the database of existing properties. The following assumptions have been made to derive this supplementary dataset:

- Numbers of residential dwellings have been derived from a *Housing Demand and Supply Forecast Methodology Statement* provided by Ballina Shire Council;
- Dwelling types have been assumed to be low set (i.e. single storey slab on ground);
- Floor levels have been assumed to be set according to the current planning level, i.e. 100 year flood level including climate change for the 2100 horizon plus 500mm freeboard;
- Commercial building areas have been assumed to be of medium size, i.e. 650m²;
- Value class for commercial buildings have been assumed to be of medium value, i.e. value class of 3; and
- The numbers of commercial dwellings have been estimated by assuming that two-thirds of the commercial development area will be covered by commercial property and that the commercial property size will be 650m² on average. The commercial development areas have been calculated based on the development footprint sizes in the model.

Note that the unbuilt assessed development contributed little to the overall flood damages because the floor levels are relatively high compared to the flood levels.

The projected population estimates have been added to the demographic database. The population linked to future development has been projected by assuming 2.16 people per residential dwelling (shire-wide long-term occupancy rate projection provided by Ballina Shire Council). Population has also been projected to 2020 in consideration of infill development. The estimated population data are summarised in Table 3-4 in Section 3 of the body of this report.

Table B- 1 Property Data

Property Data	Residential Properties	Commercial and Industrial Properties
Property type	Based on information collected during survey in 1979 and 2009, aerial photography and cadastre. See Table B-2 and B-3 for more details.	Based on information collected during survey in 1979 and 2009, aerial photography and cadastre. See Table B-2 and B-3 for more details.
Number of properties	Based on information collected during survey in 1979 and 2009, see Table B-2 and B-3 for more details. Where no information was collected the number of properties has been assumed based on aerial photography, cadastre and site visits.	Based on information collected during survey in 1979 and 2009, see Table B-2 and B-3 for more details. Where no information was collected the number of properties has been assumed based on aerial photography and cadastre.
Location of properties	As digitised in survey data. East Ballina and Shaws Bay – aerial photography and cadastre.	As digitised in survey data. East Ballina and Shaws Bay – aerial photography and cadastre.
Dwelling type	As collected in 2009 survey 2007 survey, East Ballina and Shaws Bay – determined from aerial photography and cadastre.	Not applicable.
Floor area	Not applicable.	Parcels < 200m^2 – small. Parcels 200 to 700m^2 – medium. Parcels > 700m^2 – approx building area digitised from aerial photography and cadastre.
Business value	Not applicable.	Based on information collected during survey in 1979 and 2009, see Table B-2 and B-3 for more details.
Floor level	Survey undertaken in 1979 or 2009 East Ballina and Shaws Bay – based on a digital elevation model created from airborne laser scanning and aerial photogrammetry data.	All properties – survey undertaken in 1979 or 2009
Flood level	All properties – flood level in building / at survey point.	All properties – flood level in building/ at survey point.

Table B- 2 Derivation of Property Type and Business Value based on Survey Information (2009 Survey)

2009 Survey	TYPE	Class Value
Dwelling	residential	NA
Townhouse	residential	NA
Garage	residential	NA
Units	residential	NA
Shed	residential	NA
Amenity	commercial	1
Commercial	commercial	3
Club	commercial	1
Bowls Club	commercial	1
Church	commercial	1
Pump station	commercial	4
Industrial	commercial	3
Caravan park	commercial	2
Resort	commercial	3
School	commercial	1
Motel	commercial	3
Hospital	commercial	3
Airport	commercial	4
Hall	commercial	1
Museum	commercial	3
Community Centre	commercial	1
Vets	commercial	2
Stable	commercial	2
Age care	commercial	3

Table B- 3 Derivation of Property Type and Business Value based on Survey Information (1979 Survey)

1979 Survey	TYPE	Class Value
Dual Occupancy	residential	NA
Duplex	residential	NA
Dwelling	residential	NA
Flats	residential	NA
Strata Parent	residential	NA
Aged Accommodation	commercial	3
Bank	commercial	3
Bed & Breakfast	commercial	3
Car Park	commercial	3
Caravan Park	commercial	2
Church	commercial	1
Club	commercial	1
Combined Use	commercial	3
Commercial	commercial	3
Court House	commercial	3
Hall	commercial	1
Hostel	commercial	3
Hotel	commercial	3
Industrial	commercial	3
Mobile Home Park	commercial	2
Motel	commercial	3
No Improve Details	*commercial*	*3*
Office	commercial	2
Office/Dwelling	commercial	2
Other	commercial	3
Pre School	commercial	1
Public Authority	commercial	1
Public Reserve	commercial	1
Public Utility	commercial	1
School	commercial	1
Service Station	commercial	4
Shop	commercial	2
Shop/Dwelling	commercial	2
Storage/Warehouse	commercial	2
Surgery	commercial	2

APPENDIX C: EVACUATION TIMELINE METHODOLOGY

C1 OVERVIEW

The methodology utilised in this evacuation capability assessment has been based on the 'Evacuation Timeline' approach developed by the NSW State Emergency Services (SES) (Opper, 2004). This approach utilises timeline project management to determine the estimated timeframes of various elements during an evacuation procedure. The total available time for evacuation is marked along a timeline; the timeline commences when the storm commences and ends when evacuation is no longer possible due to road closures, or when everyone is safely evacuated. Between these times, a number of key evacuation processes must occur in sequence. Mapping these on a timeline can be used to highlight a number of important features of the process, including:

- What processes must be completed during evacuation; and
- How much time is available to safely complete evacuation.

An example timeline is shown in Figure C-1 and further description of the various elements and parameters is provided in Section C4. For further detail on the SES 'Evacuation Timeline' methodology, input parameters and applications, refer to Opper (2004).

C2 UNCERTAINTY

The ECA is based upon results from a flood model in conjunction with assumptions regarding flood prediction time, SES requirements and behavioural factors such as warning response time. Flood behaviour is based on hypothetical design floods; real flood combinations and durations can result in different flood behaviour to the model. Therefore, factors such as flood behaviour and community response can be extremely difficult to predict.

Nonetheless, ECAs form a vital part of the flood risk management process and should not be avoided due to uncertainties and the risk of error. There is always a degree of uncertainty in results relying on models and assumptions. Despite this uncertainty, the flood intelligence contained in this document is considered sufficient to identify constraints in the current evacuation capability, highlight the need for action and provide guidance on future evacuation decisions.

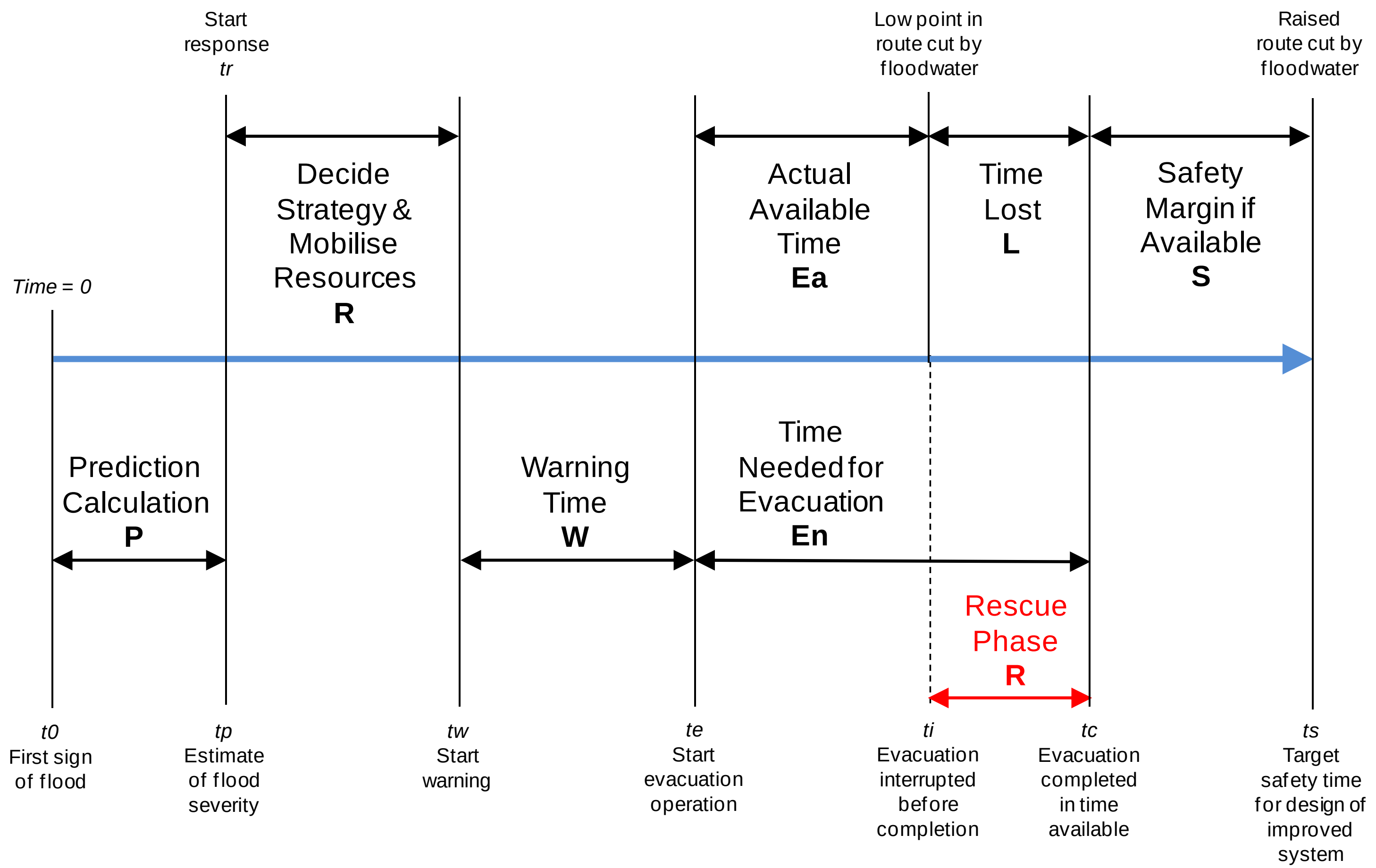


Figure C- 1 Time Line of Emergency Response for Flood Evacuation (Opper, 2004)

Note: S will be a negative value (Safety Margin <0) when ti occurs earlier than tc. S will be zero when all available time needed (En) is used. Only when ti occurs after tc does a Safety Margin begin to accrue. The magnitude of S has to be determined by reference to the capacity to cope with uncertainty and interruptions. The time elements are not drawn to scale in this diagram.

C3 KEY TIMELINE PARAMETERS

C3.1 Prediction

C3.1.1 Overview

Prediction time is one of the most significant parameters in the evacuation capability assessment. It is also one of the most uncertain, relying on a combination of quantitative data, such as stream gauge and pluviograph readings, and qualitative assessments such as lead-up storm behaviour. In addition, the following, conflicting objectives must be balanced:

- Late prediction may not allow sufficient time for safe evacuation of residents; and
- Early prediction may result in unnecessary evacuations. As well as the associated cost and inconvenience, residents may be less likely to heed evacuation advice in the future.

There are three sources of flooding considered in the study area, namely, local catchment, Richmond River and ocean storm flooding. Note that a variety of combinations of these flood sources can occur in a real flood event.

C3.1.2 Local Catchment Flooding

Local catchment flooding affects the rural regions of the study area along Emigrant, Maguire and North Creeks. Local storms in these areas produce the severest flood conditions and have a much faster response than Richmond River flooding and ocean storm surge flooding. Flash flooding conditions are known to occur.

Also, evacuation is difficult and dangerous during such flood events. Rainfall is more intense during short duration events and is likely to overwhelm local drainage systems. In addition, faster flowing water would make driving conditions extremely hazardous. Evacuation is therefore not advised during flash flooding events and it is preferred for residents to ‘shelter in place’. Such advice would remain at the discretion of the SES, who would balance the relative risks of evacuation against isolation and inundation for a particular flood event.

In light of the rapid onset of this form of flooding and uncertain practicality of evacuation and prediction, a prediction time for this source of flooding cannot be adequately estimated.

C3.1.3 Richmond River Flooding

Storms originating in the upper Richmond River catchment tend to have a much longer critical duration than local catchment flooding. This longer duration, in conjunction with a long travel time for the peak flood wave to move down the catchment, allows flood prediction to be made prior to peak flood levels reaching Ballina.

Predictions are made based on river levels recorded at stream gauges higher up the catchment, such as Kyogle, Casino and Coraki. BoM have advised that the flood wave takes approximately 24 to 48 hours to travel from these upstream gauges to Ballina. Therefore, during a Richmond River flood event, a flood prediction can be issued for Ballina 24 hours after a trigger level is reached on the upstream gauges.

No formal trigger levels are currently used for flood warning on the Richmond River. For the purposes of this assessment, the trigger level has been designated as the peak level in a 50 year ARI event. This particular size event has been selected because during an event of this size, the banks of the Richmond River are significantly overtopped. The peak 50 year ARI design flow in Ballina is estimated to be 2,700 m^3/s. In the flood model, for a PMF event, this flow is reached 38.5 hours after the commencement of the storm. The corresponding flood prediction time is therefore at 14.5 hours into the design flood simulation, i.e. 24 hours earlier than when the trigger level is reached. See Figure C-2 for an illustration of this concept.

