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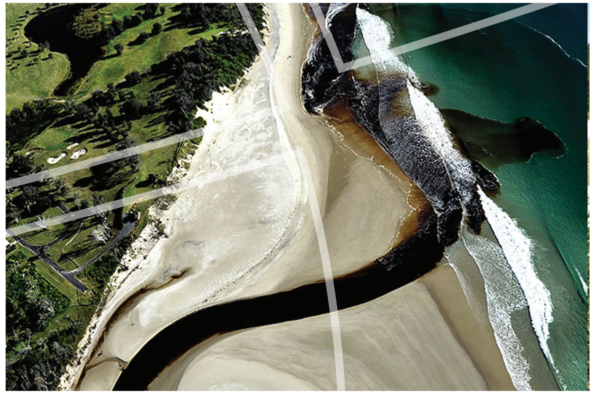

Belongil Creek Floodplain Risk Management Study and Plan

Summary

March 2015

Byron Shire Council

Document Control Sheet

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Title :	Belongil Creek Floodplain Risk Management Study Report
Author :	Jo Tinnion / Chris Huxley / Rachel Jensen
Synopsis :	Summary of the assessment and findings of the Belongil Creek Floodplain Risk Management Study

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1. Introduction

This Floodplain Risk Management Study (FRMS) draws together a wide range of floodplain management options which have been investigated and is the result of a detailed investigation and consideration of flood risk across the study area.

The role of the FRMS is to provide Byron Shire Council (Council) with a framework for delivering sustainable flood risk management for the long term. This is directed at the development of solutions to existing flooding problems in developed areas and ensuring that new development is compatible with flood hazard and does not create additional flooding problems.

The FRMS examines the existing and future flood risk for the study area and assesses and makes recommendations for an integrated range of modification measures to minimise the community's exposure to flood risk.

The study has been developed through a series of stages for which discussion papers were produced (eight in total), exploring each focus point in detail. Further methodology and modelling information can be found in these papers. Copies of the relevant discussion papers are provided in the Discussion Paper Addendum.

This document, brings together all of the analyses and investigations undertaken and detailed within the discussion papers.

The development of this study and recommendation of floodplain management measures has been overseen by the Belongil Creek Floodplain Management Committee. Byron Shire Council has prepared this document with financial assistance from the NSW Government though it's Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

Since the completion of the Discussion Papers between 2011 and 2013, Council has adopted the new Draft Revised Climate Change Strategic Planning Policy (BSC 2014). The climate change impacts reported here have been updated as have the Flood Planning Levels. In addition, the flood model has undergone an update and the new flood maps are contained within the Discussion Paper Addendum along with the costs and benefits of the floodplain management measures, which have been updated to 2014 values from 2011 values. Furthermore, the flood model digital terrain model was updated in 2015 in the vicinity of Childe Street and the flood model rerun for two design events.

The preceding discussion papers are as presented in the following table:

Table 1-1 Discussion Papers

Number	Title
1	Flood Study Review
2	Flood Damage Assessment
3	Evacuation Assessment
4	Flood Modification Assessment
5	Response Modification Assessment
6	Property Modification Assessment
7	Climate Change Assessment
8	Future Development Assessment

1.1 Key Concepts

A key concept associated with the description of flooding is the Annual Recurrence Interval or ARI as it is more commonly referred to. Annual Recurrence Interval or ARI is used for engineering and land use planning purposes representing a design flood and has a given likelihood of occurrence. This is expressed in average number of years between flood events as large as or larger than the design flood event. For example, floods with a discharge as large as or larger than the 100 year ARI flood will occur on average once every 100 years. Terms such as ARI are defined in the glossary at the back of this report.

The Probable Maximum Flood, or PMF, is an extreme flood deemed to be the largest flood that could conceivably occur at a specific location. It is generally not physically or economically possible to provide complete protection against this flood event, but should be considered for emergency response etc. The PMF defines the extent of flood prone land (i.e. the floodplain).

1.2 General Principles of Flood Risk

The primary objective of the NSW Government's Flood Prone Land Policy is to "reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property" and to "reduce private and public losses resulting from floods".

At the same time, the policy recognises the benefits flowing from the use, occupation and development of flood prone land.

The only way to completely remove flood risks from a development is for it to be located outside the extent of the PMF. This is a very risk-averse approach to floodplain management which is generally not supported by the Floodplain Development Manual (DIPNR, 2005). In particular, one of the principal tenants of the Flood Prone Land Policy is that "flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development".

When considering future development, both the Policy and the Floodplain Development Manual promote the use of a "merit approach which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable. In this way the Policy avoids the unnecessary sterilisation of flood prone land. Equally it ensures that flood prone land is not the subject of uncontrolled development inconsistent with its exposure to flooding".

In view of the above, a key issue to be determined is the level of risk that the community considers to be acceptable, noting that the elimination of all risk is generally not practical or appropriate.

As a general rule, almost any development involves some risks to property or people. For example, construction of a new subdivision introduces traffic risks which may be managed (e.g. through construction of traffic lights, signage, etc) but are not completely eliminated. Rather the risks are reduced to a level which is considered acceptable to the community. Flood risks are managed in a similar fashion. Nevertheless in some situations if the residual risks remain unacceptably high, alternative safer forms of development should be pursued. The overarching goal of floodplain management is to increase the resilience of communities to the risks associated with flooding.

1.3 Defining Flood Risk

Within the context of this report, flood risk is defined as the combination of probabilities and consequences that may occur over the full spectrum of floods that are possible at a particular location.

In deciding on how best to manage flood it is recognised that for any given flood, consequences of flooding will vary between different communities and different groups within the same community. Flood risk management aims to balance the needs of the community in order to establish an acceptable level of risk.

There are three major types of flood risk in the Belongil Catchment:

- Storm tide inundation;
- Belongil Creek flooding; and
- Local catchment stormwater runoff.

Within the floodplain risk management framework, the mapping of flood hazard is used to describe the potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies both in time and place across the floodplain. Floodwaters are deep and fast flowing in some areas, whilst at other locations they are shallow and slow moving. It is important to determine and understand the variation of degree of hazard and flood behaviour across the floodplain over the full range of potential floods. The flood hazard categories are defined (DIPNR, 2005) in the following figure.

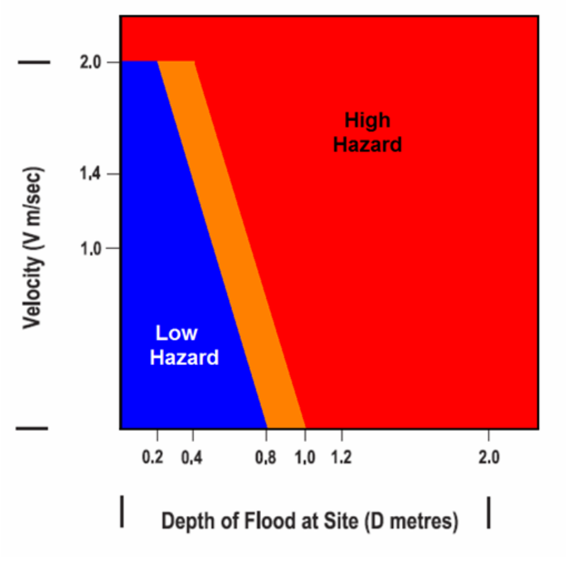

Figure 1-1 Flood Hazard Criteria

1.4 Managing Flood Risk

There are three principle options for managing flood risks:

- Avoiding the risk - land use planning is the key management action by which inappropriate flood risk can be avoided. Effective land use planning ensures that only development compatible with the flood hazard can be located within the floodplain.
- Reducing the likelihood – improvements to drainage, levees and other structural measures can reduce the probability of flooding.
- Reducing the consequences – a range of measures are available including:
  - Development controls;
  - Raising flood awareness amongst communities;
  - Improved emergency management;
  - Improved flood warning;
  - Provision of insurance; and
  - Provision of disaster relief.

In every situation, avoiding risk through effective land use planning is the preferred option, if possible. Nevertheless pressures for land development, the lack of suitable land outside the floodplain and a range of other non-flood related issues means that use of some floodplain land may still be the best option for the community. The Floodplain Development Manual guides Councils and consent authorities to use the 'merit approach' in making these land use decisions, balancing flood risk with other social, environmental and economic considerations.

1.5 Risks to Property

The most common method of reducing the consequences to property is by applying development controls that specify the minimum height of floor levels relative to a given probability of flood. A range of flood planning levels (FPLs) are usually established by Councils for this purpose, and may vary depending on the use of the building.

Other complementary development controls are used to manage property risks including the use of flood compatible building materials and methods as well as ensuring buildings are strong enough to withstand the forces of flood waters without collapse. Removing properties at high risk or raising them can also assist.

1.6 Risks to People

When considering future development, the management of risk to property can generally be managed provided appropriate controls are applied. However, risk to life is seen as the key flood constraint within several flood prone localities within the catchment, where evacuation constraints are an issue.

A range of structural and non-structural measures can be considered, including evacuation and emergency management constraints, and increasing the community's awareness and preparedness for flooding. This is particularly important in this catchment given the large tourist population.

1.7 Floodplain Risk Management Process

The NSW Government's Flood Prone Land Policy is directed to providing solutions to existing flooding 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. Policy and practice are defined in the NSW Floodplain Development Manual. (DIPNR, 2005).

Under the Policy, the management of flood prone land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provide specialist technical advice to assist Councils in their floodplain management responsibilities.

The Policy provides for technical and financial support by the State Government through the following four sequential stages as outlined below.

Table 1-2 Stages in Floodplain Risk Management Process

Stage	Description
1. Flood Study	Determines the nature and extent of the flood problem
2. Floodplain Risk Management Study	Evaluates management options for the floodplain with consideration of social, ecological and economic factors
3. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management with referred options for the floodplain
4. Plan Implementation	Implementation of flood mitigation works, response and property modification measures by Council

Overseeing the entire process is the Floodplain Management Committee, composed of representatives from the community, Council, the State Emergency Service (SES) and the Office of Environment and Heritage (OEH).

Community consultation has taken part during the development of the FRMS and commenced with a Resident's Survey undertaken at the start of the process which sought information the community's current understanding of flood risk and their ideas to reduce it.

2. Belongil Creek Catchment

The Belongil Creek is approximately 3km long and has a catchment of approximately 30km^2. The township of Byron Bay is situated towards the eastern boundary of the catchment with a large proportion of the township development on higher ground. Parts of the catchment area have undergone urban development, but over one-third of the catchment area is covered by the Cumbebin Swamp. Large areas of swamp near the town have been reclaimed and developed.

The population of Byron Bay is approximately 5,200 (ABS, 2006). In addition to the local population, Byron Bay represents a major tourist destination, attracting over one million visitors annually.

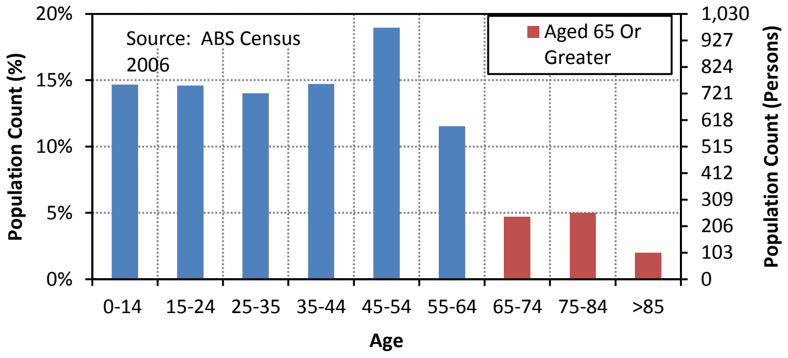

Figure 2-1 Population Data

Areas of the catchment most vulnerable to flooding are located along the creek entrance to the ocean in the north of the catchment and on the eastern side of the catchment in the Byron Bay township and adjoining areas. These areas are impacted by high ocean elevations in combination with high flood flows from the creek. Intermittent closure of the Belongil Creek entrance through sand build up can also exacerbate flood levels throughout the catchment under heavy rainfall. However, closure of the creek entrance may reduce ocean induced flooding during times of elevated ocean levels.

The Byron Bay township is susceptible to flooding from both intense short duration storms over the town catchment and elevated ocean levels. The Belongil Creek entrance condition can directly affect flood levels in the town. The lowest portions of the township are below 2mAHD and elevated ocean conditions can rise to this level under cyclonic conditions. There is no direct overland escape route for flood waters in the township, which is separated from the estuary by the North Coast Railway line. The town centre is drained to the estuary via the town drain, which receives water from the Byron Street drains under the railway line. The capacity of this drain is limited by a lack of hydraulic gradient between the low lying township and the Belongil Creek outlet. The Byron Bay township drainage system has an estimated capacity equivalent to less than a 1 year average recurrence interval (ARI) flood.

Flooding in the township of Byron Bay, east of the railway line, is independent of the flooding from Belongil Creek. It is largely caused by the limited capacity of the Byron Bay storm water network which is unable to manage local stormwater runoff. Low lying properties located adjacent to the town drain are also susceptible to stormwater flooding due to their proximity to the town drain.

The estuary mouth is intermittently open, with catchment flooding and sand transport being the main factors that influence the opening and closing of the mouth. The entrance condition depends on the relative magnitudes of the littoral drift transporting sand to the inlet which acts to close the entrance and the channel discharge which acts to keep the channel open. Channel discharge is generated by both ebb tides and precipitation on the catchment. Council has an interim license for mechanically opening the channel when deemed necessary to relieve flooding. The interim licence allows council to mechanically open the creek entrance when the gauged water level at the Ewingsdale Road Bridge reaches 1m AHD.

The transport of catchment runoff to the creek is influenced by numerous manmade drains and infrastructure. These include the Union Drain, the Byron Bay town drain (or Butler Street Drain), the North Coast Railway line, Ewingsdale Road and numerous bridges and culverts.

The Belongil catchment has a history of frequent moderate flood events, including 1974, 1984, 1995, 1998, 2003 and 2005.

Figure 2-2 Catchment Map

- Catchment Boundary
- Sub-Catchment Boundary
- Stream Line
- Major Drain
- Cadastral Boundaries

3. Flood Modelling

Flood modelling represents an effective tool to estimate flood risk within a catchment. Flood modelling looks at the way that flood behaviour (e.g. depth, velocity, duration of inundation) might change as a result of changes in the floodplain, such as improving drainage, building a residential development or opening the creek mouth. The assessment starts by using a flood model to define the design flood behaviour (e.g. a flood with a 100 year ARI) for existing conditions. The model is then altered to include the changes in the floodplain, and the results are compared to estimate the impact (positive or negative) on flood behaviour.

Flood modelling has been used to inform this Flood Risk Management Study and Plan. The output from the model is presented in the form of flood maps.

Belongil Creek was first modelled as a part of the *Belongil Creek Flood Study* (PWD, 1986) before being revised in 2009 (SMEC) and 2011 (BMT WBM). The BMT WBM flood modelling revised the 2009 SMEC model though various topography, structure and software updates. These updates include changes to land forms around the Byron Regional Sport and Cultural Complex and more accurate road, railway and gully surveys. Due to these changes, compared against the SMEC model, this revision showed some differences in modelled peak flood level, ranging from 0.1m to 0.2m during the 100 year ARI event. Additional flood model updates were undertaken in 2014.

Further description of the flood model and the updates can be found in Discussion Paper 1 within the Discussion Paper Addendum.

3.1 Flood Mapping

Three flood maps are presented on the following pages. The first depicts the maximum water surface level and extent for the 100 year ARI event; the second illustrates the depth and extent in the 100 year ARI event and third shows the maximum extent and depth attributed to the probable maximum flood event.

3.2 Existing Flooding Model Results

The critical storm duration for the Belongil Creek catchment is 12 hours. In the 12 hour storm approximately 55% of the total rainfall falls within the first 3 hours. The catchment is vulnerable to flooding caused by high intensity storms due to the lack of hydraulic gradient. This induces a rapid rise in water levels after the onset of the critical duration storm. In the 100 year ARI in excess of 250mm falls within a 12 hour period.

