Notice of Meeting

Extraordinary Floodplain Management Advisory Committee Meeting

An Extraordinary Floodplain Management Advisory Committee Meeting of Byron Shire Council will be held as follows:

Venue	Conference Room, Station Street, Mullumbimby
Date	Friday, 12 July 2024
Time	10:00 AM

Phil Holloway Director Infrastructure Services

I2024/1016 Distributed 05/07/24



CONFLICT OF INTERESTS

What is a "Conflict of Interests" - A conflict of interests can be of two types:

Pecuniary - an interest that a person has in a matter because of a reasonable likelihood or expectation of appreciable financial gain or loss to the person or another person with whom the person is associated.

Non-pecuniary – a private or personal interest that a Council official has that does not amount to a pecuniary interest as defined in the Code of Conduct for Councillors (eg. A friendship, membership of an association, society or trade union or involvement or interest in an activity and may include an interest of a financial nature).

Remoteness – a person does not have a pecuniary interest in a matter if the interest is so remote or insignificant that it could not reasonably be regarded as likely to influence any decision the person might make in relation to a matter or if the interest is of a kind specified in the Code of Conduct for Councillors.

Who has a Pecuniary Interest? - a person has a pecuniary interest in a matter if the pecuniary interest is the interest of the person, or another person with whom the person is associated (see below).

Relatives, Partners - a person is taken to have a pecuniary interest in a matter if:

- The person's spouse or de facto partner or a relative of the person has a pecuniary interest in the matter, or
- The person, or a nominee, partners or employer of the person, is a member of a company or other body that has a pecuniary interest in the matter.

N.B. "Relative", in relation to a person means any of the following:

- (a) the parent, grandparent, brother, sister, uncle, aunt, nephew, niece, lineal descends or adopted child of the person or of the person's spouse;
- (b) the spouse or de facto partners of the person or of a person referred to in paragraph (a)

No Interest in the Matter - however, a person is not taken to have a pecuniary interest in a matter:

- If the person is unaware of the relevant pecuniary interest of the spouse, de facto partner, relative or company or other body, or
- Just because the person is a member of, or is employed by, the Council.
- Just because the person is a member of, or a delegate of the Council to, a company or other body that has a pecuniary interest in the matter provided that the person has no beneficial interest in any shares of the company or body.

Disclosure and participation in meetings

- A Councillor or a member of a Council Committee who has a pecuniary interest in any matter with which the Council is concerned and who is present at a meeting of the Council or Committee at which the matter is being considered must disclose the nature of the interest to the meeting as soon as practicable.
- The Councillor or member must not be present at, or in sight of, the meeting of the Council or Committee:
 - (a) at any time during which the matter is being considered or discussed by the Council or Committee, or

(b) at any time during which the Council or Committee is voting on any question in relation to the matter.

No Knowledge - a person does not breach this Clause if the person did not know and could not reasonably be expected to have known that the matter under consideration at the meeting was a matter in which he or she had a pecuniary interest.

Non-pecuniary Interests - Must be disclosed in meetings.

There are a broad range of options available for managing conflicts & the option chosen will depend on an assessment of the circumstances of the matter, the nature of the interest and the significance of the issue being dealt with. Non-pecuniary conflicts of interests must be dealt with in at least one of the following ways:

- It may be appropriate that no action be taken where the potential for conflict is minimal. However, Councillors should consider providing an explanation of why they consider a conflict does not exist.
- Limit involvement if practical (eg. Participate in discussion but not in decision making or viceversa). Care needs to be taken when exercising this option.
- Remove the source of the conflict (eg. Relinquishing or divesting the personal interest that creates the conflict)
- Have no involvement by absenting yourself from and not taking part in any debate or voting on the issue as of the provisions in the Code of Conduct (particularly if you have a significant non-pecuniary interest)

Committee members are reminded that they should declare and manage all conflicts of interest in respect of any matter on this Agenda, in accordance with the <u>Code of Conduct</u>.

RECORDING OF VOTING ON PLANNING MATTERS

Clause 375A of the Local Government Act 1993 – Recording of voting on planning matters

- (1) In this section, **planning decision** means a decision made in the exercise of a function of a council under the Environmental Planning and Assessment Act 1979:
 - (a) including a decision relating to a development application, an environmental planning instrument, a development control plan or a development contribution plan under that Act, but
 - (b) not including the making of an order under that Act.
- (2) The general manager is required to keep a register containing, for each planning decision made at a meeting of the council or a council committee, the names of the councillors who supported the decision and the names of any councillors who opposed (or are taken to have opposed) the decision.
- (3) For the purpose of maintaining the register, a division is required to be called whenever a motion for a planning decision is put at a meeting of the council or a council committee.
- (4) Each decision recorded in the register is to be described in the register or identified in a manner that enables the description to be obtained from another publicly available document and is to include the information required by the regulations.
- (5) This section extends to a meeting that is closed to the public.

