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TWEED VALLEY FLOODPLAIN RISK MANAGEMENT STUDY

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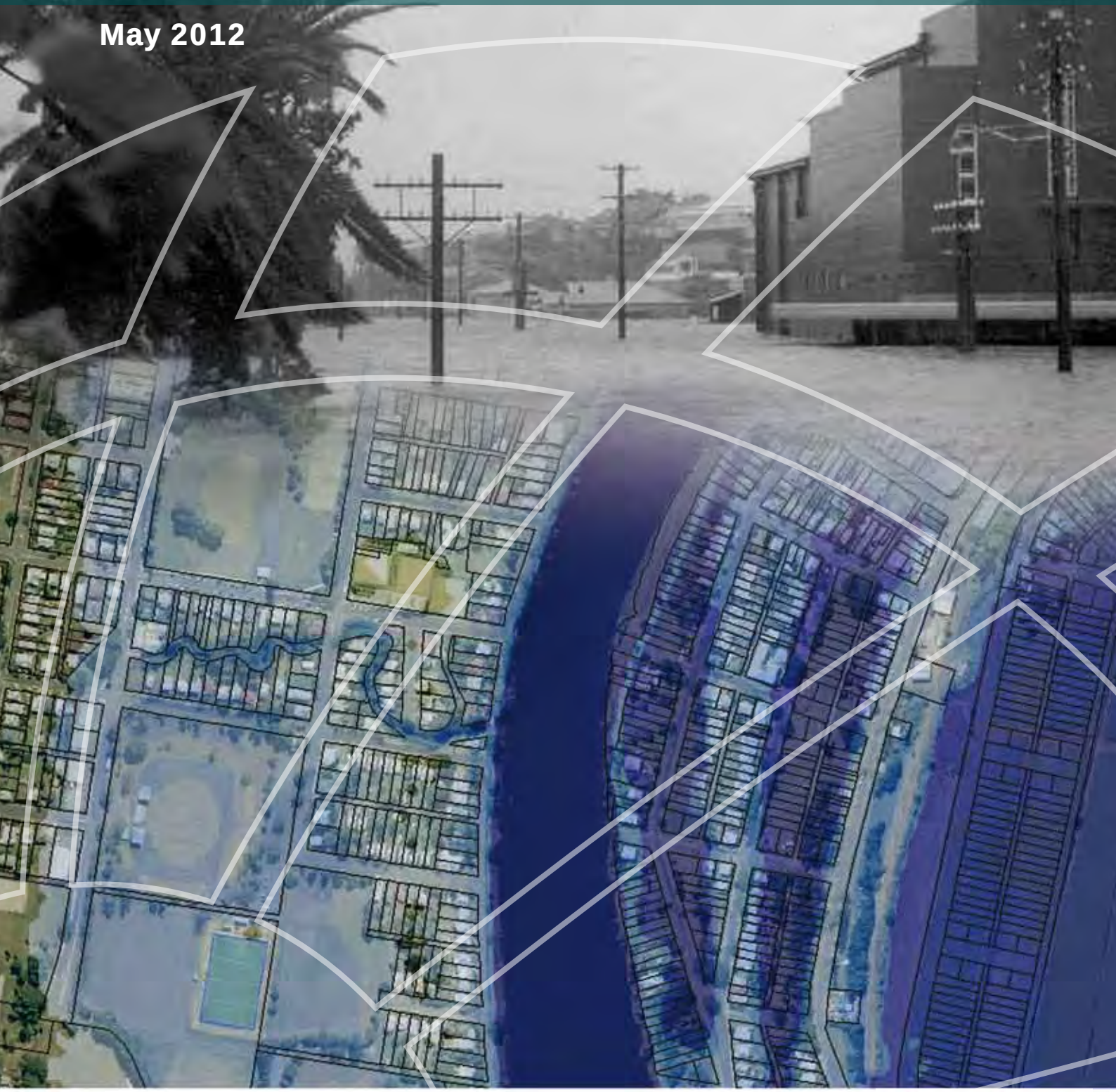

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Tweed Valley Floodplain Risk Management Study (DRAFT)

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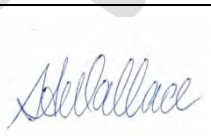
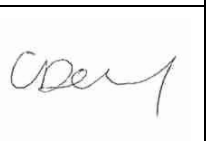
0	22 May 2012	SAW		CD	

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EXECUTIVE SUMMARY

This Study draws together a wide range of floodplain management options which have been investigated as part of the Tweed Valley Floodplain Risk Management Study. These options have been identified through extensive consultation with agencies including Tweed Shire Council, the State Emergency Service, Office of Environment and Heritage, and the Bureau of Meteorology, as well as stakeholder consultation.

Each option was investigated to determine the likely impacts to safety, the environment, property, social issues, and hydraulic behaviour. Where possible, the economic cost and benefits of implementing each measure was also estimated. A thorough analysis of each considered measure is contained in a compilation of Discussion Papers, prepared as working documents during the study. This document summarises the existing flood risk, describes relevant benefits and constraints to various floodplain management measures, and considers the planning and development issues associated with a region facing significant development pressures.

Existing Flood Risk

The Tweed Valley study area has a long history of flooding and will continue to flood in the future. The extent, behaviour and likelihood of future flooding was assessed through the Tweed Valley Flood Study Update and that information was used in this study to determine the current flood risk. There was found to be a high level of flood risk in the study area.

There is a considerable number of people and properties located in flood prone land (within the Probable Maximum Flood (PMF) extent), including a large number at risk in the 100 year Average Recurrence Interval (ARI) flood. Flood depths and flows are of a dangerous magnitude in many locations and flood waters can rise quickly, often with short warning periods. This can pose a high risk to personal safety and has the potential to cause extensive damage to properties and infrastructure. A large number of major roads are affected by flooding and would constrain the evacuation process.

Estimated population currently in flood prone land: ***41,500 people***

Estimated Average Annual Damage (AAD) due to current flood risk:
$22.3 million

The community is also recognised to be highly vulnerable to the impacts of flooding. In general, the population is older than other areas of the state, there are often a large number of tourists who are unfamiliar with local flood risk, and there are many riverside caravan parks.

Past efforts to reduce the flood risk have resulted in levees in Murwillumbah and Tweed Heads South, as well as a voluntary house purchase and house raising program. The SES has also developed an extensive Local Flood Plan, which details flood risk and evacuation procedures. However, since these flood management options were undertaken, development has intensified and we have improved our understanding of flood behaviour in the area. It is therefore timely to reassess the options to manage flood risk, whether through **flood, response** or **property modification** measures.

Flood Modification Measures

Catchment scale flood modification options, including dams and floodways, were considered but none were identified as both effective and feasible. It is however recommended that additional studies be undertaken to investigate and manage flood risk behind levees, and from local drainage and stormwater in key locations throughout the catchment.

A preliminary hydraulic analysis and cost benefit analysis was completed to determine how much additional protection the Tweed Heads South levee would provide to people and property, if it were raised to provide protection up to a 100 year ARI flood. Extension (westwards) of the Tweed Heads South levee, to provide protection to the Philp Parade area, was also considered at a preliminary level.

Tweed Heads South Levee
Estimated cost to protect up to 100 year ARI
$11 million
Additional time to evacuate during PMF
3 hours
Estimated reduction in property flood damages
$36 million

Response Modification Measures

Response modification measures are essential to the minimisation of personal flood risk in the Tweed Valley study area. Flood response is the responsibility of many organisations and individuals, including the State Emergency Service, the Bureau of Meteorology, Tweed Shire Council, community groups and individuals. The range of response modification options considered in this study aimed to address this wide cross-section of responsibilities.

The SES has been provided with a range of flood intelligence, including road closure timing, flood extents and broadscale evacuation capability assessments, which can be used to update their Local Flood Plan (LFP) and inform more detailed evacuation plans for areas of greatest flood risk. This information can be used to supplement the information already held by the SES, derived from prior flood modelling, historical floods and professional experience. Evacuation management options, such as pre-emptive evacuation and pedestrian evacuation have also been considered.

Other response modification measures considered as part of the study include additional flood awareness education, provision of personalised flood information, adoption of new storm surge prediction technology and review of evacuation centre capacity and procedures.

Property Modification Measures

Property modification was addressed via a hydraulic assessment to identify properties which are at particularly high risk in terms of either personal safety or property damage. Depending on the degree of risk, these properties have been recommended for either voluntary house purchase or voluntary house raising. These schemes would generally be conducted over a long timeframe, such as 20 years or more.

Voluntary house purchase
Suitable properties:10 - 30
Total cost: approx. $3 - $10 million
Benefit to cost ratio: 0.6 - 1.1

Voluntary house raising
Suitable properties: 25 - 30
Total cost: approx. $2 million
Benefit to cost ratio: 1.8 - 2.6

Climate Change

Council has adopted a climate change flood scenario in line with current scientific guidance and state policy which accounts for a 10% increase in rainfall intensity and a sea level rise of 91cm for the 100 year ARI event by 2100. This climate scenario will result in a greater flood extent and increase the flood risk for those already on flood prone land.

Additional climate change flood risk
(over current 100 year ARI flood risk)

***55%** more people*
***66%** more houses*
***33%** more businesses*

Outcomes from this study can be used to inform updates of Council's climate change adaptation plan that has been undertaken to manage this future risk to existing people and property. Council already has a number of planning mechanisms in place for limiting climate change risk to future development, and some additional recommendations have been made as part of a review of planning considerations for the study area.

Planning and Future Development

Despite the considerable existing flood risk and the risk posed by future climate changes, the study area should not be sterilised. Future development can occur with well designed flood controls and appropriate assessment to determine and limit the impact of development.

A range of options were hydraulically assessed to determine the effect of increasing development in particular locations in Chinderah, South Murwillumbah and Kielvale, as well as broader development of rural zoned land. In general, it was found that the Chinderah Village and South Murwillumbah areas are hydraulically sensitive and the future development potential of these areas is extremely constrained. Kielvale and the areas of Chinderah and West Kingscliff east of the Pacific Highway are hydraulically more suitable for development, and a number of acceptable cumulative development scenarios have been identified for consideration.

Evacuation safety risks for potential large scale development areas have also been reviewed to inform the strategic planning process. The Tweed City Centre North proposed development form is generally supported, subject to detailed assessment and management of evacuation risks. However, due to a lack of rising road access, Tweed City Centre South is generally not supported based on the currently proposed building form. In Chinderah / West Kingscliff, evacuation risks are considered to be manageable for areas with rising road access towards Kingscliff, however most other locations could pose unacceptable risks. Some parts of Murwillumbah and South Murwillumbah identified through the planning process for potential increases in residential density are also not recommended due to unacceptable flood risk.

Well designed flood controls are essential for the safe and sustainable development of the floodplain. Tweed Shire Council's planning instruments were reviewed and recommendations were made to update these instruments with best-practice flood planning controls together with specific flood risk management recommendations from this study. These include suitable floor and fill levels, inclusion of climate change policy and suitable flood certificate wording. These recommendations are based on updated information about flood behaviour in the study area.

Summary of Measures

A summary of the floodplain management measures under consideration in this study is presented in Table ES- 1. These measures are summarised in an options assessment matrix which highlights quantifiable impacts, costs and benefits, but also intangible considerations such as social and environmental factors. The matrix can be used to compare options and inform the selection of measures to be adopted for implementation.

Measures are also marked on Figure ES- 1 where possible / appropriate.

A number of other measures were considered during the study and documented in the Discussion Papers. Measures which were not carried over to this document were found to be not feasible or practicable based on hydraulic assessments and advice from members of the Technical Committee.

Table ES- 1 Summary of Floodplain Risk Management Options

Type	Description	Region	Considerations	Section	Option / Recommendation
Flood	Raise Tweed Heads South levee to provide 100 year ARI protection	Lower Tweed	Provides sufficient additional time for residents along Dry Dock Road to evacuate to Tweed Heads > 200 additional dwellings protected in 100 year ARI event Potential impact on visual amenity, particularly in concrete sections Cost benefit ratio > 3 Total cost approximately $11m	4.2.2.1	Further investigation, including quantity surveyor costing
Flood	Tweed Heads South Levee Overtopping Study	Lower Tweed	Improves understanding of hydraulic behaviour around levee and informs future decisions about levee works Low to moderate cost	4.2.2.2	Commission study
Flood	Extend Tweed Heads South levee to provide 100 year ARI protection to Philp Parade area	Lower Tweed	Provides sufficient additional time for residents along Philp Parade to evacuate to Tweed Heads > 60 additional dwellings protected in 100 year ARI event Potential impact on visual amenity Easement considerations Total benefit approximately $8m High capital costs	4.2.2.3	Further investigation
Flood / Planning	Preserve / enhance South Murwillumbah Condong flowpath	Murwillumbah	No worsening of flooding in South Murwillumbah basin (Potential 50 to 100mm reduction in 100 year ARI flood levels)	4.2.4.1 and 8.2.2	Decide on planning mechanism for securing (and potentially enhancing) flowpath at Lot 4 Quarry Road Further investigation of hydraulic structure at Quarry Road

Type	Description	Region	Considerations	Section	Option / Recommendation
Flood	Murwillumbah Levee Overtopping Study	Murwillumbah	Improves understanding of hydraulic behaviour around levee and informs future decisions about levee works Low to moderate cost	4.2.4.2	Commission study
Flood	Local drainage studies	Whole study area focussed on specific areas	Improve evacuation capability through better route immunity Quantify risk and identify potential mitigation Inform development planning re local flood risk Moderate study cost Medium to high implementation costs, depending on works	4.3	Commission local drainage studies in key locations (Lower Tweed, Chinderah and Murwillumbah)
Response	SES Community Engagement Program	Whole study area	Increase community awareness and community flood planning Improve community confidence due to flood planning Low cost	5.2.1.1	Support program; Prioritise high risk issues from this study and vulnerable groups
Response	Evacuation planning information	Whole study area	Improve community awareness of evacuation procedures Improve community satisfaction through inclusion / awareness Low cost	5.2.1.2	Provide information on evacuation routes, centres and process to community
Response	Relate flood prediction information to flood risk	Whole study area	More informed personal evacuation planning Improve community confidence when floods are predicted Moderate cost	5.2.1.3	Derive links between stream gauge heights and individual properties / infrastructure (for a range of flood behaviours) and disseminate

Type	Description	Region	Considerations	Section	Option / Recommendation
Response	Update Flood Intelligence Cards and LFP	Whole study area	Better understanding and quantification of flood risk; Improve response planning and evacuation procedures Low cost to incorporate existing flood intelligence Moderate cost to commission additional studies	5.2.2.1	Update Flood Intelligence Cards with information from Flood Study, FRMS and Flood Intelligence Review Undertake detailed evacuation planning where insufficient resources or evacuation capability Remove Tweed Civic Centre from LFP as designated evacuation centre
Response	Flood information website	Whole study area	Improve understanding of flood risk and access to flood information Low to moderate cost	5.2.2.2	Upgrade Council website to develop a comprehensive flood information website
Response	Supplementary warning methods	Whole study area	Improve evacuation capability through warning dissemination Low to medium cost, depending on selected method(s)	5.2.3.1	Implement additional warning methods to supplement door knocking
Response	Inclusion of Tumbulgum stream gauge in flood warning system	Whole study area	More informed prediction and response planning Low cost	5.2.3.2	Discuss inclusion of Tumbulgum stream gauge in flood warning system with Flood Warning Committee
Response	Update storm surge prediction system	Whole study area	Improve evacuation capability through earlier prediction (Already funded via BoM)	5.2.3.3	Incorporate system in LFP when available
Response	Detailed evacuation planning study	Whole study area	Improve understanding of evacuation constraints and identify risk reduction strategies Moderate cost	5.2.4.1	Commission detailed evacuation planning study (either SES or external consultant)
Response	Targeted flood education	Whole study area / high risk areas	Improve flood awareness in residents in high risk areas Low cost	5.2.4.2	Identify high risk areas and educate residents about local flood risk
Response	Early / pre-emptive warning	Whole study area / high risk areas	Improve safety by providing more time for residents in high risk areas to evacuate	5.2.4.3	Identify areas with insufficient warning time, educate residents and pre-emptively warn during evacuations

Type	Description	Region	Considerations	Section	Option / Recommendation
Response	Pedestrian evacuation	Whole study area / suitable locations	Improve safety of residents who are close to evacuation centres and reduce evacuation traffic	5.2.4.4	Identify areas where pedestrian evacuation may be viable / beneficial Educate local residents that evacuation on foot is an option
Response	Evacuation centre planning	Whole study area	Improve evacuation operations Low cost	5.2.5.1	Instigate communication between SES, TSC and DoCS Update LFP to confirm multi agency responsibilities
Response	Assess evacuation centre capacity	Whole study area	Improves safety of residents by ensuring sufficient evacuation centre capacity Moderate cost if additional centre facilities required	5.2.5.2	Prepare a review of evacuation centres
Response	Investigate alternative evacuation centres to Tweed Civic Centre	Tweed Heads	Improves safety of residents by diverting evacuation to flood proof centres	5.2.5.3	Remove Tweed Civic Centre from Local Flood Plan Replace with alternative centre
Property	Voluntary house purchase	Murwillumbah	Improve safety through removal of people from high hazard areas Cost range $3 – 10 million Benefit cost ratio 0.6 – 1.1	6.2.1	Select hazard criteria and commence VHP scheme
Property	Voluntary house raising	Murwillumbah and Tweed Heads	Improve safety (if isolated) May be some worsening of visual amenity if not consistent with existing streetscape Approximate cost $2 million Benefit cost ratio 1.8 – 2.6	6.2.2	Select hazard criteria and commence VHR scheme
Planning	Review and implement detailed planning recommendations	Whole study area	Minimise safety and property flood risk associated with new (and existing) development Implementation within normal operating budget	9	Consider recommendations for implementation / amendment

Other (non location specific) options not shown on this map include:

- *Flood Awareness measures*
- *Flood Intelligence measures*
- *Flood Warning System measures*
- *Evacuation Planning measures*
- *Evacuation Centre measures*
- *Planning measures*

Identify alternative evacuation centre to Tweed Civic Centre

Raise Tweed Heads South levee

Levee overtopping study

Extend Tweed Heads South levee

Include Tumbulgum stream gauge in flood warning system

Levee overtopping study

Ingleside
Point Danger
Coral Sea
Tweed Heads
Fingal Head
Banora Point
Glengarrie
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point

LEGEND

- Local Drainage Studies
- Potential Voluntary House Purchase and / or Raising Properties
- Tweed River
- Principal Road
- Sealed Road

Title:
Summary of Floodplain Risk Management Options

Figure: **ES-1**

Rev: **A**

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Approx. Scale

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CONTENTS

1 INTRODUCTION 1

1.1 Floodplain Risk Management Process 1

1.2 Study Area 2

1.3 Consultation 3

1.3.1 Stakeholder Consultation 4

2 METHODOLOGY 7

2.1 Information and Data 7

2.2 Hydraulic Impact Assessment 7

2.3 Evacuation Capability Assessment 8

2.4 Flood Damages Assessment 8

2.5 Cost Benefit Assessment 8

3 EXISTING RISK 9

3.1 Flood Behaviour 9

3.2 Hydraulic Categories 10

3.3 Hazard Categories 11

3.4 Demographics 16

3.4.1 Population at Risk 16

3.5 Evacuation 16

3.5.1 Lower Tweed 16

3.5.2 Chinderah, Fingal Head & West Kingscliff 17

3.5.3 Murwillumbah & South Murwillumbah 18

3.5.4 Riverside Villages 18

3.6 Risk to Property 18

3.6.1 Flood Damages 19

4 FLOOD MODIFICATION MEASURES 20

4.1 Existing Measures 20

4.1.1 Levees 20

4.1.2 Clarrie Hall Dam 20

4.1.3 Other Minor Drainage Works 20

4.2 Flood Modification Options 21

4.2.1 Whole of Study Area 21

4.2.1.1 Commission Local Drainage Studies 21
4.2.2 Lower Tweed 22
4.2.2.1 Raise Tweed Heads South Levee 22
4.2.2.2 Commission Levee Overtopping Study 24
4.2.2.3 Extend Tweed Heads South Levee to Philp Parade 24
4.2.3 Chinderah, Fingal Head & West Kingscliff 25
4.2.4 Murwillumbah & South Murwillumbah 25
4.2.4.1 South Murwillumbah Condong Flowpath 26
4.2.4.2 Commission Levee Overtopping Study 26
4.2.5 Riverside Villages 27
4.3 Flood Modification Recommendations 27

5 RESPONSE MODIFICATION MEASURES 28
5.1 Existing Measures 28
5.1.1 Flood Warning System 28
5.1.2 Flood Intelligence 29
5.1.3 Local Flood Plan 29
5.1.4 Cross Border Planning 31
5.1.5 Flood Awareness 31
5.2 Response Modification Options 31
5.2.1 Flood Awareness 31
5.2.1.1 Community FloodSafe Engagement Program 31
5.2.1.2 Evacuation Planning Information 32
5.2.1.3 Understanding Personal Flood Risk 32
5.2.2 Flood Intelligence 34
5.2.2.1 Flood Intelligence Cards 34
5.2.2.2 Flood Information Website 35
5.2.3 Flood Warning System 35
5.2.3.1 Method of Flood Warning 35
5.2.3.2 Tumbulgum Stream Gauge 36
5.2.3.3 Storm Surge Prediction 37
5.2.4 Evacuation Planning 37
5.2.4.1 Detailed Evacuation Planning Study 37
5.2.4.2 Targeted Flood Education 37
5.2.4.3 Early / Pre-emptive Warning 37
5.2.4.4 Pedestrian Evacuation 38
5.2.5 Evacuation Centres 38
5.2.5.1 Evacuation Centre Planning 38
5.2.5.2 Evacuation Centre Capacity 38

5.2.5.3 Tweed Civic Centre 39
5.3 Response Modification Recommendations 39

6 PROPERTY MODIFICATION MEASURES 40
6.1 Existing Measures 40
6.2 Property Modification Options 40
6.2.1 Voluntary House Purchase 40
6.2.2 Voluntary House Raising 41

7 CLIMATE CHANGE 46
7.1 Climate Change Scenario 46
7.2 Flood Behaviour 46
7.3 Flood Risk 47
7.4 Management Measures 50
7.4.1 Existing Adaptation Measures 50
7.4.2 Adaption Recommendations 50
7.4.2.1 Infrastructure (Recommendations a and b) 51
7.4.2.2 Flood Defences (Recommendation c) 51
7.4.2.3 Community Awareness and Education (Recommendation d) 51
7.4.2.4 Development Planning (Recommendation e) 51
7.4.2.5 General 51
7.4.3 Existing Planning Measures 51
7.4.4 Planning Recommendations 52

8 FUTURE DEVELOPMENT 53
8.1 Overview 53
8.1.1 Tweed City Centre 53
8.1.2 Chinderah, Fingal Head and Kingscliff 55
8.1.3 Murwillumbah and South Murwillumbah 57
8.1.4 Riverside Villages (Condong and Tumbulgum) 59
8.2 Hydraulic Constraints 59
8.2.1 Cumulative Development 59
8.2.2 South Murwillumbah Condong Flowpath 61
8.3 Evacuation Constraints 62
8.3.1 Concurrent Fire and Medical Risks 63
8.3.2 Evacuation Risks 64

9 PLANNING CONSIDERATIONS 67
9.1 Strategic Planning 67

9.2 Development Controls and Related Policies 69
9.3 Communication of Flood Risk 73
9.4 Other Recommendations 73

10 REFERENCES 74

APPENDIX A: INFORMATION, DATA, METHODOLOGY 76

APPENDIX B: GAUGES MONITORED BY TWEED SHIRE SES 86

LIST OF FIGURES

Figure 1-1 Consultation Process 3
Figure 1-2 Tweed River and Surrounds 5
Figure 1-3 Study Regions 6
Figure 3–1 Existing Flood Extent 12
Figure 3–2 Hydraulic Categories 13
Figure 3–3 Hydraulic Hazard Categories 14
Figure 3–4 Low and High Islands 15
Figure 4-1 Tweed Heads South Levee 23
Figure 5–1 Flood Warning Network 30
Figure 5–2 Murwillumbah Gauge Heights 33
Figure 5–3 Floor Level to Gauge Relationship 34
Figure 5–4 Comparison of Flood Warning Communication Methods 36
Figure 6–1 Voluntary House Purchase Options 42
Figure 6–2 VHR Option 2 and 3, Murwillumbah 44
Figure 6–3 VHR Option 2 and 3, Lower Tweed 45
Figure 7–1 Climate Change 100 Year ARI Flood Extent 48
Figure 7–2 Flood Impact of Climate Change 49
Figure 8-1 Tweed City Centre LEP and DCP Areas (Tweed City Centre Plan Vision 2011) 54
Figure 8-2 Tweed Coast Strategy Structure Plan (Tweed DCP 2008) 56
Figure 8-3 Murwillumbah Town Centre Urban Structure Plan (Tweed DCP 2008) 57
Figure 8-4 Murwillumbah Town Centre Precincts (Town DCP 2008) 58
Figure 8-5 Murwillumbah West Release Area Zonings (Murwillumbah Town Centre DCP) 58
Figure 8-6 Cumulative Development Locality Map 60

LIST OF TABLES

Table 1-1	Stages of Floodplain Risk Management Process	1
Table 3-1	Hydraulic Categories	10
Table 3-2	Hazard Categories	11
Table 3-3	Population at Risk	16
Table 3-4	Estimated Number of Inundated Properties	19
Table 3-5	Flood Damage Estimates (millions of $)	19
Table 4-1	Levee Summary	20
Table 4-2	Cost Benefit Ratio	22
Table 5-1	Flood Event Levels at Stream Gauges	29
Table 6-1	Properties Eligible for VHP	40
Table 6-2	VHP Cost Benefit Summary	41
Table 6-3	Properties Eligible for VHR	41
Table 6-4	Voluntary House Raising Summary	43
Table 7-1	Population at Risk, Climate Change	47
Table 7-2	Estimated Number of Inundated Properties, Climate Change	47
Table 7-3	Flood Damage Estimates, Climate Change	47
Table 8-1	Ideal Growth Dwelling Targets Tweed City Centre (now deferred)	54
Table 8-2	Cumulative Development Options	61
Table 8-3	Evacuation Risk Classes (ERCs)	63

LIST OF ABBREVIATIONS

AAD	Average Annual Damages
mAHD	metres to Australian Height Datum
ARI	Average Recurrence Interval (of flood)
BoM	Bureau of Meteorology
DCP	Development Control Plan
DECC	(former) Department of Environment & Climate Change
DECCW	(former) Department of Environment, Climate Change & Water
DIPNR	(former) Department of Infrastructure, Planning and Natural Resources
DISPLAN	(Tweed Shire Local) Disaster Plan
DoCS	Department of Community Services
DoP	(former) Department of Planning
DPC	Department of Premier and Cabinet
DPI	Department of Planning and Infrastructure
DxV	depth-velocity product
EP&A Act	Environmental Planning and Assessment Act
ERC	Evacuation Risk Class
FIC	Flood Intelligence Card
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
LEP	Local Environment Plan
LFP	Local Flood Plan
LGA	Local Government Area
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood, also referred to as flood prone land
REP	Regional Environmental Plans
RMS	Roads and Maritime Services
SEPP	State Environmental Planning Policies
SES	State Emergency Service
TSC	Tweed Shire Council

VHP Voluntary House Purchase

VHR Voluntary House Raising

1 INTRODUCTION

This document is a summary of a series of discussion papers written for the Tweed Valley Floodplain Risk Management Study. The information from this document will be used to inform the Tweed Valley Floodplain Risk Management Plan: a written document outlining a plan of management for flood risk in the Tweed Valley which will be exhibited for consultation and ultimately formally adopted by Council.