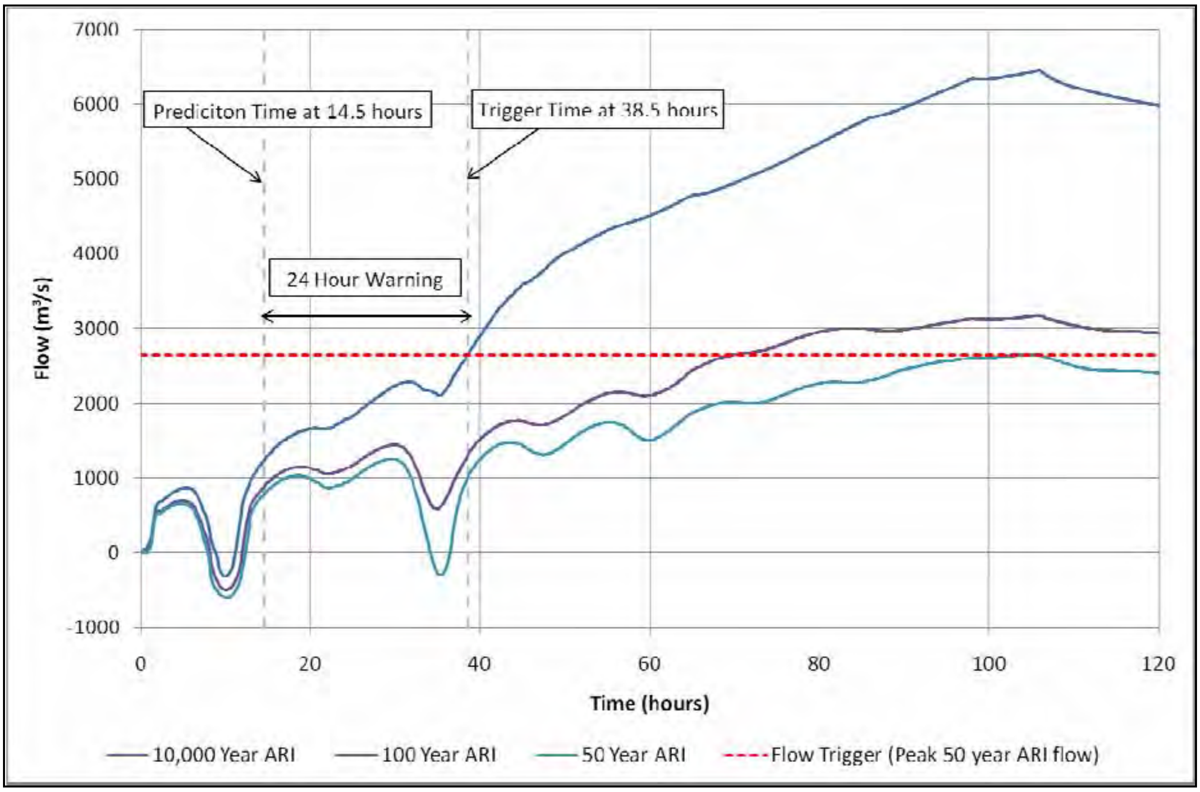


Figure C- 2 Richmond River Flood Prediction Time

C3.1.4 Ocean Storm Flooding

Ocean flooding has a faster response than Richmond River flooding. Flood warning occurs on the high tide preceding the peak surge tide, which is triggered by an anomaly in the measured tidal data compared to predicted tide levels. Therefore, storm surge predictions can be issued 12 hours in advance. Based on the relative timings adopted in the PMF flood model, this would occur 22 hours into the design flood simulation (see Figure C- 3).

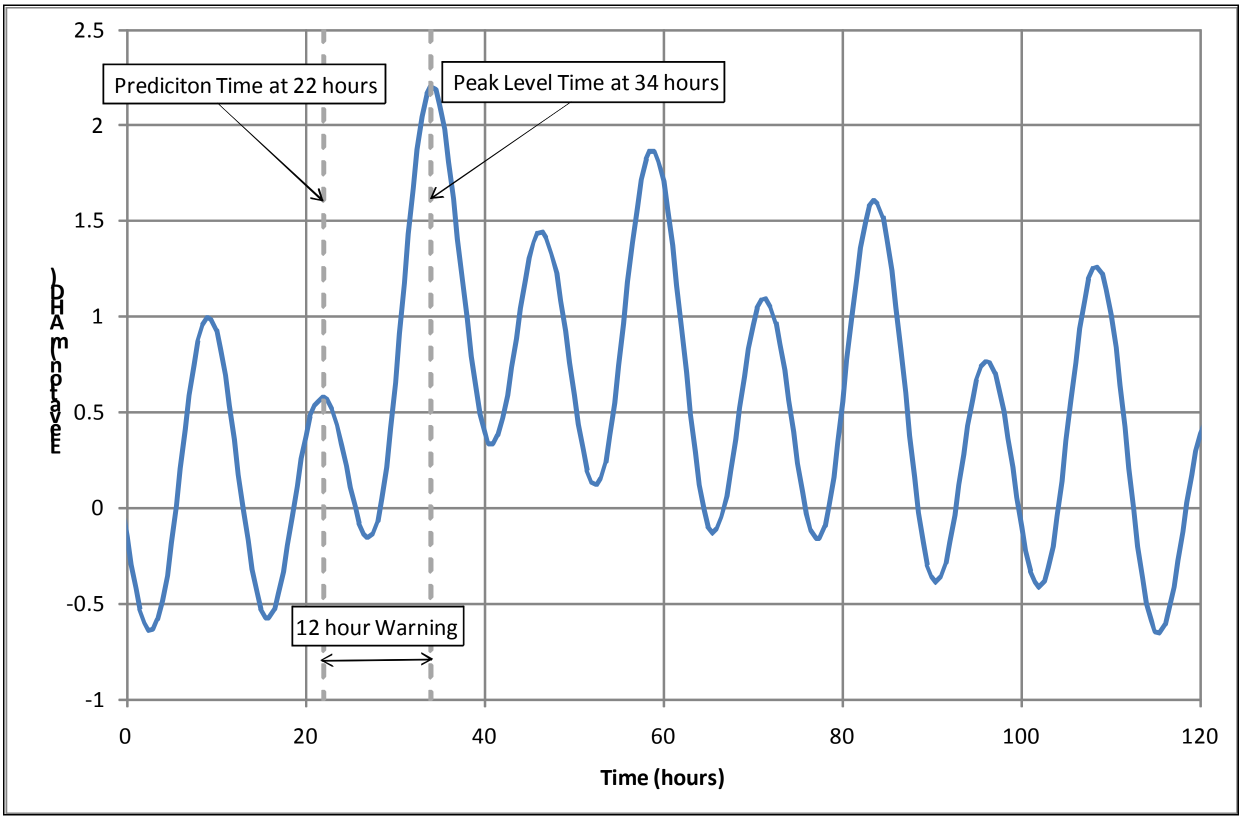


Figure C- 3 Ocean Storm Flooding Prediction Time

C3.1.5 Selected Prediction Time

The prediction time associated with storm surge flooding (i.e. at 22 hours into the design flood simulation) has been selected for use in the evacuation capability assessment for the following reasons:

- Local flooding occurs too quickly for meaningful prediction (and evacuation is not advisable);
- Storm surge flooding dominates part of Ballina Island, which is the most densely populated region of the study area; and
- The prediction time for storm surge flooding occurs after the prediction for Richmond River flooding and is, therefore, the more conservative of the two options.

C4.2 Resource Mobilisation

This is the period of time required by the SES prior to commencement of evacuation and encompasses such factors as data collection, decision and mobilisation of resources. Although this period is difficult to predict, the SES recommends a period of no less than six hours. This assessment has used a response time of six hours.

C4.3 Route Capacity

Route capacity is described by the number of available lanes and a fixed traffic flow rate. The traffic flow rate is derived from a rural design flow rate of 1200 vehicles / hour / lane, which is scaled down by a factor of two to account for adverse driving conditions, such as inclement weather. This assessment uses a traffic flow rate of 600 vehicles / hour / lane.

C4.6 Road Closures

Information regarding location and timing of route closure is captured using specific TUFLOW output. As this information is derived from design flood models, the times are indicative only and could be shorter in real flood events.

This output can be defined with multiple cut-off criteria to represent road closure for different users, such as pedestrians, standard vehicles and emergency vehicles. For the purposes of this assessment, the adopted road closure criterion was 300mm of water over the road surface.

'Evacuation interrupted' is the time of first road closure within a defined evacuation route system.

Note that road closures due to known stormwater and local drainage issues have not been used in the timeline assessment.

C4.7 Community Acceptance and Response Time

Community acceptance refers to the time lost due to initial reluctance to commence evacuation. The SES has found that most residents under-react to warnings and wait for clearer environmental cues before deciding to evacuate.

Response time is the time taken by residents to prepare and pack, following an evacuation warning.

This assessment includes a two hour delay in the commencement of evacuation to account for community acceptance and response time, as per SES recommendations.

C4.8 Doorknocking Rate

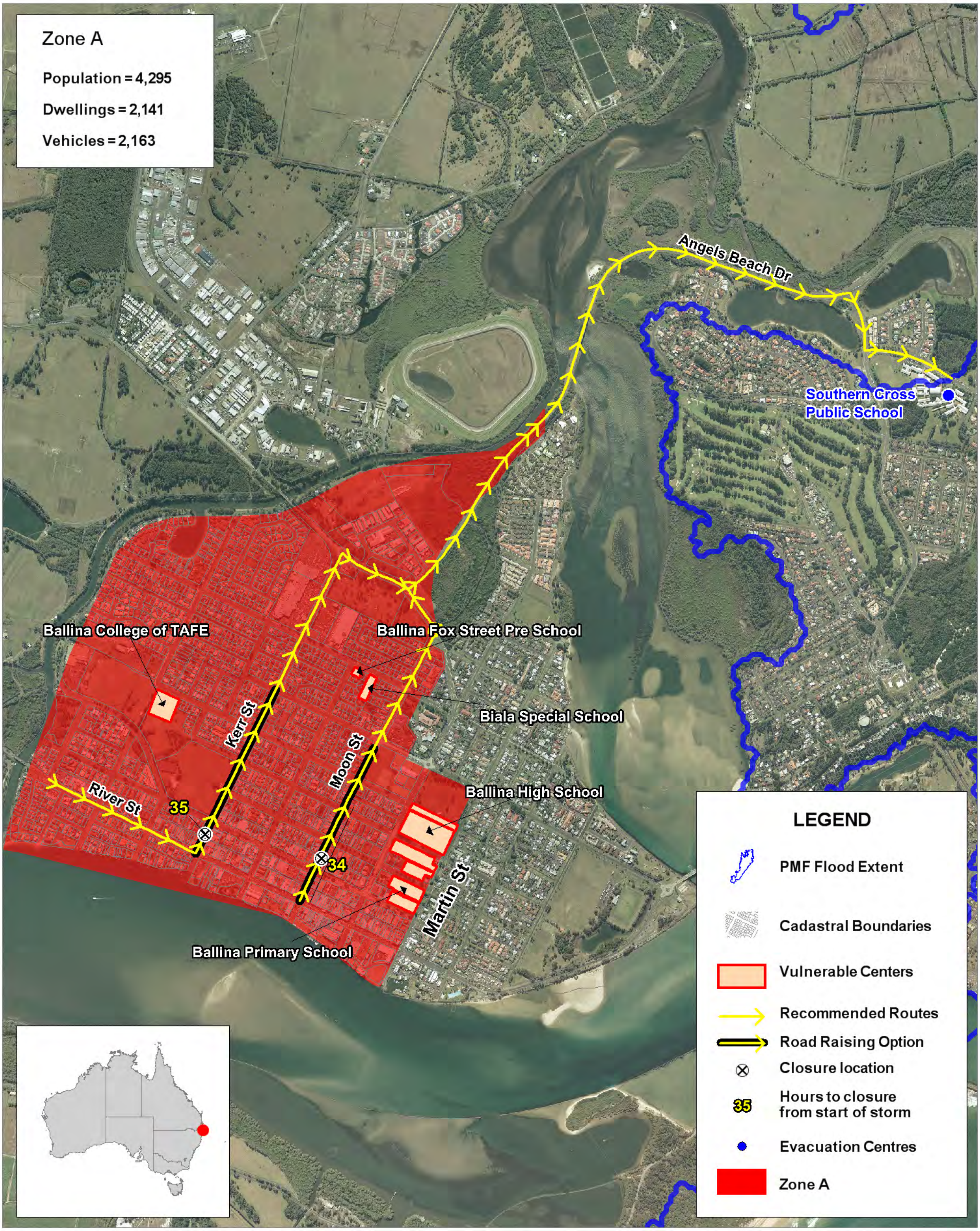
Doorknocking is considered the most conservative and reliable means of warning the community, although other means such as radio, TV, sirens and telephones can be used. The SES recommends that it takes each SES team of two people approximately five minutes to warn each house. This value has been adopted for this assessment (equivalent to 12 houses / team / hour).

C4.9 Traffic Safety Factor

A traffic safety factor, which delays the evacuation process, has been included to account for delays caused by traffic incidents or a tree / power line falling onto the evacuation route. The safety factor is dependent on the total vehicle movement time. This assessment adds one hour traffic safety factor for the first three hours of vehicle movement and an additional 30 minutes for each additional three hours of vehicle movement.