OATH AND AFFIRMATION FOR COUNCILLORS

Councillors are reminded of the oath of office or affirmation of office made at or before their first meeting of the council in accordance with Clause 233A of the Local Government Act 1993. This includes undertaking the duties of the office of councillor in the best interests of the people of Byron Shire and the Byron Shire Council and faithfully and impartially carrying out the functions, powers, authorities and discretions vested under the Act or any other Act to the best of one's ability and judgment.

BUSINESS OF MEETING

1. APOLOGIES

2. DECLARATIONS OF INTEREST - PECUNIARY AND NON-PECUNIARY

3. ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

4. STAFF REPORTS

Infrastructure Services

4.1	Community Education Strategy and Review of Flood Options / North Byron
	Flood Investigations - Projects Update

ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

	Report No. 3.1	Adoption of Minutes from Previous Meetings
5	Directorate:	Infrastructure Services
	File No:	12024/997

10 **RECOMMENDATION**:

That the minutes of the Floodplain Management Advisory Committee Meeting held on 14 May 2024 be confirmed subject to the following amendment:

Removal of the recommendation for Report No. 4.5 'Community Education Strategy and Review of Flood Options / North Byron Flood Investigations - Projects Update' and instead a note added to the minutes to say this item was deferred.

Attachments:

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1 Minutes 14/05/2024 Floodplain Management Advisory Committee, I2024/734, page 10 🗓 🛣

ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

Report

The attachment to this report provides the minutes of the Floodplain Management Advisory Committee Meeting of 14 May 2024 .

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Report to Council

The minutes were reported to Council on 27 June 2024.

<u>Comments</u>

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In accordance with the Committee Recommendations, Council resolved the following:

- **24-001 Resolved** that Council notes the minutes of the Floodplain Management Advisory Committee Meeting held on 14 May 2024. (Lyon/Westheimer)
- **24-002 Resolved** that Council adopts the following Committee Recommendations:

Report No. 4.1 Amendments to Byron Shire DCP 2014 Chapter C2: Areas Affected by Flood - Draft for Exhibition

File No: I2024/661

Committee Recommendation 4.1.1

That Council:

- 1. Notes the committee received a presentation by BMT and as contained in the report attachments; and
- 2. Adds within the public exhibition version of the DCP, and note that the committee wishes to add the following sentence in C2.1.8 "Where a significant flood has occurred and studies require updating but that has not yet happened, flood data such as reported Flood Heights (where available) should be taken into account".
- 3. Notes that committee members are able to make submissions to the proposed amendments to Byron Shire DCP 2014, Chapter 'C2: Areas Affected by Flood', for Council's consideration prior to final adoption. (Lyon/Westheimer)
- 24-003 Resolved that Council adopts the following Committee Recommendation:

ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

Report No. 4.2 Flood Levee Raising Investigation - South Golden Beach File No: I2024/161

Committee Recommendation 4.2.1

That Council, based on the reasons discussed in this report, it is recommended that raising the levee by either 300mm or 600mm is not undertaken. (Lyon/Westheimer)

24-004 Resolved that Council adopts the following Committee Recommendations:

Report No. 4.3 Flood Gate Upgrade Options Investigation - South Golden Beach File No: I2024/164

Committee Recommendation 4.3.1

That Council:

- 1. Notes that the committee was presented with the Floodgate Upgrade Options Investigation prepared by JB Pacific March 2024– Attachment 1 (E2024/47404).
- 2. Applies to the State for funding to carry out the recommendations contained in Section 4.2 and 5 of the report. (Lyon/Westheimer)
- **24-005 Resolved** that Council adopts the following Committee Recommendation:

Report No. 4.4 Post 2022 Event Flood Behaviour Analysis - Brunswick River, Belongil Creek and Tallow Creek - NSW Department of Planning & Environment

File No: I2024/676

Committee Recommendation 4.4.1

That the Floodplain Management Advisory Committee notes that the Department of Climate Change, Energy, the Environment and Water (DCCEEW) have finalised and published Post 2022 Flood Analysis Assessments for the three (3) main catchments contained within Byron Shire Council. These include the North Byron/Brunswick River, Belongil Creek and Tallow Creek catchments. (Lyon/Westheimer)

24-006 Resolved that Council adopts the following Committee Recommendation:

Report No. 4.5 Community Education Strategy and Review of Flood Options / North Byron Flood Investigations - Projects Update

File No: I2024/677

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ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

Committee Recommendation 4.5.1

That Council requests the NSW Department of Planning & Environment (DPE) to commission animation graphic models of the 2022 flood event and provide to Council to assist in future community engagement, with an extended area to the north.