1.1 Floodplain Risk Management Process

The New South Wales government's *Flood Prone Land Policy* is directed towards 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 New South Wales *Floodplain Development Manual* (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 provides 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 in Table 1-1, below:

Table 1-1 Stages of 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 in consideration of social, ecological and economic factors.
3. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management with preferred options for the floodplain.
4. Plan Implementation	Implementation of flood mitigation works, response and property modification measures by Council.

Community consultation is occurs throughout the process.

This study represents the second and third of the four stages for the Tweed Valley area. It has been prepared for Tweed Shire Council to identify and assess potential flood mitigation options and to outline how flood prone land within the study area may be managed. The floodplain management plan ensures that:

- The use of flood prone land is planned and managed in a manner compatible with the assessed frequency and severity of flooding;
- Flood prone lands are managed having regard to social, economic and ecological costs and benefits, to individuals as well as the community;
- Floodplain management matters are dealt with having regard to community safety, health and welfare requirements;

- Information on the nature of possible future flooding is available to the public;
- All reasonable measures are taken to alleviate the hazard and damage potential resulting from development on floodplains;
- There is no significant growth in hazard and damage potential resulting from new development on floodplains; and
- Appropriate and effective flood warning systems exist, and emergency services are available for future flooding.

1.2 Study Area

The Tweed River is located in Tweed Shire, the northern-most coastal region of New South Wales (see Figure 1-2). The main arm of the river has a length of about 50 km and a catchment area of about 1,100 km^2 including its various tributary systems. The main arm of the river flows in a general north-easterly direction through the towns of Murwillumbah (about 28 km upstream) and Tweed Heads (at the mouth) and past the villages of Condong, Tumbulgum, Chinderah and Fingal Head. The main tributaries include Oxley River, Rous River, Dunbible Creek and the Terranora and Cobaki Broadwaters. The river flows to the sea immediately south of Point Danger, close to the border with Queensland.

Regular flooding occurs, particularly in the low-lying cane regions of the valley. The most recent 'major' flood event was January 2008. The catchment has experienced larger flood events on a number of occasions, including in March 1974 and most severely in February 1954. This flood caused major inundation in all flood prone areas.

Regional flooding occurs via catchment inflows, ocean storm surge or some combination of these events. The small tributaries in the Bilambil and Terranora regions and local areas can also experience flash flooding; however the focus of the Tweed Valley FRMS is catchment scale inundation. The critical storm duration for catchment flooding at Murwillumbah was determined to be approximately 36 hours as part of previous flood studies.

Development in the catchment is centred on two major centres, Tweed Heads and Murwillumbah, with a number of smaller villages throughout the catchment. The Far North Coast Regional Strategy (Department of Planning, 2006) was prepared to provide guidance in planning for the growth of the six North Coast Local Government Areas including Tweed Shire for a projected population growth of 26% over a 25 year period. Of this, the Strategy aims to focus 35% of new housing in the regional centres which includes Tweed Heads (to yield an additional 19,100 new dwellings).

The study area covers the Tweed Valley floodplain downstream of Byangum defined by the extent of the Probable Maximum Flood (PMF), also referred to as the extent of 'flood prone land'.

Within the Tweed Valley, the study area has been broken down into four regions for reporting purposes:

- Lower Tweed;
- Chinderah, Fingal Head and West Kingscliff;
- Murwillumbah and South Murwillumbah; and

- Riverside Villages (Condong and Tumbulgum).

This report refers to these regions when describing risk or proposed measures which apply to specific areas, rather than the whole study area. See Figure 1-3 for the boundaries of these reporting areas.

1.3 Consultation

Consultation provides a forum for the relevant stakeholders, including the community, to work together to shape a collective vision for the catchment and future floodplain risk management. Effective consultation can increase community acceptance of the floodplain risk management plan and provide the opportunity for better decision making.

The Tweed Valley FRMS includes four distinct phases of consultation:

1 Consultation with major stakeholders. This was conducted early in the study and outcomes are used to inform the options assessment process.

2 Exhibition of the draft study and plan, online and in hard copy at Council's offices in Murwillumbah and Tweed Heads.

3 A region specific community session at Tweed Heads and Murwillumbah. These sessions will present the draft study and plan to the community. Feedback received at these sessions will be considered by the committee and inform the final study and plan.

4 Release of the final study and plan. The plan will be made public, online and in hard copy at Council's offices and the libraries in Murwillumbah and Tweed Heads.

Overseeing the entire process is the Floodplain Management Committee, composed of representatives from the community, Council, the State Emergency Service, the Office of Environment and Heritage, the Bureau of Meteorology and the consultants (BMT WBM). Within this committee sits the technical committee who discuss technical aspects of the project to ensure there is a best-practice approach to the study.

Figure 1-1 Consultation Process

1.3.1 Stakeholder Consultation

Consultation from project stakeholders was sought at the commencement of the study and feedback was addressed in the discussion papers and in committee meetings. During the study, an online survey was conducted as part of the Tweed Coastal Creeks FRMS. Many of the respondents live within the Tweed Valley catchment, and these responses have also been included in this study. Feedback predominantly addressed the following issues:

Flood Awareness. A number of responses highlighted the need to increase flood awareness within the community. It was recommended that flood awareness campaigns target particularly vulnerable sections of the community, such as schools and the elderly, as well as residents new to the area. Suggested options for increasing flood awareness included the use of flood markers with historical and design flood levels.

Evacuation. Evacuation concerns were mentioned in a number of the stakeholder responses, including issues such as:

- Evacuation centres have been closed in past flood events, despite residents being directed to these centres.
- Old Ferry Road and Piggabeen Road require improvement to ensure they were suitable to use as evacuation routes.
- Flood plans be developed for health facilities and businesses to ensure these places knew how to protect their property and safety of employees/customers/patients in the event of a flood.
- Fingal Head and Chinderah residents indicated that they did not feel evacuation was necessary from their region and they did not wish to be mandatorily evacuated.
- Isolation in the Philp Parade area (as experienced in 2012 floods).

Information. Many responses requested a greater level of information be made available, including flood maps, locations of evacuation routes and centres, details about Council's climate change policy and how this policy was derived, and details of the SES's disaster plan (DISPLAN). Alternative options for information dissemination during floods were requested by many respondents. These included suggestions for more information on Council's website, SMS warnings and increased radio announcements.

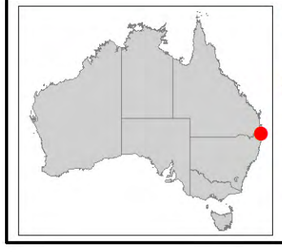
Flood Warning. A few responses mentioned flood warning as an issue of concern. In particular, there was some negative sentiment about the lack of localised flood warning with the feeling that warnings were issued 'out of Wollongong' and therefore not relevant to the Tweed Valley. There was also a request for more information about the flood warning system generally.

Development. Development of the study area was of major concern to most stakeholders. Some responses were concerned that flood controls would result in the 'sterilisation' of flood prone land, particularly in the South Murwillumbah and Chinderah areas. There was also some concern for potentially negative cumulative impact effects resulting from multiple large scale developments, with specific reference to the proposed 'bug' farm and the Rivavue development.

Other issues were raised in the stakeholder responses which were beyond the scope of the FRMS.

Tweed Heads
Coral Sea
Tumbulgum
Murwillumbah
Tyalgum
Fernvale
Mount Warning
Uki

Elevation (m)
1100
1000
900
800
700
600
500
400
300
200
100
0



LEGEND

Tweed Catchment Boundary

Tweed River
Watercourse Line
Principal Road
Sealed Road

Title:
Tweed River and Surrounds

Figure: 1-2

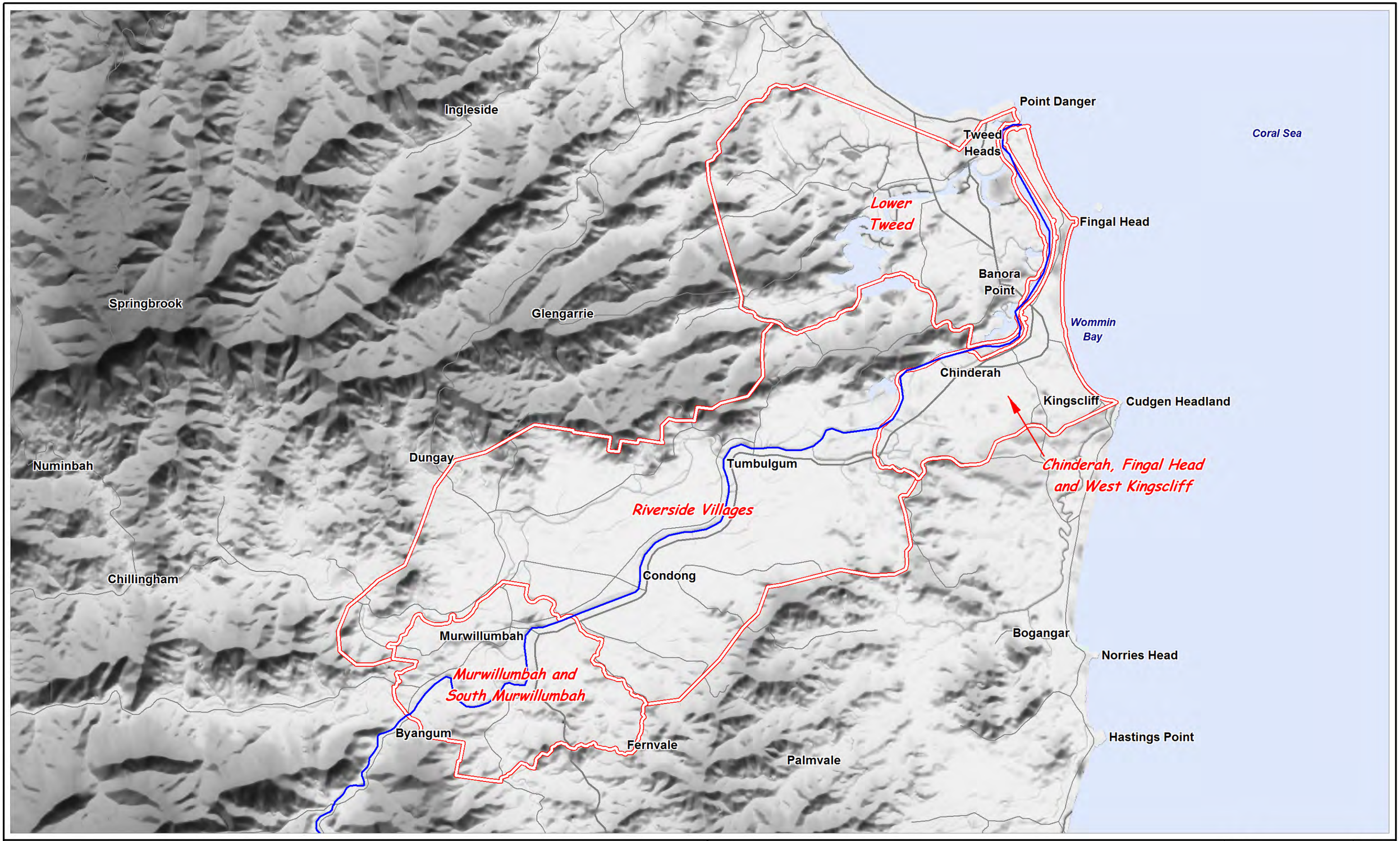
Rev: A

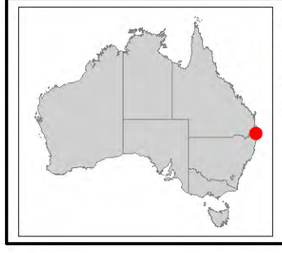
N

0km 4 8
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_001_120426_Tweed River and Surrounds.WOR





LEGEND

- Tweed River
- Principal Road
- Sealed Road

Title:
Study Regions

Figure: 1-3

Rev: A

N

0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_002_120503_Study Regions.WOR

2 METHODOLOGY

The process used to define flood risk and subsequently assess measures to manage the risk, is provided in the NSW Floodplain Development Manual (2005). This process has been followed during the Tweed Valley FRMS in conjunction with industry standard approaches. A brief description of the methodology and sources of information and data is provided below. Further detail is provided in Appendix A and the Information, Data and Methodology discussion paper.

2.1 Information and Data

The Tweed Valley FRMS covers a wide geographic area with multiple townships, a diverse range of land uses and a large population. In addition, the area is subject to multiple types of flood risk and faces significant development pressure. Therefore, a wide range of information and data sources was required for the characterisation of flood risk in this area, including flood behaviour, demographic data, property survey and planning information.

Information about flood behaviour in the Tweed Valley area was primarily derived from the Tweed Valley Flood Study Update (2009). Some additional flood modelling was required during this study, particularly to quantify the hydraulic impacts of potential management measures and future development, as well as evacuation constraints.

Demographic data was vital to highlight the flood risk to people in the study area. This information, including population, vehicles and vulnerability indices (such as age), was derived primarily from the 2006 Census and geographically distributed to help identify which sections of the population are exposed to the greatest flood risk.

An extensive property survey was commissioned as part of the FRMS to accurately identify the location of every property in flood prone land (both residential and commercial) and record information about floor levels, building and contents. This data informed the damages assessment and was also used to identify potential properties for voluntary house raising or purchase.

A review was completed of the Tweed Shire Council planning framework in relation to flood risk, including the Development Control Plan (DCP) and Local Environment Plan (LEP). This review looked at ways the existing planning documents could incorporate best-practice flood planning controls together with specific flood risk management recommendations from this study.

2.2 Hydraulic Impact Assessment

Hydraulic impact assessments look 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 raising a flood levee, building a residential development or dredging a river. An 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.

2.3 Evacuation Capability Assessment

Evacuation capability assessments consider the ability of people within the floodplain to evacuate safely during a flood event. The assessments use the timeline method developed by the SES to quantify and compare estimates of the time required to evacuate each area versus estimates of the time available.

Results of this assessment will 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. These may include for example, upgrading the capacity or flood immunity of evacuation routes, or changes to evacuation plans. In addition, evacuation capability assessments can also help quantify the potential impact of proposed development (and associated additional population) within the floodplain on the ability of the existing community to evacuate safely.

2.4 Flood Damages Assessment

The main objective of the flood damages assessment is to establish the 'baseline' economic costs of flooding (i.e. based on current conditions) which can then be used to help quantify the benefits of potential mitigation measures.

Flood damages are classified as tangible or intangible, depending on whether costs can be assigned monetary values. Intangible damages arise from adverse social and environmental effects caused by flooding, including factors such as loss of life and limb, stress and anxiety. Tangible damages are monetary losses directly attributable to flooding. The flood damages assessment estimates these tangible damages to provide information on the economic impact of flooding and potential management measures.

2.5 Cost Benefit Assessment

Cost benefit assessments are carried out on proposed management options to determine the economic merits of pursuing and / or implementing these options. The assessments compare the cost of implementing the option (e.g. construction and maintenance) with the likely reduction in flood damages (i.e. economic benefit). This comparison produces a ratio which can help inform the decision making process. It must be noted that the cost benefit assessment does not include intangible benefits, such as improved safety or environmental benefits.

3 EXISTING RISK

The Tweed Valley study area has a long history of flooding and will continue to flood in the future. The extent, behaviour and likelihood of future flooding was assessed through the Tweed Valley Flood Study Update and that information was used in this study to determine the current flood risk. There was found to be a high level of flood risk in the study area.

There is a considerable number of people and properties located in flood prone land (within the PMF extent), including a large number at risk in the 100 year ARI flood. Flood depths and flows are of a dangerous magnitude in many locations and flood waters can rise quickly, often with short warning periods.

Past efforts to reduce the flood risk have resulted in levees in Murwillumbah and South Tweed Heads, as well as a voluntary house purchase and house raising program. However, since these flood management options were undertaken, development has intensified and we have improved our understanding of flood behaviour in the area. It is therefore timely to quantify the existing risk and use this information to guide selection of flood management measures.

3.1 Flood Behaviour

There have been a number of major floods in the Tweed catchment in living memory, including the largest flood on record in 1954. During this flood, much of the floodplain was inundated with high velocities that caused significant damage to houses at South Murwillumbah. Calculations in the *Murwillumbah Floodplain Management Plan* (Tweed Shire Council, 1989) estimated the 1954 flood had a return period of 60 to 70 year ARI.

The design flood behaviour, modelled in the *Tweed Valley Flood Study Update* (BMT WBM, 2009), considered a range of events, from the relatively frequent 5 year ARI to the largest theoretical flood (the probable maximum flood, or PMF).

In the 100 year ARI event, the main high flow areas in the Murwillumbah area include the Bray Park flowpath upstream of town and the flowpath from Blacks Drain to Condong Creek via the Murwillumbah airport. In the mid Tweed, there are large areas of floodplain conveying high flow between the Tweed and Rous Rivers, as well as from Condong to Stotts Island. In the lower Tweed, the valleys of the Broadwater tributaries (Cobaki, Piggabeen, Bilambil and Duroby Creeks) all convey high flows.

During smaller flood events, water is predicted to flow from the Rous River to the Tweed River via Mayal Creek. As the floodwaters rise, the Tweed River becomes the dominant flow and floodwater flows from the Tweed River to the Rous River. Most of the floodplain between the Tweed and Rous Rivers conveys high flows in the 100 year ARI flood event.

The Tweed Valley is generally quite wide and flat with few structures that significantly control the hydraulics of the floodplain. Low natural and man-made banks and levees are present along much of the Rous and Tweed Rivers but are generally exceeded in small flood events. One exception is the constriction at Murwillumbah created by the town levees, the Murwillumbah Bridge and the sharp

bend of the river immediately downstream of the bridge. This constriction causes high velocities in the river, over 2 m/s.

In the lower Tweed, the embankment and drainage structures of the Pacific Highway and the constriction at Barneys Point influence flood behaviour in large events. In extreme events, flood levels in the lower Tweed area are controlled by the constriction at the rivermouth / entrance and the dunes between Kingscliff and Fingal Head.

The extent of the PMF is significant, with extremely high depths in some locations. In general, it is not economically or physically possible to provide protection against an event of this magnitude (DIPNR, 2005). However, it is important that the PMF be considered to define the scope and magnitude of potential flood risk, particularly with respect to evacuation and safety considerations.

Figure 3–1 shows the extent of catchment flooding in the Tweed Valley study area.

3.2 Hydraulic Categories

Hydraulic categorisation is one of the tools used to identify flood behaviour and risk in a FRMS. Outcomes of the categorisation are primarily used to inform future land use planning. The categorisation is not used to assess individual developments, but rather to give a catchment-scale overview of which areas may be appropriate for various types of land use.

Three hydraulic categories are defined in the Floodplain Development Manual, as follows:

- **Floodways** – Areas conveying a significant proportion of flood flow where partial blocking will adversely affect flood behaviour. Future development should not be allowed to take place in these areas.
- **Flood Storage Areas** – Areas outside floodways which store significant volumes of floodwaters. Reduction in flood storage would cause downstream flood flows to increase.
- **Flood Fringe** – The remaining area of land affected by flooding, after floodway and flood storage has been defined. Development in flood fringe areas would not generally cause significant hydraulic impact.

These definitions are not precise and vary in application between catchments. A number of categories were tested in the Tweed Valley based on flood flows. Of those tested, the following definitions were found to best meet the criteria outlined in the Floodplain Development Manual:

Table 3-1 Hydraulic Categories

Floodway	100 year ARI depth-velocity > 0.3 m^2/s
Flood Storage	100 year ARI depth-velocity > 0.025 m^2/s
Flood Fringe	Remainder of floodplain (up to PMF)

The hydraulic categories have been mapped in Figure 3–2.

The impacts of filling the flood fringe in Scenario 2 indicate that there is a very small flood fringe area in the catchment. Most areas in the catchment will therefore require hydraulic investigation prior to

major filling or development works. Results also indicate that a number of locations in the catchment are sensitive to filling, especially the South Murwillumbah Basin and the Terranora creeks.

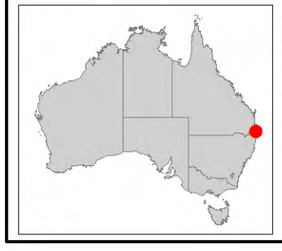
3.3 Hazard Categories

Hazard categorisation supplements the hydraulic categorisation process by considering a wider range of flood risks, particularly those relating to personal safety and evacuation. These hazard factors are derived from both hydraulic risk factors (such as depths and velocities) and human / behavioural issues (such as flood readiness). These considerations are summarised in Table 3-2 below in the context of the Tweed Valley.

Table 3-2 Hazard Categories

Size of Flood	Hydraulic categorisation was undertaken using the 100 year ARI design flood. Evacuation capability assessments were undertaken for the 20 and 100 year ARI events, as well as the PMF.
Flood Readiness	Flood readiness will be similar across the catchment, although residents in areas which have experienced historical flooding, such as South Murwillumbah, may have a greater level of flood readiness. The Lower Tweed area may have a lower flood readiness due to the high level of tourists and new residents who are unfamiliar with the local flood risk.
Rate of Rise	Flood waters will rise fastest high up in the catchment in areas prone to flash flooding, such as Bilambil. Flash flooding is not the focus of this study, however should be considered where known to be an additional hazard in high risk areas.
Hydraulic Hazard	Hydraulic hazard has been mapped for the 100 year ARI in Figure 3–3. Hazard due to high velocity (more than 2 m/s) and velocity-depth (more than 1 m^2/s) is generally confined to in-bank areas and the Bray Park flowpath. Most of the floodplain is subject to high depth hazard (more than 1 m). The areas of Tweed Heads South behind the levee have low hydraulic hazard.
Prediction, Warning and Evacuation	Flood warnings are likely to be issued at a similar time throughout the catchment; however the timing of inundation and peak varies down the floodplain and for different events. In addition, evacuation constraints such as early road closures, warning dissemination, route and evacuation centre capacities, will vary between locations.
Effective Flood Access	Effective flood access varies by location and has been considered as part of the evacuation capability assessment.
Type of Development	This flood hazard refers primarily to *future* development.
Isolation	Major low and high island areas were mapped and are presented for the study area in Figure 3–4 below.