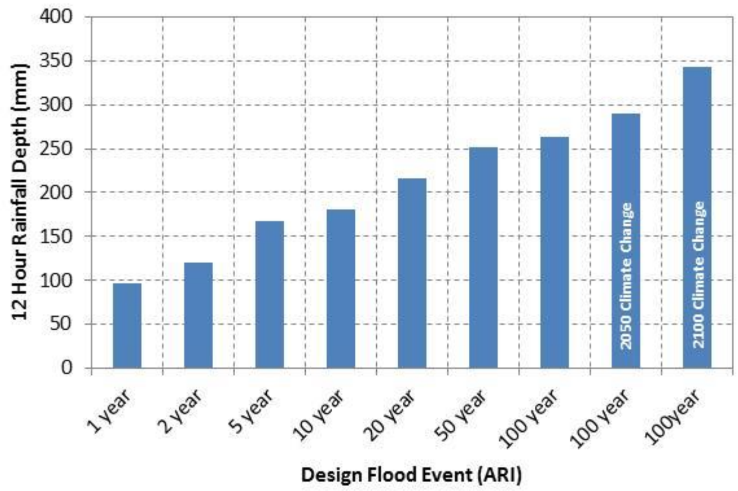

Figure 3-1 Rainfall Depth and Design Flood Event

The following presents a description of the flood behaviour in the 100 year ARI design flood event. The catchment has been divided into three separate areas for the purpose of flood behaviour description; east of the railway line (Eastern Catchment), west of the railway line (Western Catchment) and north of the railway line (Northern Catchment).

3.2.1 Eastern Catchment

Floodwaters from the eastern portion of the catchment drain:

- Westward under the railway embankment via two main pathways; through the Butler Street drain and via a set of culverts to the south of the Woolworths complex.
- Northward via the Clarkes Beach outfall.

Peak flood levels in the majority of this area are dominated by catchment runoff, the exception to this being the area in the immediate vicinity of the Butler Street drain which is susceptible to oceanic tides. Peak flood levels occur within 2-6 hours of commencement of the flood event. The peak flood level surface varies from above 3.5mAHD east of the playing fields to approximately 2.7mAHD at Fletcher Street during the 100 year ARI Event.

The town centre drains to the creek via the town drain, which receives water from the Byron Bay stormwater drainage system. The capacity of the existing stormwater drainage system is limited by a lack of hydraulic gradient between the low lying township and Belongil Creek.

3.2.2 Western Catchment

Levels in this area are dominated by a combination of catchment runoff and storm surge ocean boundary condition. Peak levels across the majority of this part of the floodplain are approximately 2.5mAHD during the 100 year ARI Event. Slightly higher levels are seen in areas north of Ewingsdale Road. Time of peak flood level occurs after approximately 11 hours across most of this area.

3.2.3 Northern Catchment

Levels in this area are dominated by the ocean boundary conditions. Due to the railway embankment, levels are slightly higher on the northern side of the embankment. Peak flood levels in this area are approximately 2.6mAHD during the 100 year ARI Event.

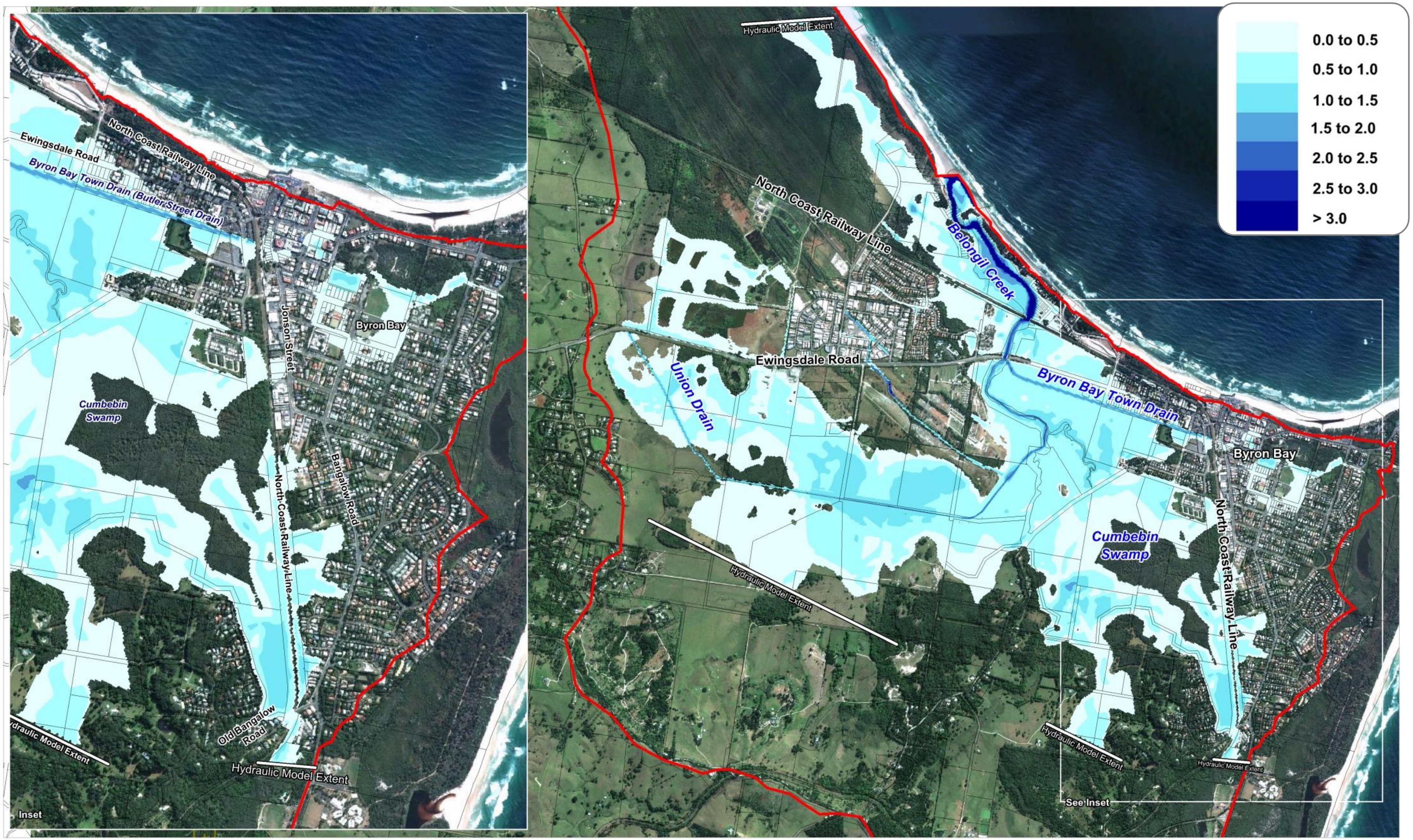

Figure 3-2 10 Year ARI Event Peak Flood Depth

Figure 3-3 100 Year ARI Event Peak Flood Depth

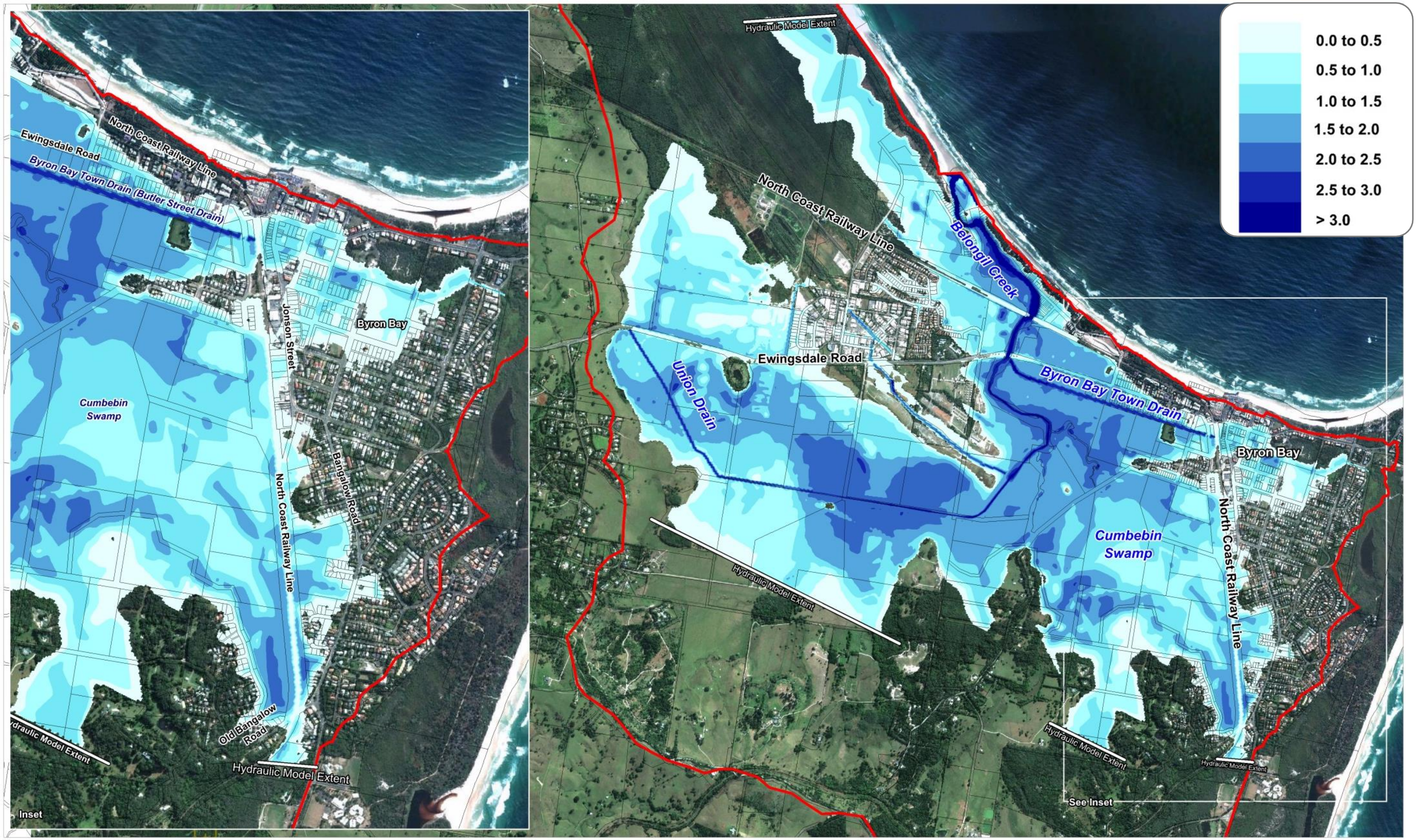

Figure 3-4 Probable Maximum Flood Event Peak Flood Depth

3.3 Future Climate Change Model Results

The Draft Revised Climate Change Strategic Planning Policy (BSC 2014) aims to mitigate impacts associated with climate change though the precautionary adoption of sea level rise and rainfall intensity parameters. The Resident's Survey completed as part of this study identified climate change, and associated impacts it may have on flood risk, as a key resident concern within the Belongil Creek catchment.

The climate change parameters and modelled results documented in this study document have been updated to reflect the 2014 BSC policy, however, further description of the impacts of climate change found in Discussion Paper 7 have not been revised and use the previously specified parameters. The parameters in Discussion Paper 7 are more conservative than the current values and the equivalent State Government guideline values for the Northern Rivers (DECCW, 2009).

Climate change may result in a significant increase in flood hazard and subsequent flood damages within the catchment. Major facets of climate change affecting the Belongil Creek catchment are rainfall intensity increase, sea level rise and an increase in storm tide levels. These values are summarised for the 100 year ARI event below. The climate change policy uses an envelope approach, combining the worst cases of ocean and catchment runoff events.

Table 3-1 Climate Change Scenarios

Scenario	Predicted Sea level Rise (m)	Increase in Rainfall Intensity
Current Conditions	0	0
2050 Climate	0.4	0
2100 Climate	0.9	0
Sensitivity Test 1	0.4	10%
Sensitivity Test 2	0.9	30%
Sensitivity Test 3	0.9	30%

The envelope of events is the 20 year ARI catchment rainfall event with elevated tailwater levels, to signify ocean dominated events combined with the 100 year ARI catchment rainfall event and reduced tailwater levels to simulate run-off dominated events. In addition, three sensitivity tests were modelled to investigate the catchment responsiveness to increases in rainfall intensity.

A coastal erosion scenario under 2100 climate conditions, based on the Byron Shire Hazard Definition Study, was considered. The coastline recession case removes any future shoreline protection from storm tide insurgence.

3.4 Impacts

The climate change assessment results highlight that flooding within the Belongil Creek catchment is sensitive to climate change related increases in sea level and rainfall intensity.

Table 3-2 Climate Change Results

Location	Existing Catchment Topography			Coastal Erosion Scenario
	Existing Climate	2050 Climate	2100 Climate	2100 Climate
Ewingsdale Road Bridge	2.3	2.3, 0.0	2.6, 0.3	2.8, 0.5
Jonson Street/ Byron Street	2.4	2.4, 0.0	2.6, 0.2	2.7, 0.4
Old Bangalow Rd	2.5	2.5, 0.0	2.6, 0.1	2.8, 0.3

Level (mAHD), increase from base case (m)

Generally speaking the greatest flood level impacts are located in the areas of the catchment most influenced by increases in sea level, namely the lower catchment from the creek entrance extending to the greater floodplain, upstream of the Ewingsdale Road Bridge.

The 2050 scenario does not show any impacts from the current conditions case as although tailwater levels in the fluvial event are 0.2m higher, the event is sea level dominated. The sea level parameters for the ocean dominated event in the current conditions and 2050 climate scenarios are the same as prescribed by the Climate Change Strategic Policy. Refer the 2050 climate change impact map below.

From the specified climate change parameters, the most affected areas are the lower catchment and areas impacted by sea level rise. This can be seen in the following impact maps as sea level rise impacts worsen further down the catchment.

As a worst case scenario, the climate change assessment considering coastline recession including no additional future shoreline protection (as per the 2100 planning horizon coastal erosion hazard line) results in greatest impacts to Byron Bay.

Table 3-3 Climate Change Sensitivity Test Results

Location	Sensitivity Test 1		Sensitivity Test 2		Sensitivity Test 3	
	Water Surface Level	Impact on 2050 Climate	Water Surface Level	Impact on 2100 Climate	Water Surface Level	Impact on 2100 Climate
Ewingsdale Road Bridge	2.3	0.0	2.7	0.1	2.8	0.2
Jonson Street/ Byron Street	2.6	0.2	2.9	0.3	2.9	0.3
Old Bangalow Rd	2.6	0.0	2.7	0.1	2.8	0.2

The results of the sensitivity testing show that the catchment is affected by increases in rainfall intensity, with areas in the upper reaches and Byron Central most impacted. Areas dominated by sea level rise, such as near Ewingsdale road bridge and in the Cumbebin Swamp, are nevertheless affected less by the increase in catchment runoff but still exhibit an increase in water surface level.