APPENDIX D: EVACUATION CAPABILITY FIGURES

LIST OF FIGURES



Title:
Ballina Floodplain Risk Management Study
Evacuation - Zone A

Figure: D-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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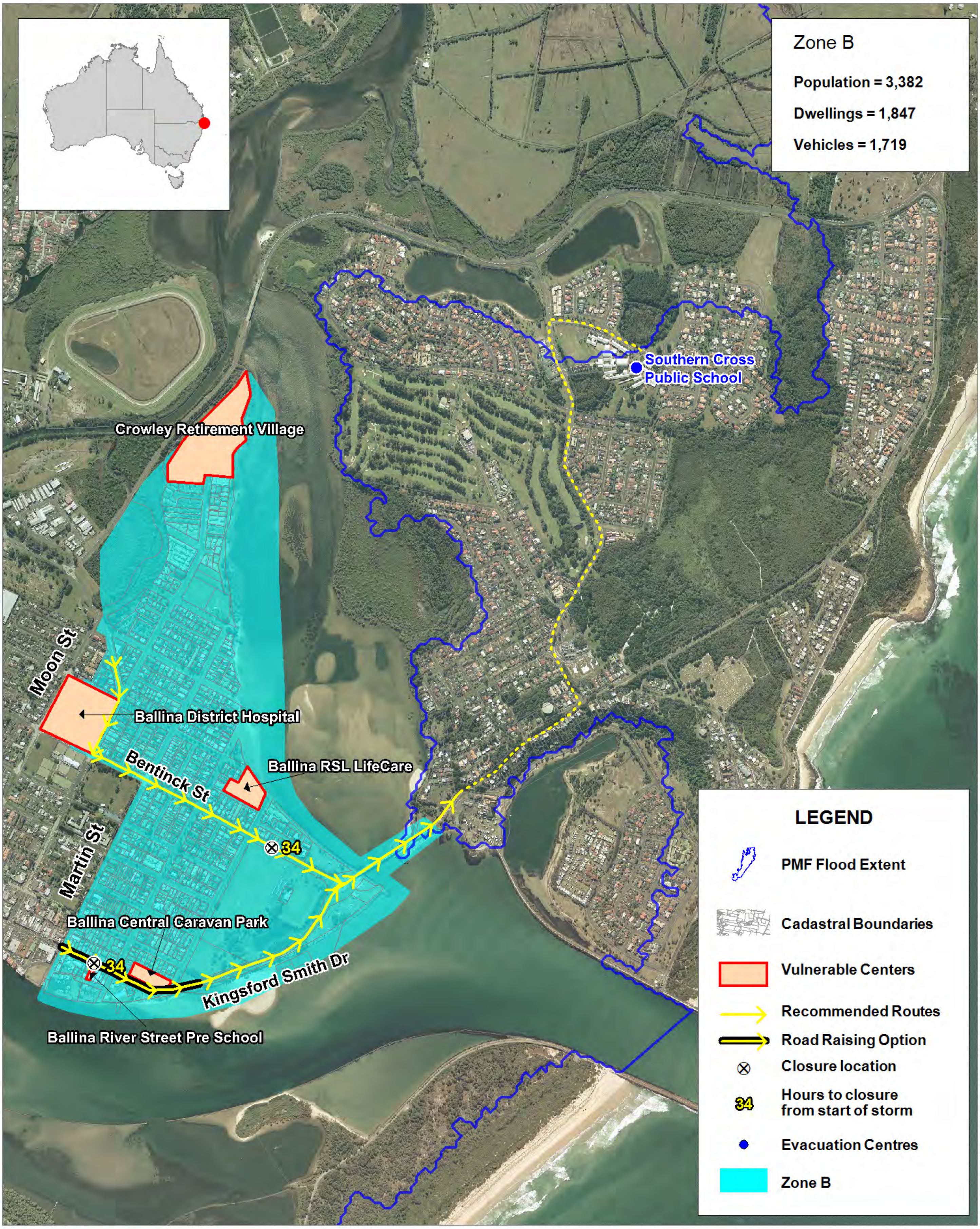

Title:
Ballina Floodplain Risk Management Study
Evacuation - Zone B

Figure: **D-2**

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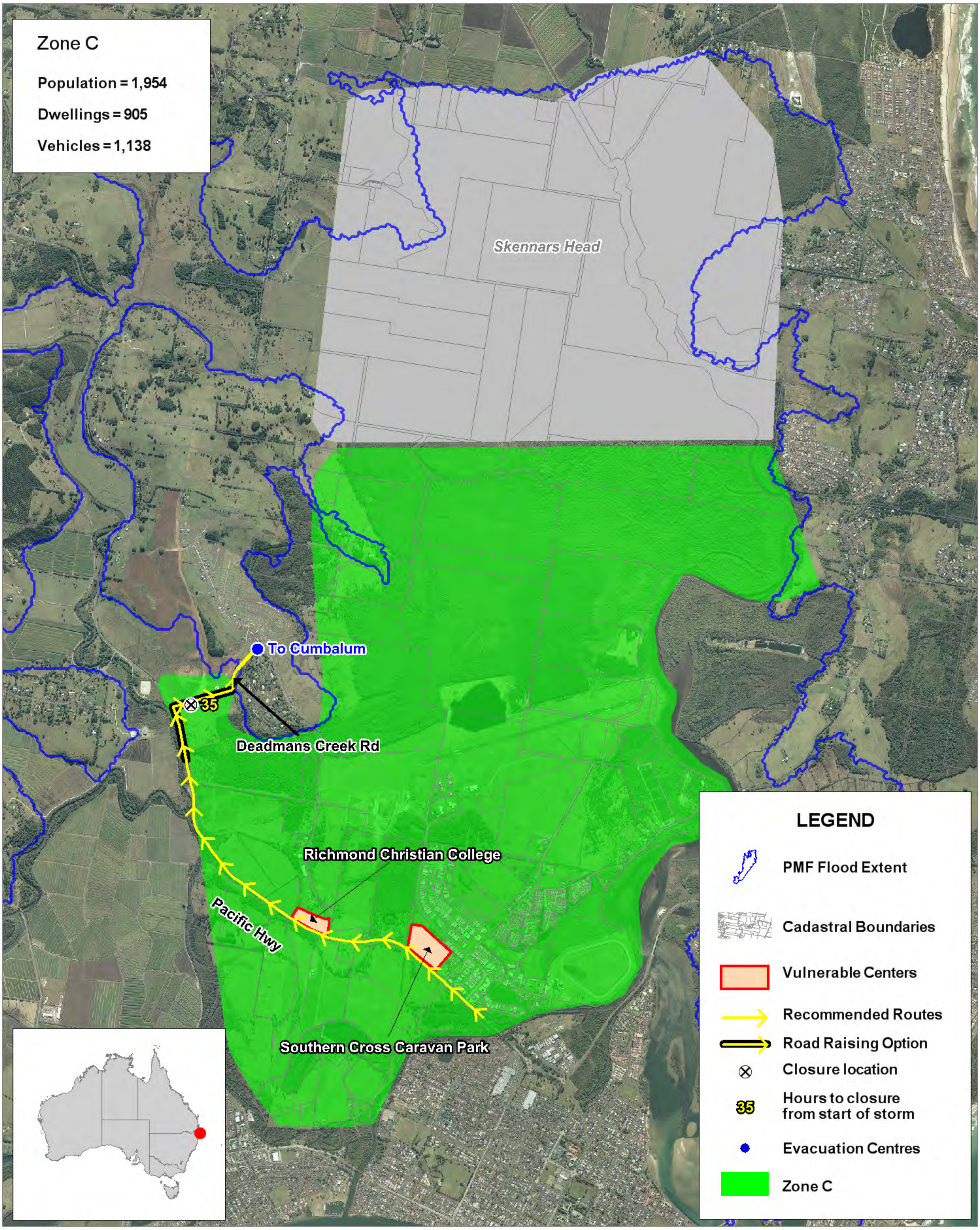

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Ballina Floodplain Risk Management Study
Evacuation - Zone C

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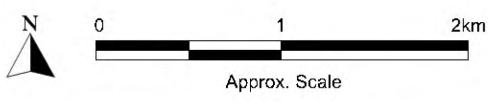

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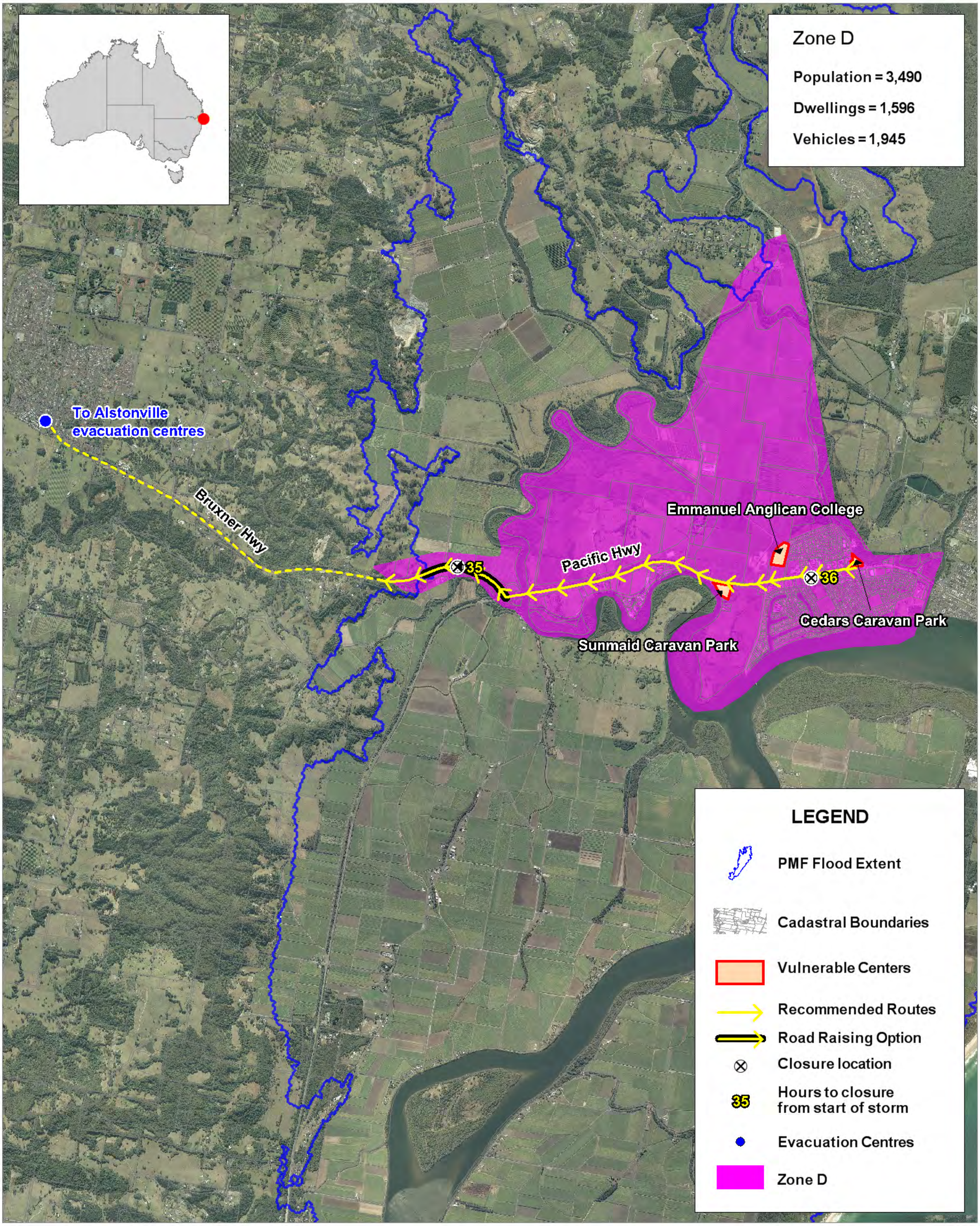

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Ballina Floodplain Risk Managment Study
Evacuation - Zone D