Ingleside
Point Danger
Tweed Heads
Coral Sea
Fingal Head
Springbrook
Glengarrie
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point



LEGEND

- 100 Year ARI Flood Extent
- Probable Maximum Flood Extent
- Tweed River
- Principal Road
- Sealed Road

Title:
Existing Flood Extent

Figure: **3-1**

Rev: **A**

N

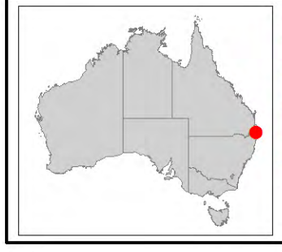
0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_007_120427_Existing Flood Extent.WOR

Ingleside
Point Danger
Tweed Heads
Coral Sea
Fingal Head
Springbrook
Glengarrie
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point



LEGEND

- Floodway (Q100 VxD>0.3m²/s)
- Flood Storage (Q100 VxD>0.025m²/s)
- Flood Fringe
- Tweed River
- Principal Road
- Sealed Road

Title:
Hydraulic Categories

Figure: 3-2

Rev: A

N

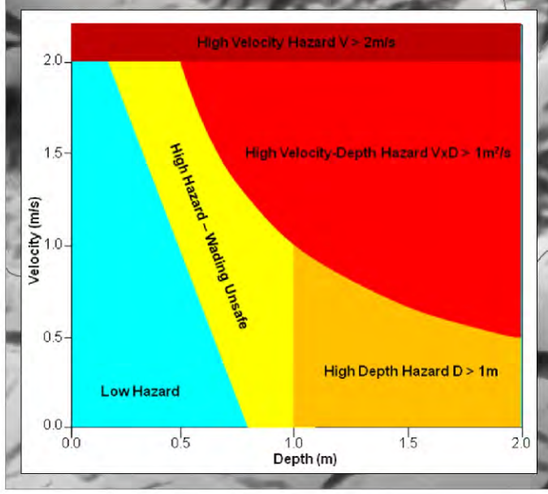
0km 3 6

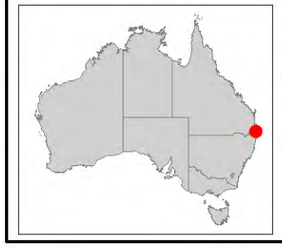
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_008_120427_Hydraulic Categories.WOR

Ingleside
Springbrook
Glengarrie
Numinbah
Dungay
Tumbulgum
Murwillumbah
Byangum
Condong
Fernvale
Palmvale
Point Danger
Coral Sea
Tweed Heads
Fingal Head
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Bogangar
Norries Head
Hastings Point





LEGEND

- Tweed River
- Principal Road
- Sealed Road
- Flood Prone Land

Title:
Hydraulic Hazard Categories

Figure: 3-3

Rev: A

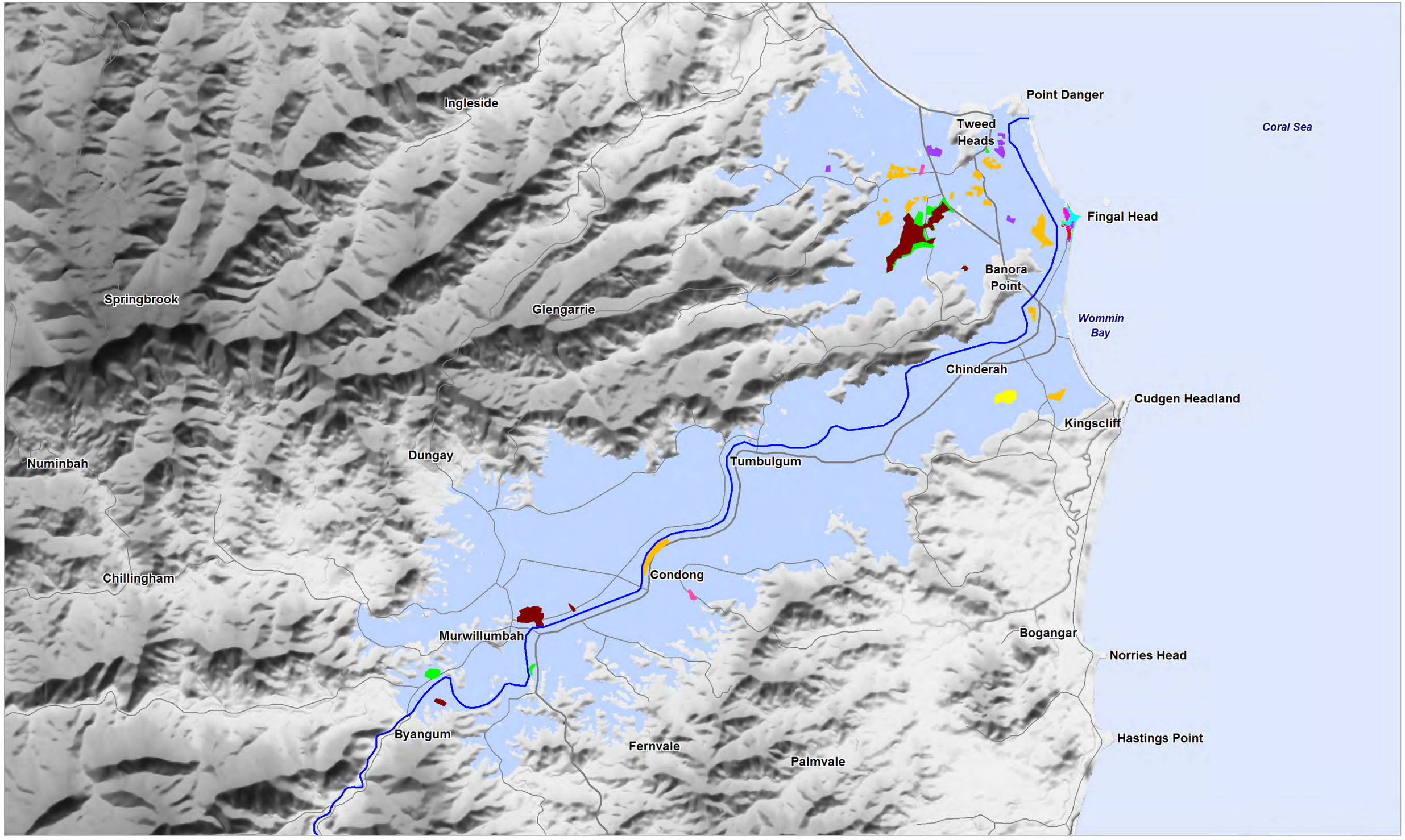
N

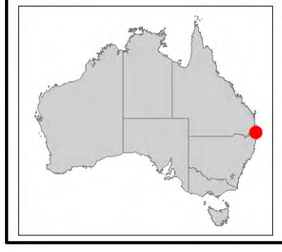
0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_009_120427_Hydraulic Hazards.WOR





LEGEND

- Low island; isolated in 5 year ARI flood; inundated in larger flood events
- Low island; isolated in 20 year ARI flood; inundated in larger flood events
- Low island; isolated in 100 year ARI flood; inundated in larger flood events
- Low island; isolated in 500 year ARI flood; inundated in larger flood events
- Low island; isolated in extreme flood; inundated in larger flood events
- High island; isolated in PMF; unlikely to be inundated
- Probable Maximum Flood Extent
- Tweed River
- Principal Road
- Sealed Road

Title:

Low and High Islands

Figure: **3-4**

Rev: **A**

N

0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_010_120427_Low and High Islands.WOR

3.4 Demographics

The Tweed LGA has an older demographic, with 26% of the population over 65 years of age (Australian Bureau of Statistics, 2008). People in this demographic are likely to require assistance during evacuation and may be socially isolated, resulting in delayed awareness of evacuation warnings (SES, 2008). Furthermore, an estimated 1,200 people reside in aged care facilities, with up to 50% of these patients classified as 'high risk', requiring one-on-one assistance for evacuation purposes (SES, 2008).

A large proportion of the population reside in caravan parks, with more than 20 caravan parks in the catchment (SES, 2008) housing an estimated 4 to 5% of the population in permanent accommodation (Housing New South Wales, 2008). Caravan parks are often located in areas of higher flood risk and tend to need additional assistance during flood evacuations.

3.4.1 Population at Risk

Numbers of people and houses estimated to be at risk during a 5 and 100 year ARI flood, as well as the PMF, is provided in Table 3-3 below. (This has been estimated based on dwellings located within the flood extent.)

Table 3-3 Population at Risk

Numbers at Risk	5 year ARI	100 year ARI	PMF
People	1,600	11,700	41,500
Residential properties	600	4,300	16,800

Risk will vary between locations due to flood behaviour, isolation etc as described in Table 3-2.

3.5 Evacuation

The Tweed Valley includes a number of distinct townships and the flood risk varies significantly throughout the catchment. Evacuation is primarily managed by the SES and guided by the Local Flood Plan document they have developed. This document summarises existing flood risk and known evacuation issues, and provides a plan for best managing flood evacuations. A summary of existing evacuation issues in each study region is provided below. Detailed evacuation assessments for each sector are provided in the location specific discussion papers and will be used by the SES to inform their flood planning.

3.5.1 Lower Tweed

Evacuation in the Lower Tweed is extremely constrained. The area is densely populated and evacuation is limited to a few key roads. Flooding occurs relatively frequently, especially in the older parts of town, leading to a high risk of isolation and/or inundation for many residential areas.

Many locations in Lower Tweed are flooded in the relatively frequent 20 year ARI flood, which is a serious evacuation concern. Most of the older parts of Tweed Heads are flooded in the 100 year ARI, although newer areas, such as Banora Point, were generally filled above this level. Almost all of the Lower Tweed area is inundated in the PMF event.

In addition to catchment and ocean flooding, there are a number of locations in the Lower Tweed area which are affected by stormwater flooding, including Dry Dock Road, Kennedy Drive, Leisure Drive, Darlington Drive, Minjungbal Drive and Piggabeen Road. Although this type of flooding is not explicitly addressed in this study, stormwater flooding can occur quickly and seriously impede evacuation.

Areas identified to have a particularly high evacuation risk are:

Philp Parade. A key location on the evacuation route for this Philp Parade closes early, prior to the issuing of evacuation warnings by the SES. This seriously affects the ability of residents to evacuate during large flood events.

Dry Dock Road. There are a number of houses in this area which all evacuate along the same, single lane route (Dry Dock Road). This route closes early in the PMF event, potentially constraining evacuation.

Kennedy Drive. This road closes early in the PMF flood event, before the SES is able to issue flood warnings. This provides a serious constraint to properties which are required to evacuate on this route.

Seagulls Estate. Access to and from the Estate is restricted to a single lane which has poor flood immunity.

Piggabeen Road. Early route closure may restrict the evacuation potential of vehicles using this route, including residents of Cobaki Lakes.

Banora Point. Evacuation is constrained by a lack of through access roads. Although many at-risk properties are within a few blocks of PMF immune land, residents are unable to drive directly to the nearest high ground and must instead take a longer route through the floodplain.

Evacuation risk in the Lower Tweed area is higher than average, due to an older demographic and a number of vulnerable institutions such as the Tweed Hospital, and multiple nursing homes and retirement villages.

3.5.2 Chinderah, Fingal Head & West Kingscliff

Evacuation is constrained in some areas of the Chinderah, Fingal Head and West Kingscliff region. Low lying roads near the Tweed River are frequently inundated and may prevent evacuation access for a number of residents. There are many caravan parks in this region, particularly around Chinderah.

Areas identified to have a particularly high evacuation risk are:

Fingal Head. Fingal Road closes early in the PMF events, restricting evacuation. This road is the only access route to the Fingal Head peninsula and would isolate all residents if closed by flooding. There is a high island on Fingal Head, but there are currently no designated evacuation centres or similar support infrastructure at this location.

Chinderah. Main evacuation routes remain open in small flood events, however local access roads are likely to be inundated, preventing residents from reaching the evacuation routes. Flood risk is

increased for Chinderah due to the high density of caravan parks and the additional time and resources required to evacuate these locations.

3.5.3 Murwillumbah & South Murwillumbah

Evacuation capability varies across the Murwillumbah and South Murwillumbah region. As this area is high up in the catchment, there is less time to predict and prepare for flooding before the peak hits. This factor adds a major constraint to the evacuation process and makes evacuation planning difficult in large flood events.

Areas identified to have a particularly high evacuation risk are:

Murwillumbah. Evacuation is possible from most areas in a 100 year ARI event, however there is much less time available in a PMF event and most evacuation routes close before warnings can be issued. Additional resources may be required to provide assistance to the hospital which would be isolated in such an extreme event.

South Murwillumbah. Evacuation is possible from most areas in a 100 year ARI event, however in a PMF event, there is early inundation of most evacuation routes before warnings can be issued.

Rural Areas. Evacuation of rural areas can be difficult, due to the isolation of these properties and the distance through the floodplain the residents may have to travel in order to reach an evacuation centre.

3.5.4 Riverside Villages

The Riverside Villages area has a moderate evacuation risk. Riverside towns, such as Condong and Tumbulgum, can be frequently inundated, however evacuation is generally possible for smaller flood events. Low-lying roads near the river flood frequently and can seriously impede evacuation. Areas with easy access to higher ground, such as Terranora, have a good evacuation capability.

Areas identified to have a particularly high evacuation risk are:

Tumbulgum. Evacuation is likely to be possible during most large flood events, but is constrained during a PMF event.

Condong. Evacuation is likely to be possible during most large flood events, but seriously constrained during a PMF event.

Dulguigan and Tygalgah. The identified evacuation route for the area, Dulguigan Road, is frequently affected by flooding, rendering it unsuitable for use as an evacuation route.

3.6 Risk to Property

In addition to personal risk, properties can also be at risk of serious structural damage due to high velocities, depths and flood flows, as well as internal, external and indirect losses. Using the flood model and property survey, the number of residential and commercial properties experiencing above floor flooding was estimated, shown in Table 3-4.

Table 3-4 Estimated Number of Inundated Properties

Flood Event	Inundated Properties (Above Floor)	
	Residential	Commercial
5 year ARI	17	35
20 year ARI	390	80
100 year ARI	1,130	340
500 year ARI	6,080	720
Extreme flood	14,320	970
PMF	14,700	1,000

3.6.1 Flood Damages

A flood damages assessment has been completed for the entire floodplain study area, using the existing flood model, as developed for the Tweed Valley Flood Study. This assessment estimated an annual average damages (AAD) cost of **$22.3 million**. This value includes damages incurred by residential and commercial properties and approximated infrastructure damages.

Results of this assessment for the entire study area are presented in Table 3-5, below.

Table 3-5 Flood Damage Estimates (millions of $)

Flood Event	Flood Damage Estimates (millions of $)			
	Residential	Commercial	Infrastructure	Total
5 year ARI	$7	$3	$1	$12
20 year ARI	$65	$6.7	$10	$82
100 year ARI	$151	$44	$27	$223
500 year ARI	$678	$182	$120	$980
Extreme flood	$2,374	$620	$417	$3,411
PMF	$2,621	$664	$458	$3,743
AAD	**$16.1**	**$3.5**	**$2.8**	**$22.3**

4 FLOOD MODIFICATION MEASURES

Flood modification measures are designed to modify the behaviour of floodwaters by either reducing flood depths and velocities, or by excluding floodwater from certain areas.

4.1 Existing Measures

There has been a long and extensive history of investigations into structural works to mitigate flooding in the Tweed Valley, particularly in the 1970s and 1980s. These have primarily resulted in the construction of levees and minor drainage works including flap gates. Other options including flood mitigation dams, floodways and channel modifications have also been considered in the past; however the benefits were not found to justify the often considerable expense.

4.1.1 Levees

Flood mitigation levees have been constructed in multiple locations within the study area, most notably around Murwillumbah and South Tweed Heads, as outlined in Table 4-1. These levees provide varying degrees of flood protection, though are generally less than 100 year ARI flood levels.

Table 4-1 Levee Summary

Levee	Approximate Construction	Design Protection	Estimated Protection
East Murwillumbah (Raised)	2006	100 year ARI	Between 20 and100 year ARI
Dorothy Street Murwillumbah	2006	100 year ARI	Between 100 and 500 year ARI
Murwillumbah Sewage Treatment Plant	1999	100 year ARI	Between 20 and100 year ARI
Murwillumbah Commercial Road	1990	Unconfirmed	Between 20 and100 year ARI
Bray Park	1990	Unconfirmed	Between 20 and100 year ARI
East Murwillumbah	1976	10 year ARI	Between 20 and100 year ARI
Tweed Heads South	Pre 1979	20 to 50 year ARI	Between 5 and 20 year ARI

4.1.2 Clarrie Hall Dam

Clarrie Hall Dam, located in the upper catchment between Doon Doon and Uki, was completed in 1982. The primary function of the dam is water supply and the dam is operated to meet this function. It was not designed as a flood mitigation dam though it may provide some limited storage.

4.1.3 Other Minor Drainage Works

A number of other drainage works that assist in mitigating Tweed River flooding have been constructed throughout the study area, including:

- Flap gates on Blacks Drain and Condong Drain (outlet behind Quarry Road);
- Flood gating of:
  - The Lavender Creek outlet;
  - Drains around Murwillumbah showgrounds and Kynnumboon Bridge;
  - Drainage outlets into the Tweed River around North Tumbulgum Flats ; and
  - Tweed River Left Bank Flats (golf course to Tweed Heads to Terranora Broadwater);
- General drainage works along Tweed River, from McLeod's Creek to Fingal Head, including flood gating and raising of the Pacific Highway.

4.2 Flood Modification Options

4.2.1 Whole of Study Area

A number of flood modification options are available to mitigate flooding on a catchment scale, however these are generally very expensive and can have significant environmental implications. None were identified as being suitable for further assessment to benefit the broader study area. The options considered during the study and reported on in the discussion papers include:

- Flood mitigation dams;
- Retarding basins;
- Bypass floodways;
- Channel modifications; and
- (Additional) levees.

A number of other flood mitigation options have previously been considered for the study area and found to be not viable. These options include:

Development of a new river mouth. This option is unlikely to be economically feasible and may cause adverse hydraulic impacts.

Dredging from Murwillumbah to Tweed Heads. This option is unlikely to be economically viable solely to reduce flooding and has associated adverse environmental impacts. However, dredging may provide some benefit to areas in the Lower Tweed, as well as Chinderah, if it were pursed for other objectives (e.g. sand nourishment of Kingscliff Beach).

4.2.1.1 Commission Local Drainage Studies

It was noted throughout the study that there are known local drainage issues affecting multiple locations throughout the study area. Whilst these were not the focus of this study, it is recommended that studies focussed on local drainage and the associated flood risks are undertaken.

Specifically, local drainage issues have been known to be key impediments to evacuation in the past, in areas that are already facing significant evacuation risks. More generally, information on local flood risk is useful for the purposes of quantifying stormwater risks, identifying potential for mitigation and development planning.

It is recommended that hydraulic models are developed which include drainage infrastructure, such as pipes and pits. Based on anecdotal evidence from past flooding events (particularly 2005), local drainage studies are recommended for the lower Tweed area (including Tweed Heads, Tweed Heads South and Banora Point), and Chinderah. A local drainage study for Murwillumbah town is also needed for the purposes of quantifying stormwater risks and development planning purposes.

Recommendation: Undertake local drainage studies focussed on specific areas. For the lower Tweed and Chinderah areas this should include consideration of local stormwater constraints to key evacuation routes. For Murwillumbah, further information is needed on extent and level of local stormwater inundation for planning purposes.

4.2.2 Lower Tweed

4.2.2.1 Raise Tweed Heads South Levee

The Tweed Heads South levee was constructed in the late 1960s / early 1970s and was designed to provide immunity for a 20 year ARI flood, with a design crest of approximately 2.0 mAHD. The *Tweed Valley Flood Study Update* (BMT WBM, 2009) and the Tweed Shire Local Flood Plan identified that the levee has been poorly maintained and does not provide the level of protection it was designed for.

The location of the levee is shown in Figure 4-1, which was based on ground survey undertaken and included in the flood model developed for the Flood Study.

Issue: There is a high flood risk to people and properties behind the levee.

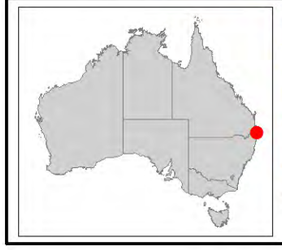
The potential benefits of raising the Tweed Heads South levee to approximately 2.8 mAHD to provide a 100 year ARI standard of flood protection (including 0.5 metre freeboard) have been assessed, including consideration of both evacuation capability and flood damages.

The assessment determined that the raising the levee would provide significant protection to properties behind the levee in larger flood events. Raising the levee would also provide an additional three hours to evacuate in a PMF event due to a delay in levee overtopping. The additional time is sufficient for the entire Dry Dock Road area (excluding Philp Parade (see Section 4.2.2.3 below) to cross Boyds Bay Bridge into Tweed Heads.

A significant reduction in flood damages of $2.6 million per year (AAD) was identified. A preliminary cost benefit assessment was undertaken, with the final values provided in Table 4-2 below.

Table 4-2 Cost Benefit Ratio

Total Benefit ($2011)	$36.1m
Total Cost ($2011)	$11.4m
Monetary Benefit-Cost Ratio	**3.2**



LEGEND

- Tweed Heads South Levee
- Area Benefitting from Raising Levee
- Philp Parade Levee
- Area Benefitting from Philp Parade Levee
- Cadastral boundaries
- 100 Year ARI Flood Extent
- Probable Maximum Flood Extent

Title:
Tweed Heads South Levee

Figure: 4-1

Rev: A

N

0m 300 600

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_011_120501_Tweed Heads South Levee.WOR

This benefit cost ratio is high and provides good support for raising the levee. However, it should be noted that levees can foster a false sense of security in the community, with the belief that their property is "flood proof". Raising the levee will require a significant outlay, although it is expected to bring significant economic benefit. It will also offset costs to raise 7 properties in Tweed Heads South as part of a voluntary house raising scheme (estimated cost of approximately $490,000, see Section 6.2).

Recommendation: Raising the Tweed Heads South levee to provide 100 year ARI protection is a viable and beneficial option. A more detailed costing by a quantity surveyor is required, along with community consultation and detailed consideration of social and environmental impacts and mitigation.

4.2.2.2 Commission Levee Overtopping Study

Levee overtopping studies consider the particular flood risk associated with levee overtopping and the effects it has on people, properties and infrastructure. A levee overtopping study for the Tweed Heads South levee would need to compare the relative overtopping risks for the levee at the current height and at the proposed raised height.

A levee overtopping study of the South Tweed Levee would likely include the following:

- Improved detail in the flood model in the levee area, including addition of the proposed (raised) levee height in the proposed scenario;
- Consideration and assessment of controlled overtopping locations;
- Assessment of time of overtopping, location of overtopping, relationship to stream gauge levels;
- Assessment of hazard behind the levee, including time of inundation following overtopping, high flow hazards, road closures;
- Assessment of impact to personal safety, properties and infrastructure following levee overtopping;
- Sensitivity analysis comparing levee overtopping for floods of different durations and / or combinations with storm surges;
- Recommendations for SES to improve flood response and emergency planning in the event of levee overtopping; and
- Recommendations for Council regarding land use and building design in the area behind the levee.

Recommendation: Additional investigations into raising the Tweed Heads South levee should include a levee overtopping assessment to better understand the impact that the measure will have on flood risk and risk management in the Tweed Heads South area.

4.2.2.3 Extend Tweed Heads South Levee to Philp Parade

It has been proposed that the Tweed Heads South levee might be extended (westwards) to protect the Philp Parade area.

Issue: Philp Parade has a high flood risk and an extremely constrained evacuation capability due to frequent inundation.

Preliminary hydraulic assessment of the levee extension modelled the levee crest at 2.8m AHD, consistent with the raised levee option. Results from the hydraulic assessment indicate that extension of the levee will protect approximately 60 properties from inundation in flood events up to and including the 100 year ARI event. This should also provide sufficient time to evacuate to Tweed Heads in a PMF event due to a delay in levee overtopping.

This measure will significantly improve the safety of residents in the Philp Parade area. Residents and properties will be protected from smaller flood events and have more time to evacuate during larger events.

Constructing a levee in the proposed location would however significantly impact the visual amenity and character of the area by blocking direct river access in this location. These factors should be considered in conjunction with hydraulic and economic impacts.

The total economic benefit is estimated at **$8 million**, based on an associated reduction in average annual damages for flood events up to and including the 100 year ARI. It would also offset costs to raise 5 properties in the Philp Parade area as part of a voluntary house raising scheme (estimated cost of approximately $350,000, see Section 6.2). A capital cost estimation has not been completed at this stage.

Recommendation: The levee extension option should be considered by the FRMS Committee and Council, in conjunction with appropriate community consultation, to determine whether it might be viable. If so, a full and separate study would need to be undertaken to analyse the hydraulic, safety, environmental, social and economic impacts of the extension.

4.2.3 Chinderah, Fingal Head & West Kingscliff

No suitable flood mitigation options were identified for the Chinderah, Fingal Head and West Kingscliff area as part of this study.

A number of other flood mitigation options have previously been considered for the study area and found to be not viable. These options include:

Levees. This option is unlikely to be viable for Chinderah due to technical difficulties, costs associated with the levee and works to existing structures, and hydraulic and visual impacts.

Floodway. There are limited opportunities to provide benefit in a very large flood event without adverse impacts and / or significant property resumption.

4.2.4 Murwillumbah & South Murwillumbah

A number of flood mitigation options have previously been considered for the Murwillumbah and South Murwillumbah region but were not found to be viable. These options include:

Levees. Levees in Murwillumbah have been raised in the past. It is unlikely that these levees will be further raised due to hydraulic constraints.

Channel Modifications. This option is unlikely to be effective for large, out-of bank flow events that cause the most impact and damage. It may also exacerbate downstream risk and the scale of works required may be prohibitive.

Floodways. There are limited opportunities to provide benefit in a very large flood event without adverse impacts. The costs associated with implementation of the floodways may be prohibitive. However, the potential to alleviate flooding via a South Murwillumbah bypass floodway from Blacks Drain to the airstrip was revisited. This would require the acquisition and lowering of land at Blacks Drain (to increase flow into the basin when the river is in flood) and at the outlet to the Condong Basin at Quarry Road.

Whilst hydraulic modelling confirmed a bypass floodway would reduce flood levels in the river (and in the areas behind the town and East Murwillumbah levees, i.e. north of the river), it would lead to higher flood levels in the South Murwillumbah basin affecting existing areas of development, and so was not considered to be a viable option. This was consistent with the findings of previous investigations undertaken as part of the 1989 Murwillumbah Floodplain Management Plan (Tweed Shire Council, 1989).

4.2.4.1 South Murwillumbah Condong Flowpath

Whilst a bypass floodway was not considered viable without some adverse impacts, it was found that flooding in the South Murwillumbah basin can be alleviated (by depths of 50 to 100 mm in a 100 year ARI flood) by increasing flow through the South Murwillumbah / Condong Basin connection at Lot 4 Quarry Road (i.e. without increasing flow into the basin via Blacks Drain). This parcel has separately been identified for preservation as a critical floodway via acquisition or planning controls (see Section 8.2.2).

If it is to be acquired, lowering of the land to the level of the airstrip upstream will increase flows from the South Murwillumbah to the Condong basin and reduce levels in the basin by approximately 50mm without significant downstream impacts. Incorporating a hydraulic structure under Quarry Road may reduce levels further.

Recommendation: Depending on the approach to secure the South Murwillumbah Condong flowpath (acquisition or planning controls), consider lowering of this lot (together with further design of a hydraulic structure under Quarry Road) to reduce flooding in the South Murwillumbah basin.

4.2.4.2 Commission Levee Overtopping Study

Levee overtopping studies consider the particular flood risk associated with levee overtopping and the effects it has on people, properties and infrastructure. A levee overtopping study for the Murwillumbah levees would primarily focus on quantifying the current level of protection, highlighting areas which may need augmenting and identifying areas of particularly high hazard which may influence local development controls.

A levee overtopping study of the Murwillumbah levees would likely include the following:

- Improved detail in the flood model in the levee area;
- Consideration and assessment of controlled overtopping locations;

- Assessment of time of overtopping, location of overtopping, relationship to stream gauge levels and degree of protection provided (e.g. protection from 100 year ARI flood);
- Assessment of hazard behind the levee, including time of inundation following overtopping, high flow hazards, road closures;
- Assessment of impact to personal safety, properties and infrastructure following levee overtopping;
- Sensitivity analysis comparing levee overtopping for floods of different;
- Recommendations for SES to improve flood response and emergency planning in the event of levee overtopping; and
- Recommendations for Council regarding land use and building design in the area behind the levee.

Recommendation: A levee overtopping assessment of the Murwillumbah levee system would improve understanding of local flood behaviour and better inform future floodplain management measures for the area.

4.2.5 Riverside Villages

No suitable flood mitigation options were identified for the Riverside Villages area as part of this study.

Levees have previously been considered for this area but found to not be viable due to high capital costs and undesirable impact on visual amenity.

4.3 Flood Modification Recommendations

Extensive previous investigations, together with a review of flood modification options as part of this study, indicate there are unlikely to be any options found to be effective or economical at the catchment scale.

Raising the existing Tweed Heads South Levee to the 100 year ARI flood level was found to have a high benefit cost ratio as well as increased protection to residents and evacuation time during extreme flood events. This option has a strong case for pursuing further.