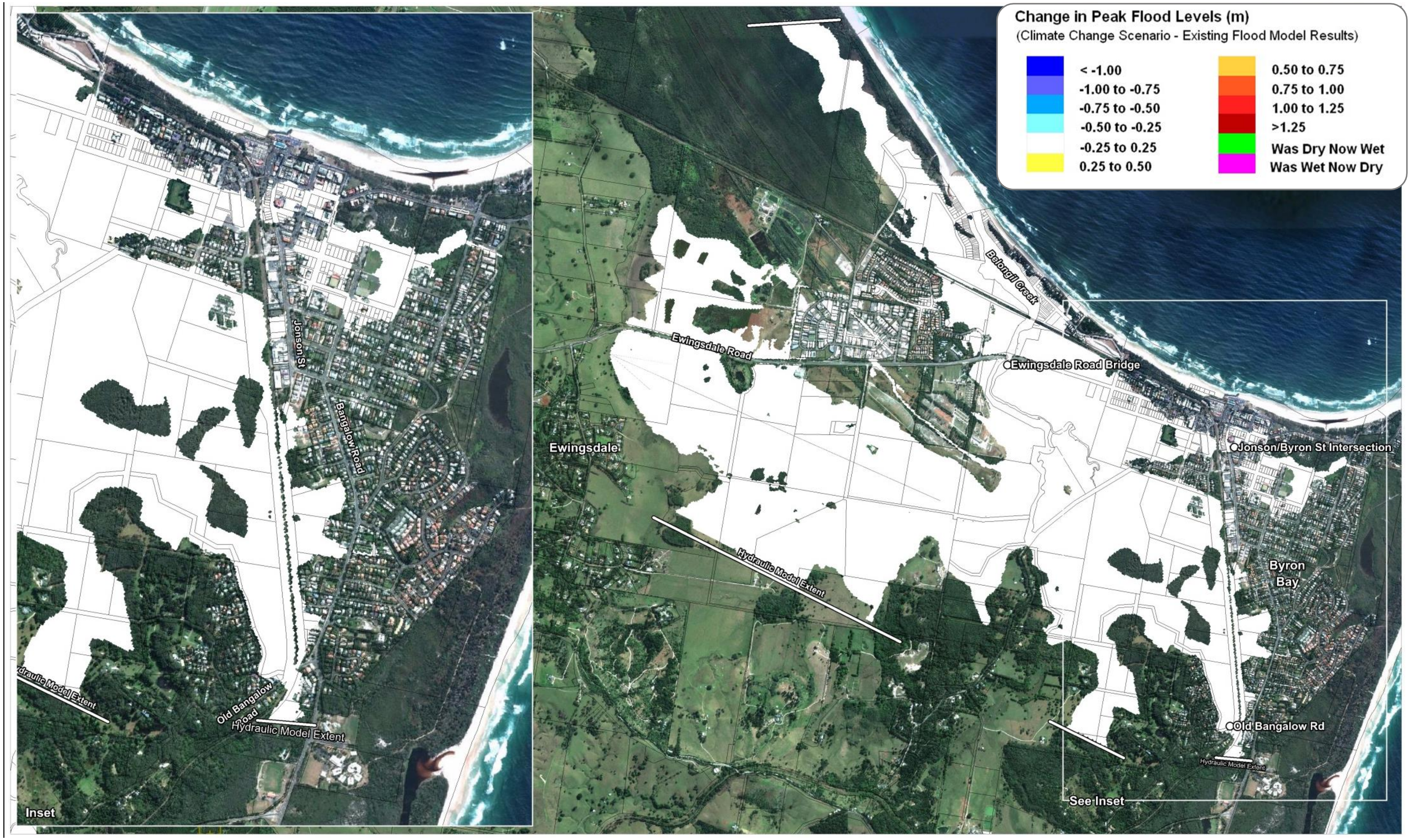

Figure 3-5 100 Year ARI 2050 Climate Change Impacts: Existing Catchment State Scenario

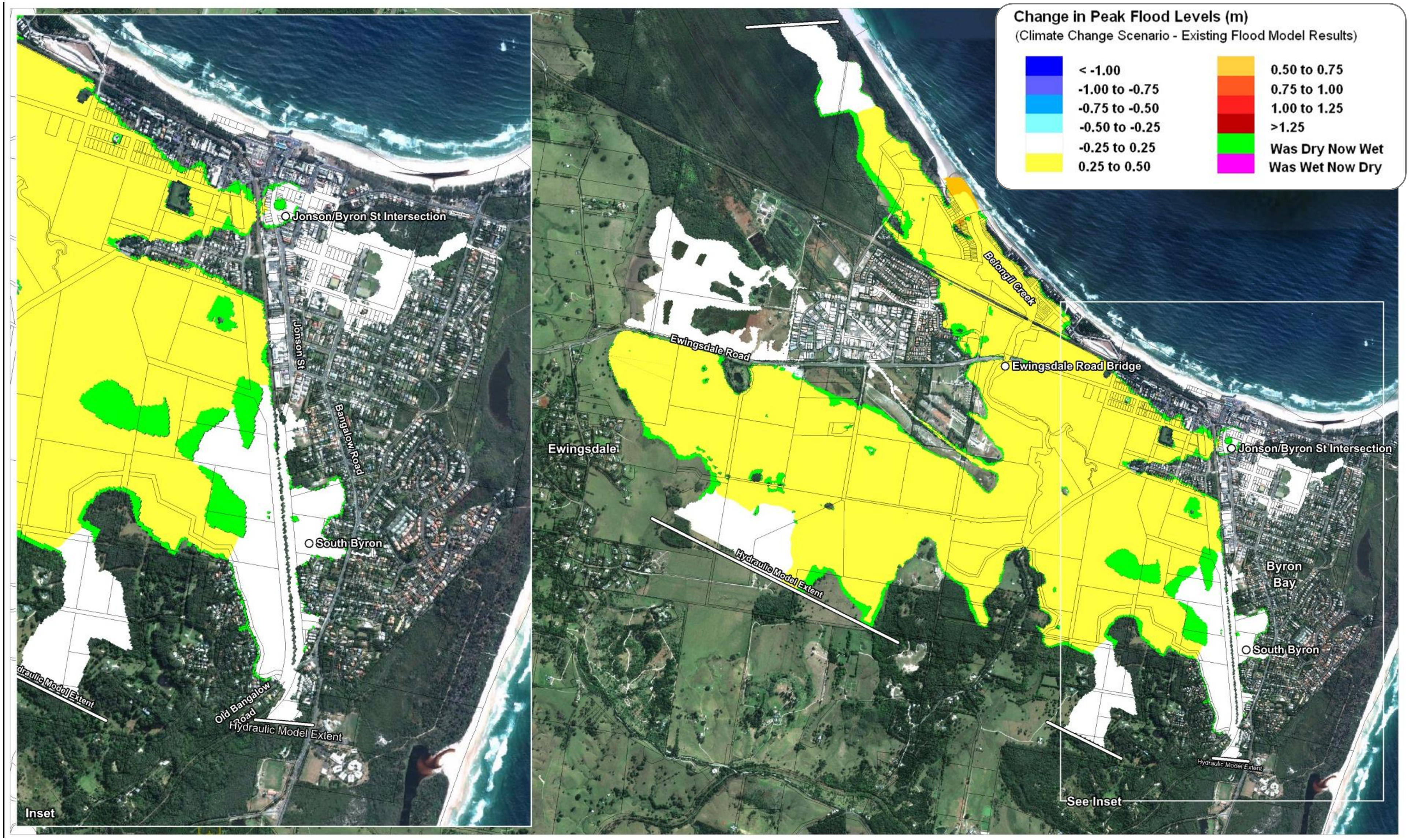

Figure 3-6 100 Year ARI 2100 Climate Change Impacts: Existing Catchment State Scenario

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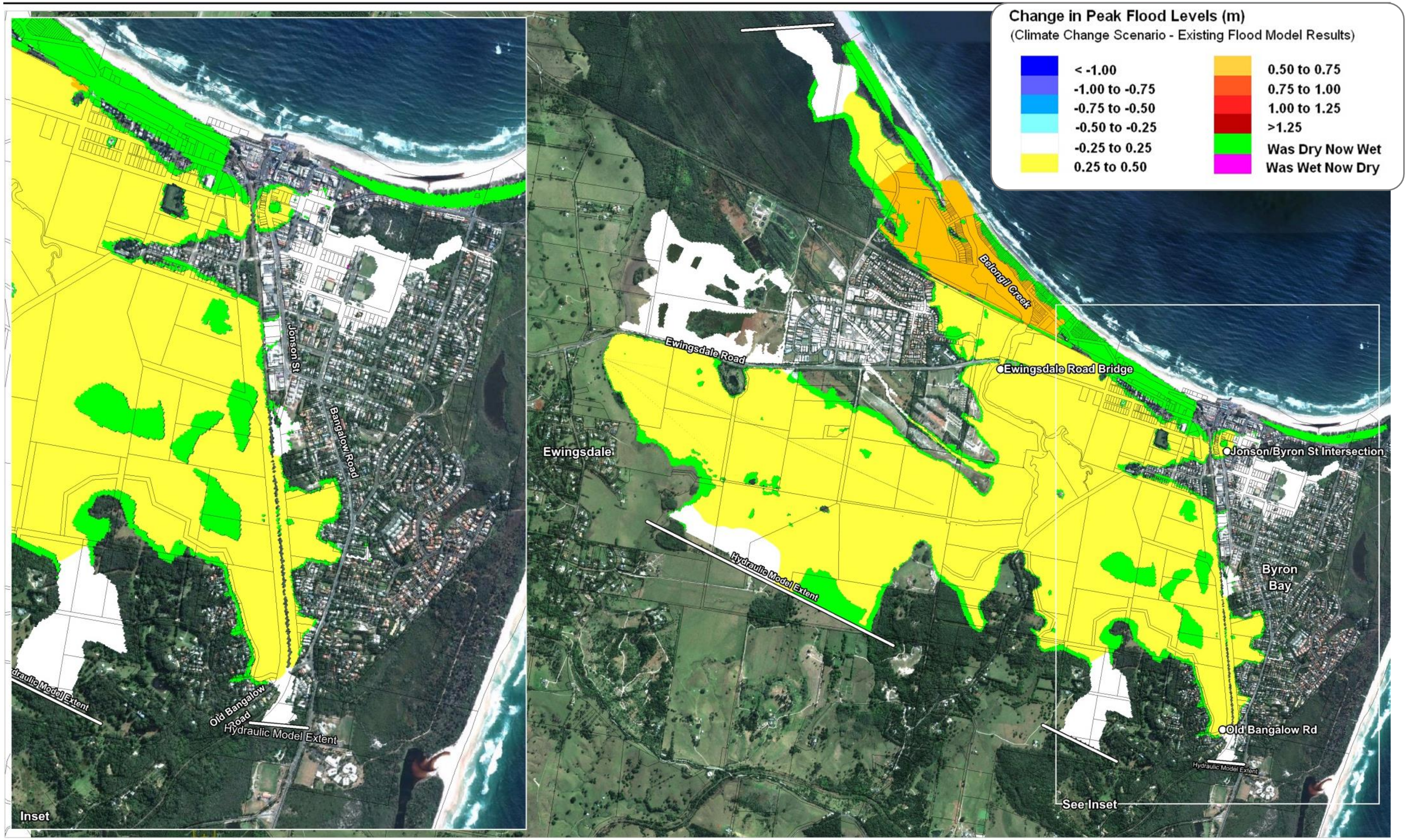


Figure 3-7 100 Year ARI 2100 Climate Change Impacts: Coastal Erosion Scenario

4. Flood Damage

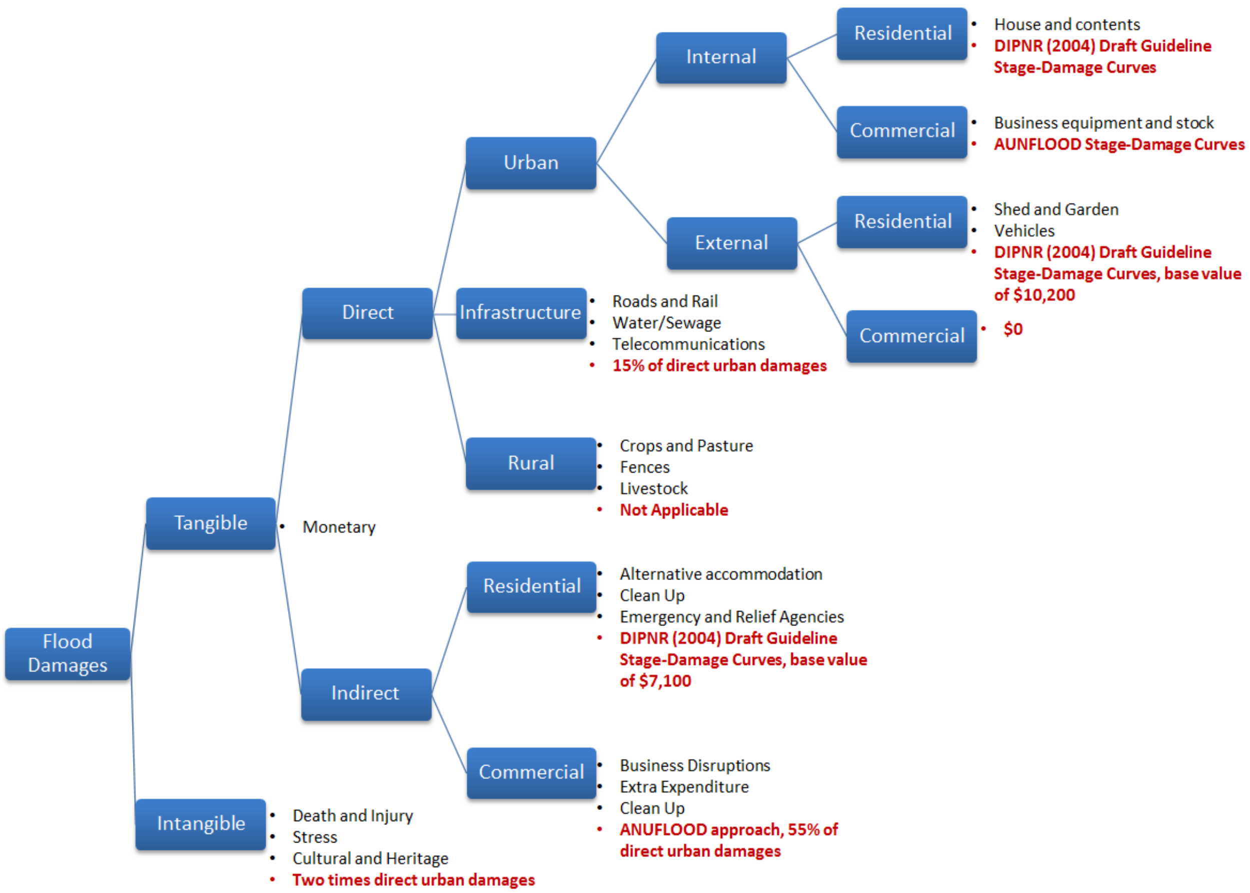
4.1 What are Flood Damages?

Flood damage assessments aim to establish the socio-economic costs of flooding for a given region and are useful for assessing the effectiveness of flood mitigation measures. Damages are expressed as a dollar value of Average Annual Damage (AAD). In some years there will be minor damage (caused by small, relatively frequent flood events) and in others there will be major damage (caused by large, rare flood events). AAD is the average cost of flooding annually for an area over a long period, accounting for variations from year to year weighted depending on their likelihood of occurrence.

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 risk to life, stress and anxiety. Tangible damages are monetary losses attributable to flooding. They may occur as direct or indirect flood damages. Direct flood 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 are the loss of sales, reduced productivity and the cost of alternative travel if road and rail links are broken.

Intangible and indirect damages tend to be difficult of quantify, so typically they are calculated as percentages of the direct damages.

Refer to figure right for examples and how each are estimated.



Stage-damage relationships (or "curves") are used to estimate the flood damage sustained by a particular property based on the depth of flooding. For example, if floodwaters entered a house to a depth of one metre, the DIPNR residential stage-damage curves have been used to estimate the average damage in dollars that water of one metre depth would cause. Similarly, if floodwaters entered a shop to a depth of half a metre, ANUFLOOD commercial stage-damage curves have been used to estimate the average damage in dollars that half a metre of water in a shop would cause.

The plateau in the number of properties between the 20 and 10 year ARI events (5% and 10% AEP respectively) indicates that the catchment is relatively insensitive to increases in event size around this magnitude. Numbers of properties spike in events larger than the 20 year ARI, this strongly reflects the increase in severity.

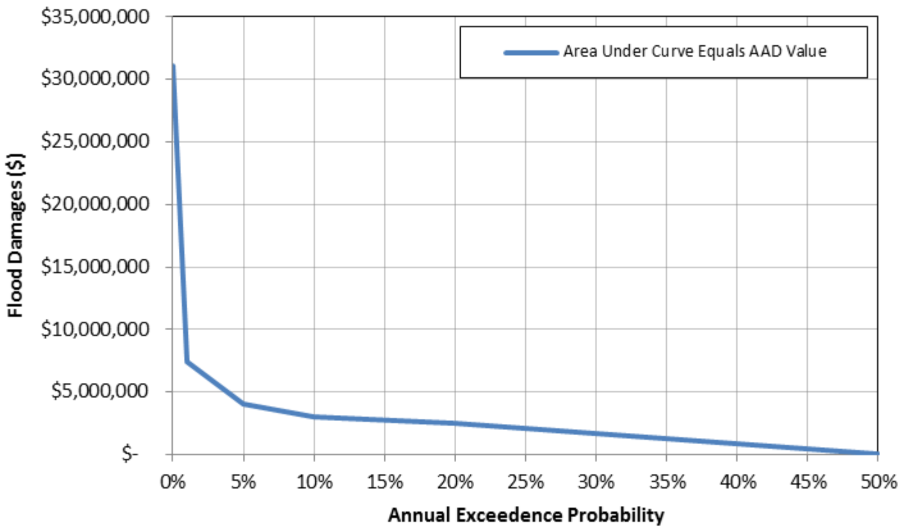


Figure 4-1 Flood Damage and Average Recurrence Interval

Further description of the flood damage assessment can be found in Discussion Paper 2 within the Discussion Paper Addendum.