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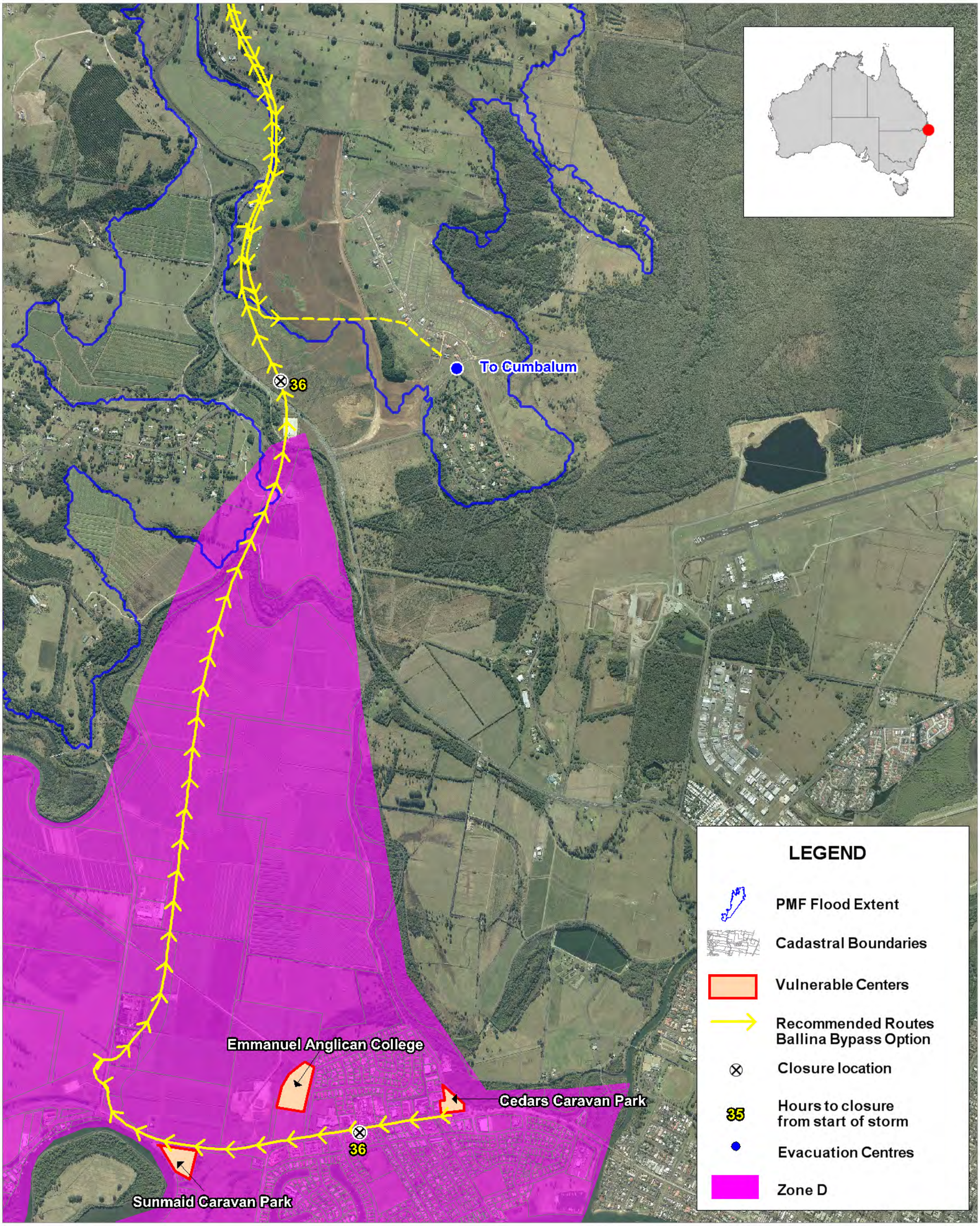

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Ballina Floodplain Risk Managment Study
Evacuation - Zone D Via Ballina Bypass

Figure: **D-5**

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Approx. Scale

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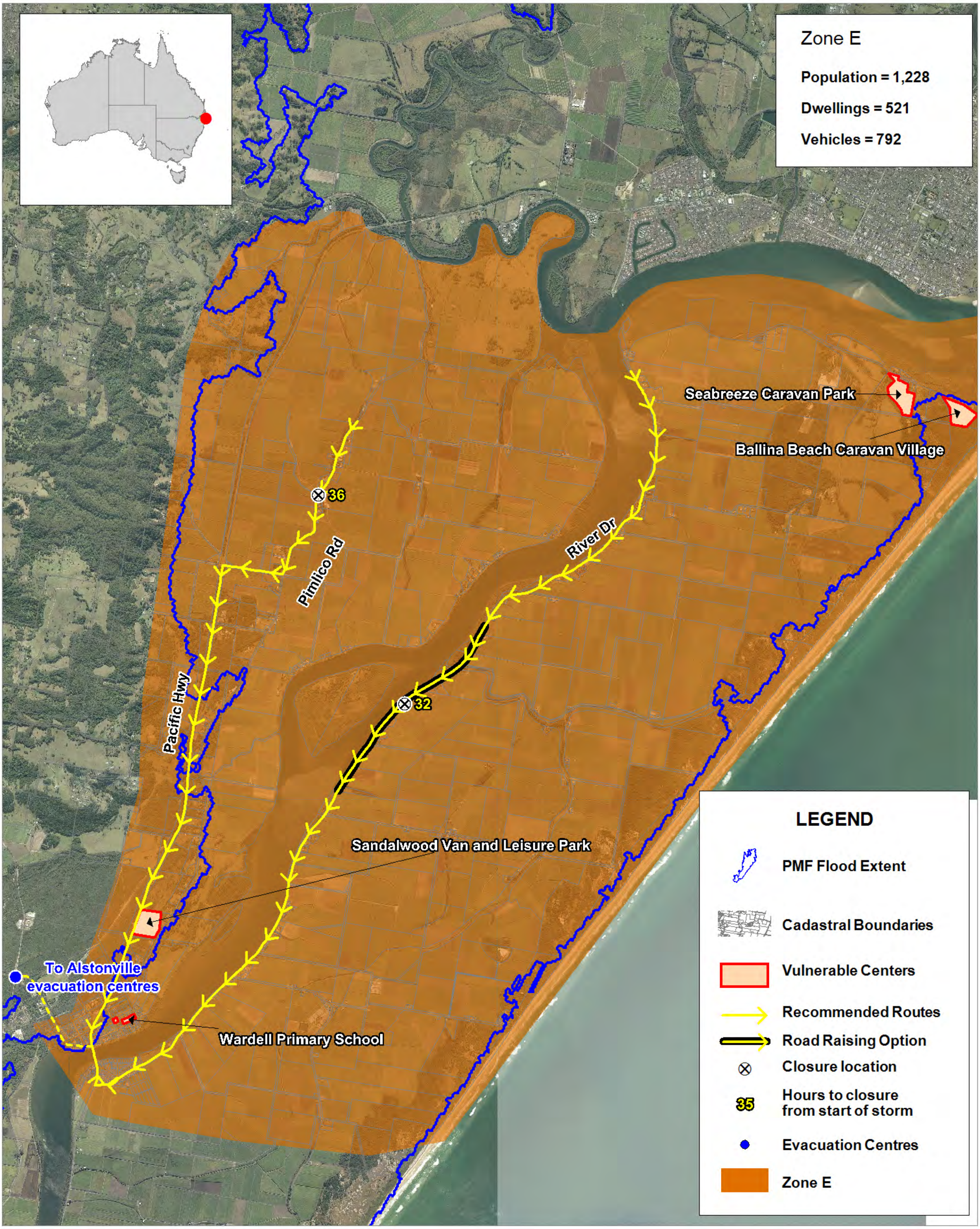

Title:

Ballina Floodplain Risk Management Study
Evacuation - Zone E

Figure: D-6

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Approx. Scale

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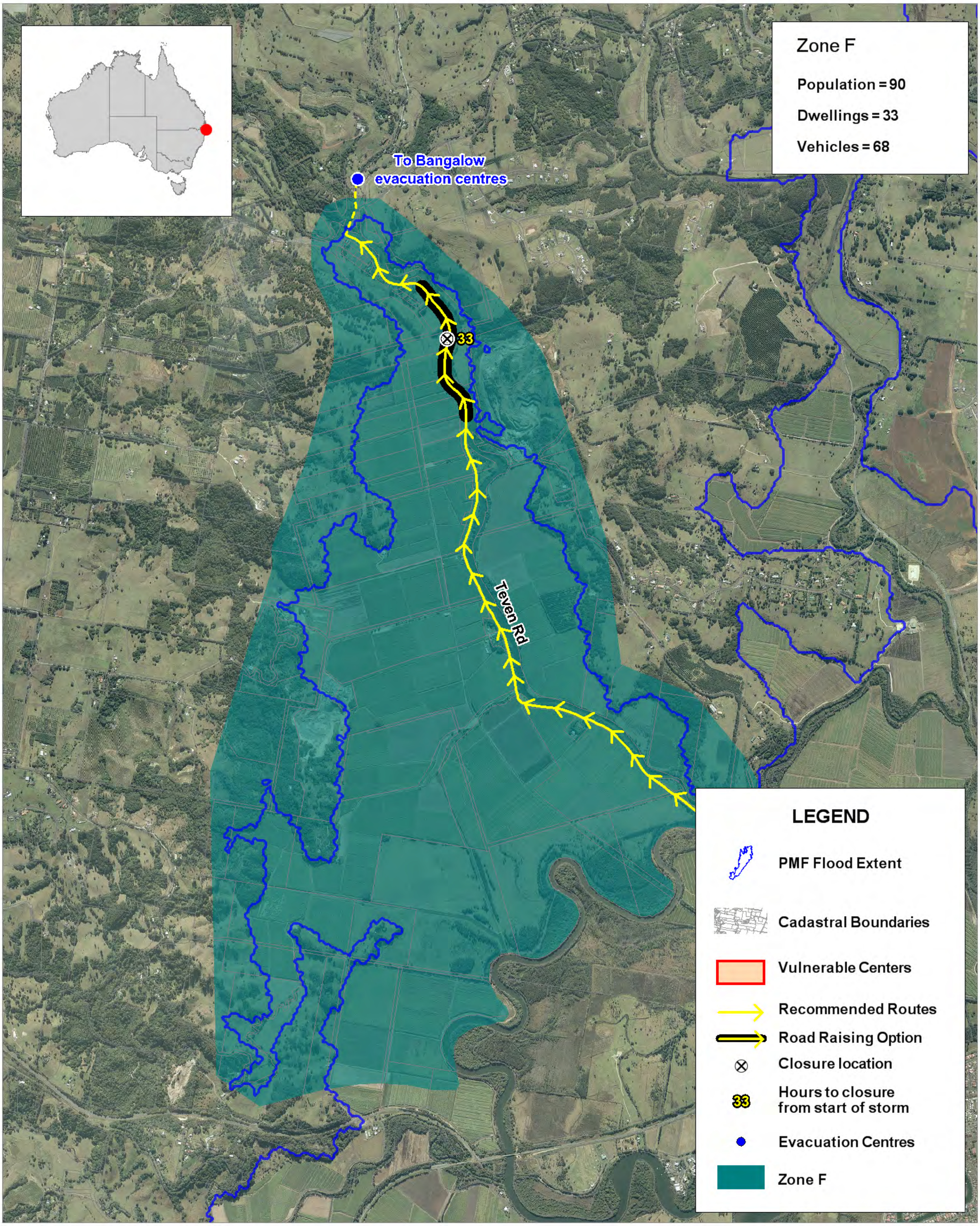

Title:

Ballina Floodplain Risk Managment Study
Evacuation - Zone F

Figure: **D-7**

Rev: **A**

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Approx. Scale

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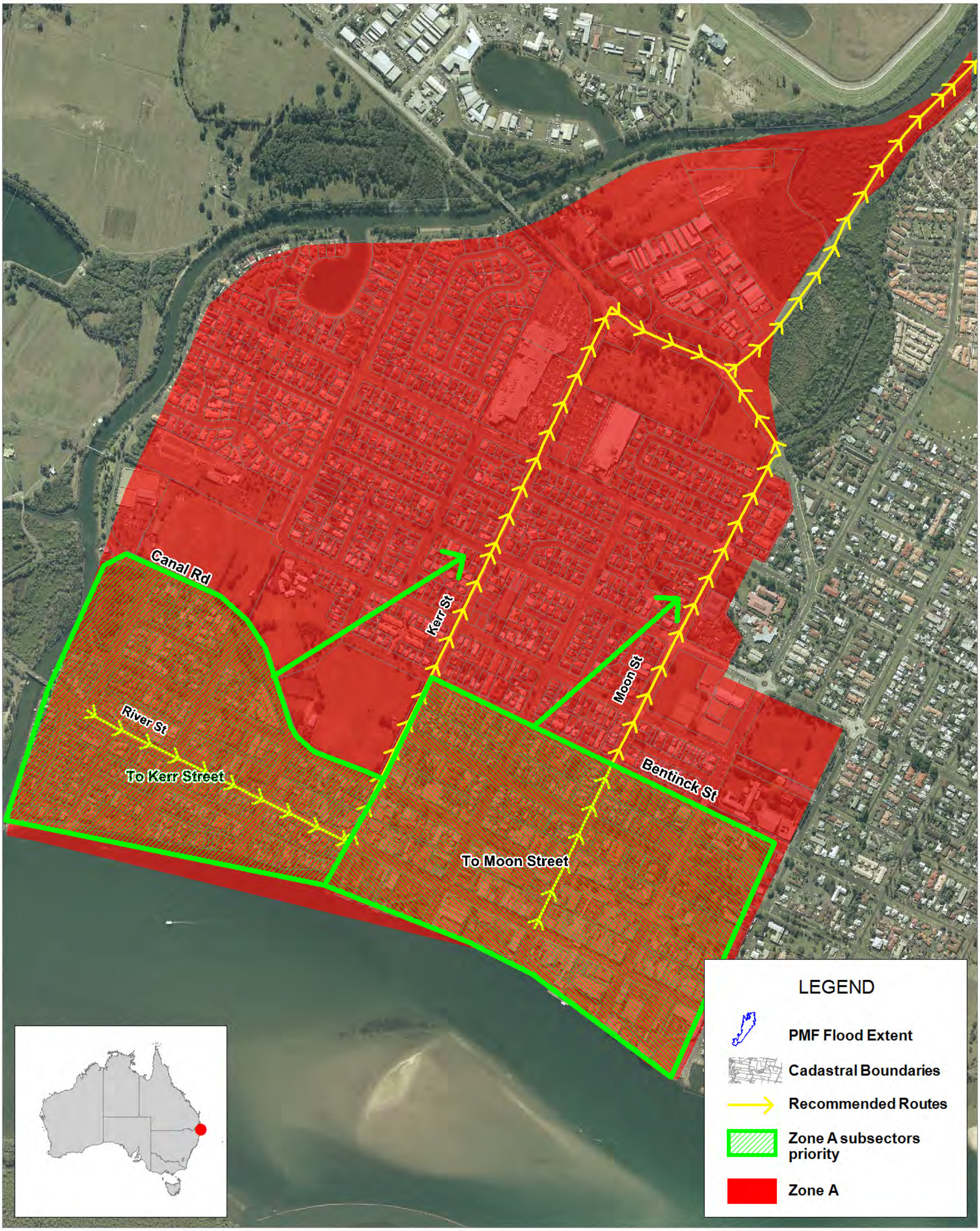