Extension of the South Tweed Levee to Philp Parade is an option which may be considered in the future to decrease the considerable safety risks in the area. A detailed analysis has not been undertaken on this option to date, however recognised constraints to the extension of the levee include loss of visual amenity and likely loss of direct river access in this location.

A number of smaller scale flood modification options might be considered to improve stormwater flooding and drainage issues across the catchment which have not been the focus of this study. These options include detailed stormwater assessments (possibly through the development of a finer scale flood model), and the inclusion of pumps and flood gates in levied areas. It is however recommended that separate studies be undertaken to investigate and manage flood risk from local drainage and stormwater in key locations, specifically the Lower Tweed, Chinderah, and Murwillumbah.

5 RESPONSE MODIFICATION MEASURES

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

5.1 Existing Measures

A number of response modification measures are currently in use in the study area including a detailed flood warning system, various sources of flood intelligence and the Local Flood Plan (LFP) developed and maintained by the SES. These measures are described below.

5.1.1 Flood Warning System

The flood warning system commences with the issue of Flood Watches and Flood Warnings from the Bureau of Meteorology (BoM) and concludes with the public receiving a detailed message about flood risk and required action.

The BoM maintains an operational (hydrologic) model of the Tweed catchment which utilises recorded and forecast rainfall to predict flooding in the catchment. It is estimated that forecast rain in excess of 120 mm per day would trigger a Flood Watch and ongoing monitoring and modelling. Stream gauges actively monitored by BoM include Murwillumbah Bridge and Barneys Point (Chinderah), as marked on Figure 5–1.

The SES monitors a number of additional stream gauges, provided in Appendix B.

The flood levels correlating to these BoM definitions for minor / moderate / major floods, as well as design flood levels, have been provided for the Murwillumbah and Chinderah gauges in Table 5-1 below.

Flood classifications of minor, moderate or major relate to the effects of flooding, as per the following BoM definitions:

- **Minor flooding**: Causes inconvenience. Low-lying areas next to watercourses are inundated which may require the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged.
- **Moderate flooding**: In addition to the above, the evacuation of some houses may be required. Main traffic routes may be covered. The area of inundation is substantial in rural areas requiring the removal of stock.
- **Major flooding**: In addition to the above, extensive rural areas and/or urban areas are inundated. Properties and towns are likely to be isolated and major traffic routes likely to be closed. Evacuation of people from flood affected areas may be required.

Table 5-1 Flood Event Levels at Stream Gauges

Flood Event	Murwillumbah Gauge	Chinderah Gauge
Minor Flood	3.0m AHD	1.5m AHD
Moderate Flood	4.0m AHD	1.7m AHD
Major Flood	4.8m AHD	2.0m AHD
5 year ARI	5.5m AHD	1.3m AHD
20 year ARI	5.8m AHD	2.2m AHD
100 year ARI	6.9m AHD	3.0m AHD
500 year ARI	7.9m AHD	4.4m AHD
PMF	12.1m AHD	7.7m AHD

5.1.2 Flood Intelligence

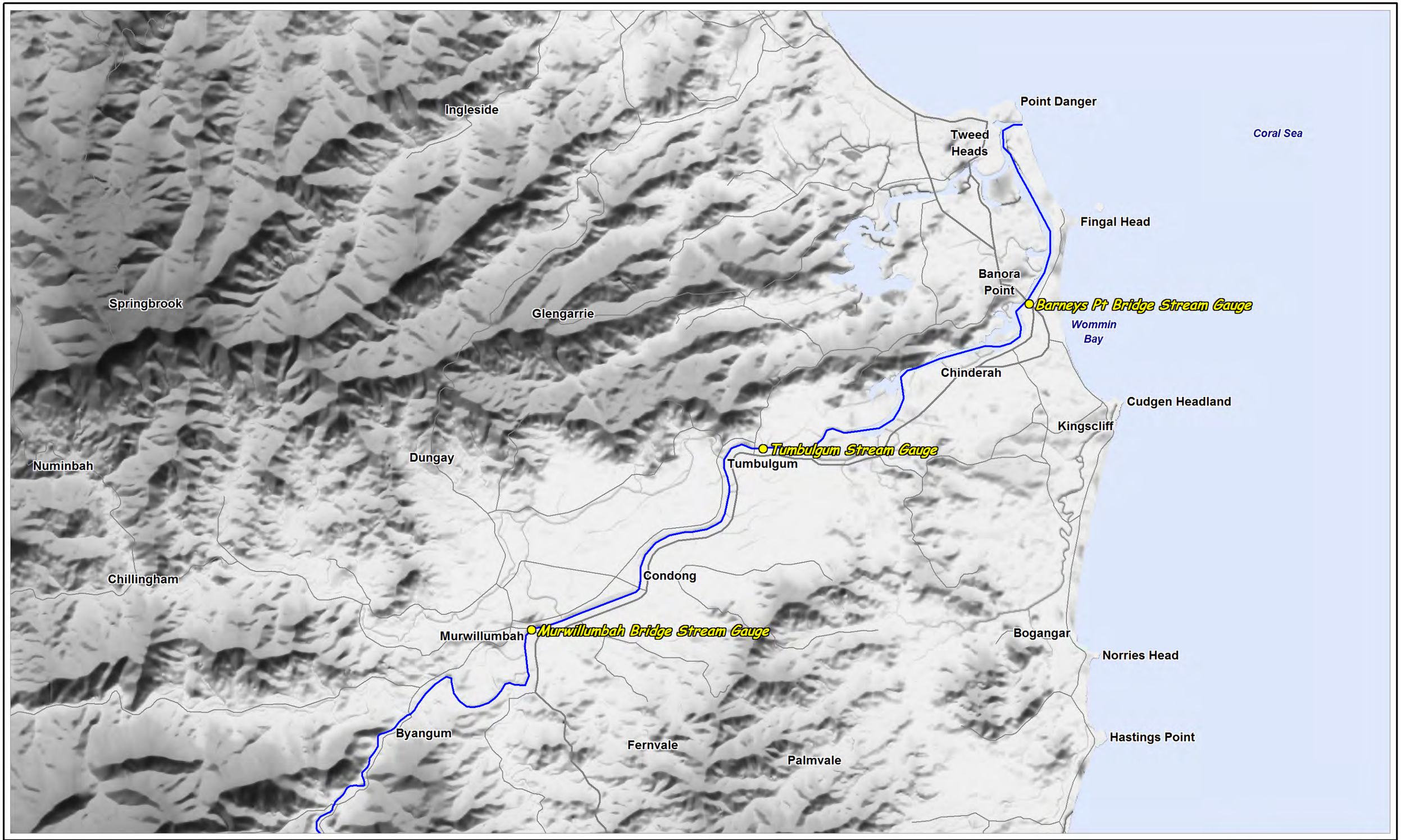
In the Tweed Valley, flood intelligence is primarily recorded in Flood Intelligence Cards. These cards detail the relationship between flood gauge heights and flood consequences. They are used by the SES to interpret the meaning of quantitative flood predictions and to help decide appropriate flood response actions. Within the study area, flood intelligence cards exist for the Murwillumbah, Tumbulgum and Barneys Point (Chinderah) gauges. These cards are maintained and updated by SES Headquarters and, as they contain sensitive information such as house addresses, are not publically available.

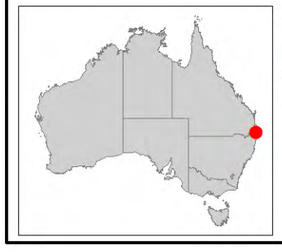
5.1.3 Local Flood Plan

The Tweed Shire Local Flood Plan (LFP) is prepared by the SES and the Local Emergency Management Committee (within Council) and is a sub-plan of the Tweed Shire Local Disaster Plan (often referred to as DISPLAN).

The LFP outlines preparedness and management operations for all flooding events within the Tweed local government area, including those generated by storm surge events. Information contained in the LFP is largely derived via local knowledge and historical record.

The SES follows the LFP, using information from Flood Intelligence Cards and BoM's predictions, to respond in actual flood events.





LEGEND

- Tweed River
- Principal Road
- Sealed Road

Title:

Flood Warning Network

Figure: **5-1**

Rev: **A**

N

0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

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5.1.4 Cross Border Planning

A Cross Border Plan has been developed by Gold Coast City Local Disaster Management Group and Tweed Shire Local Emergency Management Committee to assist coordination of emergency response between Tweed Heads and Gold Coast. Cross border disaster planning faces a number of challenges including differences in command and control structures, language and communication channels, legislative frameworks, and (during summer) time zones. The Cross Border Plan, in conjunction with continued liaison between the two Council groups, aims to minimise the effect of these challenges in preparation for, during and following a disaster event that impacts the cross border community.

5.1.5 Flood Awareness

There is no record of past formal assessments (e.g. surveys) to gauge community flood awareness in the study area, however anecdotal evidence suggests that flood awareness is low, due to the following reasons:

- There have been no major floods in recent times;
- Residents may have a false sense of security about the effectiveness of flood protection structures such as levees;
- There are a large number of new residents in the area who are unfamiliar with local flood behaviour; and
- The lower Tweed is a major tourist area, with tourists unaware of local flood behaviour or evacuation procedures.

5.2 Response Modification Options

The following response modification options have been put forward as suggestions to augment the extensive evacuation planning already undertaken by the SES.

5.2.1 Flood Awareness

5.2.1.1 Community FloodSafe Engagement Program

The SES has recently created a Community Engagement Officer position for the Richmond Tweed Division. One of the Officer's primary responsibilities is the creation of the Community FloodSafe Engagement Program. The stated aims of this program are to:

- Increase community awareness of flood risk;
- Increase community understanding of what to do before / during / after floods;
- Increase awareness of SES role and SES phone number; and
- Build partnerships with local community / business / local and state government.

Planned strategies include media releases, SES community education training, additional brochures targeting other sectors of the community, flood risk workshops with retirement village managers and business breakfasts.

Issue: Flood awareness is low.

This program is in its infancy and has yet to secure funding for all of the planned programs and strategies.

In addition to the target groups identified by the SES, based on key risks identified in this study it is recommended that the following issues also be prioritised in the awareness program:

- Understanding the limits of levee protection, as well as residual risks such as the fast rate of inundation when a levee is overtopped;
- The range and full extent of flood risk (e.g. the depth differential between a 'major' flood as predicted by the BoM, a 100 year ARI flood and PMF);
- Assistance in interpreting flood warnings; and
- The increased flood risk at caravan parks.

Recommendation: Financial assistance be provided to support the SES achieve their stated aims of increasing flood awareness.

5.2.1.2 Evacuation Planning Information

Feedback from stakeholder submissions indicates that the community would like to know more about the evacuation planning process.

Issue: The community wants more information about local evacuation planning.

Recommendation: The SES publish and publicise the locations of major evacuation routes and evacuation centres. This will also serve to enhance community flood awareness and readiness.

Some information about evacuation planning, issues and proposed response management measures will be provided to the community at the public open sessions held for this study.

5.2.1.3 Understanding Personal Flood Risk

It has been identified in previous flood events that residents have difficulty relating broad scale flood warnings (e.g. 'major' flood predicted) or predicted gauge heights to their personal level of flood risk.

This issue is particularly evident in Murwillumbah where the issue of minor/moderate/major flood classification has been contentious in the past. A major flood in Murwillumbah (i.e. capable of closing major traffic routes, isolating properties etc) is smaller than the 5 year ARI event. Relative heights at the flood gauge are shown in Figure 5–2, below.

Note that the 100 year ARI flood level at the Murwillumbah gauge is 2m higher than the 'major' flood level (and the PMF level 5m higher again).

This means that 'major' floods are likely to occur relatively frequently. As a result, when a major flood is predicted, residents in Murwillumbah don't know whether to expect flooding on a scale which is seen frequently, or something much more serious. In the case of a larger flood (such as the 100 year ARI or up to PMF), many people and properties would be at risk.

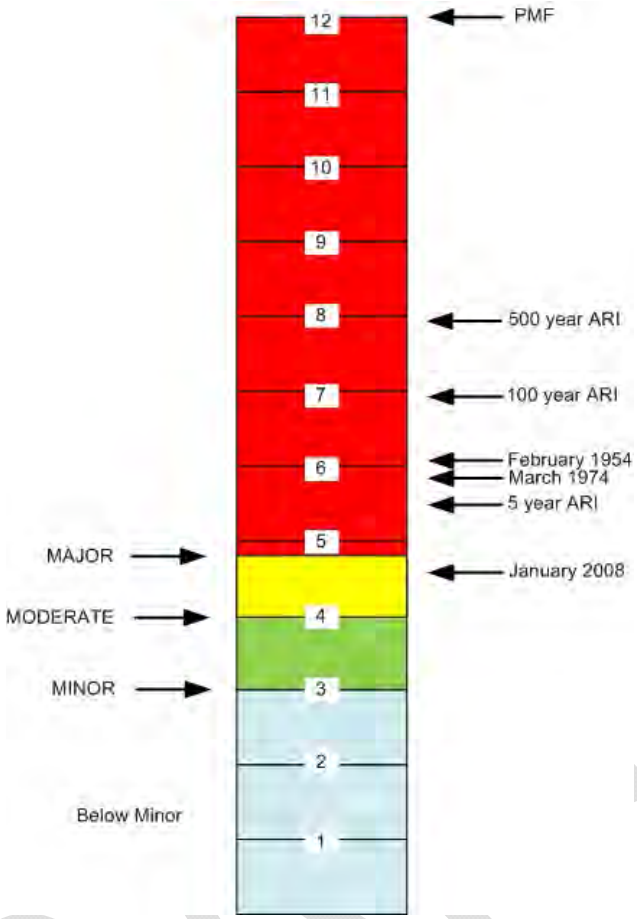


Figure 5–2 Murwillumbah Gauge Heights

In addition, although the predicted gauge height is generally given with the flood warning, most residents are unable to translate this into a personal flood risk. Very few residents would know the absolute height (i.e. in m AHD) of their property or local roads. Even if residents are aware of their property level, flood slope and local flood behaviour means that it is not a simple translational exercise to estimate flood levels at specific locations.

Issue: Residents have difficulty interpreting the scale of flood classifications and return periods, and relating this information to personal flood risk.

Recommendation: Utilise information on flood behaviour to show the relationship between individual locations (e.g. dwellings, major evacuation routes etc) and the nearest stream gauge.

If implemented, this recommendation would also serve to enhance community flood awareness of the scale of flood classifications and large to extreme flood events in excess of those previously experienced.

This option would require some modelling of additional flood events (i.e. durations, magnitudes, spatial and temporal patterns etc) to maximise the robustness of estimates, as every flood is different. It would also be necessary to ensure the community understood and was correctly interpreting individual prediction information. A potential output from this process might be a figure showing the local stream gauge in relation to the resident's property. An example is provided in Figure 5–3.

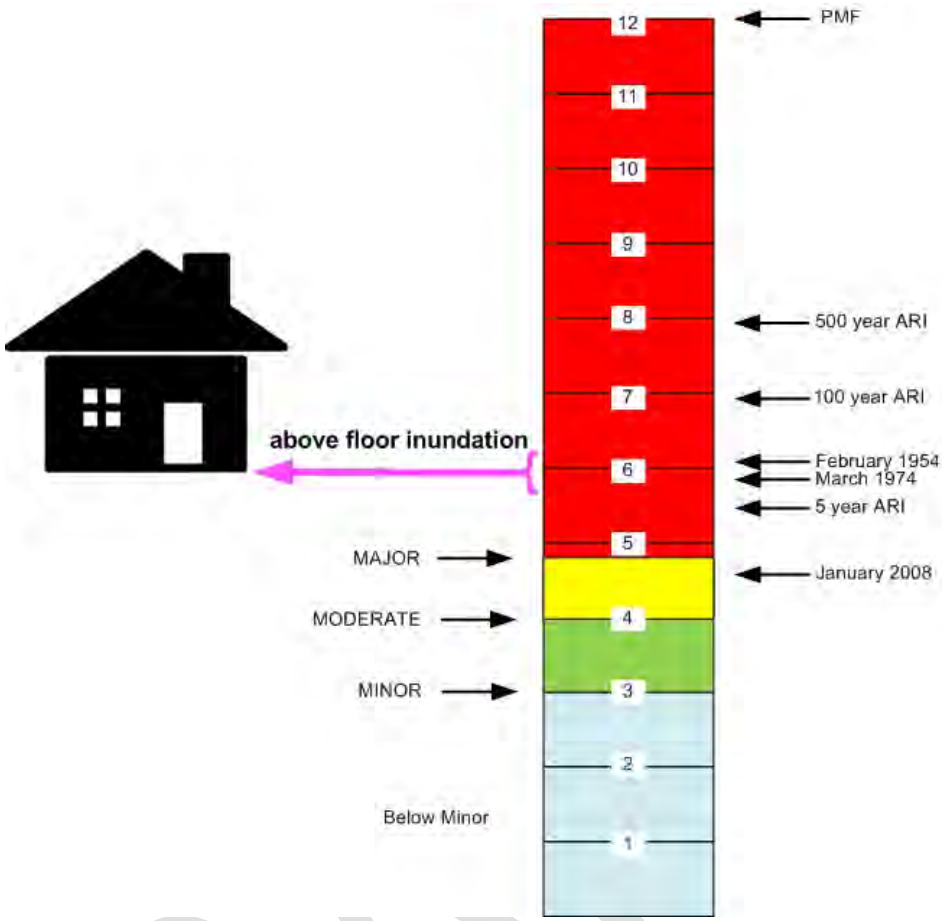


Figure 5–3 Floor Level to Gauge Relationship

5.2.2 Flood Intelligence

5.2.2.1 Flood Intelligence Cards

The flood intelligence cards used for flood planning in the Tweed Valley (i.e. Murwillumbah, Tumbulgum and Chinderah) were reviewed by Bewsher Consulting following the most recent major flood event in 2008. Recommendations included updates to the FICs and advice regarding ambiguous flood datums.

The SES has advised that recommendations provided in the review have not yet been implemented.

Issue: Flood intelligence requires updating

Recommendation: Flood intelligence cards should be updated with recommendations from the Bewsher review, design flood levels determined in the Tweed Valley Flood Study Update (2009) and any further flood intelligence developed as part of this study.

It is recommended that the SES consider the inclusion of 'triggers' in the flood intelligence cards. At present, a number of critical levels are noted along with correlated effects, such as road closures. Value could be added to this information by linking each critical level with a (lower) trigger level. If the trigger level was reached and flood levels were rising, the SES would act to minimise the impact which is predicted to occur at the critical flood level.

It is understood that the SES intend to update the cards in the near future, however the process has been delayed due to the need to verify recommendations made about flood datums in the review. This verification process will most likely be the joint responsibility of SES and Council.

5.2.2.2 Flood Information Website

Recent floods in Queensland and elsewhere in Australia have highlighted that the general public looks for flood information online during flood events.

Council have provided some flood information (such as online mapping and copies of reports), however the public still have to search multiple other websites to gain a full understanding of flood conditions and warnings etc.

In addition, standard websites can become overwhelmed when a large number of people try to access them simultaneously. Flood information websites need to be robust enough to handle high volumes of web traffic.

Issue: Tweed Valley flood information is spread over multiple, unrelated websites. Council's website may crash during major flood events.

Recommendation: Council upgrade the flood information area of their website to provide a comprehensive collection of flood information, and develop measures to divert to a more robust 'bare bones' site during high web traffic times.

5.2.3 Flood Warning System

5.2.3.1 Method of Flood Warning

Flood warnings are issued via a number of methods; however the most reliable method is doorknocking. Doorknocking requires teams of two SES staff and is estimated to take each team five minutes per house. To maximise the likelihood of safe evacuation (and minimise rescues), the SES aim to manage the warning process to best utilise route capacities. To simultaneously carry this out across the entire floodplain (i.e. the PMF extent) requires extensive staff and time resources.

Issue: SES staff resource requirements are too great and unlikely to be met.

A number of warning methods could be used in addition to doorknocking to alleviate resources requirements. A comparison of various warning methods is provided in Figure 5–4.

Recommendation: SES consider options to supplement doorknocking with alternative methods.

Outcomes from this study will provide additional information about flood behaviour and risk to the SES.

Issue: The Local Flood Plan needs updating to reflect the most recent flood information including information from this study.

Recommendation: SES review and update response plans based on the outcomes of this study, e.g. to include risk-based prioritisation of resources and plans to manage the warning process.

Sirens/alarms	• Quick; reliable; limited information and reach, but becoming more versatile with voice and remote capabilities
Text message	• Can reach wide audience very quickly; no power needed • Less reliable for areas with poor mobile phone coverage
Automated telephone	• Landlines becoming less common; people often not at home/indoors
Radio message	• Electricity not required; widest reach – home, work, travelling • Variable accuracy; requires public to be listening
Television	• Electricity required; variable accuracy; limited reach; requires public to be listening
Websites/ social media	• Quick dissemination; becoming very widespread; capacity for images • Electricity/internet required; variable accuracy
Email	• Quick dissemination, but usually has to be actively accessed; power and telecommunication infrastructure needed; internet required
Speaker phone	• Direct, specific communication • Requires access to flooded area; difficult to hear
Doorknocking	• Direct communication; chance to ask questions; high credibility • Resource intensive; requires access to flooded area
Letterbox drop	• Ability to reach almost all audiences, but may miss youth • Slow; requires access to flooded area
Noticeboards	• Useful for roads, infrastructure and location-specific information; can be controlled remotely
Print media	• Informative/detailed; ability to reach wide audience • Time needed; variable accuracy
Word of mouth	• Uses info from multiple sources; persuasive • Variable accuracy

Figure 5–4 Comparison of Flood Warning Communication Methods [1]

5.2.3.2 Tumbulgum Stream Gauge

An automatic stream gauge is in place at Tumbulgum, at the confluence of the Tweed and Rous Rivers. The SES has developed a flood intelligence card relating flood heights at the Tumbulgum stream gauge to effects in the surrounding floodplain.

However, this gauge does not form part of BoM's formal flood warning network. As a result, predictions are not issued for flood heights at this location and the SES must make their own prediction of flood height, based on predictions for the Murwillumbah gauge. These predictions may be less accurate than predictions based on the BoM hydrologic model, which will also include influences from the Rous River.

[1] (Office of the Queensland Chief Scientist, 2011)

Issue: Additional information exists for Tumbulgum but is not being best utilised.

Recommendation: Discuss this issue with the NSW Flood Warning Committee to determine whether it is feasible to expand the formal flood warning system to include predictions for the Tumbulgum gauge.

5.2.3.3 Storm Surge Prediction

Storm surge predictions are currently issued on the peak prior to the storm, i.e. 12 hours prior to peak. This may not be sufficient time to prepare, warn and evacuate the public.

Issue: Storm surges are difficult to predict more than 12 hours in advance.

The Bureau's research centre is developing storm surge predictions products that should extend this warning lead time, even to the extent of flagging this in Flood Watches. It is likely that experimental coverage for the Tweed River will be available within the next 12 months.

Recommendation: Update flood planning and warning as improved warning products become available from BoM.

5.2.4 Evacuation Planning

Detailed recommendations about improving the evacuation capability of individual locations has been provided to the SES via a series of region specific discussion papers. A number of more general evacuation planning recommendations have been provided below.

5.2.4.1 Detailed Evacuation Planning Study

The evacuation capability assessments undertaken as part of this study (reported in the Discussion Papers) were able to highlight constraints in the evacuation system, such as early road closures, lack of evacuation centre capacity and insufficient warning times. However, a more detailed evacuation planning study will be required to investigate trouble spots more closely and plan strategies for reducing evacuation risk at a local level. These strategies might include targeted flood education, early or pre-emptive warning, or pedestrian evacuation, as described below.

5.2.4.2 Targeted Flood Education

It is recommended that residents in high risk areas should be warned about the increased flood risk in their location and made aware that they may be evacuated more frequently than other areas. Residents behind levees should also be the subject of targeted education campaigns to highlight the limits of protection provided by the levee.

5.2.4.3 Early / Pre-emptive Warning

Residents in areas which may be affected by flooding before the SES are able to issue warnings (according to standard timeframes and prediction certainty) should be considered for pre-emptive warning. This would accelerate the evacuation process for at-risk areas, potentially improving evacuation capability. However, this should be weighed against the fact that the chance of residents being evacuated unnecessarily will increase.

5.2.4.4 Pedestrian Evacuation

There are some locations where they may be less risk associated with pedestrian evacuation (than by car). In particular, locations with rising road access, high density development and close to evacuation centres would be suitable. Where pedestrian evacuation is appropriate, traffic congestion and associated delays may be reduced.

5.2.5 Evacuation Centres

5.2.5.1 Evacuation Centre Planning

It is understood that responsibility for managing and operating evacuation centres lies with the Department of Community Services (DoCS). Throughout this study, Council and SES have not been able to successfully liaise with DoCS to address issues relating to the evacuation centres. Feedback from both Council and stakeholders indicates that evacuation centres have been closed during past evacuations, despite residents being directed to these locations by the SES.

Issue: Poor communication channels between SES, Council and DoCS regarding response planning.

Recommendation: Council and SES should persist in their attempts to contact DoCS to discuss the operation of evacuation centres. When communication is established, a clear procedure should be developed and documented for the establishment of evacuation centres during floods

5.2.5.2 Evacuation Centre Capacity

Although a number of evacuation centres have been identified in the study area, it is likely that there would not be sufficient capacity in the event of a complete evacuation of the floodplain. Attempts have been made by the SES and Council to liaise with the Department of Community Services (DoCS) regarding the facilities available at the evacuation centres however this issue has not yet been addressed.

The capacity at each evacuation centre has been estimated from aerial photography building footprints and minimum Department of Health NSW (2011) recommendations of 3.5m^2 per evacuee.

Note that the number of people evacuating includes all residents whose house falls within the PMF extent. In practice, many residents are likely to evacuate to friends and family on high ground. Therefore, estimates of requirements might be considered an 'upper limit' for evacuation requirements.

Issue: Most evacuation centres have insufficient space, in particular Banora Point and Tweed Heads.

Recommendation: DoCS should undertake a review of existing evacuation centre capacity, including an inventory of the available facilities. Additional facilities, such as water and sanitation requirements, must be considered when determining the capacity and suitability of each evacuation centre. Additional safe evacuation centres should be identified where required and included in the LFP.

5.2.5.3 Tweed Civic Centre

As part of the evacuation capability assessment, it was recognised that the Tweed Civic Centre is within the 100 year ARI flood extent. Therefore, the Civic Centre is not suitable for use as a flood evacuation centre.