(Lyon/Westheimer)

<u>3.1</u>

The motions **24-321** to **24-326** were put to the vote and carried unanimously.

Minutes of Meeting Floodplain Management Advisory Committee Meeting

Venue	Conference Room, Station Street, Mullumbimby
Date	Tuesday, 14 May 2024
Time	11.30am



FLOODPLAIN MANAGEMENT ADVISORY COMMITTEE MEETING MINUTES 14 MAY 2024

Minutes of the Floodplain Management Advisory Committee Meeting held on Tuesday, 14 May 2024

File No: 12024/734

PRESENT:

Councillors:	Cr M Lyon (Mayor)	In person
	Cr D Dey	In person
	Cr Coorey	Absent
Staff:	Phil Holloway	Apologies
	Samuel Frumpui (Manager Works)	In person
	James Flockton (Infrastructure Planning Coordinator)	In person
	Steve Twohill (Flood and Drainage Engineer)	In person
	Dominika Tomanek (Minute Taker)	In person
	Alex Caras	In person
Invited members:	Scott Moffett (Dept of Planning and Environment)	Apologies
	Peter Mair (State Emergency Service) – voting member	In person
	Jeremy Carpenter (SES)	Apologies
Community:	Karl Allen	Apologies
	Matthew Lambourne	In person
	Steven Harris	In person
	Catherine Lane	In person

FLOOD Floodplain Management Advisory Committee Meeting

3.1 - ATTACHMENT 1

BYRON SHIRE COUNCIL

FLOODPLAIN MANAGEMENT ADVISORY COMMITTEE MEETING MINUTES 14 MAY 2024

Robert Crossley	In person
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Visitors: Damion Cavanagh In person

Cr Lyon (Chair) opened the meeting at 11:37 am and acknowledged that the meeting was being held on Bundjalung Country.

ATTENDANCE VIA AUDIO-VISUAL LINK:

APOLOGIES:

Scott Moffett

Karl Allen

Jeremy Carpenter (SES)

Phil Holloway

Absent:

Cr Coorey

DECLARATIONS OF INTEREST – PECUNIARY AND NON-PECUNIARY

There were no declarations of interest.

ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

Report No. 3.1Adoption of Minutes from Previous MeetingFile No:12024/682

Committee Recommendation:

That the minutes of the Floodplain Management Advisory Committee Meeting held on 13 February 2024 be confirmed.

FLOOD Floodplain Management Advisory Committee Meeting

3.1 - ATTACHMENT 1

BYRON SHIRE COUNCIL

FLOODPLAIN MANAGEMENT ADVISORY COMMITTEE MEETING MINUTES 14 MAY 2024

(Lyon/Lambourne)

The recommendation was put to the vote and declared carried.

BUSINESS ARISING FROM PREVIOUS MINUTES

Minutes of 13 February 2024 to be reported to Council meeting in May 2024.

PROCEDURAL MOTION

Committee Recommendation:

That Council change the order of business to deal with Reports 4.4 first on the Agenda.

The recommendation was put to the vote and declared carried.

Report No. 4.1Amendments to Byron Shire DCP 2014 Chapter C2: Areas
Affected by Flood - Draft for ExhibitionFile No:12024/661

Committee Recommendation:

That Council :

- 1. Notes the committee received a presentation by BMT and as contained in the report attachments; and
- 2. Adds within the public exhibition version of the DCP, and note that the committee wishes to add the following sentence in C2.1.8 "Where a significant flood has occurred and studies require updating but that has not yet happened, flood data such as reported Flood Heights (where available) should be taken into account".
- 3. Notes that committee members are able to make submissions to the proposed amendments to Byron Shire DCP 2014, Chapter 'C2: Areas Affected by Flood', for Council's consideration prior to final adoption.

The recommendation was put to the vote and declared carried.