The number of properties inundated in events less than the 20 year ARI remains largely constant. 100, 115 and 131 properties are affected in the 5, 10 and 20 year ARI events respectively, an increase of only 31 properties for a significant storm magnitude increase. Property numbers inundated jump to 264 in the 100 year ARI event, as more dwellings east of the railway line are affected. In the PMF event a total of 663 properties are inundated.

For events up to and including the 100 year ARI design event, 94% on average of all properties inundated are residential. In the PMF event, this drops to 83%, as a larger number of commercial and industrial buildings are affected.

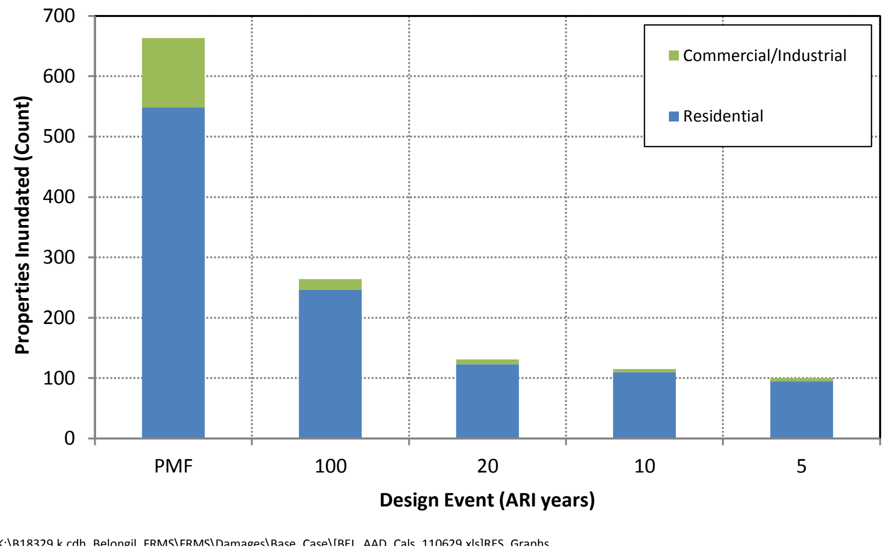


Figure 4-2 Properties Inundated per Flood Event

4.2 Current Total Tangible Damages

The total tangible Annual Average Flood Damages for the Belongil Creek catchment have been estimated at $1,255,500 (2014$). Of this number, events less than the 5 year ARI storm result in the largest proportion of damages.

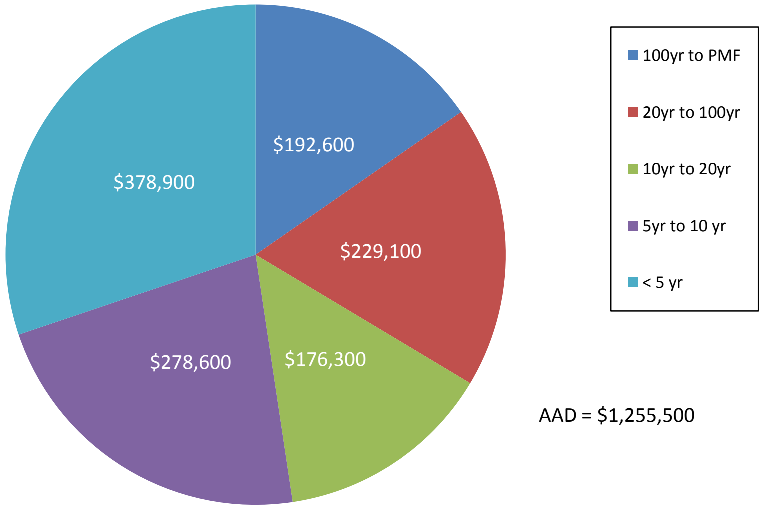


Figure 4-3 Distribution of Flood Damages Per Flood Event

Table 4-1 Distribution of Flood Damages Per Flood Event

Event (ARI)	Total Damages	AAD
5	$2,525,700	$378,900
10	$3,046,900	$278,600
20	$4,004,900	$176,300
100	$7,449,900	$229,100
PMF	$31,067,500	$192,600
Average Annual Damage		**$1,255,500**

4.3 Future Climate Change Total Tangible Damages

The predicted change in flood behaviour due to climate change results in major increases in flood damages within the catchment. The increases in Annual Average Damages presented below are conservatively high as they assume that all properties currently at risk remain in the future climate change scenarios. That is, no allowance is made for properties removed from the floodplain as a result of increasing risk.

The climate change damages assessment was carried out using parameters that predate the recent revised Climate Change Strategic Planning Policy and are expected to be significantly higher than those currently specified. Nonetheless, the figures provided below show an adequate illustration of the catchment sensitivity to climate change.

Table 4-2 Future Flood Damages and percentage increase on Current Climate Damages

Existing Damages (AAD)	2050 Climate Change	2100 Climate Change	2100 Climate Change with Coastal Erosion
$1,255,500	$2,268,000 180%	$4,649,000 370%	$6,164,000 500%

Further description of the flood damages due to climate change impacts can be found in Discussion Paper 7 within the Discussion Paper Addendum.

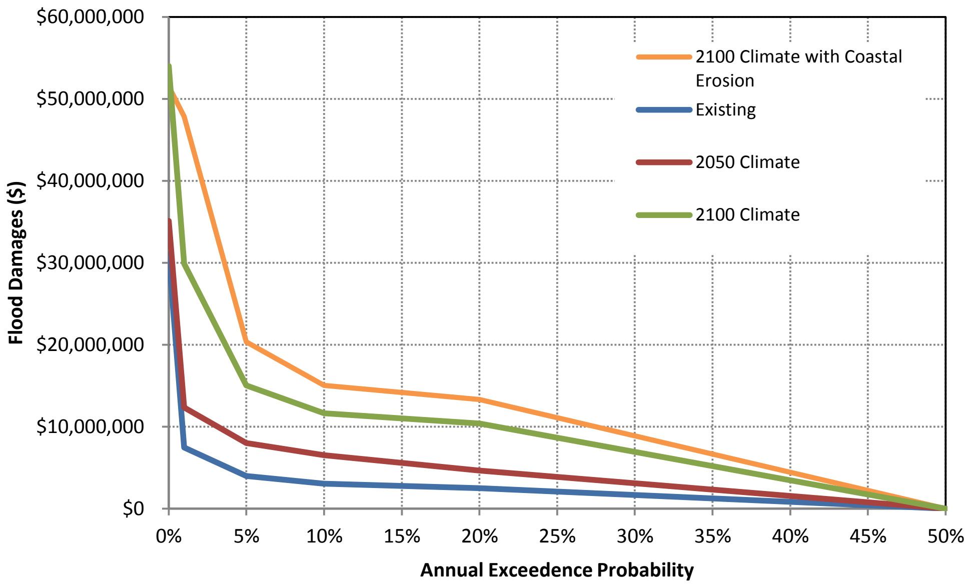


Figure 4-4 Increase in Flood Damages for Future Climate Scenarios

5. Evacuation Capability

5.1 Evacuation Assessment

Evacuation capability assessments consider the ability of people within the floodplain to evacuate safely during a flood event and to estimate the capacity for a community to evacuate safely and to investigate floodplain risk management methods to minimise isolation and risk to life. The Floodplain Development Manual (DIPNR, 2005) outlines three approaches to the management of risk:

- Property modification (e.g. modification of existing properties or imposition of development controls).
- Response modification (e.g. flood warning and emergency procedures).
- Flood modification (e.g. the construction of a levee).

An evacuation capability assessment informs all three management methods via identification of at risk communities and locations. Identification of these areas helps to address the existing risk via response modification measures, such as increased community awareness in vulnerable areas. In addition, the effectiveness of proposed property and flood modification measures can be assessed, assisting planning decisions.

Results of this assessment can assist the SES to plan for flood evacuations and identify options to reduce risk, particularly in areas where there may be insufficient time to safely evacuate everyone.

The methodology utilised in this evacuation capability assessment is based on the 'Evacuation Timeline' approach, developed by the NSW 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.

Critical facets of the timeline method include:

- Number houses affected and, correspondingly, number of residents and vehicles.
- Emergency response resource requirement, such as door-knocking team requirements.
- Constraints to the process such as early road closure and insufficient warning time.
- At-risk communities, such as caravan park residents and older demographics.

Further description of the evacuation capability assessment can be found in Discussion Paper 3 within the Discussion Paper Addendum.

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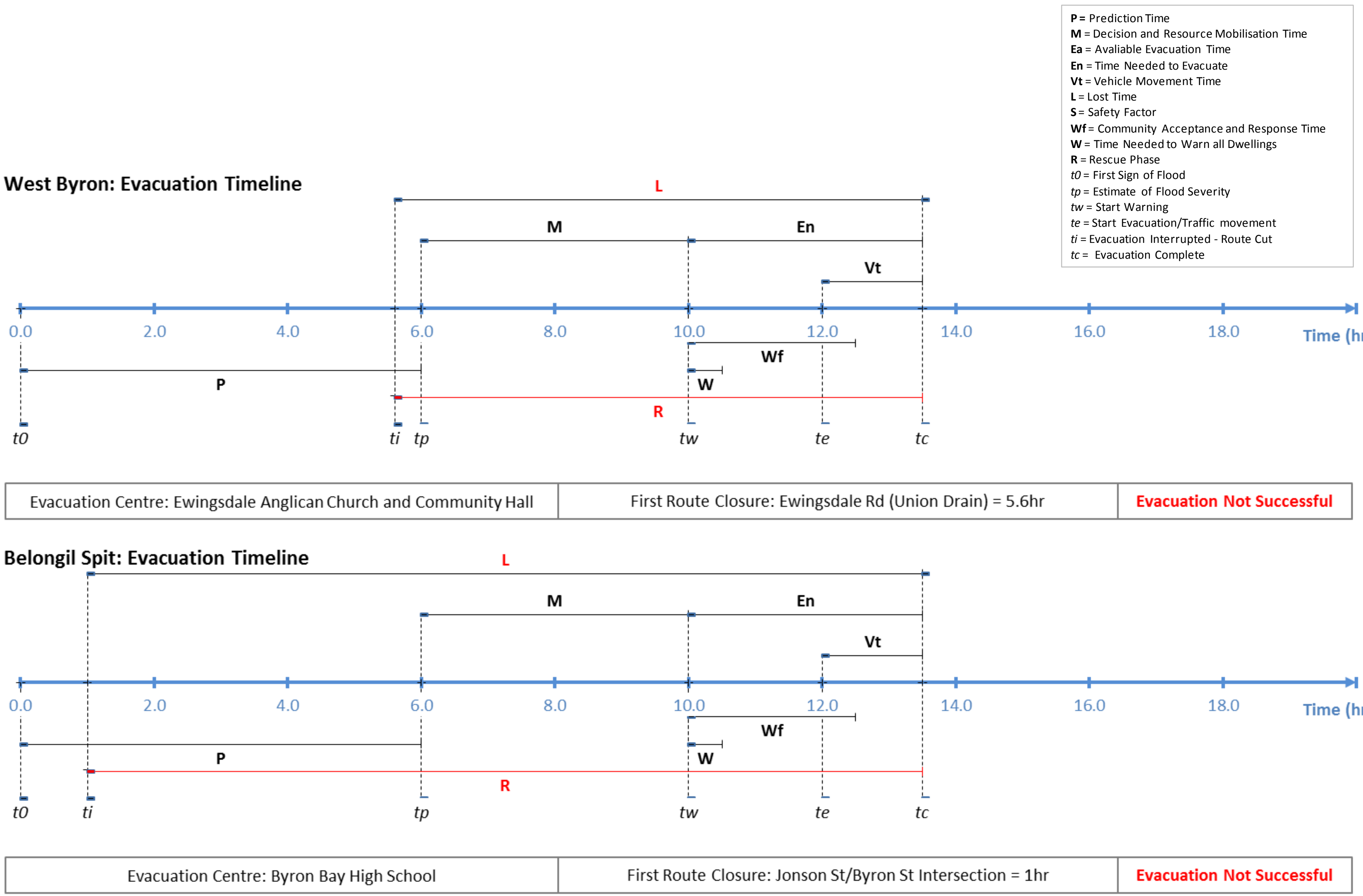

Figure 5-1 Belongil Spit and West Byron Evacuation Timeline

5.2 Evacuation Summary

In addition to the local population, Byron Bay represents a major tourist destination, attracting over one million visitors annually. Sourced from the Byron Shire Council Tourism Numbers Media Release (BSC, 2011), the total recorded number of tourists visiting Byron Bay from 2006 to 2010.

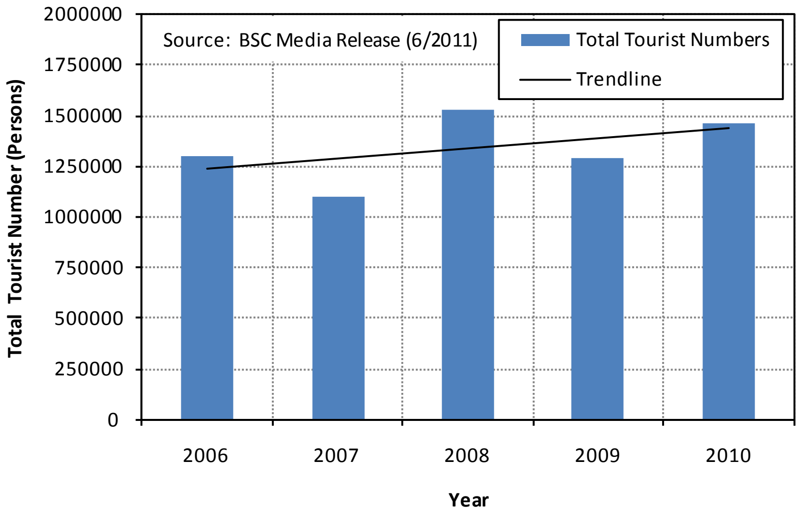

Figure 5-2 Tourist Count Per Year, 2006 - 2010

The Belongil catchment has a relatively quick catchment response time, i.e. flood levels typically rise and subside quickly (within 24hrs). In major events, inundation of evacuation routes occurs between one and six hours, before evacuation can begin. This flood behaviour poses a significant constraint on successful evacuation during a major flood event.

The table overleaf summarises the evacuation capability results for five defined evacuation sectors. The results highlight that the quick flood response of the Belongil Creek catchment during the PMF event results in inundation of the Ewingsdale Road, Jonson Street and Old Bangalow Road evacuation routes prior to mobilisation of required resources to issue of a flood evacuation warning.

However, compared to the PMF event, flood risk associated with smaller more frequent flood events is reduced. During flood events smaller than the PMF event (10 and 100 year ARI events) all evacuation routes remain trafficable, with the exception of Ewingsdale Road, east of Belongil Creek, and Jonson Road.

As a practical response to the quick rise of flood waters, given the short duration of flood events within the Belongil Creek catchment, the SES have defined assembly points within the catchment, to be used when inundation of evacuation routes prevent access to primary evacuation centres. The defined assembly points include the Byron Bay Hospital, Byron Bay Scout Hall and the Belongil Fields Caravan Park. All assembly points are flood free during the PMF flood event.

As part of the current review of the Byron Shire Local Flood Plan (SES, 2006) the SES have identified the Ewingsdale Anglican Church and Community Hall as the primary evacuation centre for the residents within the West Byron evacuation sector, in place of Byron Bay High School. This addition to the Byron Shire Local Flood Plan significantly reduces the impacts associated with the inundation of Ewingsdale Road. Residents of the West Byron evacuation sector would be able to access the new evacuation centre to the west, unaffected by the inundation of Ewingsdale Road to the east of Belongil Creek.

The inundation of the Jonson Street evacuation route results in a failed evacuation for residents from the Belongil Spit evacuation sector for all assessed design flood events. Although these residents do have direct access to the Byron Bay Hospital assembly point.

The evacuation assessment was undertaken prior to the development of proposed route for the Byron Bay bypass and as such the impact of this on the evacuation for the township has not been considered.