Issue: The Local Flood Plan directs residents to an unsafe evacuation centre.

Recommendation: Tweed Civic Centre be removed from the Local Flood Plan as an evacuation centre and an alternative evacuation centre(s) be identified.

5.3 Response Modification Recommendations

A number of response modification options have been put forward based on the outcomes of this study. Response modification options are the simplest and cheapest ways of reducing risk to life.

The recommendations addressed five general areas:

1 **Flood awareness**: improved flood awareness helps the community to better understand the flood risk and how it relates to them. An informed community is more likely to respond appropriately and safely during flood evacuation.

2 **Flood intelligence**: better use and understanding of flood information will enable the SES to better predict and plan for floods.

3 **Flood warning system**: improvements to the ability to convey flood warnings, either between agencies (such as BoM and SES) or to the community will increase the chance that evacuation will happen in a timely fashion.

4 **Evacuation planning**: detailed evacuation capability analyses highlighted which areas of the catchment have the greatest evacuation risk. This information should be used by the SES to create detailed evacuation plans, which may require different approaches for different areas.

5 **Evacuation centres**: better communication between the agencies responsible for evacuation planning will increase community safety by ensuring that there is sufficient evacuation centre capacity and that the centres are located in flood free areas.

6 PROPERTY MODIFICATION MEASURES

Property modification measures seek to reduce flood risk through careful planning of future developments. Property modification measures can also be applied to existing developments to either reduce the flood risk by raising the house, or by removing the property from the flood prone location altogether.

6.1 Existing Measures

As part of the 1989 Murwillumbah Floodplain Management Plan, a number of properties were identified as being at high flood risk. These properties were included in voluntary purchase and voluntary raising schemes, as detailed below.

Voluntary Purchase Scheme

- 13 properties identified (along River Street between Greville and Colin Streets).
- Of these, 4 properties currently remaining.

Voluntary House Raising Scheme

- 54 properties identified (including 15 in Bray Park and 39 upstream of Colin Street).
- All properties have been raised.

6.2 Property Modification Options

A number of criteria (or combinations of criteria) were compared for identifying and prioritising at-risk properties. These were derived from the Floodplain Development Manual, floodway classification and other hydraulic criteria.

6.2.1 Voluntary House Purchase

Properties which may be eligible for VHP have the highest hydraulic hazard in the study area. A number of hydraulic criteria were tested.

Issue: Identify an hydraulic criterion which targets those properties with the highest flood risk, while being economically feasible to implement.

A number of hydraulic criteria were tested for the 100 year ARI event for properties with above floor flooding. The following two criteria were found to be feasible.

Table 6-1 Properties Eligible for VHP

Potential Criteria	Eligible Properties
Option 2 (velocity > 2m/s or VxD > 1m^2/s or depth above ground > 2.5m)	29
Option 3 (velocity > 2m/s or VxD > 1m^2/s or depth above ground > 3.0m)	8

Prioritising houses with greater hazard, the houses identified in options 2 and 3 are located in Murwillumbah, as shown in Figure 6–1. These include the 4 remaining properties from the 1989 scheme.

A summary cost benefit analysis of the VHP scheme options is provided in Table 6-2, below.

Table 6-2 VHP Cost Benefit Summary

	Option 2	Option 3
Properties Purchased	29	8
Mean Property Price	$350,000 - $400,000	
Total Cost	$10,300,000	$2,800,000
Annual Average Benefit	$407,000	$220,000
Total Benefit	$5,619,000	$3,039,500
Benefit Cost Ratio	0.6	1.1

Recommendation: Option 3 has a significantly better cost benefit ratio but only removes eight properties from high hazard areas. Cost benefit is only a secondary consideration in the VHP scheme, as the primary objective is to reduce risk to personal safety by removing dwellings from high hazard areas.

6.2.2 Voluntary House Raising

Voluntary house raising (VHR) is aimed at reducing the flood damage to houses by raising the habitable floor level of individual buildings. Such measures can only be undertaken on a voluntary basis. VHR is a suitable management measure for houses in low hazard areas of the floodplain (DIPNR, 2005).

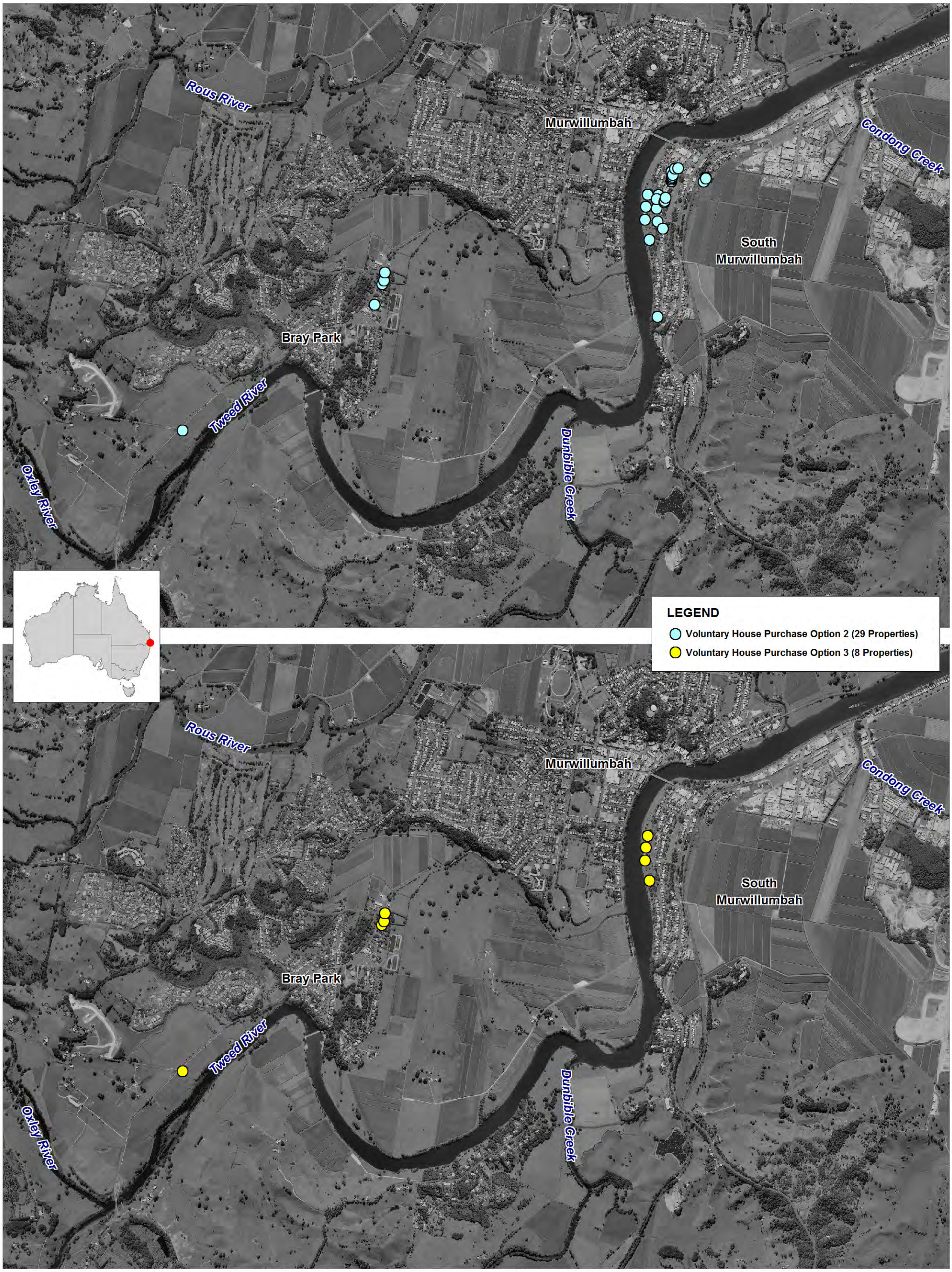
Potential eligible properties were identified based on above floor flooding in the 5, 20 or 100 year ARI events, excluding those identified for VHP in high hazard areas above. Houses also had to be structurally suitable for raising (i.e. wooden, not slab on ground) confirmed from the property survey.

Issue: Identify an hydraulic criterion which targets those properties with the highest flood risk and suitable for house raising, while being economically feasible to implement.

The following two criteria were found to be feasible.

Table 6-3 Properties Eligible for VHR

Potential Criteria	Eligible Properties		
	100 year ARI	20 year ARI	5 year ARI
Option 2 (not eligible for VHP option 2)	192	25	0
Option 3 (not eligible for VHP option 3)	211	30	2



Title:

Voluntary House Purchase Options

Figure: 6-1

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

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Prioritising houses with greater hazard in the 20 year ARI event, the houses identified in options 2 and 3 are located in Murwillumbah and the lower Tweed, as shown in Figure 6–2 and Figure 6–3.

A summary cost benefit of the VHR scheme options is provided in Table 6-4, below for raising of eligible properties to the 100 year ARI design flood level plus 0.5m freeboard.

Table 6-4 Voluntary House Raising Summary

	Option 2	Option 3
Properties Raised	25	30
Mean Property Raising Price	$70,000	
Total Cost	$1,750,000	$2,100,000
Annual Average Benefit	$223,000	$389,000
Total Benefit	$3,079,000	$5,368,000
Benefit Cost Ratio	1.8	2.6

Recommendation: Both schemes have a good cost benefit ratio (greater than 1), with Scenario 3 providing a better ratio and reducing the flood risk for a greater number of properties (but at slightly greater cost).

Note that if the Tweed Heads South levee is raised and / or extended (see Section 4.2.2) this would reduce the number of properties to be raised by 7 and 5 respectively in the Tweed Heads South and Philp Parade areas.

Murwillumbah

Mayal Creek

Condong Creek

Tweed River

South Murwillumbah

LEGEND

- Voluntary House Raising Option 2 (1 Property)
- Voluntary House Raising Option 3 (6 Properties)

Title:

VHR Option 2 and 3, Murwillumbah

Figure: 6-2

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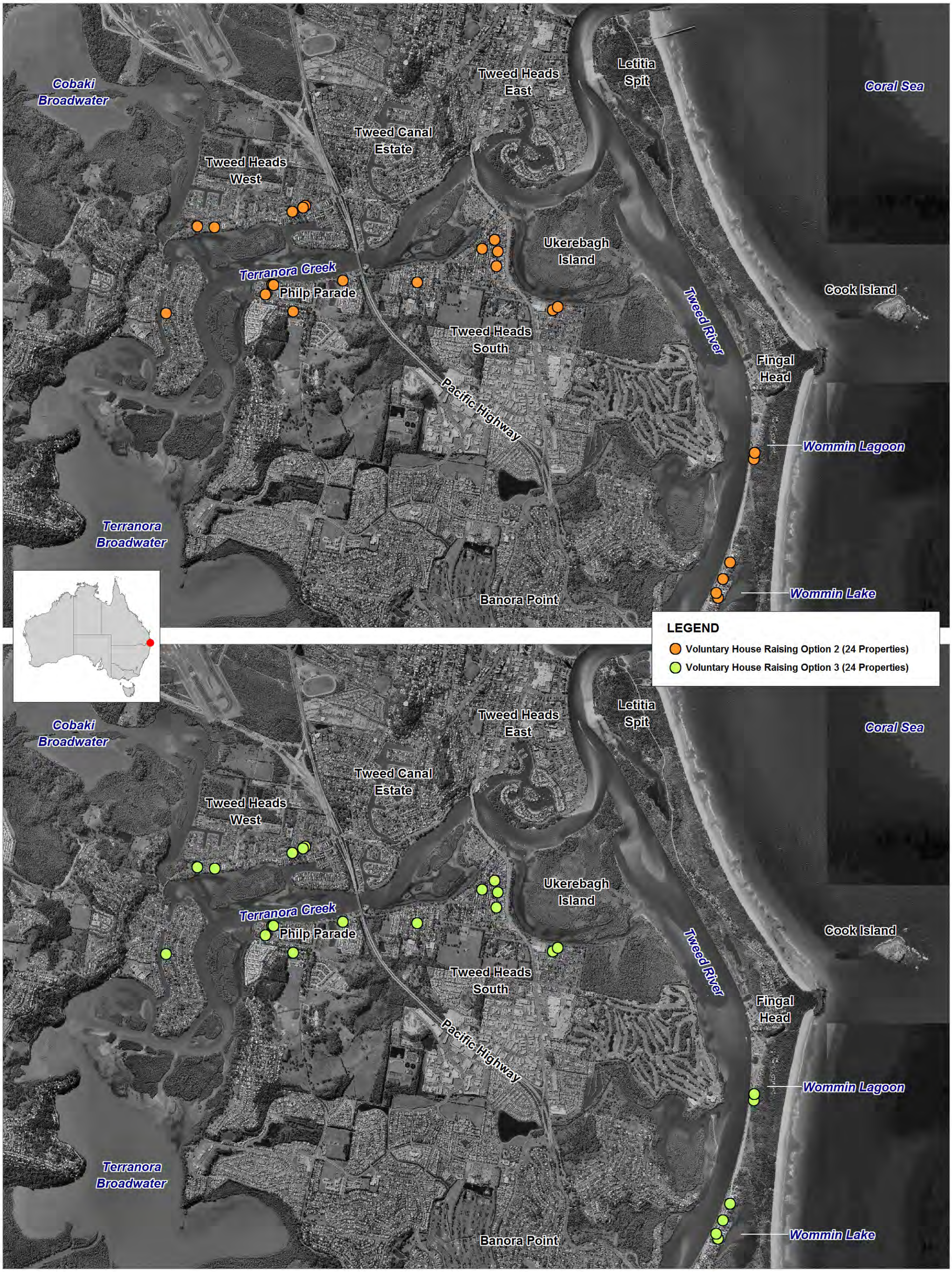

Title:

VHR Option 2 and 3, Lower Tweed

Figure: 6-3

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7 CLIMATE CHANGE

As the Earth's climate changes, it is anticipated that the intensity and frequency of flooding will also change. Tweed Shire Council adopted a climate change policy to plan for the impacts caused by changed flooding behaviour.

7.1 Climate Change Scenario

The climate change scenario adopted by Council in 2010 is derived from the latest climate science and CSIRO region-specific projections, presented in New South Wales government guidelines and policy:

- Floodplain Risk Management Guideline: Practical Consideration of Climate Change (DECC, 2007); and
- NSW Sea Level Rise Policy Statement (DECCW, 2009).

The scenario includes for rainfall projections for the year 2070 to be increased by 10% (although it is predicted that there will be fewer storms overall). In addition, sea levels for the year 2100 are projected to increase by 0.9m. This scenario was applied to the two 100 year ARI design flood events as follows:

- 100 year ARI catchment / rainfall dominated flood + 10% increase in rainfall intensity (combined with a smaller storm surge); and
- 100 year ARI storm surge dominated flood + 0.9m sea level rise (combined with a moderate catchment flood).

7.2 Flood Behaviour

The change in rainfall intensity and sea level caused by climate change is likely to cause the following flood impacts in the above scenario:

- Flood levels increase by ~0.5m in the lower Tweed area;
- Flood levels increase by 0.2 to 0.4m throughout the broader valley area;
- Flood levels increase by up to 3.9m[2] behind the town levee in Murwillumbah (in the area of Knox Park and Commercial Road / Wharf Street intersection);
- Flood extents increase to include the area north of Cobaki Creek and Cobaki Broadwater;
- Flood extents increase to include the southern part of Seagulls Estate;
- Flood extents increase to include water-front properties in the Tweed canal estates;
- Flood extents increase to include additional small areas in the Dry Dock Road region; and
- Flood extents increase to include low-lying areas of Greenbank Island.

[2] In the existing (current climate) 100 year ARI flood, the Murwillumbah levee is *almost* overtopped. With the increased peak flood level under climate change conditions, the levee overtops and fills the basin around Knox Park. This causes the significant increase in flood levels between existing and future climate conditions at this location.

A comparison of the 100 year ARI flood extent under existing and future climate conditions is shown in Figure 7–1. The impacts on peak levels due to climate change in the 100 year ARI flood event are shown in Figure 7–2.

7.3 Flood Risk

The effects of climate change will increase the risk for most properties which are already affected by flooding and increase the number of properties at risk. The number of people and properties within the 100 year ARI flood extent under both existing and future climates is presented in Table 7-1 below.

Table 7-1 Population at Risk, Climate Change

Numbers at Risk	100 Year ARI Existing Climate	100 Year ARI Future Climate	% Increase
People	11,700	18,200	55%
Residential properties	4,300	7,200	66%

Issue: The large increase in people and properties which will be affected by flooding under the climate change scenario has undesirable impacts on the evacuation capability of the study area. Much of the study area already faces evacuation constraints in a large flood event, and most in an extreme flood. Some roads will close earlier under climate change conditions, reducing the amount of time available to evacuate. Higher flood levels and velocities will mean that residents face more dangerous conditions if they become inundated or isolated.

The additional risk to properties and estimated damages resulting from climate change conditions in a 100 year ARI flood is presented in Table 7-2 and Table 7-3 below.

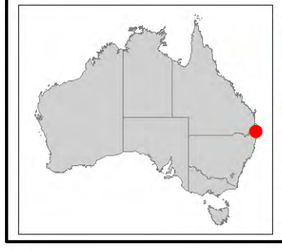
Table 7-2 Estimated Number of Inundated Properties, Climate Change

Inundated Properties (Above Floor)	100 Year ARI Existing Climate	100 Year ARI Future Climate	% Increase
Residential properties	1,130	3,040	170%
Commercial properties	340	510	50%

Table 7-3 Flood Damage Estimates, Climate Change

Flood Damage Estimates	100 Year ARI Existing Climate	100 Year ARI Future Climate	% Increase
Residential properties	$150m	$365m	140%
Commercial properties	$45m	$100m	120%

Ingleside
Point Danger
Coral Sea
Tweed Heads
Fingal Head
Springbrook
Glengarrie
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point



LEGEND

- 100 Year ARI Flood Extent; Current Climate
- 100 Year ARI Flood Extent; 2100 Climate
- Flood Prone Land
- Tweed River
- Principal Road
- Sealed Road

Title:
Climate Change 100 Year ARI Flood Extent

Figure: 7-1

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Ingleside
Point Danger
Coral Sea
Tweed Heads
Fingal Head
Springbrook
Glengarrie
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah[1]
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point

Change in Flood Level (m)
- Was wet now dry
- < -1.5
- -1.5 to -1.0
- -1.0 to -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to 0.1
- 0.1 to 0.2
- 0.2 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
- Was dry now wet

LEGEND

- Tweed River
- Principal Road
- Sealed Road

[1] In the existing (current climate) 100 year ARI flood, the Murwillumbah levee is *almost* overtopped. With the increased peak flood level under climate change conditions, the levee overtops and fills the basin around Knox Park. This causes the significant increase in flood levels between existing and future climate conditions at this location.

Title:
Flood Impact of Climate Change

Figure: 7-2

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7.4 Management Measures

The measures available to manage the increased flood risk to existing people and property are generally the same as those available to manage current flood risk, i.e. the same flood, property and response options. Similarly, future development will manage climate change risk primarily through development controls. The management of climate change risk to future development is discussed in Supplementary Report 1 and summarised in Section 7.4.3.

Climate change management measures which are responding to the effects of climate change (rather than trying to change the severity of climate change) are referred to as adaptation measures.

7.4.1 Existing Adaptation Measures

A climate change adaptation plan was developed for Tweed Shire Council (in conjunction with Byron Shire Council) in 2009. This plan utilised information provided by Council representatives to highlight climate change related risks and develop actions to address these risks.

Following consultation with both Councils, eight issues were identified as priority concerns, including flooding. Flooding was recognised to pose a 'high risk' in the present climate and for the planning time frames of 2030 and 2070. Potential consequences arising from increased flooding in a changed climate were identified, including increased insurance premiums, increased risk of injury and death during flood events, and loss of agricultural yield.

Following identification of these consequences, five broad recommendations were made. These recommendations were categorised as engineering, policy/planning, or engagement, as marked in brackets below:

a) Upgrade design standards for infrastructure (policy);

b) Replace infrastructure (engineering);

c) Implement other defences, such as levees (engineering);

d) Community awareness and education (engagement); and

e) Improved development planning (policy/planning).

In addition to these flood specific risks, the adaptation plan also recommended that climate change policy be applied consistently across all of Council's planning documents and that further quantitative assessments are commissioned to support the qualitative recommendations in the report.

Further detail about these recommendations can be found in the *Byron and Tweed Shire Councils Climate Change Adaptation Action Plan* (GHD, 2009).

7.4.2 Adaption Recommendations

It is recommended that the flood model developed for the Tweed Valley Flood Study Update (2009) be used to hydraulically assess the level of risk present and quantify the actions required to meet the recommendations provided in the adaptation plan. The evacuation capability assessment can also be used to quantify the additional evacuation risk likely as a result of climate change. Discussion is provided below with respect to the five recommendations made in the adaptation plan.

7.4.2.1 Infrastructure (Recommendations a and b)

Due to the changing climate, infrastructure which was designed to provide a particular standard of protection may not provide sufficient protection throughout the design life of the structure. It is therefore important to consider future climate projections when designing new infrastructure. To ensure that e.g. a road continues to be 100 year ARI flood immune in the year 2050, it is recommended that the adopted climate change flood scenario be incorporated into design standards. This will apply to the design of new infrastructure and the replacement / retrofitting of existing infrastructure.

7.4.2.2 Flood Defences (Recommendation c)

As for infrastructure, consideration should be given to the level of flood protection provided by flood defences (levees) now and in future climates. Under climate change, existing levees are likely to provide less protection than at present, increasing the risk of personal and property damage due to flooding. It is recommended that investigations into flood defences consider the future climate projections and the implications that this may have on flood risk.

7.4.2.3 Community Awareness and Education (Recommendation d)

A comprehensive community awareness and education campaign is recommended as part of this study to address existing flood risk. It is recommended that this campaign also includes information from climate change flood modelling to discuss the increased flood risk which will likely occur due to climate change.

7.4.2.4 Development Planning (Recommendation e)

Climate change related controls are recommended as part of the review into development controls in Section 7.4.4 and Supplementary Report 1.

7.4.2.5 General

It is recommended that Council consider both existing and future flood risk when determining appropriate floodplain management measures (including development controls) for the Tweed Valley study area. A careful balance must be maintained between addressing the present risk and planning for the future. The existing risk in the study area is widespread and significant and must be addressed as a priority. However, it must not be forgotten that the risk will increase substantially in a changed climate.

It is also recommended that the 'adopted' climate change scenario be reviewed periodically and updated where new science is available.

7.4.3 Existing Planning Measures

In June 2010, Section A3 of the Tweed DCP (Development of Flood Liable Land) was amended to incorporate climate change predictions as described in Section 7.1 above. Based on this climate change scenario, climate change design flood levels and climate change flood maps were inserted into Appendix D of the DCP. The DCP requires residential land as part of a greenfield subdivision to

be above or filled to the climate change design flood levels. The climate change design flood levels to not apply to all other development.

7.4.4 Planning Recommendations

The 2010 NSW Sea Level Rise Policy recommends that strategic and statutory planning documents could respond to the projected 2050 and 2100 coastal flood risk area by restricting the intensification of development in areas subject to predicted climate change flood risk or applying planning controls to manage the additional risk. The mechanisms that might be applied include:

- Adopting climate change design flood levels where assessing the suitability of rural land for future urban purposes at the strategic planning stage;
- Increasing the design flood levels that would otherwise apply to buildings and land required of development to take into account predicted climate change effects. This would typically be practical in greenfield developments but often impractical for developments within established areas; and
- Imposing time-limited consents to provide the potential to remove, replace or adapt development in the future.

The application of these mechanisms varies depending on the stage of planning and nature of the development proposed. The aim is to take a precautionary approach to contain flood risks at those levels otherwise considered acceptable today where this can be practically achieved.

The first two mechanisms above are currently being applied by Council in respect of residential development and these are endorsed as appropriate having regard to current Government policy and guidelines and best planning practice. However, it is recommended that at the strategic planning level, climate change flood risks also be considered when assessing the suitability of rural land for non-residential urban development such as commercial or industrial uses.

The third mechanism could be beneficial for development types that have a shorter typical life span and a higher design flood level would be cost prohibitive to a development that is otherwise considered acceptable and supportable in the public interest.

In addition to the above, there is a need to consider how climate change flood risks should be communicated to the public, irrespective of whether related planning controls are imposed. Recommendations in respect of this are included in Section 9.

8 FUTURE DEVELOPMENT

8.1 Overview

Parts of the Tweed Valley are subject to significant development pressure and whilst it is always preferable to avoid flood risk through effective land use planning, it is also recognised that pressures for land development, the lack of suitable land outside the floodplain, and a range of other non-flood related issues mean 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.

As part of this study, a review of flood risks associated with possible large scale developments has been undertaken. These developments include:

- Identification of existing zoned land with potential for additional development (including land with current development consents that may not have been acted upon);
- Planning strategies that have been formally considered by Council as part of a broader planning exercise, including:
  - Tweed City Centre as outlined in the Tweed City Centre Plan Vision 2011 and supporting Tweed City Centre LEP and DCP;
  - Parts of Chinderah, Kingscliff and Cudgen as outlined in the Tweed Coast Strategy (Section B9 of the Tweed DCP);
  - Murwillumbah and South Murwillumbah as outlined in the Murwillumbah Town Centre DCP (Section B22 of the Tweed DCP); and
  - Murwillumbah West as outlined in the Murwillumbah West DCP (Section B6 of the Tweed DCP).
- Representations made formally or informally to Council but not yet considered as part of a broader planning exercise (including in the localities of Chinderah, West Kingscliff, Fingal Head, Kielvale and South Murwillumbah).

These last development scenarios have not been evaluated having regard to the broader range of planning issues and their assessment as part of this study should not be considered as an endorsement by Council. The inclusion of these areas as part of this study provides an opportunity to determine as part of a comprehensive FRMS whether there are any flood risk issues and management responses to consider, should they be the subject of broader planning studies in the future. Notwithstanding, flood risk issues could provide a basis upon which Council rules out considering a particular area for intensive development.

8.1.1 Tweed City Centre

The majority of future development in the Lower Tweed area is envisaged to occur within the Tweed City Centre as set out in the Tweed City Centre Plan Vision 2011. The Vision was prepared by Council in collaboration with the NSW Department of Planning & Infrastructure's City Centre Taskforce, exhibited in early 2010 and adopted by Council in December 2011. It is accompanied by

the Tweed City Centre DCP (which applies to the whole Tweed City Centre) and Tweed City Centre LEP (which applies to Tweed City Centre North). The Tweed City Centre South is covered by the draft Tweed LEP 2010.