Title:

Response Modification Option
Zone A Sequencing

Figure: **D-8**

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Approx. scale

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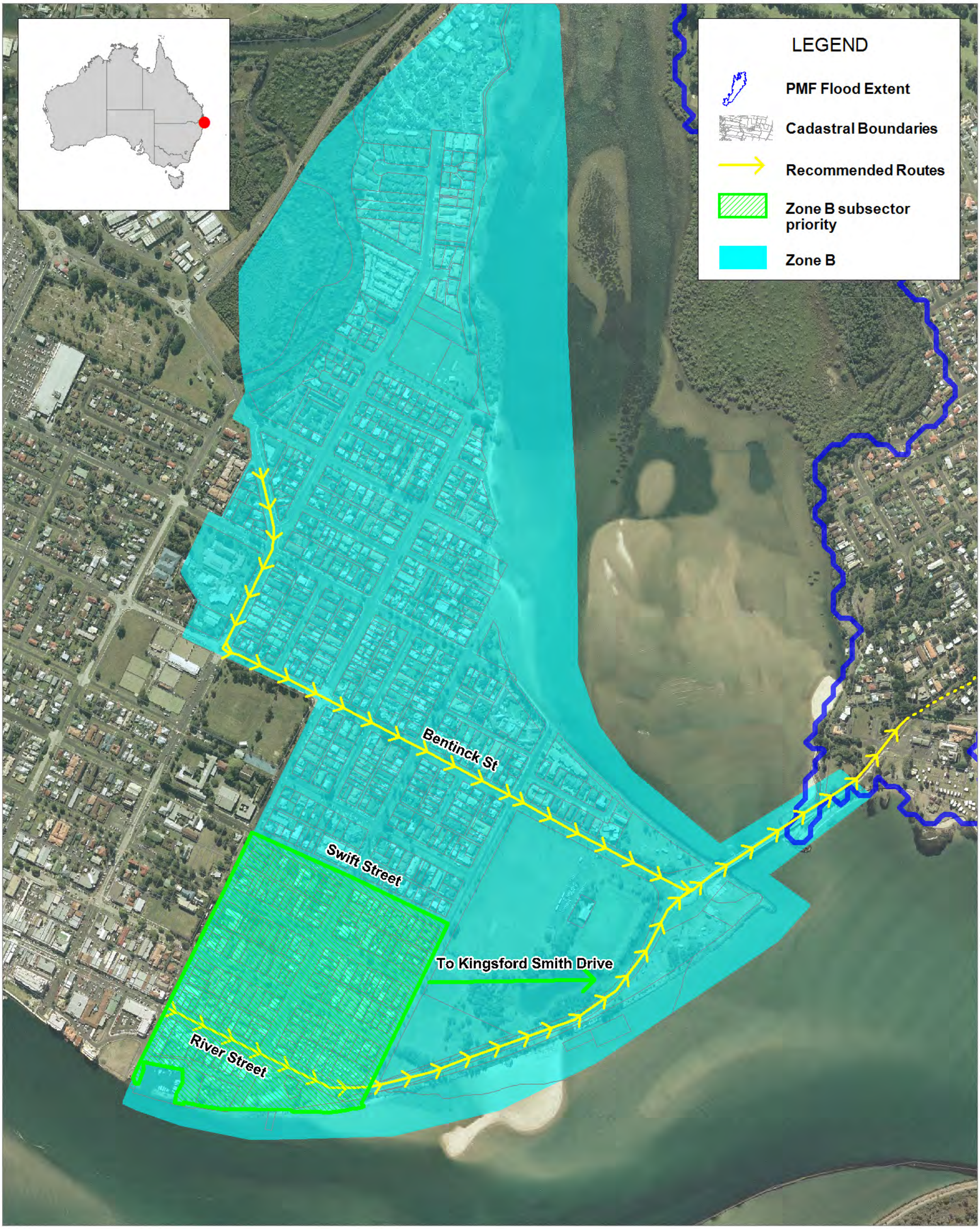

Title:

Response Modification Option
Zone B Sequencing

Figure: **D-9**

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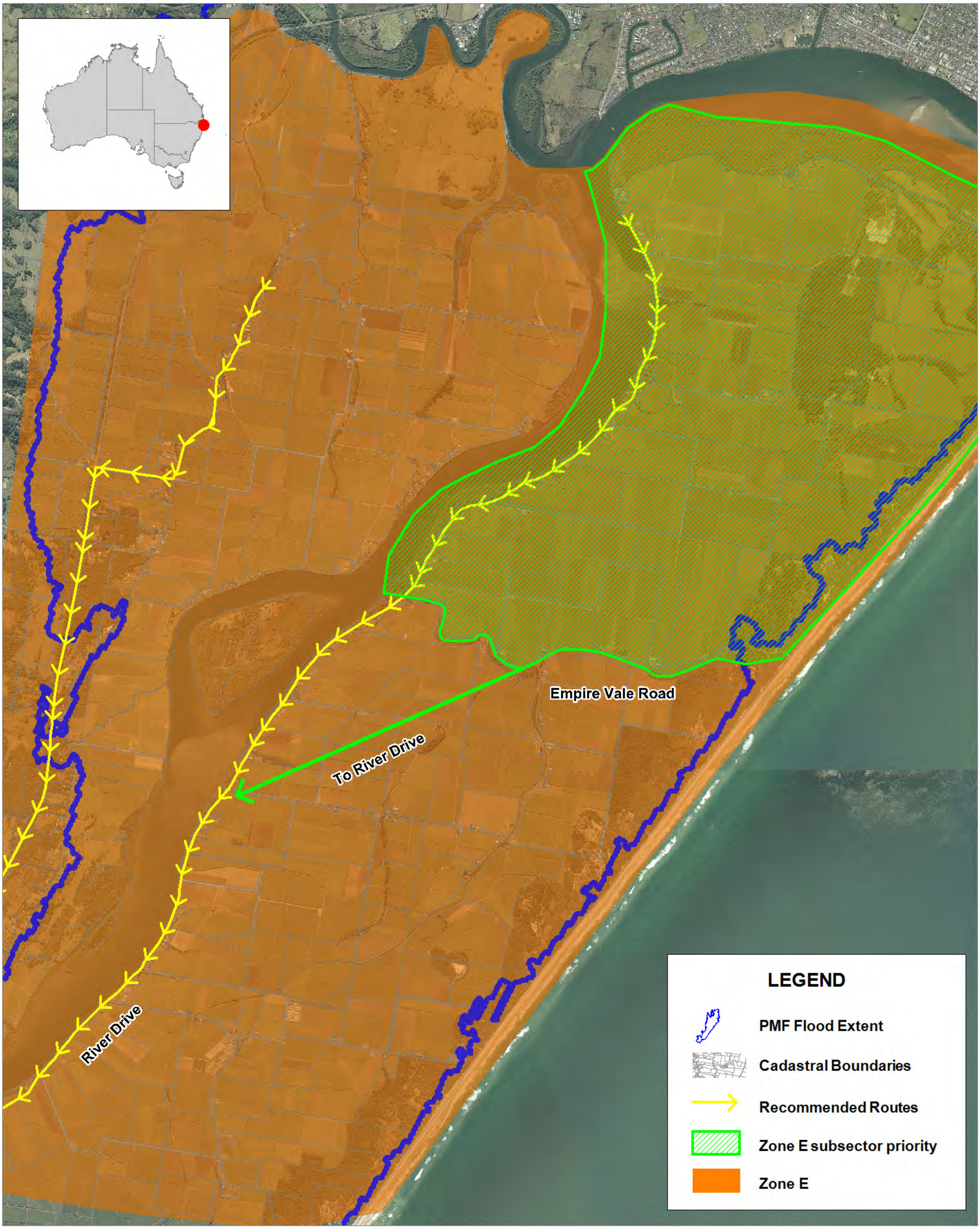

Title:

Response Modification Option
Zone E Sequencing

Figure: **D-10**

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Approx. Scale

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APPENDIX E: FLOOD DAMAGES METHODOLOGY

E1 BACKGROUND

Flood damages are classified as tangible or intangible, reflecting the ability to assign monetary values. Intangible damages arise from adverse social and environmental effects caused by flooding, including factors such as loss of life and injury, stress and anxiety. Tangible damages are monetary losses directly attributable to flooding.

Tangible damages may be direct or indirect flood damages. Direct damages result from the actions of floodwaters, inundation and flow, on property and structures. Indirect damages arise from the disruptions to physical and economic activities caused by flooding. Examples include losses due to the disruption of business, expenses of alternative accommodation, disruption of public services, emergency relief aid and clean-up costs.

Direct damages are typically estimated separately for urban, rural and infrastructure damages. The assessment focussed on quantifying estimates of urban damages and rural damages, together with preliminary estimates of infrastructure damages. Urban damages are typically further separated into damage to residential and commercial / industrial properties, and internal, external and structural components.

A detailed breakdown of flood damage classifications is provided in Figure E-1.

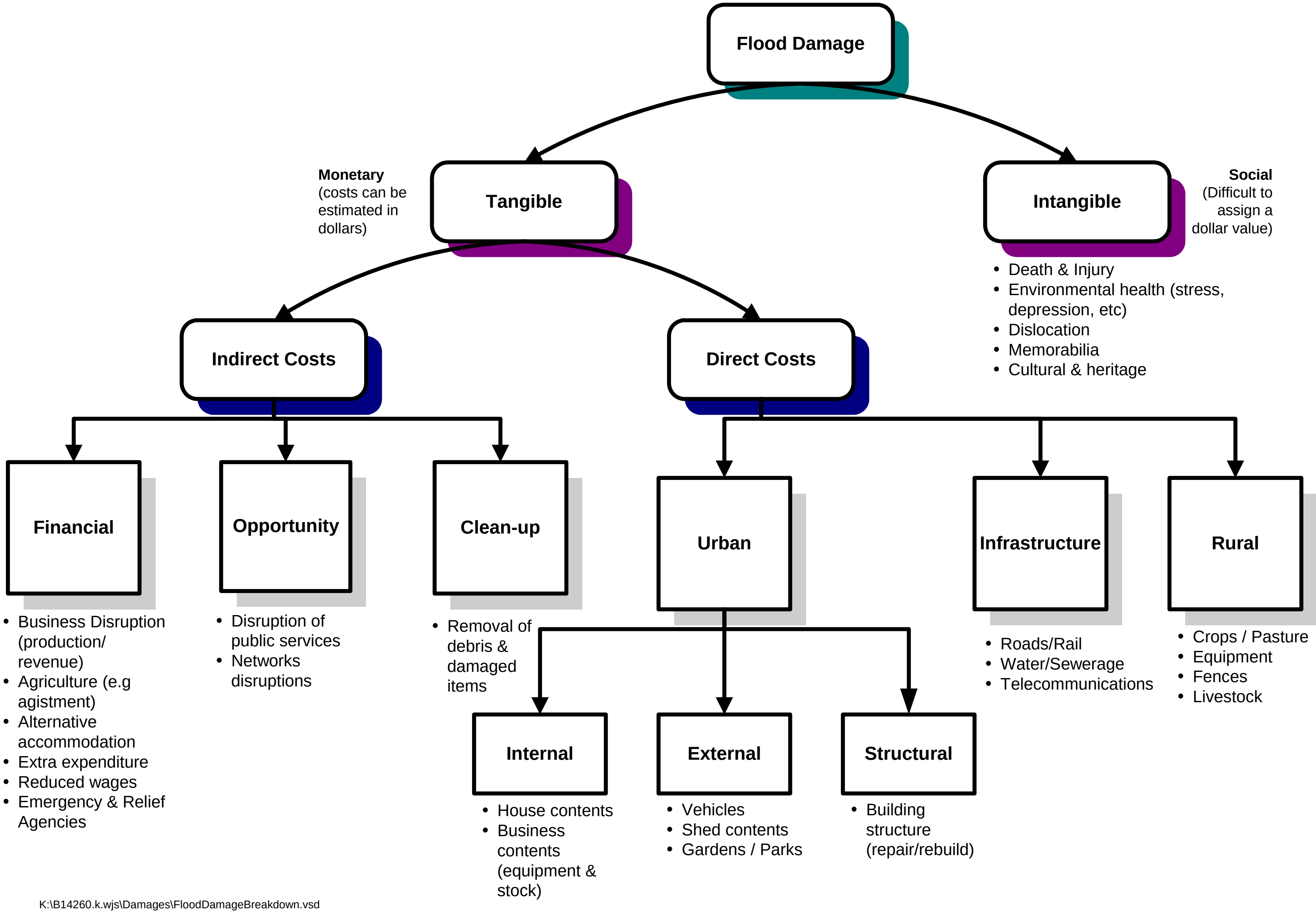


Figure E- 1 Flood Damages Classification

E2 INPUT DATA

E2.1 Overview

The assessment of flood damages required the following input data:

- Property data, as outlined in Appendix B;
- Design flood data including peak flood level, velocity and depth at the properties for a range of flood event magnitudes (used for the estimation of internal and structural damages);
- Ground level data at the properties (used for the estimation of external flood damages);
- Spatial coverage of sugar cane crops;
- Standardised methods for estimating tangible damages; and
- Other relevant information.