Table 5-1 Evacuation Assessment Summary

Town Sector	Evacuation Centre	Evacuation Route	Time to Evacuate (hrs)	Time of Evacuation Route Closure (hrs)			Evacuation Status		
				10 year ARI	100 year ARI	PMF	10 year ARI	100 year ARI	PMF
West Byron	Ewingsdale Anglican Church and Hall	Ewingsdale Road	13.3	-	-	5.3	Successful	Successful	Failed
Belongil Spit	Byron Bay High School	Jonson Street	13.5	0.1	0.2	1.2	Failed	Failed	Failed
Byron Town	Byron Bay High School	Jonson Street	13.2	-	-	2.6	Successful	Successful	Successful
Byron South	Byron Bay High School	Bangalow Road	13.2	-	-	-	Successful	Successful	Successful
Cemetery Road	Byron Bay High School	Old Bangalow Road	13.1	-	-	3.6	Successful	Successful	Failed

“-“ indicates no route closure

6. Flood Modification

Flood modification measures represent structural measures designed to alter the behaviour of the flood by reducing flood levels and/or velocities, or by excluding floodwaters from certain areas.

Flood modification measures aim to minimise current creek and storm tide inundation risk. These modification measures have been assessed using Average Annual Benefit (AAB) and the benefit cost ratio. AAB is the reduction in average annual flood damages associated with the proposed measure. The benefit cost ratio is total benefits divided by total costs. Measures with a ratio of greater than 1.0 indicate that the benefits are greater than the costs, while a ratio less than 1.0 indicates that the costs are greater than the benefits.

It is important to recognise that the monetary benefit-cost ratio represents only one of the issues that must be considered in respect to the viability of a measure. Other issues such as social and psychological impacts, although difficult to quantify, must also be considered. It is due to these factors that measures with a benefit-cost ratio less than 1.0 may still be considered viable, given that the economic analysis does not include the intangible benefits of a measure.

The Byron Bay township is susceptible to flooding from both intense short duration storms over the town catchment and elevated ocean levels. The condition of the Belongil Creek entrance can directly affect flood levels in the town. The lowest portions of the township are below 2mAHD and elevated ocean conditions can rise to this level under cyclonic conditions. There is no direct overland escape route for flood waters in the township, which is separated from the estuary by the North Coast Railway line. The town centre is drained to the estuary via the town drain, which receives water from the Byron Street drain under the railway line. The capacity of this drain is limited by a lack of hydraulic gradient between the low lying township and the Belongil Creek outlet.

Five measures have been assessed seeking to reduce the risk of flooding in the catchment. A summary table at the end of this section presents the results of the assessment and the proposed flood modification measures recommended for inclusion in the floodplain management scheme by the Floodplain Management Committee.

Further description of the assessments can be found in Discussion Paper 4 and the supplementary letter within the Discussion Paper Addendum.

6.1 Permanent Belongil Creek Entrance Opening

Artificial and permanent opening of the Belongil Creek entrance was investigated using the flood model as a means of reducing flood levels in the Western and Northern catchment areas. Consideration was given in the assessment to flood reduction, environmental factors, water quality and cost.

Belongil Creek operates as an intermittently closed and open lake or lagoon (ICOLL) system. When the creek entrance is closed, the Belongil Creek is separated from the ocean by a sand beach barrier (or berm). Following heavy rainfall, water levels in the closed creek system can rise rapidly and cause flooding in nearby properties. If the water level gets high enough, water will spill over the entrance sand berm and drain to the ocean. The force of the water over the berm scours an entrance channel and consequently opens the ICOLL to the ocean. Over time, the entrance can become closed again, as waves and tides push sand from offshore into the creek entrance.

Artificial opening of the ICOLL system would aim to address problems around flood mitigation and water quality. The mitigation measure requires the construction of training walls at the mouth of Belongil Creek to permanently maintain the entrance and prevent the creek from becoming a closed system.

It has been argued that permanent opening of the creek entrance may reduce flooding by allowing catchment runoff to flow to the ocean, rather than remaining trapped in the creek. This argument was investigated and is discussed in discussion paper 4. It has also been proposed that permanent opening of the creek entrance may improve the water quality of the creek system by allowing pollutants in the creek to be ‘flushed’ to the ocean. This argument has not been investigated, but doubts have been raised for this and other catchments with ocean entrances. In addition, the effect of lowering groundwater levels in the lower catchment would likely lead to acid runoff as experienced in the recent drought.

Flood modelling of the mitigation measure indicated that whilst peak flood levels were somewhat reduced (up to 20cm) in events where catchment runoff dominated, storm tide events increased in severity (up to 30cm). As the creek mouth would be permanently open, the surrounding areas would be more vulnerable to projected sea level rise. In addition, permanent opening of the creek may reduce groundwater levels within the catchment which could result in to acid runoff. While water quality within Belongil Creek may improve, this is achieved through flushing pollutants into the ocean, not reflecting best practice.

Furthermore, the local ecology in Belongil Creek has evolved in response to the intermittent opening and closing of the creek entrance. The lower portions of the Belongil Creek catchment are of high conservation significance. Four endangered ecological communities, listed under the Threatened Species Conservation Act (1995) have been identified in the Belongil Creek system (Australian Wetlands 2008).

For the purpose of this assessment, it has been estimated that the indicative costs associated with the design and construction of a trained entrance at the Belongil Creek entrance is likely to be in the order of $10,000,000. On-going maintenance costs (eg. dredging) will be in addition to this.

As a consequence of the increased flooding, ecological impacts and costs, this flood modification measure has not been recommended for inclusion within the floodplain management scheme.

6.2 Byron Drainage Strategy

Due to limited hydraulic gradient between the low lying areas of Byron Bay township and Shirley Street areas to the receiving waters in Belongil Creek, levees combined with pump stations represent the only viable flood modification option available to protect existing properties in these regions properties from flooding.

The estimated capacity of the existing drainage system is less than the 1 year ARI flood (SMEC, 2010), i.e.: it is expected that at least once per year, the stormwater system will be overwhelmed. This results in flooding within the township on a regular basis.

To address this, the Byron Drainage Strategy aims to reduce localised flooding though a network of overland flow paths, levees, two pump stations and culverts. This strategy is designed to reduce the impact of flooding at various locations (including Cooper Street, the Town Centre, Shirley Street and Western Industrial Areas). It also seeks to improve the main town area's flood immunity against storm surges (not including properties located on Belongil Spit) and reduce storm water pollution at Clarkes Beach via diversion of first flush flow from the Clarkes Beach inlet in combination with a wetland and Belongil Creek though gross pollutant traps.

This strategy relies on a series of pumps to direct floodwaters west towards the town drain and mechanical failure of any of the pumps during a flood event will result in failure of this flood modification measure. As a consequence, additional mitigation measures are required to reduce both the likelihood and consequence of the flood risks associated with pump failure, which include:

- Operations and maintenance plans for the pump stations
- Annual maintenance of the pump stations
- Dual pump station to provide a level of contingency in case of breakdown
- Power sub station to be located outside the PMF flood extent.

This measure is estimated to cost $8,943,800.

This measure is pending recommendation subject to a review of land purchase costs associated with the Preferred Byron Drainage Strategy.

6.3 Preferred Byron Drainage Strategy

The elements proposed within the Byron Drainage Strategy for the Town Centre, Shirley Street and Western Industrial areas have been included within the Preferred Drainage Strategy option. The design features within the Cowper Street Area have been modified.

The Byron Drainage Strategy requires two separate pump stations to mitigate the flood problems within the Cowper Street area. The associated infrastructure with this design is costly, requiring design and construction of an underground pipe network through the town centre for over 500 metres. Additionally, there are significant residual risks associated with the pump station design.

The Alternative Byron Drainage Strategy proposes that the pump stations and their associated underground infrastructure be avoided through the construction of a larger wetland/detention basin in combination and doubling the existing capacity of the Clarkes Beach drain.

This preferred strategy greatly reduces the number of properties inundated and reduces catchment annual average damages by approximately 40%.

The major constraint is the greater land area required for the wetland. Currently the strategy is pending investigation into this land purchase prior to recommendation within the floodplain management scheme.

The Preferred Byron Bay Drainage Strategy has been costed at $9,440,000.

6.4 Drainage Infrastructure Maintenance

Due to the lack of hydraulic gradient between the low lying areas of Byron Bay and the Belongil Creek outlet it is essential that the existing drainage infrastructure within the Belongil catchment is maintained, ensuring that the drainage network works efficiently.

Council have identified five (5) major drainage lines which service the Byron Bay township. These drainage lines are currently constrained to varying degrees by a combination of built up vegetation, debris and sediment.

Flood modelling indicates the clearing of drainage lines reduce upstream flood levels east of the North Coast Railway line for all the assessed drainage lines with the exception of town drain. However, these flood level reductions do not change the number of properties affected by flooding. However the reduced flood levels do lessen the severity of flood damage when it does occur.

Although the clearing of the Byron Bay town drain shows limited flood benefits, it is likely that regular maintenance of the drain will improve the drainage efficiency of stormwater runoff during smaller more regular flood events (<<5 year ARI event) which may not dominated by backwater inundation from the Belongil Creek.

Council have costed the initial and on-going maintenance of the drain at approximately $1,092,400.

This flood modification measure has been recommended for inclusion in the floodplain management scheme.

6.5 North Coast Railway Bridge Widening

The existing railway bridge north of Ewingsdale Road is 40m wide and acts a control structure in both storm tide and creek flooding events. In storm tide dominated events, the bridge restricts the ingress of sea water up Belongil Creek and reduces levels upstream. Conversely, in creek events the bridge restricts the egress of floodwaters to the sea and exacerbates flooding upstream.

Widening the North Coast Railway bridge was proposed as a flood mitigation measure and tested. The measure doubled the width of the bridge to 80m and deepened the channel.

Flood modelling of the measure indicated mixed impacts for the catchment. Storm tide dominated events resulted in an increased level upstream with an associated increase in flooding. However when creek flooding events were analysed there was a reduction in flood and a positive impact. It is likely that the widening of the railway bridge would also increase vulnerability to sea level rise and increased intensity of storm tide events. As a consequence, this flood modification measure has not been recommended for inclusion within the floodplain management scheme.

6.6 Belongil Creek Entrance Alignment

The Belongil Creek entrance alignment varies over time due to natural geomorphic processes, resulting in channel meandering and creek bank erosion/accretion. This is currently actively occurring between the creek entrance and the North Coast Railway line. Bank erosion is threatening built infrastructure adjacent to Childe Street/Manfred Street and also the Byron Bay Beach Resort. Engineering works aimed at limiting these erosion threats were discussed by the Committee (e.g. hard armour protection). These measures will have a negligible impact on the hydraulic flood behaviour and will have an insignificant benefit in terms of reducing flood damages within the catchment. As such, these measures are unlikely to have a favourable benefit cost ratio. Due to this, these measures will not be eligible for state government funding support within the flood risk management framework. Further assessment of these measures has not been completed due to these funding constraints.

6.7 Belongil Creek Entrance Strategy

Belongil Creek operates as an intermittently closed and open lake or lagoon (ICOLL) system. During the last 50 years, the entrance to Belongil Creek has been artificially opened on numerous occasions by excavating a channel through the sand berm to the ocean. Following the artificial opening, the entrance has closed over time as ocean waves and tides push sand back into the entrance channel. Since 2001, Council has operated under a licence condition (granted as an interim licence) which allows the Council to open the creek entrance when water levels reach 1.0mAHD at the Ewingsdale Bridge (WBM, 2007). The current sand extraction licence is valid until 11th September 2019. These works are undertaken to reduce flood levels under Council's duty of care responsibility to the community.

The Floodplain Risk Management Study investigated the flood benefits of permanent opening of the creek mouth. The assessment identified limited impact on peak flood levels within the main town area of Byron Bay. This is due to flood levels within Byron Bay largely being dominated by the limited capacity of the Byron Bay stormwater drainage network, not the creek entrance conditions. Furthermore the costs associated were far in excess of the benefits and there may be negative impacts to the low lying ecosystems.

Due to these reasons, the current Belongil Creek ICOLL management approach is supported and it is recommended that Council continue to manage the creek entrance via manual opening, rather than establishing a permanent opening. However, due to the dynamic nature of tidal and flood conditions in the area, including future sea level rise, it is recommended that a long-term management plan is developed for the ICOLL. This management plan should be developed with consideration to the current opening trigger water level, and in combination with other floodplain management measures, such as relocation or modification of properties and infrastructure. The plan would be considered a dynamic document, with regular reviews embedded in the plan to ensure the management strategy remains suitable for natural conditions and floodplain objectives. Development of the plan should be completed prior to expiration of the current sand extraction license in 2019.

Table 6-1 Flood Modification Summary

Flood Modification Measure	Recommended	Benefit	Cost	Benefit Cost Ratio	Benefits	Constraints
Permanent Belongil Creek Entrance Opening	No	$210,000	$10,000,000	0.02	Slightly reduced peak in catchment runoff events Potentially better water quality in Belongil Creek	Higher peaks in storm tide events, more vulnerable to sea level rise impacts Prohibitive costs Negative impact on wetlands
Byron Drainage Strategy	Pending*	$7,516,000	$8,943,800	0.84	Reduces flooding at nominated flood prone sites, significant reduction of inundated properties Provides immunity against ocean storm surges within main town area Reduced stormwater pollution at Clarkes Beach and Belongil estuary	Annual maintenance of pumping stations Pump failure in flood event would cause significant residual risk
Preferred Byron Drainage Strategy	Pending*	$7,511,700	$9,440,100	0.80	Reduces flooding at nominated flood prone sites, significant reduction of inundated properties Provides immunity against ocean storm surges within main town area Reduced stormwater pollution at Clarkes Beach and Belongil estuary Development of wetland detention basin instead of pumps	Purchase of land for larger wetland detention basin
Drainage Infrastructure Maintenance	Yes	$106,800	$1,092,400	0.10	Reduced flood levels east of North Coast Railway line, reduction in inundation level for properties Reduce nuisance flooding	Initial and on-going costs of maintenance clearing of five major drain lines
North Coast Railway Bridge Widening	No	-	-	-	Slightly reduced peak flood levels in catchment runoff events	Higher peaks in storm tide events, more vulnerable to sea level rise impacts
Belongil Creek Entrance Strategy	Yes	-	$150,000	-	Reduction in flood levels under Council's duty of care responsibility to the community	-

* The Preferred Byron Drainage Strategy is the preferred scheme - pending land purchase prices. Should land purchase be prohibitively expensive, the secondary scheme, Byron Drainage Strategy, will be recommended.

7. Response Modification

Response modification measures are aimed at increasing the ability of people to respond appropriately in times of flood and/or enhancing the flood warning and evacuation procedures in an area.

Response modification measures are essential for managing residual flood risk. In general response modification measures are the simplest and most cost effective measures to implement, alongside planning measures for reducing risk to future development.

Byron Bay is a major tourist destination in Australia and attracts many visitors annually, consideration of how these non-resident people will behave in flood events is important within this FRMS.

The evacuation capability assessment indicated that in certain flood events, sectors within the catchment do not have sufficient time, prior to mobilisation of required resources, to issue a flood evacuation warning.

Real-time water level and rainfall data greatly assists disaster response management to monitor flood severity within a catchment. However, very little real-time monitoring is currently undertaken in the Belongil Creek Catchment.

The following response modification measures have been investigated as part of the Belongil Creek Floodplain Risk Management Study:

- Community Awareness:

As the community becomes more aware of the potential for flooding, preparedness for a flood event increases. Raised preparedness in a community increases the likelihood that a community will respond effectively to flood warnings. It is also noted that recovery after an event may also be quicker if a community is aware of the relative flood risk.

- Flood Warning, Flood Information & Emergency Planning:

An effective flood warning system, in combination with a high level of community awareness, is invaluable in minimising the flood damages and trauma associated with flooding. An accurate, prompt warning system ensures that residents are given the best opportunity to move themselves and their possessions out of the danger of floodwaters. Comprehensive emergency planning ensures that minimal time is wasted in the event of a flood and response measures are implemented efficiently.

A detailed description of the response modification assessments can be found in Discussion Paper 5 within the Discussion Paper Addendum. A summary table at the end of this section presents the results of the assessment and the proposed response modification measures recommended for inclusion in the floodplain management scheme by the Floodplain Management Committee.