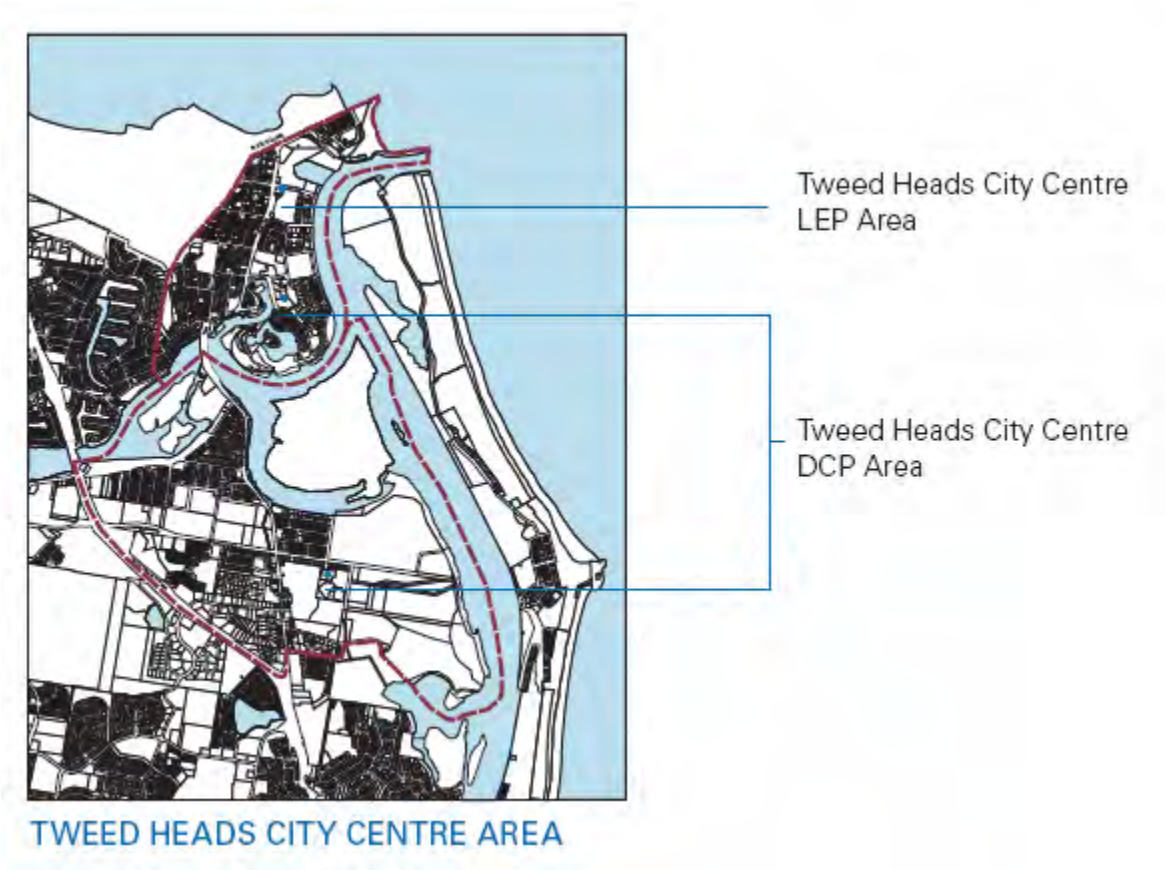


Figure 8-1 Tweed City Centre LEP and DCP Areas (Tweed City Centre Plan Vision 2011)

The Vision describes a vision and strategic framework for Tweed Heads as a regional city and includes an action plan to facilitate the city's growth, in particular the LEP and DCP.

Based on an ideal planning outcome, the following dwelling growth targets were originally considered but subsequently deferred for Tweed City Centre South and part of North (east of Wharf Street) due to flooding and evacuation issues.

Table 8-1 Ideal Growth Dwelling Targets Tweed City Centre (now deferred)

Area	Existing Dwellings	Additional Dwellings	Total Dwellings
Tweed City Centre North	2,541	10,459	13,000
Tweed City Centre South	2,198	5,502	7,700

The exhibited plans provide for growth within Tweed City Centre North of about 9,600 dwellings and 215,000 m^2 of commercial / industrial floor space. Some limited infill development could be expected in Tweed City Centre South in line with current planning controls. An additional 180,000 m^2 of commercial / industrial floor space was proposed for Tweed City Centre South.

Building forms will vary as generally reflected by the proposed zonings and heights outlined in the planning instruments. Outside of the commercial core, developments are likely to be standalone with side and rear setbacks. Within the commercial core and mixed use zones, the lower 3 to 6 storeys are proposed to be "built to boundaries" (i.e. no boundary setbacks) while the storeys above are to be a series of towers (setback from boundaries).

8.1.2 Chinderah, Fingal Head and Kingscliff

Development in the region is guided by the Tweed Coast Strategy outlined in Section B9 of the Tweed DCP, which covers parts of Chinderah, Kingscliff and Cudgen, as well as land to the south of the Tweed Valley study area in the Cudgen Creek catchment.

The population of the Tweed Coast was estimated as 6,900 people at 1999. Under this planning strategy, it is envisaged that when fully developed, this area will have a population of approximately 26,150 people. Of the population growth, an estimated 3,600 are anticipated within the study area in Chinderah / West Kingscliff, Kingscliff and Cudgen Village. Figure 8-2 shows the Structure Plan which depicts existing and future urban areas.

Notwithstanding the above current planning strategy, this study has also assessed other large scale development options including some informal options including:

- Development compatible with current zoning and DCP controls;
- Potential residential and industrial development in Chinderah based on a relaxation of DCP controls; and
- Potential rezoning and development of Rural 1(a) zoned land between Chinderah village and West Kingscliff, and via Old Ferry Road.

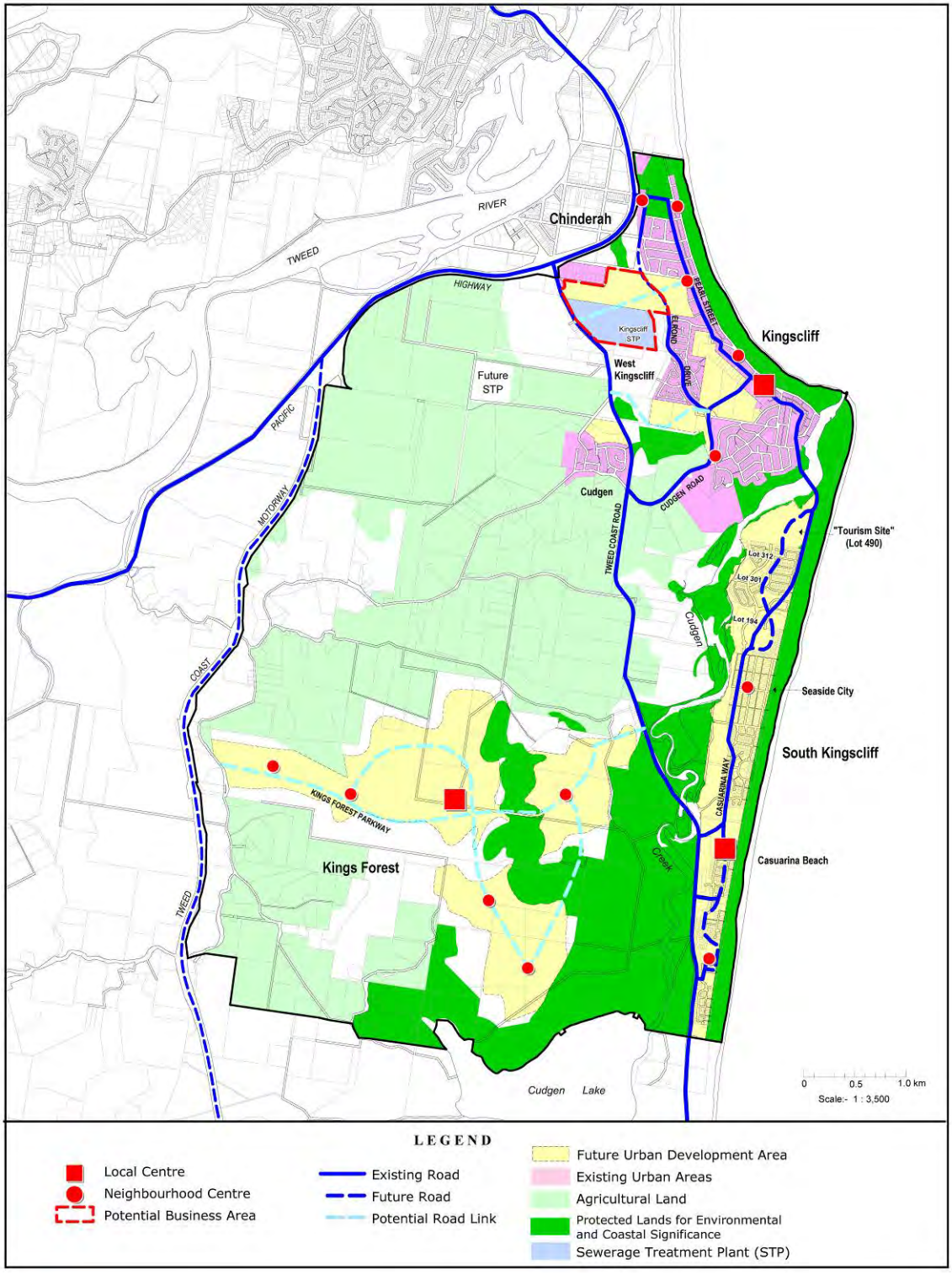


Figure 8-2 Tweed Coast Strategy Structure Plan (Tweed DCP 2008)

8.1.3 Murwillumbah and South Murwillumbah

Future development in the Murwillumbah region is guided by Sections B22 and B6 of the Tweed DCP, Murwillumbah Town Centre and Murwillumbah West respectively. This includes parts of the existing urban area of the town that have been deferred with the relevant provisions of the current DCP, as well as possible future expansion to the urban area. Development within the scope of the existing planning controls includes the following:

- Infill development in residential zoned land in Murwillumbah and Murwillumbah West;
- Potential redevelopment within the town centre; and
- Minor growth in the existing industrial area adjacent to the airport.

Figure 8-3 and Figure 8-4 show the Urban Structure Plan and precincts respectively for the Murwillumbah Town Centre. Figure 8-5 shows the release area zonings for Murwillumbah West.

In addition, this study has also assessed other large scale development options including some informal options:

- Potential for expansion of the town southwards of the existing industrial area;
- Mixed use commercial development in South Murwillumbah, including some filling; and
- Residential development in South Murwillumbah, including 'Fernvale' and 'Dickinson's'.

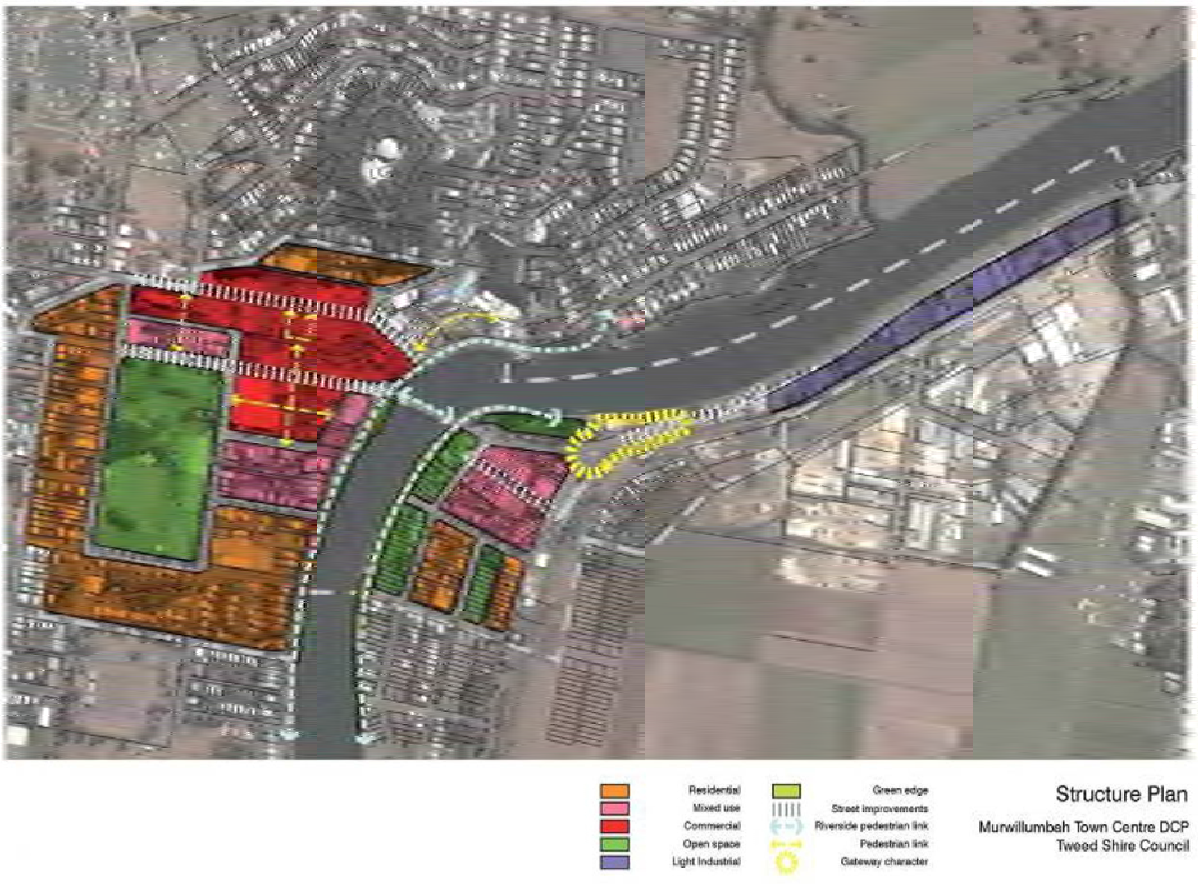


Figure 8-3 Murwillumbah Town Centre Urban Structure Plan (Tweed DCP 2008)

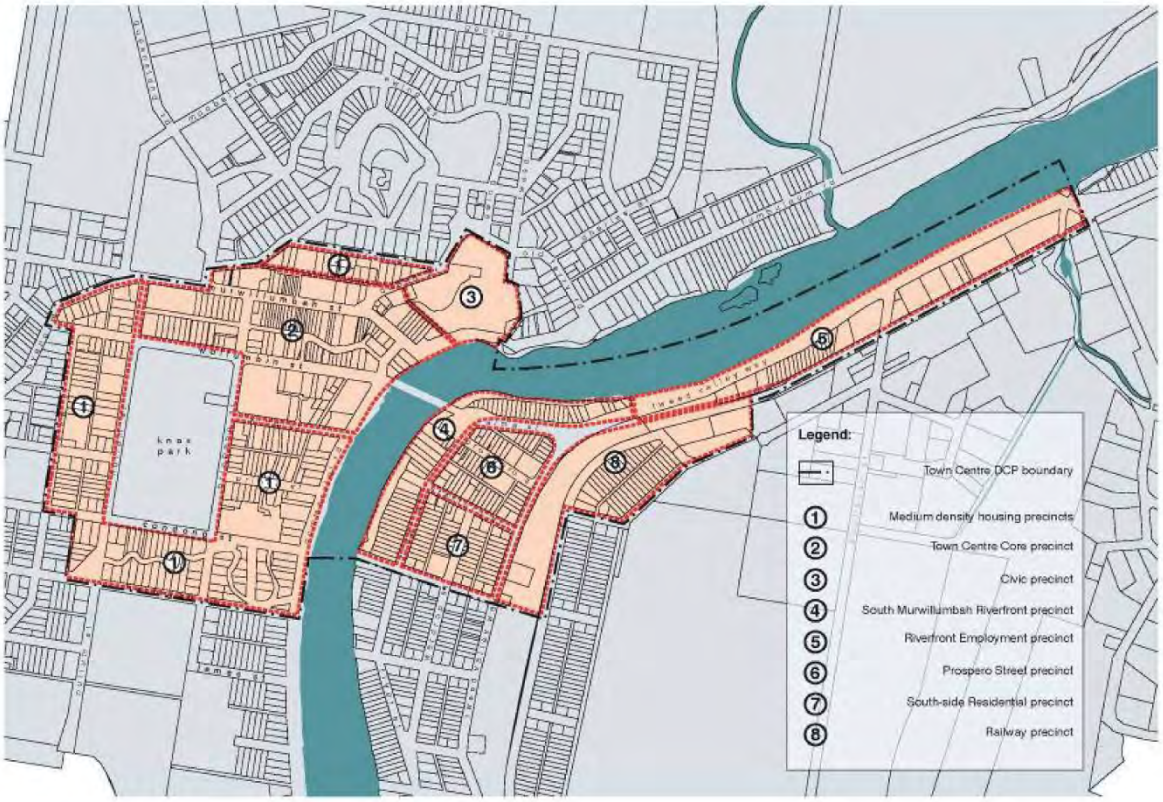


Figure 8-4 Murwillumbah Town Centre Precincts (Town DCP 2008)

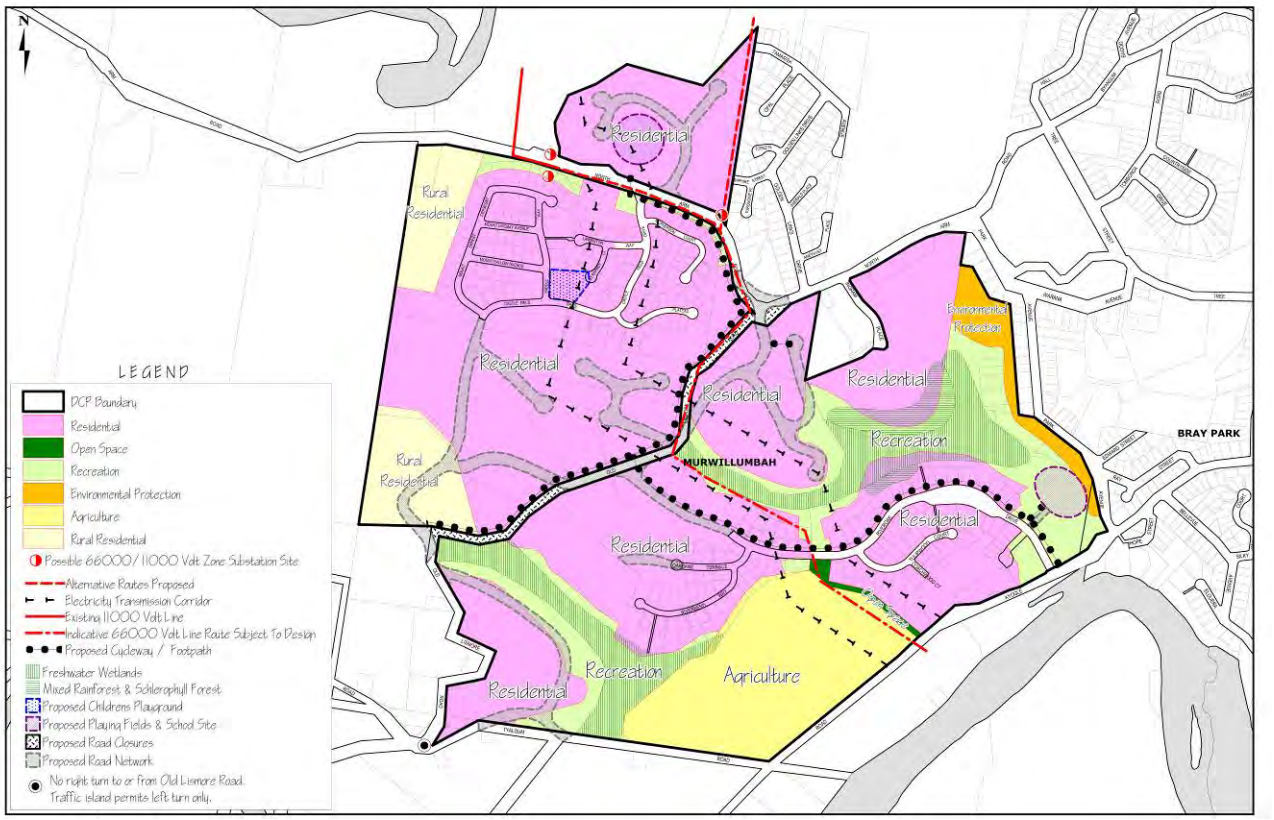


Figure 8-5 Murwillumbah West Release Area Zonings (Murwillumbah Town Centre DCP)

8.1.4 Riverside Villages (Condong and Tumbulgum)

The riverside villages of Condong and Tumbulgum generally have minimal further development potential, and future development is likely to be predominantly in the form of redevelopment of existing housing. No formal planning proposals exist for the region.

Notwithstanding this, this study has assessed an informal large scale development option including the development of remaining urban zoned land in Kielvale.

8.2 Hydraulic Constraints

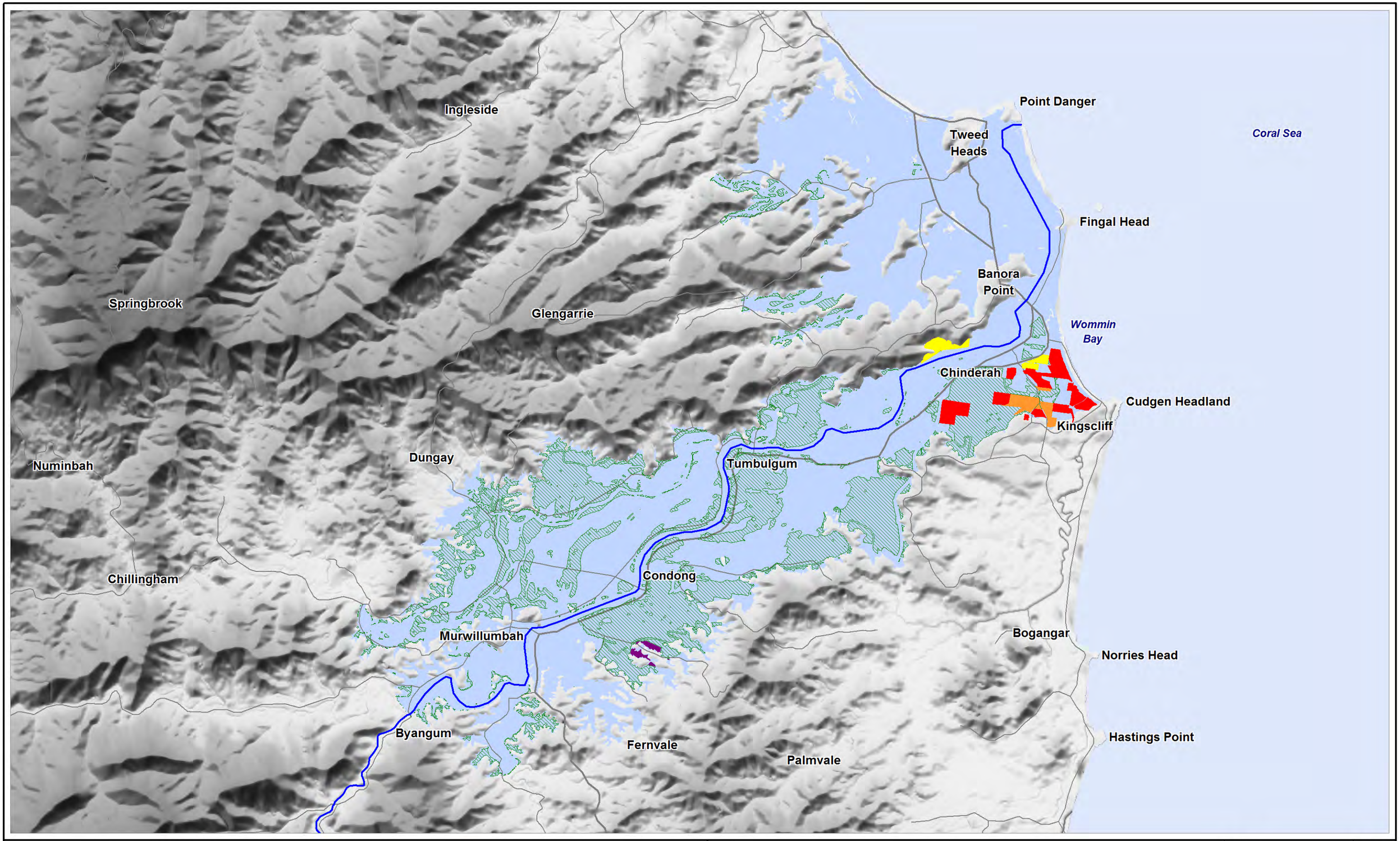
8.2.1 Cumulative Development

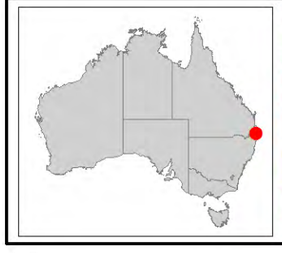
Hydraulic assessments were undertaken for large scale urban development in three separate regions in the study area: Chinderah / West Kingscliff, South Murwillumbah and Kielvale (within the Riverside Villages region). (Development in Tweed City Centre is not expected to have significant hydraulic constraints in a 100 year ARI flood event.)

The hydraulic assessments were completed individually with the intention that viable developments be assessed together to identify a suitable cumulative development scenario. Figure 8-6 is a locality map of the assessed cumulative development.

When assessed individually, the following flood behaviour and impacts were identified:

- **Chinderah / West Kingscliff**: Development of the Chinderah village area (between the Pacific Highway and Tweed River) produced unacceptable impacts and cannot be included in a cumulative development scenario. An optimal Chinderah development scenario was identified, which allowed the greatest amount of other potential development in the area, without Chinderah village. This development scenario (referred to as Scenario 1 + 2C + 3), slightly increased flood levels in the catchment, but within acceptable levels. Further detail is provided in Discussion Paper 4.
- **South Murwillumbah**: Despite many options being investigated, results of the hydraulic assessment found that development in the South Murwillumbah is extremely constrained and cannot be included in the cumulative development scenario in any form. The primary constraints are caused by loss of floodplain storage associated with filling of any areas within the basin and constriction of the floodplain in the industrial area. Further detail is provided in Discussion Paper 5.
- **Kielvale**: Development of Kielvale (in isolation) slightly raised flood levels in the catchment, but within acceptable levels. This development option is suitable for inclusion in a cumulative development scenario.