The source of the input data and relevant assumptions are discussed below.

E2.2 Sugar Cane

The primary crop grown in the study area is sugar cane. In order to estimate the flood damage associated with sugar cane, its spatial coverage in the study area had to be determined. Aerial photography has been used to manually digitise areas identified as being sugar cane fields.

E2.3 Flood Data

The flood model results have been used to derive peak flood levels at each property in the dataset for a range of design flood events, including the 5, 10, 20, 50, 100 and 500 year ARI[1], as well as the PMF[2].

Together with the floor levels, the flood levels have been used to estimate the depth of above-floor flooding at each property for internal damages. The flood model results have also been used to derive peak depth, velocity and depth-velocity product at each property for estimating structural damages. The methodology for deriving these damages is outlined in Section E3.

E3 TANGIBLE DAMAGES

E3.1 Overview

As discussed in Section E1, tangible damages are those for which a monetary value can be assigned. Direct damages are perhaps the most easily quantifiable damages, as they are those damages that are directly attributable to the floodwater, such as damage to house and business contents. Direct damages are typically estimated separately for urban, rural and infrastructure damages. Indirect damages, such as disruption of business and alternative

[1] Average Recurrence Interval
[2] Probable Maximum Flood

accommodation costs, tend to be more difficult to quantify and are often included as a proportion of direct damages. A summary of the adopted methodology for assessing tangible damages is provided in Table E-1 with more detail provided in the following sections.

Table E- 1 Tangible Damages – Summay of Methodology and Assumptions

<table>
<tr><td rowspan="9">TANGIBLE</td><td rowspan="7">DIRECT ▶</td><td rowspan="5">Urban▶</td><td rowspan="2">Internal▶</td><td>Commercial▶</td><td>NRM Stage-Damage Curves</td></tr>
<tr><td>Residential▶</td><td>DECCW Stage-Damage Curves</td></tr>
<tr><td rowspan="2">External▶</td><td>Commercial▶</td><td>Negligible</td></tr>
<tr><td>Residential▶</td><td>DECCW Stage-Damage Curves</td></tr>
<tr><td>Structural▶</td><td colspan="2">$20,000 per property based on high depth / velocity criteria</td></tr>
<tr><td>Infrastructure▶</td><td colspan="3">15% of total direct damages (DECCW)</td></tr>
<tr><td>Rural ▶</td><td colspan="3">15% reduction in sugar cane yield where flood depth is greater than 1.2m (BSES 2008)</td></tr>
<tr><td rowspan="2">INDIRECT▶</td><td>Commercial▶</td><td colspan="3">55% of Direct Damages (NRM)</td></tr>
<tr><td>Residential▶</td><td colspan="3">DECCW Stage-Damage Curves</td></tr>
</table>

E3.2 Urban Damages

E3.2.1 Stage-Damage Curves

Stage-damage curves (or relationships) are typically used to estimate internal damage sustained by a particular property based on the depth of flooding. For example, if floodwaters inundate a house to a depth of 1 metre, a stage-damage curve is used to estimate the average damage (in $) that water 1 metre deep is likely to cause. Similarly, if floodwaters inundate a shop to a depth of 0.5 metre, a stage-damage curve is used to estimate the average damage that 0.5 metre of water in a shop is likely to cause. An example of how a stage-damage curve is used to estimate flood damage for a particular type of building is shown in Figure E-2.

Derivation of stage-damage curves can be a complex and time-consuming process, based on loss adjustor surveys of houses, businesses and contents to estimate the relationship between depth of flooding and damage. For the purposes of this study, two different approaches have been adopted for residential and commercial properties. These approaches are discussed further in the following sections.

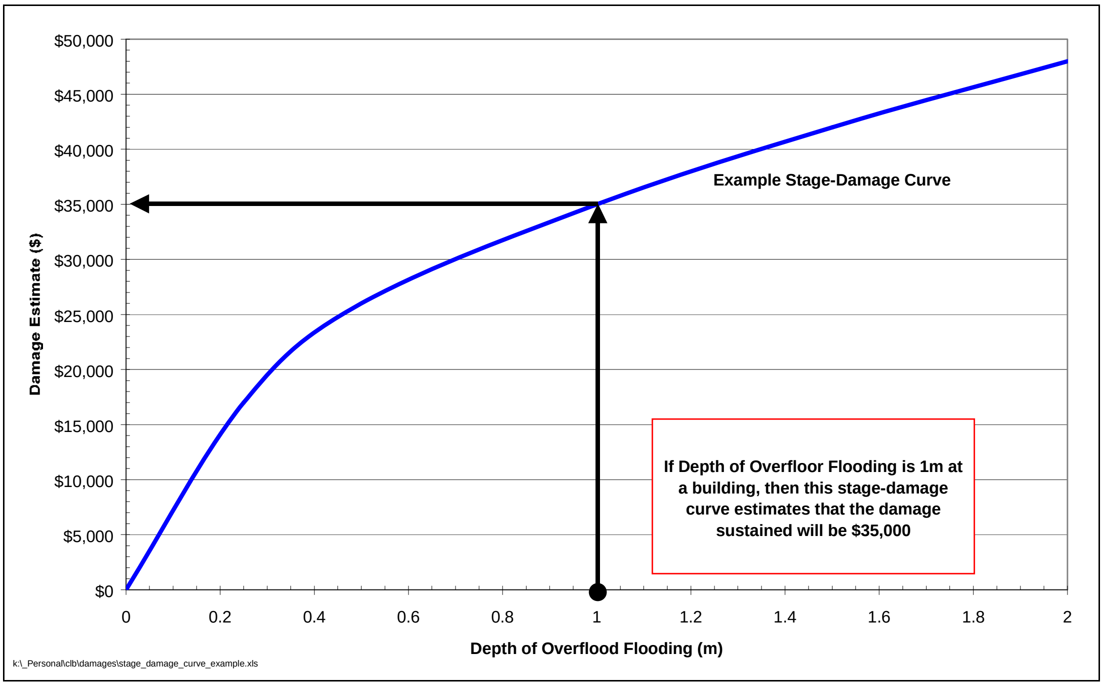


Figure E- 2 Example of Stage Damage Curve

E3.2.3 Residential Damages

For residential properties, the DECCW[3] methodology outlined in *Floodplain Risk Management Guideline: Residential Flood Damages* (DECCW, 2007b) has been adopted. This approach is based on stage-damage curves developed by Risk Frontiers for three different typical types of residential dwellings in the floodplain; low set, high set and double storey. The curves are based on a number of input parameters including typical house size, bench and storey heights, CPI, regional and scale cost factors, and awareness and warning times. The parameters adopted for this study are detailed in Table E-2. The three resultant residential stage-damage curves for low set, high set and double storey dwellings in the Ballina Shire are shown in Figure E-3.

It is noted that the DECCW methodology does not explicitly account for multi-unit dwellings. In lieu of any data specific to multiple unit damages, it has been agreed to directly factor estimated damages by the number of units per storey.

[3] *Now Office of Environment and Heritage*

Table E- 2 Input Parameters for DECC (2007) Residential Stage-Damage Curves

Input Parameters	Adopted	Explanation
Post 2001 $ Adjustment Factor	1.46	Calculated based on changes to average weekly earnings since late 2001 based on data collected from Australian Bureau of Statistics.
Regional Cost Variation Factor	1.07 (Rawlinsons, 2006)	Adjusting material cost to be specific to Tweed
Post Flood inflation Factor	1.4 (DIPNR, 2004)	Ranges from 1.0 to 1.5 (DIPNR, 2004)
Building Damage Repair Factor	1 hour	Typical reduction factor for long duration immersion (DECC 2007)
Typical House Size	300m^2	
Average content value	$75,000 (DIPNR, 2004)	Average content value, calculated based on average house size (DIPNR, 2004)
Flood level awareness	Low (DIPNR, 2004)	Flood level awareness, used to calculate the preparedness of the resident and opportunity to relocate possessions above flood waters (DIPNR, 2004)
Effective flood warning time	0 hours	
Contents Damage Limitation Factor	0.80 (DIPNR,2004)	Typical for a short to medium duration event (DIPNR, 2004)
Typical Bench Height	0.9m	Typical Bench Height used to calculate damages to property shifted to bench level instead of total relocation to higher ground

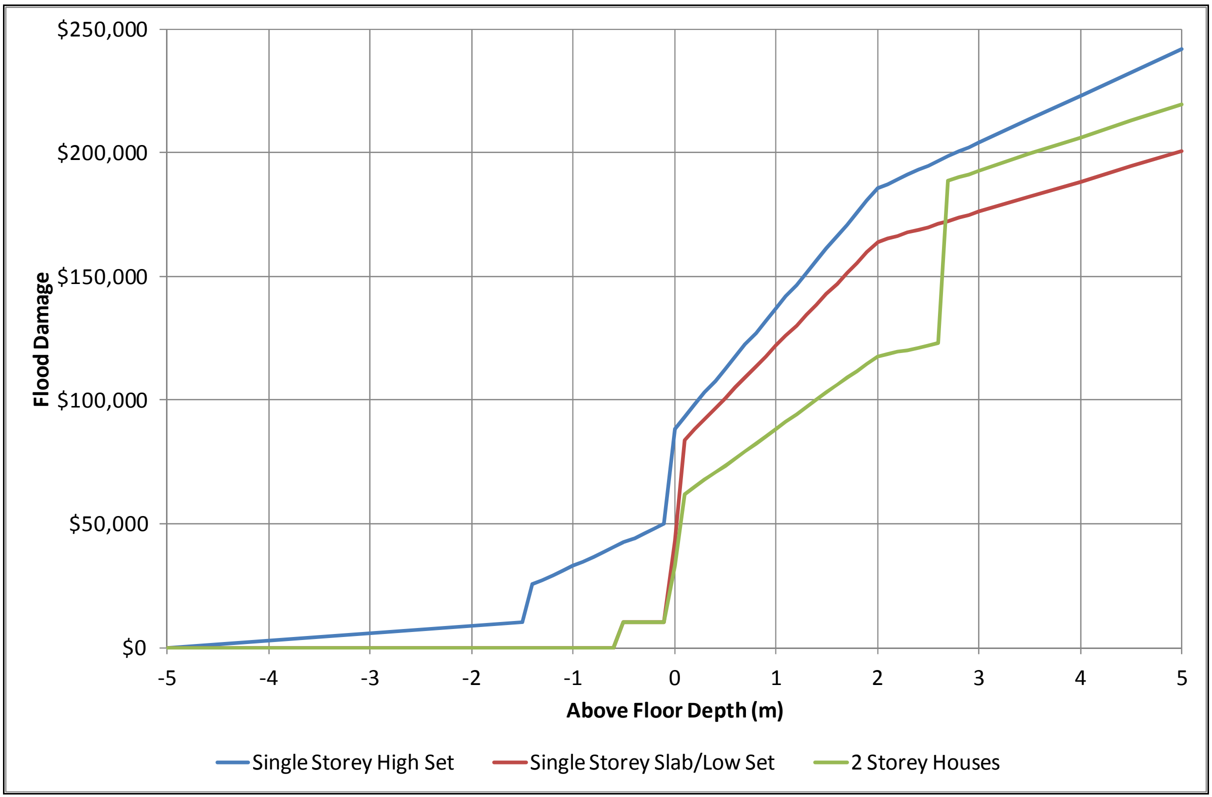


Figure E- 3 Ballina Shire Residential Stage Damage Curves

E3.2.4 Commercial Damages

The Office of Environment and Water does not presently have specific NSW guidance on commercial flood damages. The Queensland NRM[4] methodology has therefore been adopted, as outlined in *Guidance on the Assessment of Tangible Flood Damages* (2002) and based on stage-damage curves developed for ANUFLOOD[5]. This is consistent with approaches adopted for a number of other northern NSW assessments.