7.1 Community Awareness

A Resident's Survey was carried out at the beginning of the study to gauge flood awareness and preparedness within the catchment. Flood awareness was found to be lower than other areas (such as Lismore) which had experienced major flooding in the recent past.

Very few respondents believed there was any significant personal risk of flooding, despite many of the surveyed areas being prone to flooding. Feedback from the community also indicated that Severe Weather Warnings were not reaching many of the population and that of those who did receive warnings, many did not believe them.

In addition to the information derived from the Resident's Survey, it is known that Byron Shire has a relatively transient population, with a high number of tourists and new residents in the area. As a result, the population is likely to be unfamiliar with flooding behaviour in the catchment and unaware of how to respond should a flood occur.

Due to the high level of transience in the Byron Shire population, standard flood education approaches may not be effective at reaching all of the population. Instead, a multi-pronged approach to community education is recommended which targets accommodation providers and new residents, as well as standard information for existing residents.

The measure would involve Council and the SES helping accommodation providers develop site-specific flood evacuation plans. These plans would likely include information about local flood behaviour, list sources of flood warnings and information (e.g. local radio stations) and identify the nearest evacuation centre (and route to get there). The plan should also outline how the accommodation provider intends to distribute the information to guests. For large accommodation providers, it may be prudent for the SES to issue flood warnings directly to these businesses.

New residents would be best targeted via real estate agents. It is recommended that a standard brochure is developed for new residents and provided to real estate agents to issue in rental information packs or at time of settlement.

To supplement the above approaches, the measure would involve a wide range of flood information be displayed in public places. This information could include signage to evacuation centres (or high ground), historic flood markers and informative signs about flood management infrastructure.

This measure has been recommended for inclusion in the floodplain management scheme by the committee.

7.2 Flood Warning

This measure would involve additional data sources being installed in the Belongil Creek catchment to supplement the existing rainfall and stream gauging stations. Installation of additional gauges should aim to improve the ability for Council and the SES to plan for floods. In particular, new gauges should increase the geographical coverage of data and /or provide data more frequently.

The measure would involve an ALERT stream gauge station being installed to provide real-time water level data in the catchment. A suitable location for the gauge would be the Ewingsdale Road Bridge, at the site of the existing manual gauge.

The measure would also include an additional rainfall gauge be installed in the catchment to improve the geographical coverage of information. This gauge is particularly important due to the lack of radar coverage in the Byron area. St Helena has been identified as a potential location for this gauge.

This measure has been recommended for inclusion in the floodplain management scheme.

7.3 Flood Information

A further benefit of a real-time stream level gauge would be the wide range of data which could be used by Council and the SES. The stream gauge height prediction could be converted into practical information on what a gauge height flood warning means and what action may need to be taken. This information can link predicted flooding (based on stream height predictions) with concrete actions, including the following:

- Identification of road closures for particular gauge heights;
- Identification of above floor inundation in buildings (if floor levels are provided); and
- Critical gauge heights for important infrastructure such as electricity substations and water treatment plants.

This information can be used to provide residents and tourists with a clearer idea of how much time they have, whether they need to move possessions to a higher level or remove them completely, if they need to gather sandbags or if they need to do anything at all.

Information can be provided in database (e.g. Excel), GIS formats or both. The information can also be used by the SES to generate a Flood Intelligence Card linked to the gauge.

For each flood level gauge, it is suggested that a "Flood Consequences" table be developed. The table should contain information on the consequences of flooding associated with a range of gauge heights (e.g. evacuation route inundated at gauge level of 2.1m).

The records that the SES currently hold regarding flooding are based on historical flood records. As part of the response modification measure associated with enhancing flood information the records could be enhanced and expanded to include information about very large flood events, which have not been experienced in the Belongil Creek catchment in recent history.

This measure has been recommended for inclusion in the floodplain management scheme.

7.4 Emergency Planning

There are several response modification measures that are considered to improve emergency planning which are detailed below.

In a flood event, once the SES has assessed the data received, their primary role is then to inform the community. To improve flood warning communication the response modification measure involves a review of flood and evacuation warning procedures, extending beyond the traditional methods (radio broadcasts, door knocking etc) to include internet based technologies, such as websites and social media. In addition, the measure includes setting up of automated telephone and SMS systems which can reach a wide audience. Using multiple warning methods will ensure that a high number of residents receive the warning and have sufficient time to evacuate safely. This review should also seek to identify suitable triggers which would prompt the evacuation of Belongil Spit before other areas in the catchment.

The evacuation capability assessment indicates that Jonson Street becomes inundated in small flood events and is unsuitable as an evacuation route during events exceeding the 10 year ARI for residents of BelongiI Spit. Anecdotal evidence from the SES confirms that Jonson Street is frequently affected by flooding. To take account of this, the response modification measure involves the investigation of an alternate route which is primarily on high ground and will have far greater flood immunity and Belongil Spit residents will be prioritised as a part of targeted evacuation and warned in advance of other sectors to improve the likelihood of safe evacuation from this area. However, it should be noted that a small section of the route at the intersection of Middleton Street and Lawson Street is likely to be inundated in the PMF. It may be possible to construct flood free access behind the dunes should this risk of inundation in the PMF be considered unacceptable. The measure also includes specific targeted education for the residents and businesses in the Belongil Spit area about their increased flood risk and the likelihood of early evacuation.

This measure has been recommended for inclusion in the floodplain management scheme.

Figure 7-1 Alternate Evacuation Route Map

LEGEND

- Primary Evacuation Centre
- Alternate Assemby Areas
- Evacuation Route Closure Location and Time
- Evacuation Route
- Alternate Evacuation Route
- Potential Future Evacuation Route
- Evacuation Sector
- Cadastre

PMF Event Peak Flood Depth (m)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- > 3.0

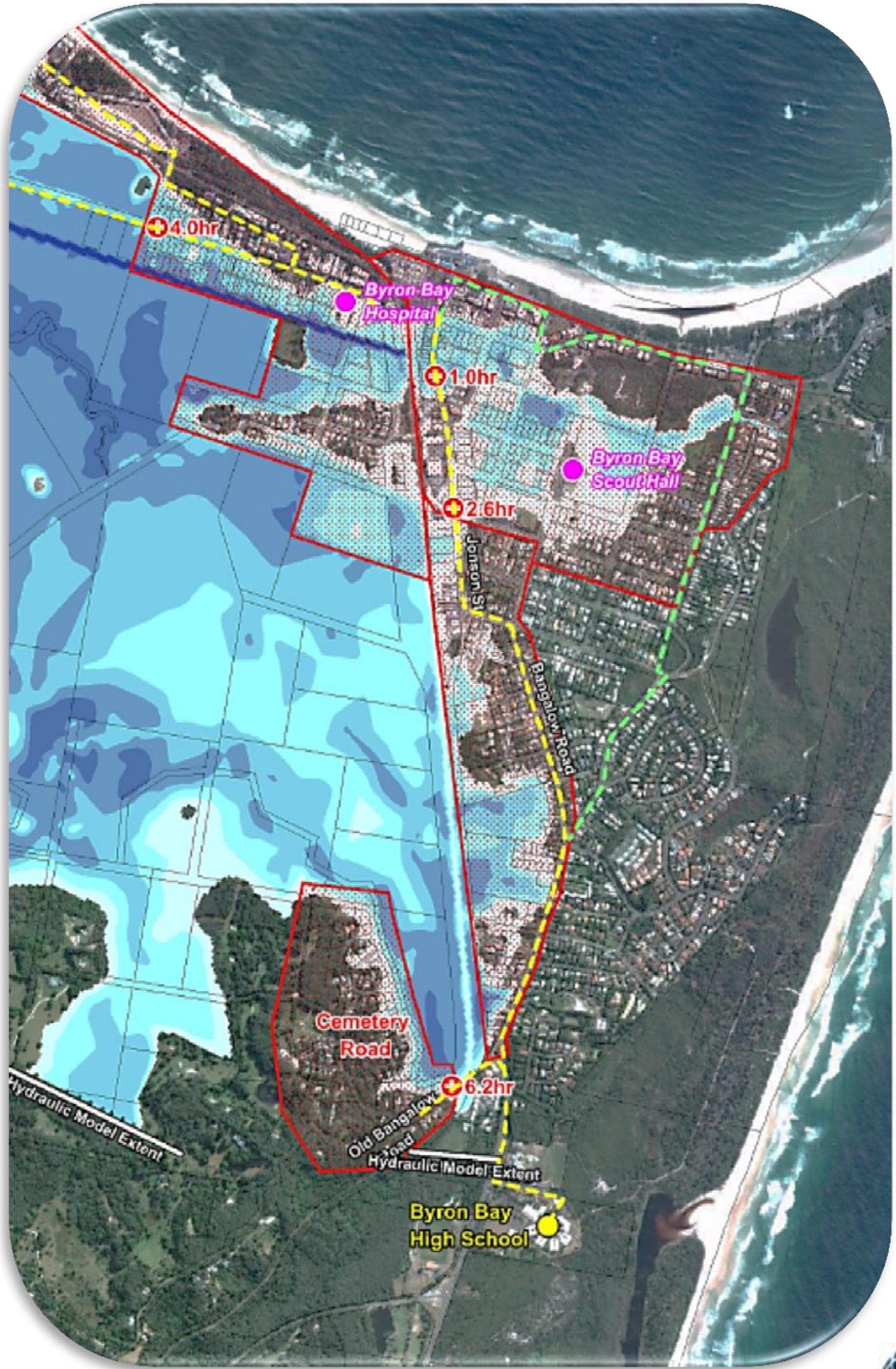

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Table 7-1 Response Modification Measure Summary

Response Modification Measure	Recommended	Plan	Target	Benefit
Community Awareness	Yes	Multi-faceted community awareness campaign	Accommodation providers, new residents and existing residents	Familiarity with local risk factors, residents able to appropriately respond to flood warnings
Flood Warning	Yes	Real time ALERT gauge at Ewingsdale Road Bridge	SES and Council	Source of real time water level information, replacing need for manual checking
	Yes	Rainfall gauge at St Helena	SES and Council	Spatial coverage of local rainfall to better predict and plan flood impact
Flood Information	Yes	Develop flood information data set	SES and Council	Better understand how predicted water level will affect catchment
	Yes	Review flood emergency procedures using design storms	SES	Expansion of emergency plans to include larger events
Emergency Planning	Yes	Internet based flood communications and SMS systems	Residents	Improves community information and warning times
	Yes	Identification of an alternate evacuation route for Jonson Street	SES	Alternate route with greater flood immunity for safer and more efficient evacuation
	Yes	Prioritise evacuation of Belongil Spit	SES	Most vulnerable residents evacuated first
	Yes	Targeted education of Belongil Spit residents	SES and Council	Better understanding of flood risk

8. Property Modification

Property modification measures can be applied to existing developments to either reduce the flood risk by raising a house or by removing the property from the flood prone location. They also seek to reduce flood risk through careful planning of future developments; this is dealt with separately in Section 9.

Property Modification is a non-structural solution to manage existing and future flood risk. This is usually achieved through two means:

- Voluntary house purchase.
- Voluntary house raising.

A detailed description of the property modification assessments can be found in Discussion Paper 6 within the Discussion Paper Addendum.

8.1 Voluntary House Purchase and Raising

Voluntary house purchase aims to reduce risk to life-and-limb by purchasing houses located in high hazard flood prone areas, removing residents from areas of high flood risk. Such measures can only be undertaken on a voluntary basis with the property owner. Post-purchase the property should be rezoned for flood compatible use (e.g. parks). The voluntary purchase of houses is specifically undertaken to protect the lives of the occupants and intangible damages such as health, trauma and stress; as such a benefit-cost ratio to assess this measure’s relative value is not quantifiable. No properties were identified within the Belongil Creek catchment, as being eligible under the State Government’s funding scheme for houses in high hazard areas.

Voluntary house raising aims to reduce flood damage to houses located in areas of low flood hazard by raising the habitable floor level of individual buildings to a specified level. Thus, the number of houses that are inundated during a flood event may be reduced. Houses considered have floor levels below the 20 year ARI peak flood level and are not slab-on-ground constructions or double storey. Four houses were identified to be raised, resulting in reduced flood damages of approximately $227,000 and benefit cost ratio of 0.84

The adoption and subsequent implementation of either the Byron Drainage Strategy/Alternative Byron Drainage Strategy and the Drainage Infrastructure Maintenance flood modification measures will reduce the impact of flooding within Byron Bay. As a result, three of the four properties identified for voluntary house raising will no longer be at risk in events up to the 20 year ARI. The remaining property is classed as a small building and would cost $60,000 to raise. The reduction in damages is expected to be $54,500.

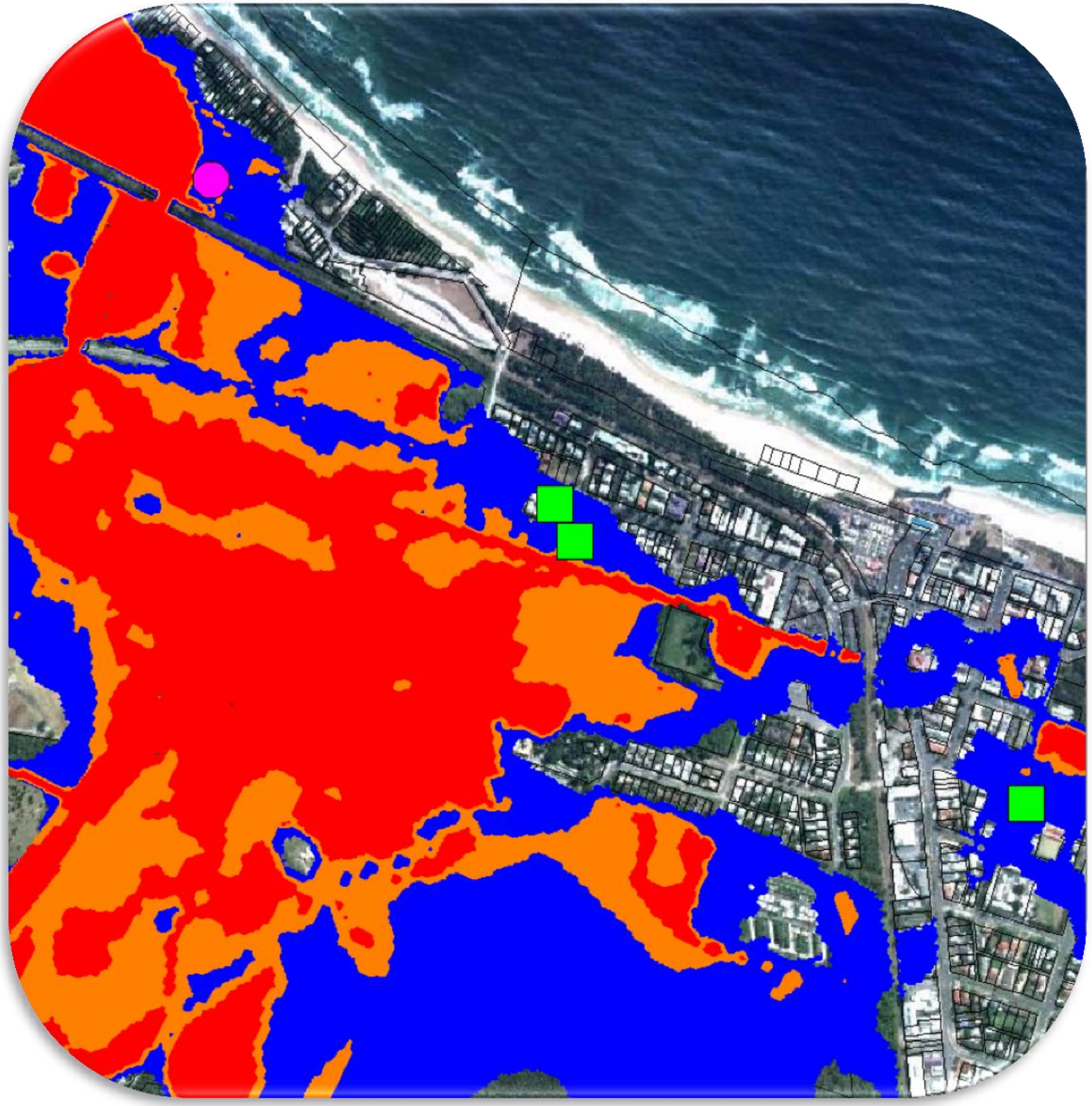
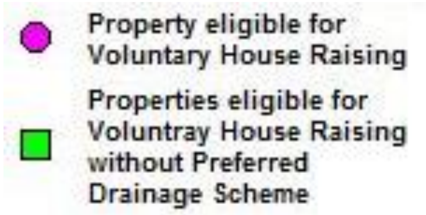
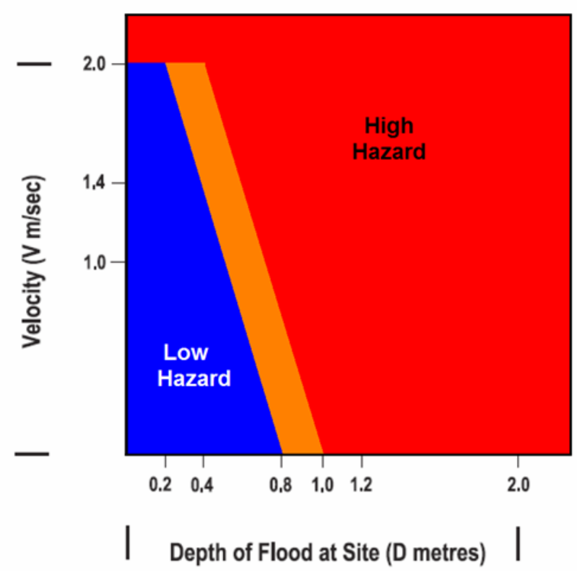


Figure 8-1 Property Modification





9. Planning and Future Development

Land use planning and development controls are the most effective measures for managing flood risk to future development. Planning mechanisms can maximise the compatibility of new development with flood risk, taking into consideration both current and potential future climate conditions. They can also gradually reduce the risk to existing development over time through sensible redevelopment.