LEGEND

- 1% Rural Fill
- Chinderah / West Kingscliff Development 1
- Chinderah / West Kingscliff Development 2c
- Chinderah / West Kingscliff Development 3
- Kielvale
- Flood Prone Land
- Tweed River
- Principal Road
- Sealed Road

Title:

Cumulative Development Locality Map

Figure: **8-6**

Rev: **A**

N

0km 3 6

Approx. Scale

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In addition to these region-specific development scenarios, a further scenario was hydraulically modelled which aimed to identify rural zoned land which may be suitable for permissible development. This included all rural zoned[3] flood fringe or flood storage areas, i.e. excluding floodways. As the large scale urban development scenarios above were already approaching predetermined acceptable limits of hydraulic impacts, it was found that filling of suitable rural zoned land was limited to 1% of these areas.

A range of combinations of the above were modelled and the following summarises the potential cumulative development limits in the Tweed Valley (based on the assessed large scale urban and permissible rural development options):

Table 8-2 Cumulative Development Options

Cumulative Development Scenario	Chinderah / West Kingscliff	Kielvale	Rural (1% Fill)	Impacts
1	Including rezoning (1 + 2C + 3)	Yes	No	Borderline acceptable
2	Excluding rezoning (1 + 2C)	Yes	No	Acceptable
3	Including rezoning (1 + 2C + 3)	No	No	Acceptable
4	Excluding rezoning (1 + 2C)	Yes	Yes	Borderline acceptable
5	Including rezoning (1 + 2C + 3)	No	Yes	Borderline acceptable

It is recommended that one of these cumulative development scenarios be adopted for management of cumulative hydraulic impacts associated with future development. The adopted scenario could be updated as development plans change into the future on the basis of revised hydraulic assessment and acceptable impacts. This cumulative development scenario should be linked to a development control requiring appropriate hydraulic assessment and management of both local and cumulative development impacts.

In a practical sense, application of this control would require developers to:

- **For all developments:** Quantify and mitigate *local* hydraulic impacts of their proposed development (i.e. using the base case flood model);
- **For developments not included in the adopted cumulative development scenario:** Quantify and mitigate *regional* hydraulic impacts of their development (i.e. using the cumulative development case flood model).

8.2.2 South Murwillumbah Condong Flowpath

The hydraulic impact of future development on Lot 4, Quarry Road was investigated. This lot had been flagged by Council as a property of interest to preserve the flow path through industrial zoned land between the South Murwillumbah and Condong basins. This lot is the sole remaining

[3] As per the 2010 Local Environment Plan.

undeveloped lot between the two basins and previous investigations have shown that the South Murwillumbah basin is very sensitive to changes in floodplain hydraulics. The estimated land value is $428,000.

The effects of filling this lot are:

- Low level impacts (up to 0.1m) in the South Murwillumbah basin affecting existing residential and commercial / industrial development;
- Significant localised impacts (up to 0.3m);
- No properties would be newly inundated as a result of this development but 54 houses would be inundated by up to a further 0.1m; and
- Reduction in levels in the downstream floodplain (Condong basin).

Filling Lot 4, Quarry Road generates unacceptable impacts in the South Murwillumbah basin. Preservation of this flow path is required to avoid impacts on existing property. Mechanisms for achieving this have been identified as part of the review of planning considerations.

8.3 Evacuation Constraints

A range of factors influence evacuation constraints associated with development. These factors are dependent not only on the flood (hazard and hydraulic) characteristics of the site but also the nature of the proposed development. These factors include:

- Proposed land use and demographic characteristics of occupants;
- Access to evacuation facility including time available / required to evacuate;
- Topographical constraints;
- Availability of a refuge above the reach of flood waters; and
- Availability of support facilities within the refuge.

A classification system has been developed to provide the planning process with appropriate advice on the gradations in the severity of the evacuation safety risk. This advice relates to the development proposal, including any mitigation measures that have been incorporated to minimise evacuation risks within the floodplain. The advice is provided principally in relation to strategic planning and rezoning proposals.

Table 8-3 Evacuation Risk Classes (ERCs)

Class A	**Risks are Minor – No Detailed Consideration is Required** Whilst potential for inundation and/or isolation exists, there are no significant evacuation constraints.
Class B	**Risks are Moderate – Detailed Consideration is Required** Evacuation constraints exist although in most situations these are not so severe as to significantly influence the planning decision.
Class C	**Risks are Serious – Very Detailed Consideration is Required** Serious evacuation risks exist. These may be close to the limit of community acceptance. Careful consideration of these risks must be undertaken when evaluating the appropriateness of the development having regard to all social, economic and environmental issues.
Class D	**Risks are Intolerable/Unacceptable – Development Should Not Proceed** Evacuation risks are so serious that irrespective of other considerations, the development should not proceed.

These ERCs have been determined for formal planning proposals based on evacuation capability assessments (ECAs), the nature of the floodplain topography, access to support facilities and other risk considerations in the region specific discussion papers.

8.3.1 Concurrent Fire and Medical Risks

Various discussions were held with the NSW Ambulance Service and Fire and Rescue NSW concerning the potential for flood emergencies to be compounded by concurrent fire and / or medical emergencies. Recommendations in relation to measures to address fire and medical risks that might be coincident with floods include:

- Provision of more information to both agencies on completion of the Tweed FRMS so that the potential impact on their existing operations and facilities could be further evaluated;
- When major new buildings are constructed in areas that could be potentially isolated by floodwaters they should be provided with their own fire fighting equipment to make them self-sufficient;
- When multi-storey buildings are designed which could potentially have their lower storey inundated in a major flood, fire stairs need to provide egress at various lower levels below the PMF, not just at street level;
- Council to ensure that the potential flood height range is made known to building designers when considering concurrent fire / flood risks to ensure buildings are built in accordance with the Building Code of Australia and properly maintained to ensure ongoing compliance;
- In areas where potential isolation could occur due to inundation by floodwaters, approval of development should require preparation of an evacuation management plan including all stakeholders requiring regularly (say two yearly) exercises challenging the practicality and functionality of the plan.

8.3.2 Evacuation Risks

The preferred means of managing the risk to life that can arise from flood inundation or isolation is evacuation to an evacuation centre or suitable alternative accommodation. Based on a review of evacuation risks in the area and specific to the nature of the proposed development, the following evacuation constraints and classifications have been identified:

- **Tweed City Centre:**
  - The existing evacuation capability assessment has been carried out at a sector level; refinement of the assessment will provide greater detail across sub-areas of the proposed development area and allow the classifications to be provided for each sub-area.
  - When planning new large scale developments, reliance on road access to evacuation centres or pedestrian access to local refuges, should be determined using 2100 climate change 100 year flood planning levels.
  - Any large scale development proposed in the area should be provided with on-site refuges (as a fall-back provision in the event that residents fail to heed evacuation warnings).
  - A flood free refuge would generally need to be located on the first (or higher) storey of a multi-storey development.
  - Recommendations have been made in relation to measures to address fire and medical risks that might be coincident with floods (see above).
  - When road access is cut by floodwaters, evacuation can still generally occur to the existing evacuation centre on high ground. The evacuation risks for Tweed City Centre North have been classified as:
    - Class C for areas where rising road access is available, given the multi-storey form of the development proposed in Tweed City Centre North and the availability of access to the evacuation centre;
    - Class B for areas where rising road access is available, given the unique development form proposed for the Tweed City Centre North and the conditioning of new development to comply with Council's existing controls for critical infrastructure (which would ensure suitable support facilities were available for the health and wellbeing of any residents isolated in these elevated buildings);
    - Class D where rising road access is not available, unless measures are provided to improve road access or otherwise provide the necessary support facilities on site.
    - In order to meet the existing and future population needs of the area, a further evacuation centre(s) may need to be provided and / or cross-border arrangements developed to share facilities in Queensland.
  - The evacuation risks for Tweed City Centre South have been classified as:
    - Class D for areas where rising road access is not available, given the form of development proposed (and likely associated lack of support facilities within refuges and isolation within individual buildings, i.e. without potential to access communal facilities in adjacent buildings);

- Class B for areas where rising road access is available, or could be provided as part of the development;
- Class C for areas where there may be sufficient time to evacuate via Fraser Drive (although rising road access is not available).
- Class C for areas where significant alterations are made to the proposed building form (e.g. to provide support facilities within elevated interconnected buildings as is being considered for Tweed City Centre North); these changes are not consistent with Council's current strategic planning intent for the area.

- **Chinderah:**
  - There is potential to provide rising road access for each of the formal planning proposals to Marine Parade or Kingscliff Street with sufficient time for safe evacuation to Cudgen.
  - The evacuation risks of the formal planning proposals have been classified as:
    - Class B for areas where rising road access is available, irrespective of whether support facilities and / or on-site refuges were provided within the development areas;
    - Class B for areas where rising road access is not available, but with provision of on-site refuges;
    - Class C for areas where rising road access is not available and without the provision of on-site refuges.
  - The evacuation risks of the informal planning proposals have not been assessed in detail, however it is noted that they appear significant without road access improvements.
- **Murwillumbah and South Murwillumbah:**
  - The existing evacuation capability assessment has been carried out at a sector level; refinement of the assessment will provide greater detail across sub-areas of the Murwillumbah CBD and allow the classifications to be provided for each sub-area.
  - The evacuation risks for infill residential development have been classified as:
    - Class B in areas with rising road access;
    - Class C in areas without rising road access, but with a refuge and support facilities;
    - Class D for elevated housing without rising road access or a refuge and support facilities (which may occur in the lower lying areas away from higher ground to the west including the Prospero Street, South Murwillumbah Riverfront and the South-Side Residential Precincts).
  - The evacuation risks for other types of development have been classified as:
    - Class B for Fernvale / Dickinsons large scale residential development given access to adjacent high ground, subject to provision of safe evacuation through subdivision layout and road design;
    - Class C for new industrial development east or west of the airport, as it is (or will be) a low flood island.

- **Riverside Villages:**
  - The provision of on-site refuges will reduce the risk to development and should be viewed as a secondary but necessary emergency management strategy.
  - There is currently insufficient time for evacuation of existing residents of Condong and Tumbulgum to occur in an extreme event.
  - The evacuation risks for Condong and Tumbulgum have been classified as:
    - Class B for concessional development involving the redevelopment of existing dwellings in a manner which reduces flood risk, and with the provision of on-site refuges;
    - Class C for new development on existing zoned with the provision of on-site refuges;
    - Class D for any subdivision or intensification of development due to the inability to evacuate existing residents.

More detailed discussion of evacuation risk factors, classification and fire and medical risks is provided in Supplementary Report 1.

9 PLANNING CONSIDERATIONS

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.

Ultimately the planning recommendations of this FRMS will need to be reflected in planning instruments and policies brought into force in accordance with the EPA Act. There are three mechanisms for achieving this:

- **Strategic planning:** Providing direction at a local and state strategic planning level to manage flood risks (e.g. where new urban areas should be located and the distribution of land uses therein).
- **Development controls and related policies:** Recommending development controls and related policies to be incorporated in appropriate planning instruments (i.e. LEPs, DCPs and Section 94 Contributions Plans) to mitigate the risk to development where permitted in the floodplain.
- **Communication of flood risk:** Ensuring that the planning controls and associated documents (e.g. Section 149 planning certificates) appropriately inform the community about the flood risk.

A separate, comprehensive report has been prepared which reviews the existing and planned context of the study area (including specific localities within it) and its flood hazards (including the existing and potential risks to people and property). This Planning Considerations report is included as Supplementary Report 1 and should be read in conjunction with the key conclusions and recommendations summarised below.

9.1 Strategic Planning

It is necessary to consider hydraulic and evacuation constraints to development at a strategic (as well as individual) planning level for the Tweed Valley.

- **Hydraulic Constraints:** Substantial parts of future urban areas are low lying and will require filling to a minimum 100 year ARI flood level (including an allowance for climate change). Where required, this fill has the potential to impact on flood storage and flood conveyance. The cumulative effects of this fill have been assessed as part of this study (see Section 8) to determine the hydraulic constraints to future development and inform appropriate planning control recommendations.
- **Evacuation Constraints:** Some of the future urban areas have significant evacuation constraints and associated public safety risks. Four graded evacuation risk classes (ERCs) have therefore been derived to provide advice to planners and consent authorities concerning these evacuation risks (see Section 8). These ERCs have been determined for formal planning proposals based on evacuation capability assessments, the nature of the floodplain topography, access to support facilities and other risk considerations.

Based on the hydraulic and evacuation constraints to proposed development, the following direction is provided for strategic planning in the various regions:

- **Tweed City Centre North:** The current strategic planning directions for this area could be supportable on flood risk grounds, subject to more detailed assessment; road access improvements where required; and / or provision of necessary on site refuges and support facilities. This includes the area both west and east of Wharf Street.
- **Tweed City Centre South:** The presence of low flood islands and the lack of rising road access present significant person safety risks that are a serious impediment to any future expansion. It would appear that significant alterations to the proposed building form (e.g. to provide support facilities within elevated interconnected buildings as is being considered for Tweed Heads) are required in order to reduce the risk to life. Areas where there may be sufficient time to evacuate via Fraser Drive may also be lesser risk, though still serious requiring very detailed consideration when evaluating the appropriateness of any development in this area.
- **Tweed Coast Strategy (Section B9 of the Tweed DCP):** Evacuation of development areas could be considered to be within manageable limits subject to satisfying other planning criteria. Hydraulic impacts due to the cumulative filling of land and associated loss of floodplain storage were found to be acceptable.
- **Chinderah village:** Hydraulic impacts associated with filling of land limits development potential in Chinderah village. Further, incremental development that leads to substantial cumulative expansion in the population could result in unacceptable risks due to existing evacuation constraints (specifically evacuation route capacities and local drainage issues).
- **Other informal planning proposals (Chinderah / West Kingscliff):** Hydraulic impacts due to the cumulative filling of land and associated loss of floodplain storage were found to be acceptable for other informal planning proposals, however must also be considered in conjunction with other cumulative development in the study area (this is outlined in Section 8). Evacuation of areas with rising road access to Marine Parade or Kingscliff Street could be manageable. However, substantial cumulative expansion in the population in any other areas could result in unacceptable risks due to existing evacuation constraints.
- **Murwillumbah**:
  - Review appropriateness of increasing residential development within the Town Centre Core Precinct and the Medium Density Housing Precinct of the DCP, particularly in the parts of the precincts that are more distant from the higher ground to the west.
  - Undertake a study of stormwater and local drainage issues behind the levee to define flood immunity and examine the potential for filling of allotments to reduce flood storage and exacerbate flooding caused by local catchment runoff behind the levee.
- **South Murwillumbah**:
  - Any increases in residential densities in the Prospero Street, South Murwillumbah Riverfront and the South-Side Residential Precincts, which have been “Deferred” in the DCP, are not supported, due to low flood immunity, very high hydraulic hazard, and unacceptable evacuation risks.
  - Commercial redevelopment which reduces flood risk is supported and desirable. Where possible, strategic planning of the area should consider the incorporation of a flood path.

- Fernvale / Dickinsons: Whilst evacuation issues would need further detailed consideration, these issues would not be a basis for ceasing further assessment. However, hydraulic constraints limit the potential to fill within the floodplain.
- The industrial development proposals should not be rezoned without further detailed consideration of evacuation risk. Filling should be limited due to hydraulic constraints.
- Critical flowpath (Lot 4, Quarry Road): Various planning mechanisms have been identified to secure the critical flowpath through the industrial zoned land.

- **Condong and Tumbulgum:** No new development involving subdivision or intensification of existing development; very detailed consideration of the evacuation risks to new development on existing zoned land; and actively promote redevelopment in a more flood-safe manner.
- **Kielvale:** Hydraulic impacts due to the cumulative filling of land and associated loss of floodplain storage were found to be acceptable, however must also be considered in conjunction with other cumulative development in the study area (this is outlined in Section 8).

9.2 Development Controls and Related Policies

The following summarise the key recommendations for development controls and related policies.

- **Exceptional circumstances application:**
  - Pursue the Department of Planning and Infrastructure (DPI) for a resolution to the pending exceptional circumstances application in order that the duty of care of Council and the DPI can be properly discharged in accordance with the requirements of the Floodplain Development Manual (as amended by the Flood Planning Guidelines). While approval of the exceptional circumstances application has been received from the Department of Premier and Cabinet (DPC), the DPC should nonetheless be included in future communication regarding this matter.
  - The purpose for seeking the exceptional circumstances dispensation is to confirm the continued application of Section A3 of the DCP and to allow for the progression of draft LEP 2010 to include a singular flood clause that applies to the whole floodplain.
  - The justification for exceptional circumstances variation should reiterate past submissions and include those matters itemised in Section 6.6 of Supplementary Report 1.
- **Draft comprehensive LEP:**
  - The flood provisions in the draft LEP 2010 (clauses 7.7 and 7.8) should be reviewed in consultation with the DPI. Preferably a singular flood clause should be adopted that is consistent with the DPI Model Clause with the exception that its application should be to the whole of the floodplain (i.e. up to the PMF) as defined by the Floodplain Development Manual, whether or not mapped as the flood planning area. It is understood that the current flood clause in Draft LEP 2010 has been based on Council's past protracted negotiations with the DPI, and therefore the implementation of the preferred clause may need to be in stages.
  - The Flood Planning Map to accompany LEP 2010 should delineate the PMF extent as the "flood planning area" (for the purposes of the LEP). This wold effectively mean deleting the 100 year flood extent from these maps, to simplify the application of the relevant clause and

the requirements of any future amendments to the Map as further information becomes available.

- The legend of the draft LEP 2010 Flood Planning Map does not presently include floodways and none have been identified on the LEP map. Due to the absence of an industry consistent approach to mapping floodways and the potential for the omission of critical floodways from the LEP Map, it would be advisable to adopt the more general Floodplain Development Manual definition of a floodway and not endeavour to have them mapped.
- The draft LEP flood maps should also include a note that not all flood liable lands may have been mapped. This is consistent with Departmental directions.
- The draft LEP flood maps should also have climate change flood extents included for the year 2050 and 2100.

- **DCP provisions:**
  - More detailed flood maps showing the 100 year flood extent (with climate change scenarios) should be adopted as part of Council's DCP as is currently the case. It is at the DCP level that this more detailed information is of relevance. This would also allow for other information to be more easily included such as "high flow areas" if known. Although it is useful information, there is no necessity for flood depth maps to be part of the DCP and these maps could be separately maintained by Council as part of its general GIS information.
  - The application of a risk management approach to the structure and content of the DCP controls and mapping would be desirable. However, as Council has only recently progressed with an alternate approach, pursuance of such an approach may be deferred until a future review of the DCP. That review could include the adoption of flood maps that categorise the whole floodplain based on risk.
  - The following recommendations are made for review of the Tweed DCP, in particular Section A3, including:
    - Update controls to reflect hydraulic constraints to development fill (see Section 8.2) including adoption of a cumulative development scenario, permissible rural development scenario and associated hydraulic assessment requirements;
    - The introduction of floor level controls that encourage the attainment of a minimum floor level (typically the 100 year ARI flood level) on commercial and industrial development for at least those that meet the 'habitable room' definition but with sufficient flexibility to allow for dispensation when such controls can clearly not be practically met;
    - Support for the intent of the DCP provisions relating to enclosures below habitable floors, with refinement to specify the objectives of the controls, define what constitutes enclosure and non-habitable uses, and specifying the uses of flood compatible material for all parts of a building below the design flood level;
    - Review car parking and driveway controls and ensure consistency in particular for basement car parking across the study area;
    - Support for the intent of the DCP provisions relating to caravan parks and moveable dwellings, with refinement to impose equivalent controls on long term residents as

standard residential development; clarification of 'high land'; and greater specificity in regard to assessing hydraulic impact;

- The application of the 2100 climate change design flood level for habitable floors of new rural dwellings and an associated fill pad;
- Support for the existing DCP provisions relating to evacuation from rural dwellings where there is an existing dwelling house entitlement (i.e. provision of an on-site refuge as a secondary measure);
- A requirement for high level vehicular or pedestrian access to a refuge outside of the PMF for development proposals on rural zoned land that relates to a subdivision that would create an additional dwelling entitlement or a use not related to the residential or agricultural use of land (such as an educational establishment, child care centre, aged care facilities or the like);
- Additional detail as to what would constitute an acceptable on-site or communal refuge where proposed as a secondary emergency management measure and for special types of development such as aged care;
- Guidance for assessing climate change effects;
- Controls for management of flood risks from stormwater and overland flow paths.

➢ The following recommendations are made for review of the Tweed DCP referenced to the provisions for Tweed City Centre:

- The 2100 climate change 100 year flood level (plus freeboard) as the habitable residential floor level in Tweed City subject to variations in some circumstances;
- A preferential emphasis on providing for evacuation away from the floodplain in preference to sheltering on-site; and
- If the above cannot be practically achieved then the DCP should specify the nature of an on-site refuge that would be acceptable, including the facilities to be provided within the refuge, procedures to access the refuge, and procedures for rescue from the refuge in case of fire or the need for medical attention; those that meet the requirements of Section 3.2.5(a) (Essential Community Facilities and Critical Services) of the existing DCP would likely be suitable, together with those recommended for addressing coincident fire and medical risks (see Discussion Paper 2).

➢ The following recommendations are made for review of the Tweed DCP specific to the Chinderah, Fingal Head and West Kingscliff region:

- The provisions of Section B9 should be expanded to clarify the requirements for a detailed evacuation risk assessment prior to proceeding with areas identified for future urban development;
- No changes to the DCP controls should be made to land within the floodplain, which would have the effect of increasing development potential on an incremental basis; and
- Existing emergency response provisions should be retained.

➢ The following recommendations are made for review of the Tweed DCP specific to the Murwillumbah and South Murwillumbah region:

- Any further consideration of the large development options would necessitate detailed planning of evacuation routes. Any new or augmented roads identified as necessary should be shown within the DCP;
- Any increases in residential densities in the Prospero Street, South Murwillumbah Riverfront and the South-Side Residential Precincts, which have been 'deferred' in the DCP, are not supported;
- It would be desirable, from a flood risk perspective, for the whole of the River Front precinct to form a continuous river front park (between the River and River Street as proposed in the DCP); and
- Within Murwillumbah, subject to further levee overtopping and drainage studies, a concession to allow lower storey habitable floor levels below the current habitable floor level standard provided other property damage mitigation measures were also included.

- **Complying development**
  - The FRMP should specify that only areas identified and mapped by Council to be other than land below the 100 year flood level and not evacuation constrained (e.g. a low flood island) are deemed to be high risk for the purposes of the Codes SEPP. This information should desirably be mapped so it can be readily provided to private certifiers and the general public upon enquiry.
- **Section 94 contributions plans**
  - Contribution Plans could be established within the study area, where it is necessary or appropriate to fund flood mitigation works through such plans. This would be relevant in new greenfield release areas or substantial urban renewal areas (such as the Tweed City Centre) where such works are required to ensure the acceptability of the development (e.g. for the upgrading of evacuation routes or evacuation centres to cater for increased population densities).
  - The Plans cannot be used to rectify existing problems in established areas. Where such works are required for both existing and future development the cost could be apportioned between the future development (within a Section 94 Plan) and existing development (to be funded by Council through general revenue or other sources such as special grants).
- **Flood policy**
  - The Tweed Shire Flood Risk Management Policy 2007 should ultimately be replaced with FRMPs that apply to the various floodplains in the LGA. The Tweed FRMP would be the first of these.
  - The individual FRMPs should contain Council's policies for all matters relating to flood risk management, including town planning recommendations relating to strategic planning, development controls and the communication of information where shown in planning documents.
  - A number of SEPPs including deemed SEPPs (being the North Coast REP) refer to, and sometimes define, flood liable land. These policies are note entirely consistent in this regard. Council does not have control of these policies but the FRMP should be forward to the DPI when adopted with a request that any future policy reviews have regard to this FRMP.

9.3 Communication of Flood Risk

The following summarise the key recommendations for communication of flood risk:

- **Section 149 notifications**
  - As Section A3 of the Tweed DCP applies to all land up to the PMF, Council must notify this on Section 149(2) certificates.
  - Include a notation that not all flood liable land may be mapped.
  - Include a notation that flood extents projected into the future may change due to climate change effects.
  - It is recommended that a notation be included on all certificates to indicate that further information in regard to flood risks may be available upon enquiry with Council or in a Section 149(5) Certificate.
  - Council's Section 149 certificates should recognise that inundation from stormwater and overland flow (except for 'local drainage') is 'flooding' under the Floodplain Development Manual and the presence or absence of such inundation risks and policies should be notified accordingly.
- **Release of flood information to the public**
  - Ensure that flood risk information (such as flood studies or an FRMS or FRMP) once obtained by Council, and checked for its integrity, is made available to persons upon enquiry. Such information may require qualification as to its status in Council (e.g. whether adopted by Council) and its purpose (e.g. for general FRM actions, to provide a basis for the assessment of development applications, etc) when made available.
  - Undertake periodic audits of protocols and information provided by all Council staff relating to the release of flooding information and provide training as required.

9.4 Other Recommendations

A comprehensive understanding of evacuation risks is key to responsible management of future floodplain development. The existing evacuation capability assessments typically have a coarse resolution and it is recommended that more detailed assessments be carried out in conjunction with the SES. These should provide much finer resolution within development areas and include more detailed analyses of vulnerable road low points, alternative evacuation centres, and alternative evacuation routes.

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APPENDIX A: INFORMATION, DATA, METHODOLOGY

A1 Quantitative Assessments

This section provides an overview of the key quantitative assessments used in the study, in particular hydraulic impact, evacuation capability, flood damages and cost benefit assessments. Additional detail is provided in Discussion Paper 1 for further reference, as required.

A1.1 Hydraulic Impact Assessment

Hydraulic impact assessments are a standard approach to quantifying changes in flood behaviour as a result of potential changes in the floodplain (including impacts on depth, velocity, duration of inundation). This includes assessment of floodplain management options to reduce existing risk (such as structural measures like levees designed to mitigate the extent, depth or timing of inundation) as well as potential changes in future risks (as a result of future development, climate change or both).

Existing flood behaviour is as defined by the flood model derived during the Flood Study which represents existing floodplain conditions. As part of this study, the model has been used to simulate potential changes in the floodplain to determine the hydraulic impact (positive or negative) for various scenarios.