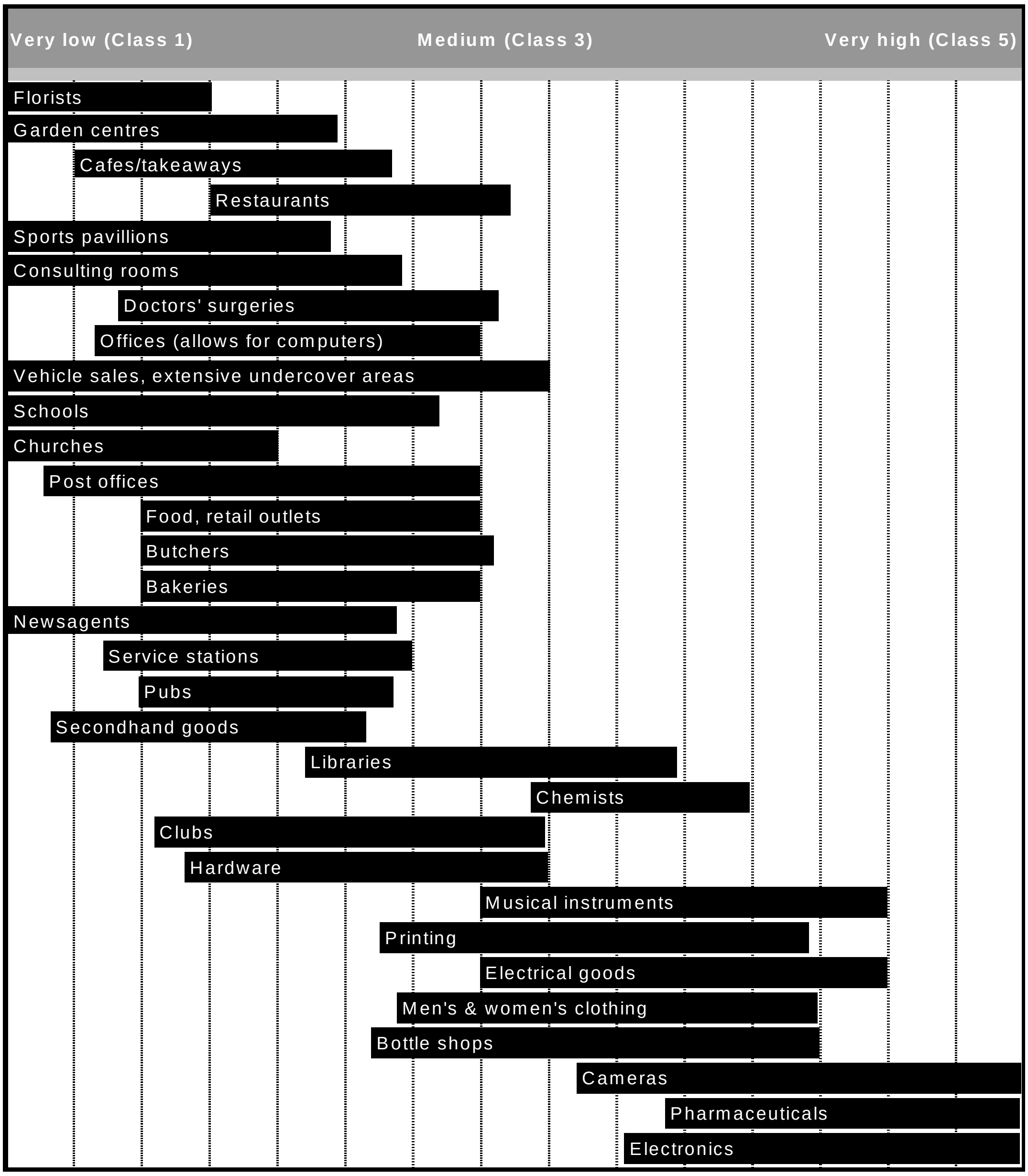
The NRM methodology comprises 15 different stage-damage curves based on a combination of building size and contents value categories:

- 3 building size categories based on floor area:
  - Small < 186 m^2;
  - Medium 186 to 650 m^2; and
  - Large > 650 m^2.
- 5 contents value categories based on the nature of the business, from class 1 (low) to class 5 (high).

Examples of the contents value categories are presented in Figure E-4. The curves for small and medium buildings provide typical damage estimates per property, however the curves for large buildings provide damage estimates per unit floor area (i.e. per m^2).

[4] *Department of Natural Resources and Mines*

[5] *Computer model developed by Australian National University to assess flood damages to urban buildings.*



Source: CRES (1992)

Figure E- 4 Value Categories for NRM (2002) Commercial Stage-Damage Curves

The commercial stage-damage curves have been updated using CPI to present day values. Figure E-5 shows the lower and upper range of curves for each of the 3 building size categories (small, medium and large) based on the low (class 1) and high (class 5) contents value curves respectively.

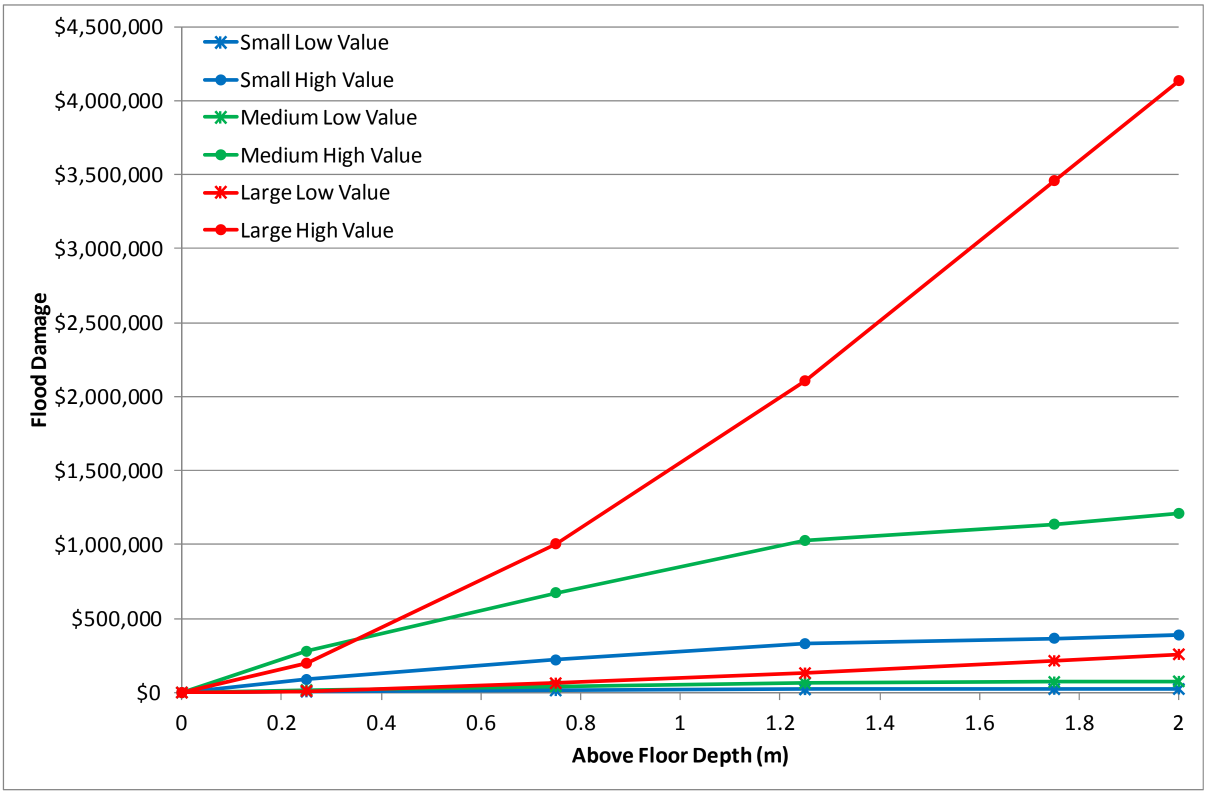


Figure E- 5 Ballina Shire Commercial Stage-Damage Curves

Note: Large commercial property flood damages are based on the property area. An area of 650m² has been used in the figure above.

E3.2.5 Actual versus Potential Damage

Potential damage is the maximum damage that would occur if there was no action taken by residents to protect their possessions from floodwaters. As residents usually do take some action in times of flood, actual damages are typically less than potential damages. The amount by which actual damages are less than potential is a function of warning time, flood preparedness and depth of flooding. For example, with no warning time a resident would be unable to move many belongings to a higher area but the number of belongings moved to a safe position would increase with the increase in warning time. Alternatively, a resident may be unprepared for flooding. They may not expect to be affected by a flood and so may not move any belongings regardless of warning time as they do not realise that they are threatened.

The DECCW residential stage-damage curves are actual damage estimates, taking warning time into account. The NRM commercial stage-damage curves are potential damage estimates. For this initial assessment however, it has been assumed that businesses will be unprepared for flood events, and that actual commercial damages will be similar to potential estimates.

E3.2.6 External Damages

The DECCW residential stage-damage curves include for external damages to items such as mowers, gardens, tools and shed contents. Based on the adopted methodology, this has been estimated at approximately $9,200 per inundated residential property in the study area.

Vehicles are typically not included in damage assessments, despite being classed as a valid external damage, as these are often moved to higher ground during a flood, and to ensure vehicle damage does not drive justification for mitigation works.

External damages to commercial and industrial property have been assumed to be negligible, with the majority of property damage typically expected to be attributable to the contents of the building.

E3.2.7 Structural Damages

Structural damage can include water damage to the fabric of the building, water damage to wiring, gas piping, g√ates and fences. Internal structural damage (such as built-in cupboards, internal walls, and wiring) is estimated as part of the internal damages (Sections 5.5.2 and 5.5.3) however structural failure of a building needs to be assessed separately.

Structural failures can begin at a range of flood depth-velocity combinations. Even at shallow depths, velocities greater than 2 m/s can lead to scour of foundations. Conversely, at low velocities with depths greater than 2 metres, damage to light-framed buildings from water pressure, flotation and debris loads can occur. Typically, such damage is considered likely to occur when the velocity-depth product is greater than 1 m^2/s (DIPNR, 2005; NRM, 2002).

Based on these criteria, structural failure of buildings has been assumed for properties experiencing any of the following flood conditions:

- Velocity-depth product > 1 m^2/s; or
- Depth (above floor) > 2 metres; or
- Velocity > 2 m/s.

Note that 'structural failure' may not necessarily mean complete destruction of a building. Structural damages have been nominally based on $20,000 per property in line with some other northern NSW assessments (Walcha Floodplain Risk Management Study, 2009).

E3.4 Infrastructure Damages

It is often difficult to estimate infrastructure damages due to flooding, as it usually requires input from several agencies, which may or may not know the value of their asset nor the damage that it is likely to sustain in a flood. To overcome this difficulty, DECCW recommends that infrastructure damages be estimated as being 15% of direct damages (pers. comm. Duncan McLuckie, January 2005). This recommendation has been adopted for the Ballina study area. Typical infrastructure damaged during a flood event includes (non-exhaustive list) schools, hospitals, bridges, railway, energy and telecommunication networks, sewers, wastewater treatment plants.

E3.5 Rural Damages

The estimation of rural damages has been restricted to sugar cane, due to the dominance of this crop in the rural areas of the Ballina floodplain. Although other rural land uses are likely to be flood affected, their damages are difficult to estimate and are considered to be relatively small compared to the more extensive sugarcane plantations. Therefore other rural land uses have been omitted from this study. As such, rural damage estimates are likely to be underestimated in areas of other rural land uses.

The methodology used to estimate sugar cane damages is the same as that used by BMT WBM on the Johnstone River Flood Study (2003), which was largely derived from Kingston et al (1999).

Sugar cane crops in the floodplain have been mapped, with flood damages estimated using the following assumptions:

- Flooding typically occurs when stalks are relatively mature with an average height of over 1.2m;
- 84 Ha of sugar can is harvested from an average sized 110 Ha plot of sugar cane (CANEGROWERS 2008). This equates to approximately 27% of land remaining fallow at any time.
- An average yield in the northern NSW area is 131 tonnes per hectare (Hooper 2008);
- Yield loss is between 15 and 20% after 5 days submergence, with the least loss for mature cane (BSES 2008). A 15% reduction in yield has been assumed for this study; and
- According to the Australian Sugarcane Annual (2009), the average return to Australian growers for cane in 2009–10 is forecast to be $43.40 a tonne, compared with $30.78 a tonne in 2008–09 and $26.39 a tonne in 2007–08. An average price for cane of $43/tonne has been assumed.

E3.6 Indirect Damages

The DECCW residential stage-damage curves include for indirect damages such as clean-up costs and alternative accommodation. Based on the adopted methodology, this has been estimated at approximately $6,400 per inundated residential property in the study area.

Indirect damages for commercial properties can be much more substantial as they include loss of production / revenue, extra expenditure, disruption of public services, network disruptions, and clean-up costs. While it is difficult to place a value on these losses, the NRM methodology recommends an estimate of 55% of direct commercial damages, which has been adopted for this study.

E4 INTANGIBLE DAMAGES

Intangible damages incorporate direct and indirect impacts for which there is no commonly agreed method of evaluation (EMA, 2002). Intangibles compose of things without market value i.e. cannot be brought or sold, which makes their dollar value difficult to calculate. Most methods are experimental or not generally accepted (EMA 2002).

There are a number of intangible costs to the community including:

- Loss of life and injury;
- Inconvenience;
- Isolation/evacuation;
- Stress and anxiety;
- Disruption; and
- Health issues.

Some of the above are discussed further below.

E4.1 Health Issues

Health issues related to flooding can include stress and psychological problems and physical health problems. In VDNRE (2000), "*The anxiety and stress which residents experience as a result of a flood probably depend both upon the characteristics of the resident and the nature of the event*". For example, a resident with prior experience to flooding is usually better able to cope with the stress induced by floods (BTRE, 2001). Flooding can induce stress through mechanisms such as loss of personal possessions, injury to individuals and others, fear of future flooding, inconvenience (eg. disruption to daily routines), isolation and evacuation.

Physical health issues resulting from flooding include over-exertion through relocating personal belongings eg. furniture, contact with contaminated water, and injury directly related to the flooding (VDNRE, 2000).

Health issues are difficult to assign monetary values to as every individual reacts differently to the one event. Self-reporting surveys have been used for a range of studies to determine the impacts of flooding on a community's health. While self-reporting has obvious implications (all individuals perceive their losses differently), several studies have suggested this method to be reliable (BTRE, 2001).