Appropriate planning policies are required to ensure future development within the floodplain is flood compatible, managing the level of flood risk exposure and also associated flood damages for future residents.

Previous development controls permitted consideration of development for various land use types in high flood hazard area.

A number of assessments have been used to inform planning and future development measures for the Belongil Creek catchment.

A detailed description of the planning and climate change and future development assessments can be found in Discussion Papers 6, 7 and 8 located within the Discussion Paper Addendum.

9.1 Cumulative Development Assessment

The Belongil Fields assessment considered the likely flood impacts associated with a single large scale greenfield development. In addition to this, it is important that the cumulative impact of progressive development be evaluated, particularly with respect to floodway and flood storage areas. Whilst the impact of individual developments may be small, the cumulative effect of the ultimate development of an area can be significant and may result in unacceptable increases in flood levels and flood velocities elsewhere in the floodplain.

Cumulative development has been assessed via the definition of the following hydraulic categories, as defined by the NSW Floodplain Development Manual (DIPNR, 2005):

- Floodways
- Flood storage areas
- Flood fringe.

The results of the cumulative development assessment if adopted would define four zones based on hydraulic category.

Table 9-1 Development Zones

Development Zone	Floodplain Location	Hazard Level	Development Actions
No Development	Floodway	High	No Development
Low/ Intermediate Hazard Flood Storage	Flood Storage Area	Low/ Intermediate	Development applications should be assessed for potential impacts on offsite flood levels No net floodplain storage change
Low/ Intermediate Hazard Flood Fringe	Flood Fringe	Low/ Intermediate	Development applications should be assessed for potential impacts on offsite flood levels
Low Hazard Flood Affected	Outside 100 year ARI flood event but within PMF flood extent	Low	Development applications within this zone should be approved without the requirement for a flood impact assessment, with the exception of critical infrastructure.

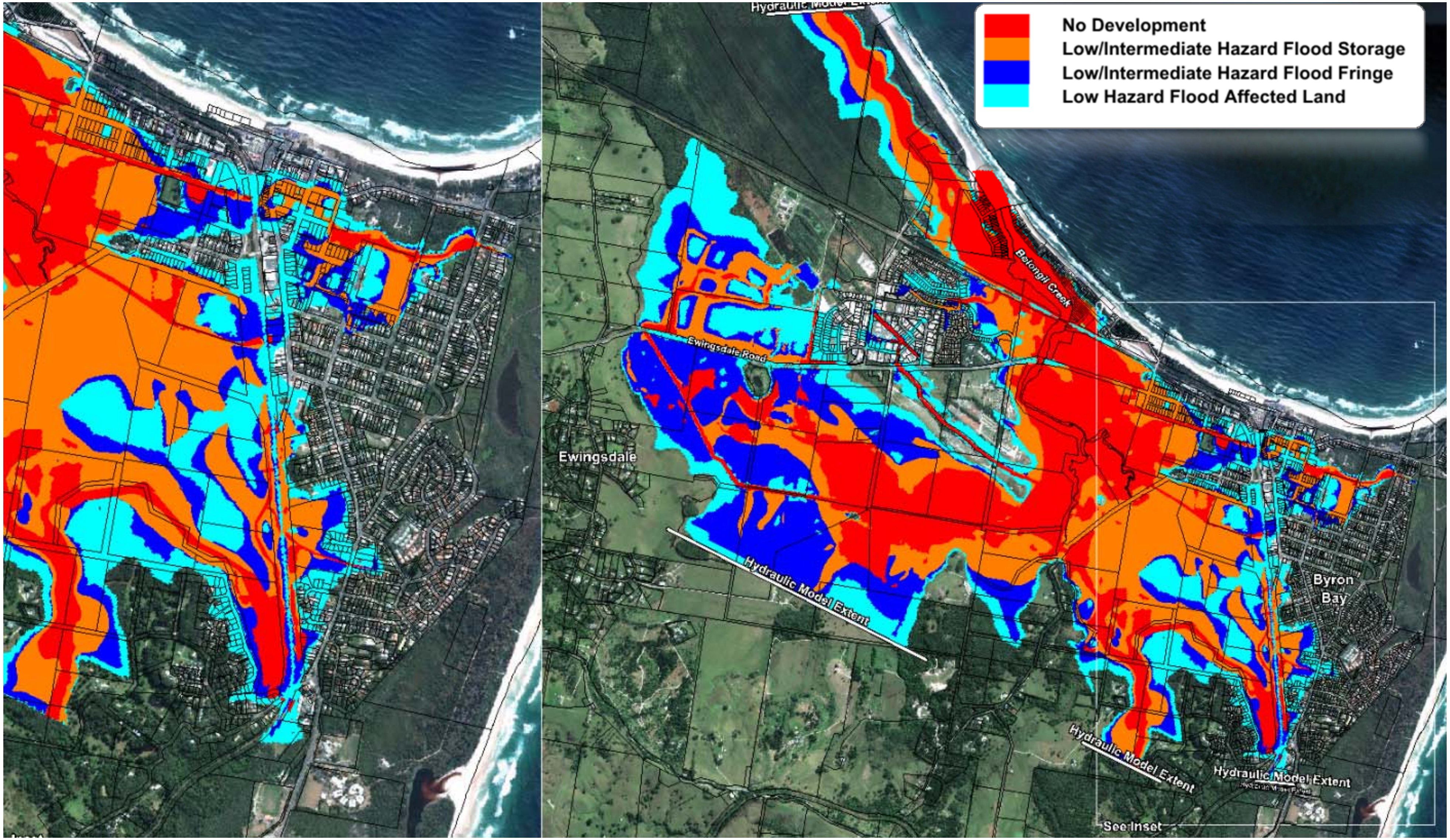


Figure 9-1 Future Development Zones

9.2 Flood Planning Levels

Flood planning levels (FPL) represent an important development control tool used to manage future flood risk within the floodplain. Appropriately defined flood planning levels aim to define fill and floor levels required for future developments within the floodplain.

Consideration of climate change impacts during the selection of the flood planning levels is an effective flood risk management measure aimed at mitigating the increased flood risk for future residents and the increased flood damages associated with future development within the areas likely to be impacted by future climate change.

Different FPLs should be recommended for different building types based on importance, from sheds to hospitals and critical infrastructure. The measure has been developed in accordance to the Draft Revised Climate Change Strategic Planning Policy (BSC 2014).

Table 9-2 Flood Planning Levels

Code	Name	Description			General Applicability
		Flood Event	Climate Change Allowance	Freeboard (m)	
FPL1	Projected 2050 Flood Planning Level	100 year ARI, 2050 Climate	0.4m sea level rise	0.5m	All development with the exception of new release areas, re-zonings, critical infrastructure and special purpose facilities
FPL2	Projected 2100 Flood Planning Level	100 year ARI, 2100 Climate	0.9m sea level rise	0.5m	New release areas, re-zonings, critical infrastructure and special purpose facilities.

9.3 Potential Future Development Areas

The future development assessment aimed to determine any potential changes in flood behaviour and the associated flood risk due to the potential development of key greenfield sites within the Belongil Creek catchment. Currently, the Byron Bay and Suffolk Park Settlement Strategy 2002 recommends that there be no intensification of development on flood prone land until such time that a floodplain risk management plan is adopted for the Belongil Creek catchment.

Within the Settlement Strategy, four areas are identified which may be suitable for rezoning and development. Area 1 is entirely inundated in storms as small as the 5 year ARI and is within a high hazard zone; as such it is not considered appropriate for further development. Areas 3 and 4 are both located outside the PMF flood extent and will not have an impact on surrounding flood levels and were consequently not assessed.

Area 2, generally referred to as the Belongil Fields area is located on both sides of Ewingsdale road. Council's Strategy states that the area north of Ewingsdale Road is not suitable for residential subdivision due to ecological constraints. However, the area south of the Ewingsdale Road is environmentally unconstrained and physically capable of residential development, with significant portions of the site remaining flood free during the PMF event. As such, from a flooding perspective, this site may be viable for future development. Within the Draft Byron Local Environmental Plan 2012, the landuse zoning for the Area 2 site was listed as a deferred matter. If rezoning of the site is considered by Council in the future, the results of this assessment will be used to inform the change in land use.

Various scenarios of fill and development were tested in Area 2 to demonstrate the application of the future development zones. If rezoning of Area 2 for residential or commercial/industrial development is considered by Council the rezoning should be limited to the 'Low/Intermediate Hazard Flood Fringe and Flood Storage Zones'. The rezoning approval should be conditioned, pending the completion of a flood impact assessment which demonstrates that the proposed development layout does not adversely impact surrounding flood levels. Development within the Low/Intermediate Hazard Flood Storage zone will require compensatory cut/fill earthworks to ensure that floodplain storage is not impacted within this region.

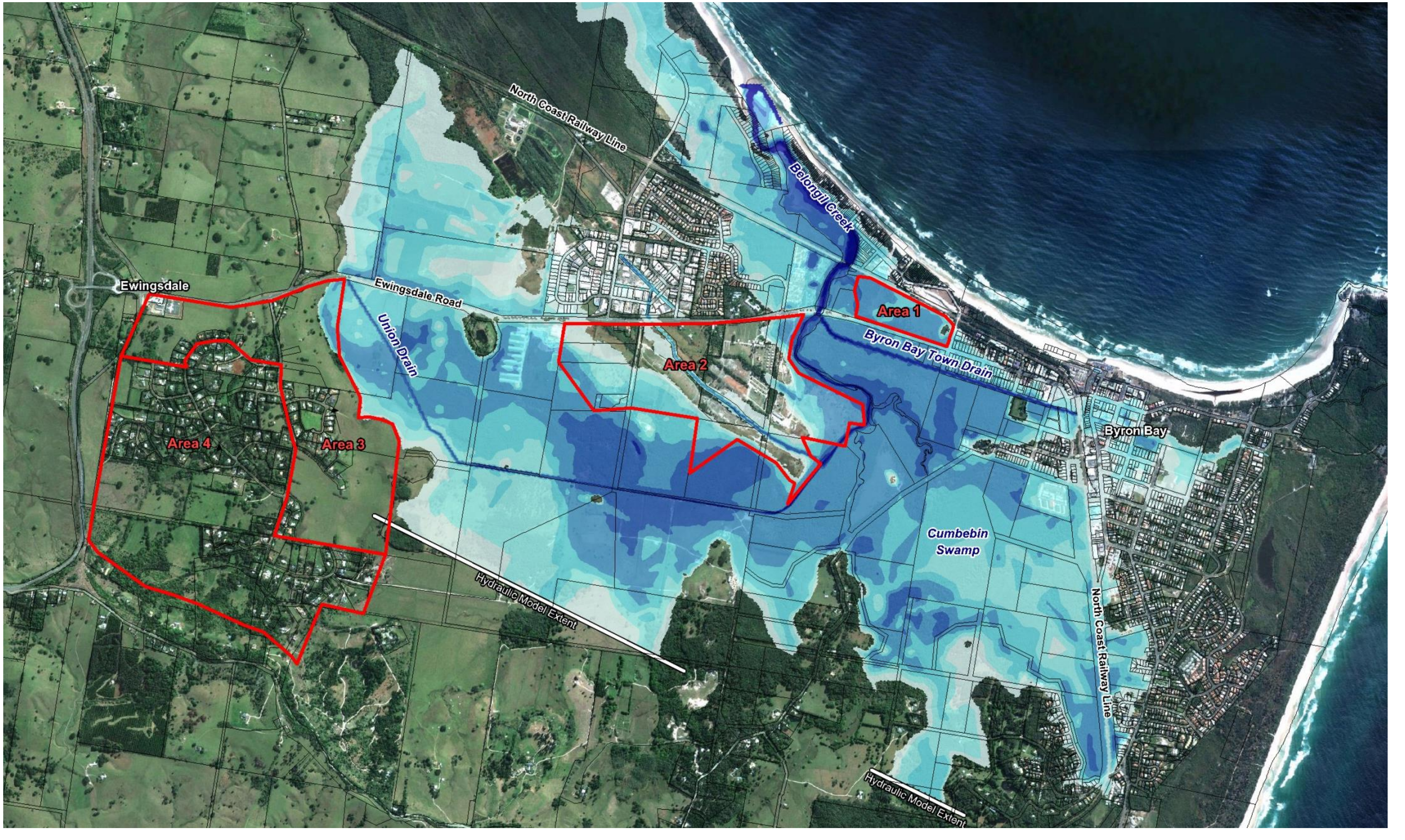


Figure 9-2 Potential Future Development Areas

9.4 Flood Planning Matrix

Development in flood prone areas needs to be tailored to manage the potential exposure of future residents to unacceptable levels of risk. To inform development in these areas a flood planning matrix has been recommended. The flood planning matrix divides the floodplain into bands flood hazard and prioritises different land use categories based to sensitivity to that hazard. The Flood Planning Matrix aims to provide an assessment framework which prevents inappropriate development within the floodplain.

Consideration is given to human safety, property protection, economic factors and social impacts. This is used to determine which land uses are desirable or unsuited in each flood hazard band and prescribe planning controls. Appropriate planning policies are required to ensure future development within the floodplain is 'flood compatible', managing the level of flood risk exposure and also associated flood damages for future residents.

The flood planning matrix utilises three newly developed FPLs derived through the climate change assessment. These FPLs define minimum fill and floor levels for future development.

The flood planning matrix also references the appropriate development zones based on the cumulative development assessment previously described in this section.

The adoption of the flood planning matrix will result in:

- More stringently restricted incompatible floodplain development within high hazard areas.
- Restricted development of critical infrastructure and emergency services to flood liable lands.
- Prescriptively listed development control measures based on land use type and flood hazard category.

In addition, the development controls derived in the cummulative development assessment should be adopted within the Flood Planning Matrix to manage the possible flood impacts associated with future cumulative development within the Belongil Creek catchment.

Refer to Discussion Paper F for flood planning matrix details.