For management options requiring cost benefit assessment, the full range of flood event magnitudes are modelled (from the 5 year ARI flood to the PMF) to quantify the reduction in damages for a range of event probabilities. Future development and climate scenarios have generally been modelled for the 100 year ARI flood, which is typically accepted as the minimum design flood level for most types of development.

For each scenario assessed, maps have been provided in the discussion papers, showing the key hydraulic impacts. In general, the key consideration is change in peak 100 year ARI flood level, however in some cases the change in the onset or duration of inundation is also a key consideration. The results of the hydraulic impact assessment have also been utilised to more specifically detail impacts on existing property (such as changes in internal or external inundation).

A1.2 Evacuation Capability Assessment

An evacuation capability assessment has been undertaken to identify areas where there is a risk of insufficient time and / or resources available to complete a full evacuation. These assessments help identify suitable options for reducing that risk and maximising the safety of the community.

A1.2.1 Context

The purpose of an evacuation capability assessment is to describe the current evacuation capability of the region as well as determine the benefit of potential floodplain management measures and / or impacts of future floodplain development. It is not a detailed evacuation plan, although much of the information and output can be used to inform response planning.

Evacuation capability based on current emergency response plans has been assessed using information on flood behaviour from the flood model, together with estimates of flood prediction time,

human behavioural factors (such as whether to follow evacuation orders and when) and route vehicle capacities.

It is recognised that all of these aspects (flood behaviour, community response and traffic) are difficult to predict and introduce a high level of uncertainty in the estimations of a community's evacuation capability. Nonetheless, the assessment forms a vital part of the flood risk management process and should not be avoided due to uncertainties and the risk of error. The flood intelligence contained in this study is considered sufficient to identify constraints in the current evacuation capability, highlight the need for action and provide guidance on future evacuation decisions.

A1.2.2 'Timeline' Approach

The assessment is based on a 'timeline' approach developed by the NSW SES (Opper, 2004 and 2009) which utilises timeline project management to determine the estimated timeframes of various elements during an evacuation procedure. The total available time for evacuation is marked along a timeline; the timeline commences when the storm commences and ends when evacuation is no longer possible due to road closures, or when everyone is safely evacuated. Between these times, a number of key evacuation processes must occur in sequence. Mapping these on a timeline can highlight a number of important features of the process, including:

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

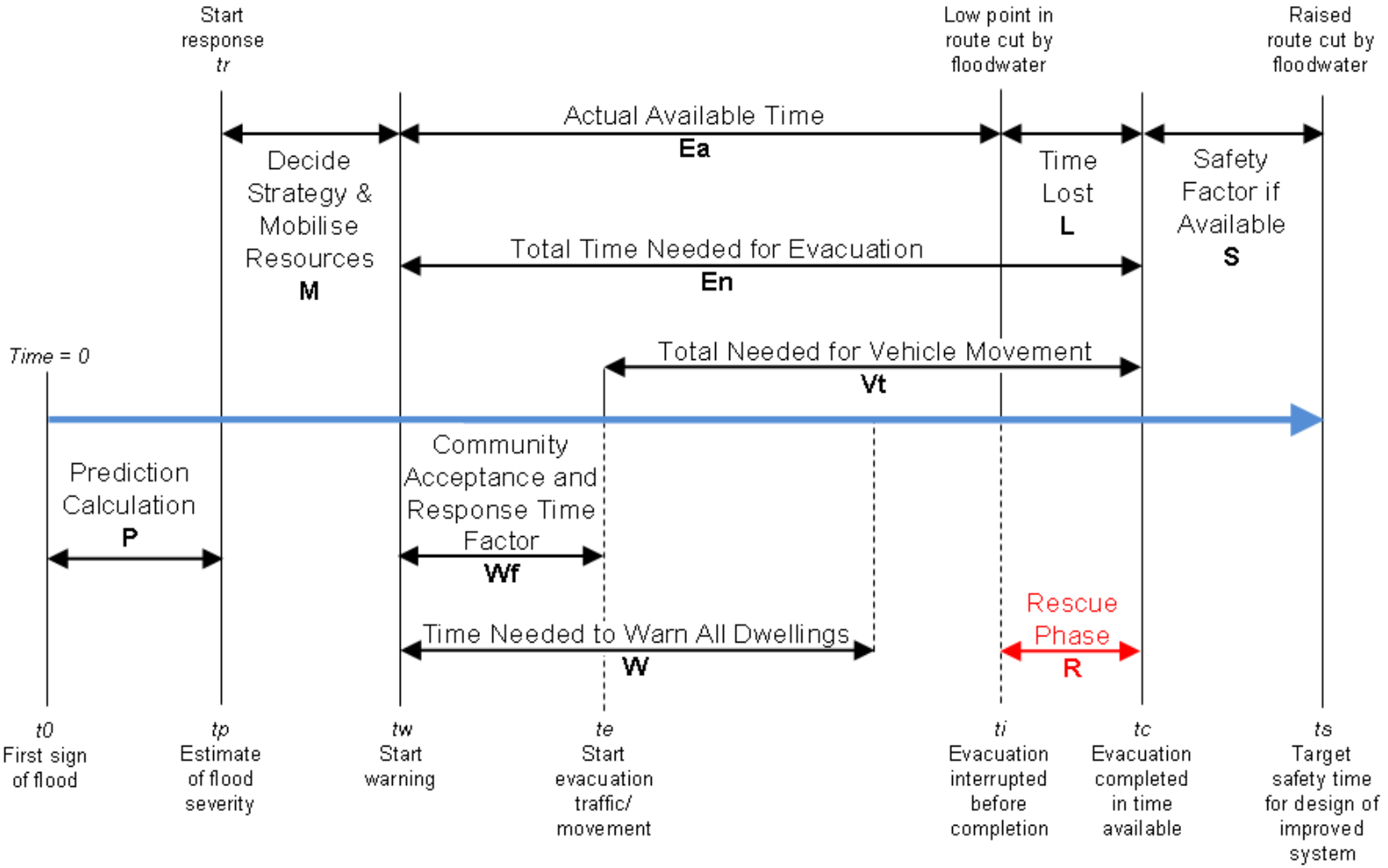
An example timeline is shown in Figure A- 1 with Table A- 1 describing the key components in the evacuation process.

A1.2.3 Application

Existing evacuation capability has been assessed based on current plans for emergency response and evacuation as outlined in the SES's Local Flood Plan, including the sectors, routes and evacuation centres outlined in the plan that have been assessed in this study. The assessment has been undertaken in consultation with local, regional and state SES representatives.

The key objective of the SES during a flood evacuation is to maximise the numbers of at-risk residents safely evacuated prior to road closure, and minimise the likelihood of people requiring rescue. To achieve this, the SES aim to manage the warning process so that evacuation routes are at maximum capacity throughout the process. Critical roads were identified in the sectors which act as 'bottlenecks'. For most single lane routes, these are the roads immediately leading to an evacuation centre. The rate of warning (in this case door knocking) is planned to match the road capacity. Slower warning and the roads will be below capacity, increasing the risk of incomplete evacuation. Faster warnings and resources (such as door knocking teams) are wasted.

Table A- 1 summarises the application of the timeline approach to evacuation capability assessments of the Tweed Valley evacuation sectors.



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

Source: (Opper *et al*, 2009)

Figure A- 1 Flood Evacuation Timeline Schematic

Table A- 1 Summary of Timeline Approach

Component	Description	Application
Prediction	BoM assessment of recorded rainfall and gauge levels and estimation of flood severity.	Flood prediction timeframe based on actual rainfall (not taking into account predicted rainfall) which is conservative for the purposes of evacuation planning (and minimises likelihood of unnecessary evacuation). BoM have indicated that based on the design 100 year ARI and PMF rainfalls, major flood levels would be predicted at Murwillumbah and Chinderah approximately **9 hours** from the start of event.
Resource mobilisation	SES assessment of the severity and likelihood of a flood event (also based on the information provided by BoM during prediction), formulation of a response strategy and mobilisation of resources.	Allow minimum duration of **6 hours**.
Warning	SES warning of all 'at risk' dwellings to evacuate, currently undertaken via door knocking. Also includes time for 'community acceptance and response' to allow for people to process and accept the warning instructions and organise themselves prior to evacuating.	Rate of warning (door knocking) planned to match road capacity. Duration therefore dependent on Evacuation component below. Numbers of door knocking teams (generally 2 people per team) based on field testing estimates that a team can warn approximately 12 houses per hour.
Evacuation	Full evacuation of all people using cars as the primary means of transport. Also includes a traffic safety factor to allow for traffic incidents.	Duration dependent on the number of vehicles within each sector evacuating at maximum road capacity (nominally 600 vehicles per lane per hour, which makes some allowance for adverse weather conditions).
Safety factor / Rescue phase	Safety factor indicates how much time is left (if any) after completion of evacuation until the route is inundated. Rescue phase indicates the shortfall in time available (if any) based on early inundation of the route prior to completion of evacuation.	Safety factor indicates that safe evacuation of the sector is possible. The safety factor allows for uncertainty / unforeseen events in the process, and does not necessarily mean that evacuation can be delayed. If any of the routes close before evacuation of the sector is complete, the sector may require a 'rescue' phase. It is an indication of how much additional time is required to complete evacuation, not how long rescue may take (which will depend on various factors such as method of rescue and resources). Note that rescue may not be necessary if evacuation can be managed on a local (i.e. sub-sector) level (e.g. through the re-direction and / or prioritisation of areas) despite earlier inundation of a route.

A1.2.4 Other Issues

The evacuation capability assessment has been used to estimate the ability to evacuate the general floodplain community in a regional flood event based on existing emergency response plans. There are some additional issues that can not easily be quantified as part of a catchment scale assessment, but that have been identified and included where possible for consideration in the assessment of evacuation issues and management.

- **Local flooding of evacuation routes.** Local flooding, caused by stormwater or flash flooding, may coincide and exacerbate a regional flood event. Where there is anecdotal or other information to indicate key evacuation routes are at risk of local flooding, these have been noted in the assessment and included in the mapping. If the routes are critical for regional evacuation, separate studies have been recommended to investigate and address local flooding issues.
- **Community vulnerability.** Known vulnerable communities have been identified for specific consideration in emergency response plans. These communities may need evacuation resources and assistance surplus to broader community requirements. Vulnerable populations include high proportions of over 65s, people requiring assistance with everyday tasks, caravan parks, nursing homes, hospitals and schools.

A1.2.5 Data

The assessment of evacuation capability required the following data:

- **Flood data** was obtained from the Tweed Valley flood model including information on flood extent (the evacuation area), time of inundation of evacuation routes and immunity of evacuation centres. The PMF was the focus of the assessment, however less extreme events were also considered (the 20 and 100 year ARI).
- **Demographic data** was sourced from census and property survey to inform estimates of affected population, dwellings and vehicles requiring evacuation.

A1.2.6 Outputs

The primary output of the assessments is an estimate of whether each sector can be safely evacuated in a PMF (and other, less extreme events) based on current response plans and evacuation routes. In addition to this key output, the assessment also provides information on:

- The geographical extent of evacuation required;
- The number of houses affected and, correspondingly, the number of residents and vehicles requiring evacuation;
- Trouble spots and key areas, including low-islands and high-island isolated areas;
- At-risk communities, such as caravan park residents and older demographics;
- Constraints to the evacuation process, such as early cutting of key routes, or insufficient warning/ prediction time; and
- Emergency response resource requirements, including evacuation centre capacities and door knocking teams.

In addition to an assessment of the current capability, the outputs can be used to identify options to reduce risk, particularly in sectors where there may be insufficient time to safely evacuate everyone. Alternatively, where future development within the floodplain is proposed, recommendations can be made for the management of the additional evacuation requirements. It is noted that in areas where there is an existing safety factor, the floodplain management committee, in representing the community, would need to decide what to accept in terms of balancing future development with an increase in evacuation risk (i.e. reduction in safety factor) to the existing residents.

A1.3 Flood Damages Assessment

A flood damages assessment has been undertaken to identify and, where possible, estimate the cost of damages associated with the risks of flooding. The main objective of the flood damages assessment is to establish the 'baseline' economic costs of flooding (i.e. based on current conditions) which can then be used to help quantify the benefits of potential mitigation measures.

It is important to note that the assessment of flood damages is never referred to as the *calculation* of flood damages, but rather the *estimation* of flood damages. The distinction is important. Estimating flood damages is not an exact science as methodologies and data used in the valuation process vary. Certain assumptions within the process can have a noticeable impact on damage estimations.

A1.3.1 Types of Flood Damages

Flood damages can be classified as tangible or intangible, depending on whether costs can be assigned monetary values. **Intangible damages** arise from adverse social and environmental effects caused by flooding, including factors such as loss of life and limb, stress and anxiety. **Tangible damages** are monetary losses directly attributable to flooding. The flood damages assessment estimates tangible damages to provide information on the economic impact of flooding and potential management measures. Intangible impacts by their nature can not generally be quantified in the flood damages assessment; however they are considered throughout the study, alongside the economic impacts, in terms of identifying key risks and weighing up the costs and benefits of various management options.

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

Direct damages are typically estimated separately for urban, rural and infrastructure damages. **Rural damages** have not been estimated or included in the damage totals here, as the scope of this study does not include assessing measures for mitigating rural losses. The assessment therefore is focussed on quantifying estimates of **urban damages** together with preliminary estimates of **infrastructure damages**. Urban damages are typically further separated into damage to residential and commercial / industrial properties, and internal, external and structural components.

Figure A- 2 depicts the different classifications of flood damages.

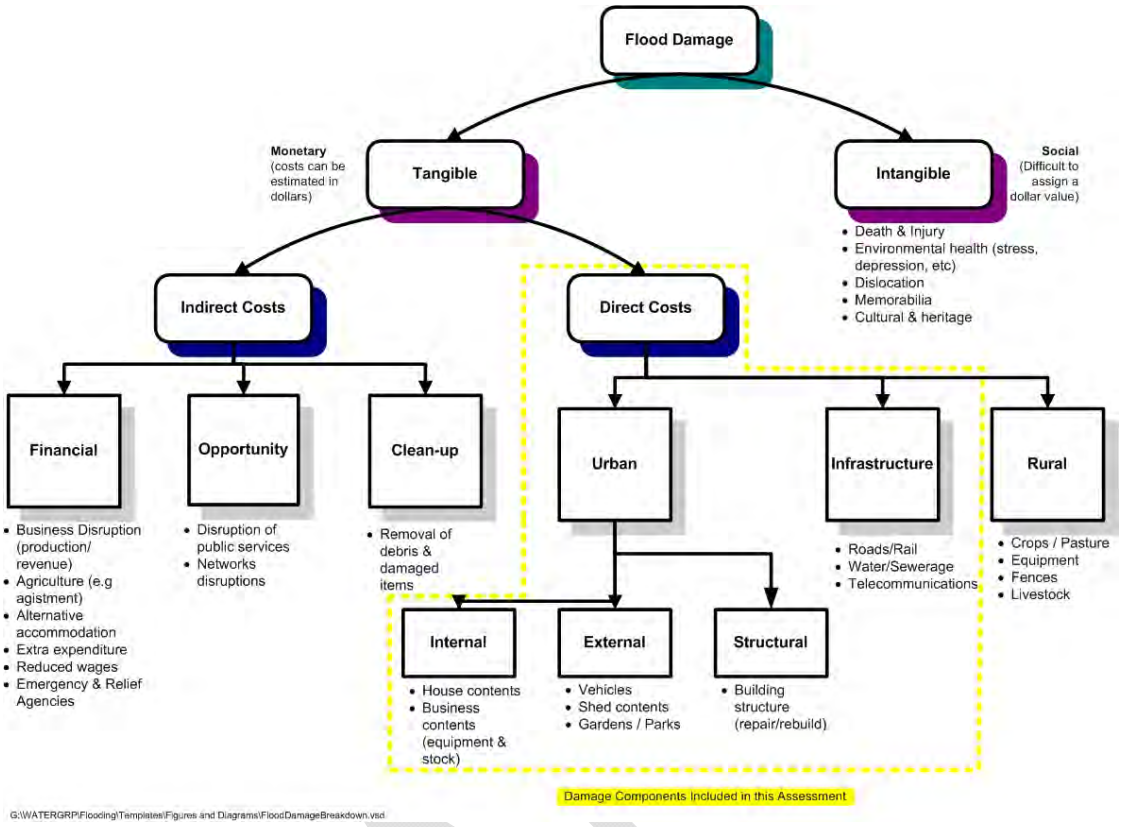


Figure A- 2 Types of Flood Damages

A1.3.2 Methodology

There are a range of industry-standard approaches for estimating the cost of the different types of flood damages described previously. **Stage-damage curves** are typically used to estimate internal damage sustained based on the depth of flooding through the property. These curves are estimated relationships between damage and depth generally derived from loss adjustor surveys which vary for different types of property and contents. An example of a stage-damage curve and how it is used in the estimation of damages is shown in Figure A- 3. External, structural, infrastructure and indirect damages are generally estimated using other approaches.

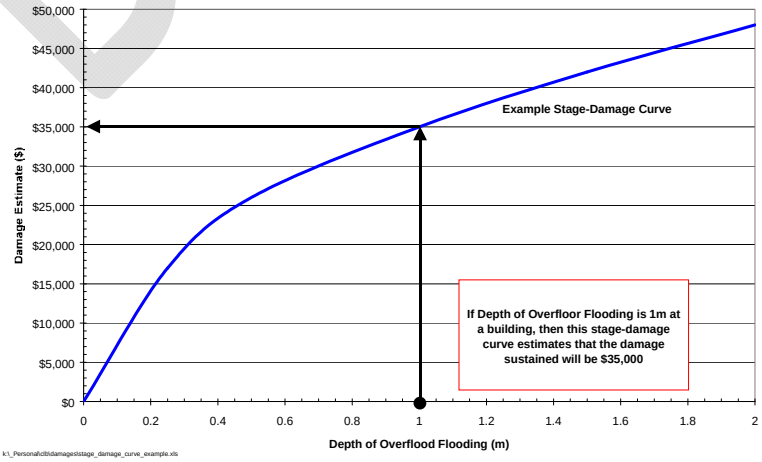


Figure A- 3 Example of Stage-Damage Curve

The following is an overview of the methodology adopted for the Tweed Valley flood damages assessments. This is also summarised in Table A- 2.

- **Residential damages** are based on *Floodplain Risk Management Guideline: Residential Flood Damages* (DECC, 2007b). This utilises stage-damage curves for three typical dwelling types; low set, high set and double storey. The curves include external and indirect damages. It does not however include multi-unit dwellings or vehicles. Units have been directly multiplied by number of units per storey. Vehicles have been excluded as they are often moved to higher ground, and also to ensure vehicle damage does not drive justification for mitigation works.
- **Commercial damages** are based on *Guidance on the Assessment of Tangible Flood Damages* (NRM, 2002). This utilises a set of stage-damage curves for different types of businesses based on size and contents value. For simplicity, commercial and industrial properties and damages are referred to in this study as *commercial*, but in all cases refer to both. Indirect damage to commercial property can be substantial due to loss of production / revenue etc, for which the guidance suggests an estimate of 55% of direct damages. External damage has been excluded with the majority of damage typically expected to be allowed for when assigning appropriate contents value.
- **Structural damage** to buildings was assumed for properties where the velocity-depth product exceeded 1 m^2/s, the depth above floor exceeded 2 metres, or the velocity exceeded 2 m/s. Following a sensitivity analysis, the technical committee decided to assign a nominal value of $20,000 per property.
- **Infrastructure damages** are difficult to quantify without an extensive valuation and assessment of each of the individual infrastructure at risk. Instead, infrastructure damages have been approximated as 15% of direct urban damages.

Table A- 2 Summary of Flood Damages Assessment Approach

TANGIBLE	DIRECT ►	Urban►	Internal►	Commercial►	NRM Stage-Damage Curves
				Residential►	DECC Stage-Damage Curves
			External►	Commercial►	Not explicitly included
				Residential►	DECC Stage-Damage Curves
			Structural►	$20,000 per property based on high depth / velocity criteria	
		Infrastructure►	15% of direct urban damages (DECC)		
		Rural ►	Not included in this assessment		
	INDIRECT►	Commercial►	55% of Direct Damages (NRM)		
		Residential►	DECC Stage-Damage Curves		

A1.3.3 Data

The assessment of flood damages required the following data:

- **Flood data** was obtained from the Tweed Valley flood model for a range of event magnitudes from the 5 year ARI to the PMF. This included estimates of peak flood levels at each property to inform estimates of internal damages, as well as peak depth, velocity and depth-velocity product (required to estimate structural damages).
- **Property data** from the property survey including location, floor level and other building information (e.g. type, size etc) was used to select appropriate stage-damage curves and above-floor depths for estimation of internal damages.
- **Ground level data** was derived from the DEM developed for the Tweed Valley Flood Study Update and used to estimate external inundation and damages.

A1.3.4 Outputs

Using the above data and methodology, flood damages were estimated for a range of event magnitudes. Estimates have been reported in the study for the area as a whole, as well as a breakdown by census zone to provide more detail.

These range of event estimates were then used to calculate the **Average Annual Damage**, or **AAD**, which represents the estimated economic cost of flooding on average each year. AAD takes into account both the likelihood and consequence of flooding, from events such as a 5 year ARI that may cause millions of dollars damage, to extremely rare and unlikely events where damage may be in the billions of dollars.

AAD is calculated by combining estimated damages for each magnitude event with probability, and represents the area under the curve, as per the example shown in Figure A- 4. The reduction in damages in individual events (and thus AAD) due to a particular mitigation option then represents the tangible, economic benefit of that option. This benefit can then be used to inform a cost-benefit assessment for the option.

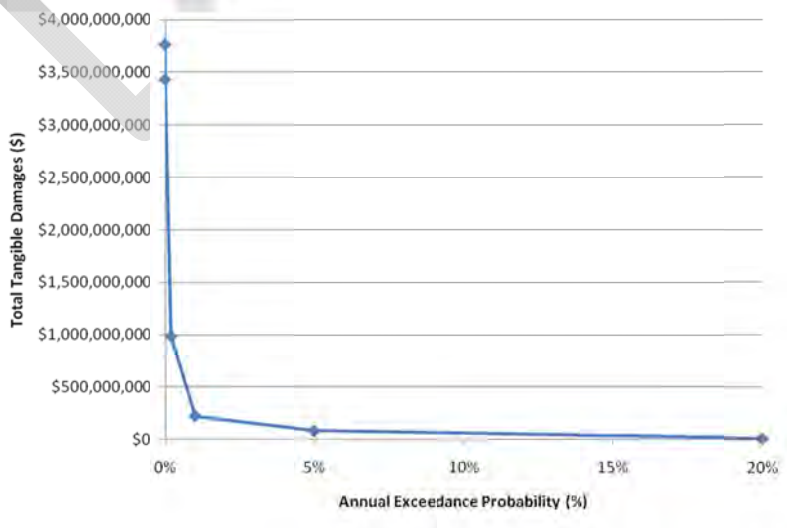


Figure A- 4 Average Annual Damage Curve

A1.4 Cost Benefit Assessment

The flood damages assessment and AAD described above provides an estimate of the current financial cost of flooding in the study area. This can be used in a cost benefit assessment to determine the relative merits of different options identified to reduce flood damage, and inform selection and prioritisation of preferred measures.

The general procedure for undertaking a cost benefit assessment is as follows:

- **Estimate average annual benefit** associated with the measure, based on the reduction in annual average damages from a flood damages assessment;
- **Estimate total benefit** by multiplying by the present worth factor (see below);
- **Estimate total cost** of the measure; and
- **Calculate monetary benefit-cost ratio** (BCR) as a factor of the total benefit to total cost:

The **present worth factor** is a standard economic approach to quantify future benefits in today's dollars. The adopted present worth factor is 13.8 over a 50 year period (i.e. the annual average benefit is converted to total benefit by multiplying by 13.8).

Monetary BCRs are used to evaluate the economic potential for the measure to be undertaken. A BCR greater than 1 indicates that the monetary benefits outweigh the costs, while a ratio less than 1 indicates that the costs outweigh the benefits. It is important to reiterate however that economics and financial viability is only one criteria for consideration in respect to the value of a measure. As mentioned previously, other issues such as social and psychological impacts, although difficult to quantify, must be taken into account in the complete assessment.

APPENDIX B: GAUGES MONITORED BY TWEED SHIRE SES

Gauge Name	River	AWRC No	Easting	Northing	Projection	Datum	Zero Gauge	Conversion to AHD	Type	Owner
Boat Harbour No.3	Rous River	201005	532938.255	6868452.004	MGA 94	ASS	3.738	N/A		DWE
Kynnumboon	Rous River		538179	6867895	MGA 94	TRHD		-0.926	Telemeter	MHL
Eungella‡	Oxley River	201001	528723.666	6863585.036	MGA 94	ASS		+13.285	Telemeter	DWE
Uki‡	Tweed River	201900	532742.434	6856977.060	MGA 94	ASS		+9.04	Telemeter	DWE
Tyalgum (Oxley River)‡	Oxley River	201006							Manual	
Bray Park Weir	Tweed River		536209	6864484	MGA 94	TRHD		-0.934	Telemeter	MHL
Chillingham‡	Rous River	201008							Manual	
Tyalgum‡	Pumpenbil Ck	201901							Manual	
Murwillumbah Bridge	Tweed River	201420	539219	6866353	MGA 94	TRHD		-0.909	Telemeter	MHL
Murwillumbah*‡	Tweed River	201902	539295	6866485	MGA 94	AHD		0	Telemeter	TSC/BoM
Tumbulgum‡	Tweed River	201432	545172	6871996	MGA 94	TRHD		-0.893	Telemeter	MHL
Tumbulgum			545212	6872325	MGA 94					TSC
Barneys Point (Chinderah) *^	Tweed River	201426	554110	6877724	MGA 94	TRHD		-0.883	Telemeter	MHL
Barneys Point	Tweed River		554505	6877666	MGA 94	AHD		0	Telemeter	MHL
Dry Dock	Tweed River	201428							Telemeter	TSC
Letitia 2A	Tweed River	201429	554314	6882414	MGA 94	TRHD		-0.886	Telemeter	MHL
Terranora	Broadwater	201447	548941	6880375	MGA 94	TRHD		-0.853	Telemeter	MHL
Cobaki	Broadwater	201448	549348	6883136	MGA 94	TRHD		-0.863	Telemeter	MHL
Point Danger‡	Tweed River	201904							Manual	

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