E4.2 Loss of Life and Injury

There is always a possibility of loss of life and injury during a flood event. Considerable research has been conducted on the value of human life. There has been, however, no commonly agreed method for valuing the loss of a life (VDNRE, 2000). Economic methods have been developed including the 'human capital approach', which uses the lifetime earnings of the individual concerned as the value of their life and the 'willingness to pay approach', which considers the value of an individuals life to be the price they are willing to pay to achieve a reduced risk of death. Both of these methods result in a broad spectrum of values for different individuals and cause a moral dilemma with different individuals being valued higher than others (VDNRE, 2000).

A method developed by the NRE as part of the Rapid Appraisal Method (RAM) is the Average Annual Population Affected (AAPA). The AAPA is calculated using the same process as the

AAD, determining the population affected for a range of flood events and calculating the area under the curve to provide the AADA. The AADA should be used in conjunction with, and as a supplement to, the benefit-cost analysis (VDNRE, 2000). VDNRE, 2000 discusses the AAPA, "…*the assumption that the impact of flooding on human temperament, health and mortality is directly proportional to the size of the resident population is a very crude one. Nevertheless, it is a readily available measure that is likely to capture rapidly the scale effects involved for most forms of management measures. The concept of AAPA, however, does not provide a good measure of the change of health, safety and personal impacts in the case of changes in warning times."*

It was recognised from the outset that evacuation capability would be a significant issue facing this study. The Ballina floodplain has a large number of people that could require evacuation, as well as a large number of relatively new residents that are unfamiliar with local flood behaviour. This aspect of the floodplain risk management process has been investigated by assessing the evacuation capability.

E4.3 Environment

Environmental losses tend to be perceived as minor costs in natural disasters such as flooding (BTRE, 2000). Impacts caused by flooding to the environment can be interpreted as natural processes for which the environment has built in mechanisms to cope with. As flooding is a natural phenomenon the reduction of flooding produced by mitigation measures should be considered as losses. These include benefits to floodplains from enhanced fertility and ground water recharge, maintenance of wetland communities and floodplain vegetation, movement of species between stream and floodplain and provision of conditions for important lifecycle stages (VDNRE, 2000). The NSW EPA has produced a database collating environmental valuation studies. This online database called ENVALUE provides a range of studies and the method used to determine indirect costs. The methods suggested include the 'Travel Cost Method' and 'Contingent Evaluation'. The Travel Cost method assumes the costs that people are willing to incur in travelling to an area represents a minimum of what they would be willing to pay for the recreational experience. Contingent Evaluation uses surveys to find out what people are willing to pay for a specified improvement in the provision of a good, which has no market price. These, along with most methods of assessing indirect costs are highly variable, controversial and are yet to achieve widespread acceptance through the economic community (EMA, 2000).

E4.4 Summary

Intangible damages are inherently difficult to measure in monetary terms. The greatest difficulty faced by those calculating indirect damages is finding uniformity in the value assigned to various intangibles including loss of life, loss of possession and illness. This is made difficult as different individuals react differently and perceive their losses in different ways (eg. some individuals may value their gardens more than their memorabilia.

The Bureau of Transport and Regional Economics (BTRE, 2001) states, "*Estimating costs for intangibles when a method of estimation is not well developed, or the data are unreliable, may lead to results that are no better than guesses. Estimates of intangible costs are best limited to those costs for which the data and method are both capable of producing defensible results.*

Unfortunately there will still remain a large body of cost for which estimation is not feasible".

For the valuation of stress, stress related illness, and mortality, the AAPA approach allows impacts on the population to be incorporated into the damages assessment without requiring a monetary value to be assigned. This method is non discriminatory as the levels of population that could be affected in a location is weighted against the probabilities of that location being inundated. This method can prove useful in damage assessments by providing an indication of the population benefiting from flood mitigation methods.

Due to these limitations, intangible damages have not been determined.

E5 UNCERTAINTY

The certainty of the flood data depends on the flood model characteristics and resolution. The most recent, integrated flood model results have been used in the flood damage assessment, thereby maximising the degree of certainty that can be achieved with current hydraulic modelling practice.

It is acknowledged that, as a result of the approach to estimation of property parameters, the property dataset adopted for this study has an inherent degree of uncertainty. Floor level data are considered appropriate as these have been primarily surveyed.

While the methodologies used to estimate flood damages are well established (as laid out by DECCW[3] and Department of Natural Resources and Mines), it is recognised that the urban flood damages estimation methodology is an uncertain process. The purpose of the assessment is not to derive highly accurate flood damage estimations, but to develop a general understanding of flood damage in the study area and to assist with appraising flood mitigation options. As such, the input data and urban flood damage estimation methodology are considered appropriate for the purposes of this study.

For rural damages the location and spatial extent of sugar cane has been determined by observation of aerial imagery. This process carries an innate uncertainty in the observer's interpretation of the imagery. However sugar cane stands can be clearly distinguished in the aerial photographs, and is overwhelmingly the main crop grown in the floodplain. Therefore substantial errors are unlikely and the main cause of uncertainty will be from the methodology used to estimate the reduction in yield. It should be noted that sugar cane prices are affected by market volatility, and depending on the extent of forward hedging and foreign exchange activity, the final selling price for sugar cane could be significantly different from that used in this assessment. As mentioned above, the focus of this assessment is not on absolute damages, but on relative damages. The methodology is therefore considered appropriate for the objectives of this study.

APPENDIX F: DEVELOPING THE FLOOD RISK PRECINCTS

F1 INTRODUCTION

The draft DCP defines development controls according to four different Flood Risk Precincts (FRPs).This Appendix describes the methodology that has been used to delineate the study area into different FRPs.

F2 EXTREME FLOOD RISK PRECINCT

The extreme FRP layer has been developed by first looking at high flood hazard areas; where flood hazard is defined by the product of flood depth and flow velocity (VD). The 100 year ARI 2100 flood event results have been used to identify the high hazard areas. As a starting point, VD values of greater than $0.4m^2/s$ (critical value for pedestrian safety according to the *Queensland Urban Drainage Manual*) have been classified as high FRPs. The results generated disconnected patches of extreme FRP areas, and therefore required some manipulation to ensure that the extreme FRP layer was contiguous. VD values of $0.3m^2/s$ have been mapped out as a guide for connecting patches of extreme FRP. In many places patches of extreme FRP have also been connected by inspection of the DEM and following paths of low lying land.

Areas in the floodplain that are critical for interconnection of flood storage areas have also been marked out and included in the extreme FRP layer. This has been done by inspection of the DEM, aerial photography and flood extent maps.

F3 HIGH FLOOD RISK PRECINCT

Extreme and medium FRPs have been mapped prior to development of the high FRP. High FRPs have been defined as areas within the 100 year ARI flood extent that have not been classified as extreme or medium FRPs.

F4 MEDIUM FLOOD RISK PRECINCT

Two steps have been undertaken to derive the medium FRP layer. These steps are as follows:

Step 1 – assess potential for fill in existing urban areas

Historically filling has been the standard approach adopted to mitigate flood risk in and around Ballina. There is considerable pressure for more development in the study area. To continue with this approach, it is important to determine how much more filling can take place in the floodplain without causing excessive flood impacts to existing development. There is substantial flood risk to existing development, particularly when accounting for current climate change predictions. It is therefore expedient to first assess the capacity for further fill in areas with existing development before considering potential future development; thus facilitating management of future flood risk in established urban areas. The first step towards defining the flood risk precincts was therefore to assess the flood impact caused by filling areas of existing development in Ballina Island, West Ballina, North Ballina and East Ballina. Areas that have been filled in this assessment are shown in Figure F-1.

Note: Yellow hatching marks the areas that have been filled

Figure F- 1 Existing Development Fill Areas

The results showed that there was negligible flood impact (less than 5mm). This suggests that the filled areas lay within flood storage portions of the floodplain, and the lost flood storage due to the fill is small relative to the total flood storage available in the floodplain. Filling in existing urban areas is therefore acceptable in terms of flood impact.

Step 2 – assess potential for fill in rural areas

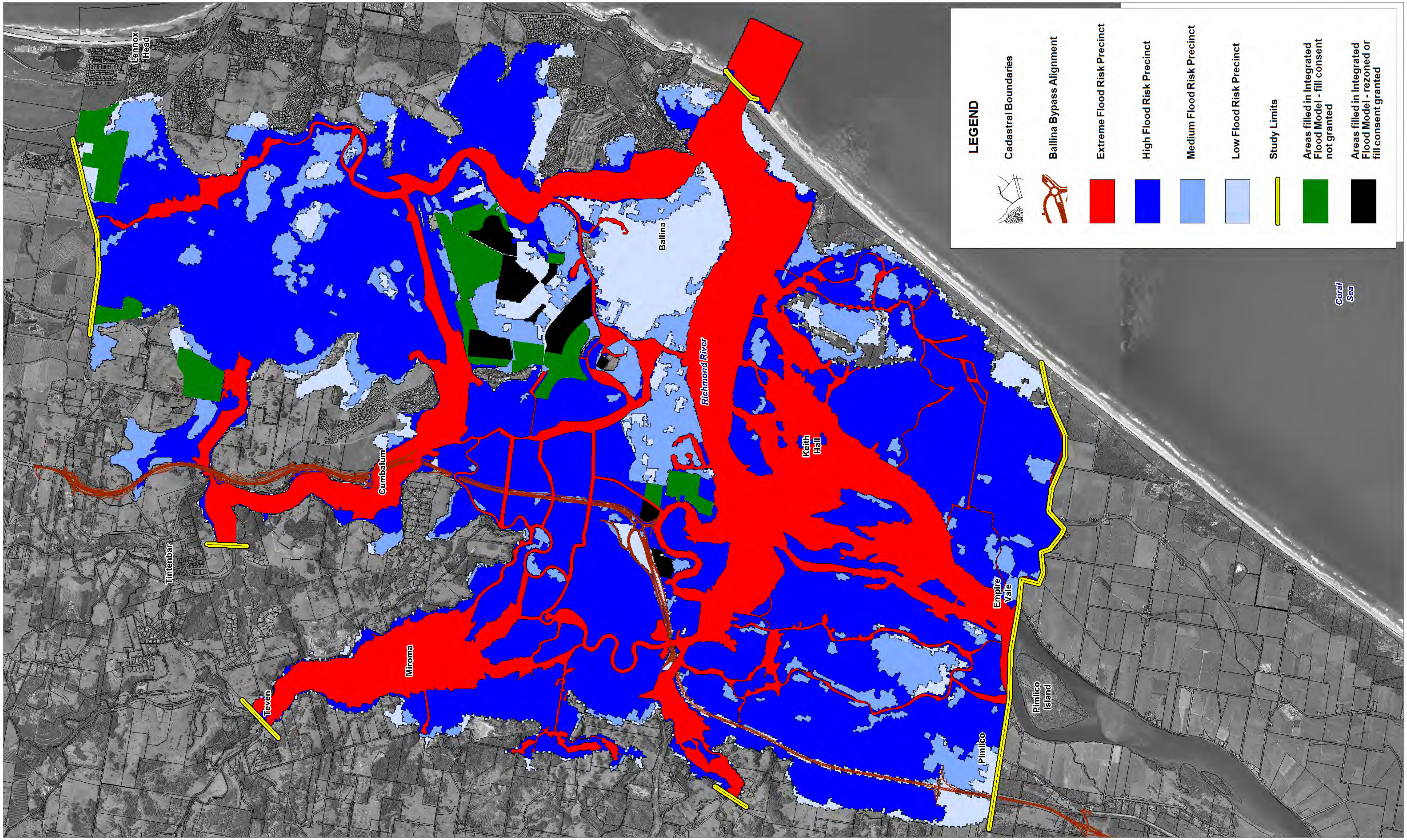
The results in step 1 also indicate that there is potential for further fill in the catchment. An assessment of the capacity for further filling in currently undeveloped areas has therefore been undertaken. Filling is most appropriate in areas where the consequences of flooding are low, i.e. shallow flood depths and low flow velocities. Areas of low flood hazard have been selected using the flood model results (VD of 0.025m²/s and 0.05m²/s for the 100 year ARI flood event) and filled in the model. The flood impact resulting from the filled low hazard areas (in combination with the urban fill areas from *Step 1*) has been assessed. Fill areas where the resulting flood impacts were significant (i.e. greater than 100mm) have been revised, and the corresponding flood impacts reassessed. This trial and error process has been repeated through a number of iterations. Many small islands of fill (areas less than 0.5ha) surrounded by flooding have also been removed to produce a cleaner more practical solution. The final combination of low hazard rural fill and urban fill areas which cause insignificant flood impact at a regional scale (less than 100mm) have been defined as medium flood risk precinct.

F5 LOW FLOOD RISK PRECINCT

Low FRPs have been defined last. They are the remaining areas in the floodplain (i.e. within the PMF flood extent) which are not classified as extreme, high or medium FRPs.

F6 RATIONALISE FLOOD RISK PRECINCTS

The FRP layers obtained at the pre-rationalised, stage are shown in Figure F-2. The FRP layers have subsequently been rationalised by removing isolated 'islands' and smoothening the edges of the layers. This process has been done in consultation with Council's planning team. The final (rationalised) map is shown in Figure 6-1 in Section 6 of the main body of this report.



Title:
Pre-rationalised Flood Risk Precinct Map

Figure:
F-2

Rev:
A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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APPENDIX G: DRAFT DEVELOPMENT CONTROL PLAN

SEE SEPARATE LINK