Table 9-3 Flood Planning Matrix (from BSC DCP 2014)

CONTROLS	DEVELOPMENT / BUILDING TYPE	Primary Constraints[1] Existing Climate Flood Hazard Categories			Additional Constraints[1] Future/Extreme Event Flood Hazard Categories	
		No Hazard	**Low/Intermediate Hazard**	**High Hazard**	**2100 Climate Change Planning Horizon - 100 Year Low/Intermediate Hazard**	**2100 Climate Change Planning Horizon - 100 Year High Hazard**
Land Use	Development in **New Release Areas**, unless separately defined below	N/A	SF2		SF2	SF2
Suitability & Fill Level	Development in all other areas unless separately defined below	N/A	SF1		SF1	SF1
	Non-Habitable Building or Room (e.g. shed, carport, garage, toilet, laundry, shelter, etc)	N/A	SF1	SF1	SF1	SF1
	Emergency Services **Critical Facilities** Site (Hospitals, etc.)	N/A	SF3a		SF3a	
	Other **Special Purpose Facilities** (School, etc.)	N/A	SF3b		SF3b	
Floor Level	Development in **New Release Areas** unless separately defined below	FL3	FL3		FL3	FL3
	Development in all other areas unless separately defined below	FL2	FL2		FL2	FL2
	Dwelling Additions, except in **New Release Areas**	N/A	FL4		FL4	FL4
	Non-Habitable Building or Room (e.g. shed, carport, garage, toilet, laundry, shelter, etc)	N/A	FL1		FL1	FL1
	New **Critical Facilities** (Hospitals, etc.) or **Special Purpose Facilities** (School, etc.)	FL3a	FL3a		FL3a	
Building Components	All	N/A	BC1		BC1	BC1
Structural Soundness	Ancillary Building (e.g. shed, carport)	N/A	SS1	SS1	SS1	SS1
	Other Building	N/A	SS1	SS2	SS1	SS1
Flood Effect	Development in **New Release Areas**, unless separately defined	N/A	FE2		FE2	FE2
	Development in all other areas unless separately defined below	N/A	FE2		FE1	FE2
	Alterations and Additions, Non-Habitable Building or Room (e.g. shed, carport, garage, toilet, laundry, shelter, etc)	N/A	FE1		FE1	FE1
	Other Developments (road raising, etc)	N/A	FE3	FE3	FE3	FE3
Evacuation &	Development in all other areas unless separately defined below	N/A	EA1		EA1	EA1
Access	Development in **New Release Areas**, unless separately defined	N/A	EA2		EA2	EA2
	Critical Facilities (Hospitals, etc.)	N/A	EA3a		EA3a	
	Other **Special Purpose Facilities** (Schools, etc.)	N/A	EA3b		EA3b	

1. Refer to relevant flood study for definition of hazard categories

N/A	Controls Not Applicable

	Unsuitable Land Use - Not considered suitable for development
CONTROL MEASURES	
	LAND USE SUITABILITY & MINIMUM FILL LEVEL
SF1	Consider for development subject to the controls below. No minimum fill level required.
SF2	Consider for development subject to the controls below. For new residential, commercial and industrial release areas, the minimum fill level to be greater than or equal to the 1:100 ARI (average recurrent interval) flood event plus projected climate changes allowances for the year 2100
SF3a	Consider for development subject to the controls below. Where possible Emergency Services should be located on land currently flood free during the **PMF** event. Where practical the minimum fill level should be greater than or equal to the existing climate **PMF** flood level.
SF3b	Consider for development subject to the controls below. Council to give consideration on the benefits of using the development during and after a flood emergency. existing climate **PMF** flood level.
	MINIMUM FLOOR LEVEL
FL1	All floor levels to be greater than or equal to the 10 year flood level plus 0.3m.
FL2	All floor levels to be greater than or equal to the ***Projected 2050 Flood Planning Level*** (FPL2).
FL3	All floor levels to be greater than or equal to the ***Projected 2100 Flood Planning Level*** (FPL3).
FL3a	If practical, all floor levels to be greater than or equal to the ***Projected 2100 Flood Planning Level*** (FPL3), so that these buildings will be available for accommodation / storage during and after a flood emergency.
FL4	Floor levels to be as close to the *minimum floor level* above (FPL2) as practical and not less than the floor level of the existing building being extended if the existing floor level is less than or equal to the minimum floor level. If the extended weatherproof area exceeds 50% of the existing weatherproof area, the extension is treated as a new building. The extended weatherproof area is measured as the cumulative area of any previous extensions plus the proposed extension. If building is identified as being suitable for voluntary house raising scheme, Council to discuss potential house raising with owner.
	BUILDING COMPONENTS
BC1	Buildings to have **flood compatible material** below the relevant ***flood planning level*** according to development/building type. Refer to Flood Proofing Section.
	STRUCTURAL SOUNDNESS
SS1	No structural soundness requirements for the force of floodwater, debris & buoyancy. Must still comply with Building Code of Australia requirements.
SS2	Engineers report to prove that structures subject to a flood up to the 100 year event can withstand the force of floodwater, debris & buoyancy.
	FLOOD EFFECT
FE1	No action required
FE2	The flood impact of the development to be considered by Council, with Council having the right to request an engineer's report (see FE3 below)
FE3	Engineers report required to prove that the development will not result in adverse flood impact elsewhere
	EVACUATION/ACCESS
EA1	Council to provide information on flood evacuation strategy
EA2	Site specific Flood Evacuation Strategy be developed consistent with Council / SES overall Flood Evacuation Strategy.
EA3a	Emergency service site - should have good access up to the **PMF** and preferably not cut-off from the main residential area(s). Council to evaluate suitability of site in this respect.
EA3b	If site to be used during and after a flood emergency (see FL3a above), should have good access up to the **PMF** and preferably not cut-off from the main residential area(s).

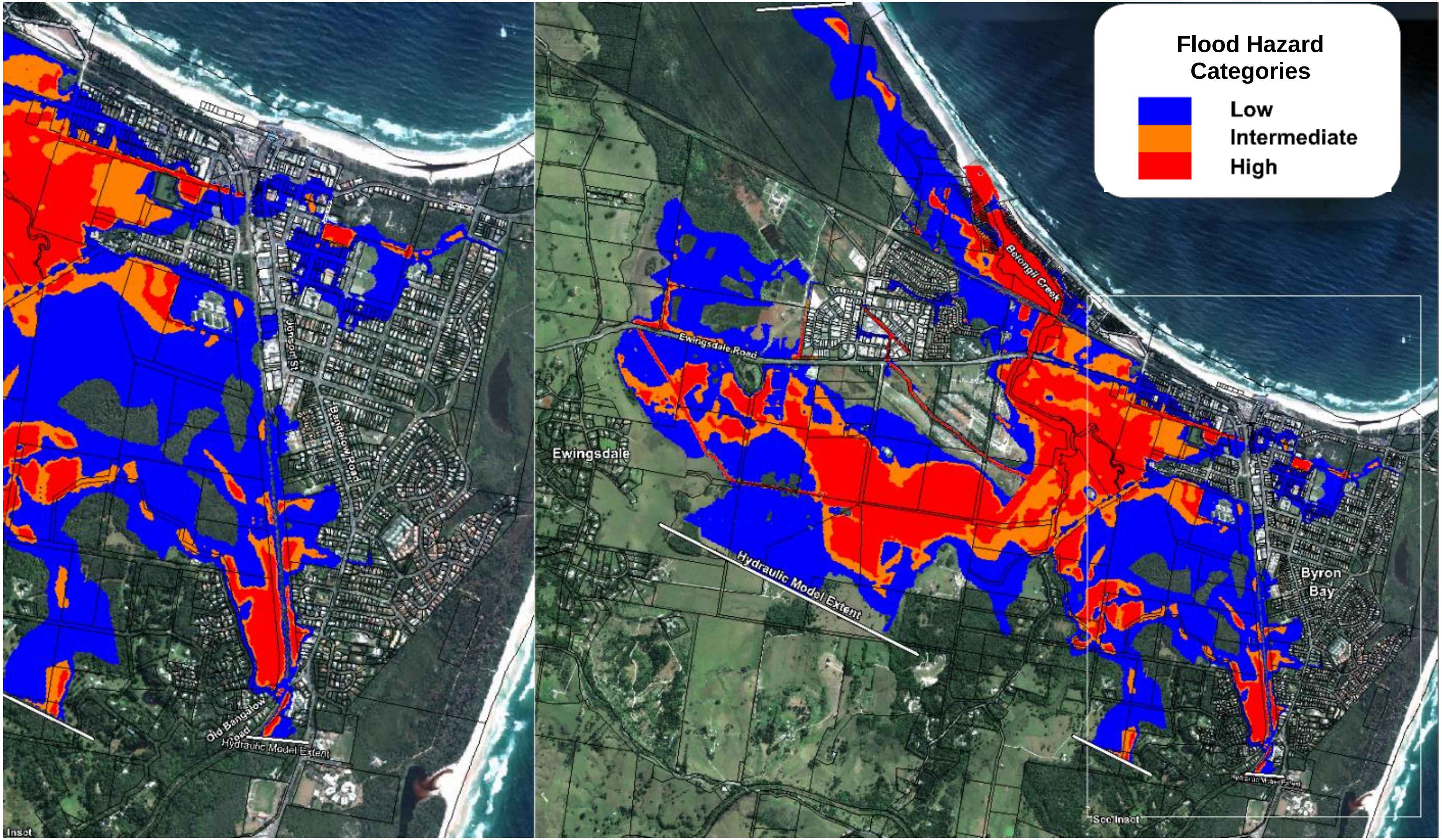


Figure 9-4 100 Year ARI Event Peak Flood Hazard

Table 9-4 Property Modification Summary

Property Modification Measure		Recommended	Plan	Target	Benefit
Voluntary House Raising		Yes	Engage owners regarding possible raising of flood prone property	Residents	Reduction in flood damages
Flood Planning Matrix	Limit Future Development in Area 2	Yes	Limit development of Area 2 to portions of the floodplain which are classified as being low flood hazard	Council	Ensure that future development is compatible with flood hazard.
	Definition of Four Planning Zones	Yes	Define four zones based on hydraulic category	Council	
	Flood Planning Levels	Yes	Adoption of two flood planning levels corresponding to development type.	Council	

10. Floodplain Management Scheme

The Floodplain Risk Management Study is the result of detailed investigation and consideration of flood risk across the Belongil Creek catchment. The FRMS provides for the assessment of options that form the basis for the consideration and decisions in future floodplain risk management planning. Detailed considerations have been made into the risks to both people and property, now and in the future. The Belongil Creek Floodplain Risk Management Committee has guided and informed the selection of measures. The recommended floodplain management scheme reduces Annual Average Damages in the catchment by 49% from $1,255, 500 to $634,700.

Most of the floodplain management measures are non-structural, such as community awareness, emergency planning and development control planning. The major structural option recommended is the Preferred Byron Drainage Strategy, which is designed to reduce localised flooding at nominated sites, increase flood immunity against storm surges within the main town area and reduce pollution at Clarkes Beach and Belongil Estuary though wetlands and pollutant traps.

The following table summarises the cost of each of the recommended floodplain management measures and the total cost of the floodplain management scheme.

Table 10-1 Floodplain Management Scheme Measures and Costs Summary

Floodplain Modification Measure	Description	Cost
Flood Modification	Preferred Byron Drainage Strategy	$9,440,100
	Drainage Infrastructure Maintenance	$1,092,400
	Belongil Creek Entrance Strategy	$150,000
Response Modification	Community Awareness	$10,000*
	Flood Warning ALERT gauge and Rain gauge	$40,000*
	Flood Information	$35,000
	Emergency Planning (SMS messaging)	$2,000*
Property Modification	Voluntary House Raising (1 Property)	$60,000
	Flood Planning Matrix	Operating Costs
	Total Scheme Cost	**$10,829,500**

* Not including additional annual maintenance and operating costs.

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The following table summarises the benefits or damages avoided of each of the recommended floodplain management measures and the total benefits of the floodplain management scheme.

Table 10-2 Floodplain Management Scheme Benefits and Costs

Event (ARI)	Base Case		Floodplain Management Scheme		Average Annual Benefit
	Total Damages	AAD	Total Damages	AAD	
5	$2,525,700	$378,900	$1,249,000	$187,400	$191,500
10	$3,046,900	$278,600	$1,437,500	$134,300	$144,300
20	$4,004,900	$176,300	$1,678,900	$77,900	$98,400
100	$7,449,900	$229,100	$3,657,000	$106,700	$122,400
PMF	$31,067,500	$192,600	$22,019,400	$128,400	$64,200
Average Annual Damage		$1,255,500		$634,700	$620,800
Total Scheme Benefit					$8,567,500

The overall benefit cost ratio of the scheme is presented below.

Table 10-3 Floodplain Management Scheme Benefit Cost Ratio

Total Scheme Benefit	Total Scheme Cost	Scheme Benefit Cost Ratio
$8,567,500	$10,829,500	0.79

The monetary benefit-cost ratio represents only one of the issues that must be considered in respect to the viability of a floodplain management measure. Issues classed as intangible such as social and psychological impacts, risk to life and cultural factors are difficult to assign a monetary value and are not included within the analysis. Therefore, measures with a ratio of less than 1.0 may be considered appropriate, given that the economic analysis does not include the intangible benefits.

It should be noted that the economic case presented for the floodplain management scheme includes the Preferred Byron Drainage Strategy which is currently pending recommendation while the outcome of land purchase considerations are on-going. Should the Preferred Byron Drainage Strategy be unfeasible due to land purchase considerations, the Byron Drainage Strategy will be recommended for inclusion in the floodplain management scheme.

The costs of the Byron Drainage Strategy are estimated to be $4,000 more than the Preferred Byron Drainage Strategy (not including land purchase or detailed design costs). The benefits of both schemes are similar with a resulting benefit cost ratio for the scheme with the Byron Drainage Strategy of 0.65.

The floodplain management measures are complimentary to each other, building resilience across the community in terms of current, future and residual flood risk. No one single measure will result in flood free community but as an integrated set they build towards increased reduction in the impacts of flooding across the Belongil Creek catchment.

A summary of all measures recommended in the floodplain management scheme is provided overleaf. The table describes the type of flood risk reduced (current, residual or future) and provides information on the measures benefits e.g. reduction of risk to people, property, awareness and improvements to the environment.

Floodplain Management Measures	Description	Flood Risk Reduced				Measure Result		
		Belongil Creek			Storm Tide	Reduction of Risk to People	Reduction of Risk to Property	Ecological Improvement
		Current	Residual	Future				
Alternative Byron Drainage Strategy	Improved drainage and wetland creation	●			●	●	●	●
Drainage Infrastructure Maintenance	Clearing and maintenance of drainage lines	●			●	●	●	●
Belongil Creek Entrance Strategy	Develop long term opening strategy for creek mouth	●		●		●	●	●
Community Awareness	Multi-faceted community awareness campaign		●			●	●	
Flood Warning	Real-time ALERT gauge at Ewingsdale Road Bridge		●	●	●	●	●	
	Rain gauge at St Helena		●	●		●	●	
Flood Information	Develop detailed flood information data set		●	●	●	●	●	
	Review flood emergency procedures using design storms		●	●	●	●	●	
Emergency Planning	Internet based flood communications and SMS systems		●		●	●	●	
	Alternative evacuation route for Jonson Street		●			●		
	Prioritise evacuation of Belongil Spit	●	●	●	●	●		
	Targeted education of Belongil Spit Residents	●	●	●	●	●	●	
Voluntary House Raising	Voluntary House Raising		●	●		●	●	
Flood Planning Matrix	Limit future development in Area 2 to low hazard area in DCP			●	●		●	
	Inclusion of 4 planning zones into DCP			●			●	
	2 FPLs according to development type into DCP			●			●	

Glossary

Average Recurrence Interval (ARI) – the likelihood of occurrence, expressed in average number of years, between flood events as large as or larger than the design flood event. For example, floods with a discharge as large as or larger than the 100-year ARI flood will occur on average once every 100-years (Flood Victoria)

Average Annual Damage (AAD) - average damage per year that would occur in a particular area from flooding over a very long period of time. Damages are weighted by likelihood, in some years there will be minor damage (caused by small, relatively frequent flood events) and in some years there will be major damage (caused by large, rare flood events).

Australian Height Datum (AHD) - the adopted national height datum that generally relates to height above mean sea level. Elevation is in meters.

Probable Maximum Flood (PMF) - the largest flood that could conceivably occur at a particular location. This flood defines the maximum extent of land liable to flooding.

Critical Duration – The duration of a specific flood event (ie: the 100 year ARI) which creates the greatest depth

Average Annual Benefit – Average benefit per year that would occur should a particular plan be implemented.

Benefit Cost Ratio – Comparison of the present value of an investment decision with its cost. Values smaller than 1 indicate that costs outweigh benefits and values larger than 1 indicate benefits outweigh costs.

Fluvial – produced by the action of a river. Eg: a fluvial floodplain, fluvial flooding as opposed to storm tide flooding

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