(Dey/Lambourne)

FLOOD Floodplain Management Advisory Committee Meeting

ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

BYRON SHIRE COUNCIL

FLOODPLAIN MANAGEMENT ADVISORY COMMITTEE MEETING MINUTES 14 MAY 2024

STAFF REPORTS - INFRASTRUCTURE SERVICES

Report No. 4.2Flood Levee Raising Investigation - South Golden BeachFile No:12024/161

Committee Recommendation:

That Council, based on the reasons discussed in this report, it is recommended that raising the levee by either 300mm or 600mm is not undertaken.

(Lyon/Lane)

The recommendation was put to the vote and declared carried. Matthew Lambourne voted against.

Report No. 4.3 Flood Gate Upgrade Options Investigation - South Golden Beach File No: 12024/164

Committee Recommendation:

That Council:

- 1. Notes that the committee was presented with the Floodgate Upgrade Options Investigation prepared by JB Pacific March 2024– Attachment 1 (E2024/47404).
- 2. Applies to the State for funding to carry out the recommendations contained in Section 4.2 and 5 of the report.

The recommendation was put to the vote and declared carried.

(Dey/Lyon)

FLOOD Floodplain Management Advisory Committee Meeting

FLOODPLAIN MANAGEMENT ADVISORY COMMITTEE MEETING MINUTES 14 MAY 2024

 Report No. 4.4
 Post 2022 Event Flood Behaviour Analysis - Brunswick River , Belongil Creek and Tallow Creek - NSW Department of Planning & Environment

 File No:
 12024/676

Committee Recommendation:

That the Floodplain Management Advisory Committee notes that the Department of Climate Change, Energy, the Environment and Water (DCCEEW) have finalised and published Post 2022 Flood Analysis Assessments for the three (3) main catchments contained within Byron Shire Council. These include the North Byron/Brunswick River, Belongil Creek and Tallow Creek catchments.

(Lyon/Dey)

The recommendation was put to the vote and declared carried.

Report No. 4.5	Community Education Strategy and Review of Flood Options /
	North Byron Flood Investigations - Projects Update
File No:	12024/677

Committee Recommendation:

That Council requests the NSW Department of Planning & Environment (DPE) to commission animation graphic models of the 2022 flood event and provide to Council to assist in future community engagement, with an extended area to the north.

The recommendation was put to the vote and declared carried.

(Lyon/Crossley)

There being no further business the meeting concluded at 1:40 pm.

FLOOD Floodplain Management Advisory Committee Meeting

STAFF REPORTS - INFRASTRUCTURE SERVICES

STAFF REPORTS - INFRASTRUCTURE SERVICES

Report No. 4.1 Community Education Strategy and Review of Flood Options / North Byron Flood Investigations - Projects Update

Directorate:	Infrastructure Services
Report Author:	Steve Twohill, Flood and Drainage Engineer
File No:	12024/677

10 **Summary:**

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This report provides an update to the Floodplain Advisory Committee requested in their recommendation of Report 4.2 tabled at the Friday 8 December 2023 committee meeting. This recommendation has not been ratified with a council resolution. However, Council staff provide this report in good faith to keep the committee informed of the responses to these matters acknowledging that the Committee will end in September under this current

15 these matters acknowledging that the Committee will end in September under this current Council term.

The list of items is as follows and is discussed in this report: -

1. That the Floodplain Management Advisory Committee receive a further update on the 'Community Education Strategy and Review of Flood Options' project and a briefing on ways of further engaging community, for example with animations from existing and future flood models.

Consultants JBP have progressed this assessment and project since the public meeting held on 6 December 2023 and the ensuing Christmas holiday period. Council staff have met with the Consultant JBP in late December 2023 and February 2024 to discuss ways of further engaging the community in relation to improved flood awareness to this region.

In addition, Council sought permission from the NSW Department of Planning & Environment (DPE) to provide and release the confidential 2022 Flood event review report that was presented to the committee late last year. DPE have agreed to that request in late December 2023, this information has been provided to JBP.

30 This project has budgetary constraints that are already committed with an agreed scope. Staff have negotiated with the consultant JBP to undertake a review of the DPE 2022 flood event review report and integrate outcomes where appropriate in this assessment. The report is well underway however too premature to release for this committee meeting.

Animation and graphical recreation of the flood event are supported, however that aspect is not included in the scope for this project. Given that DPE has commissioned this review by WMA Water and the fact that it is their report and work, we recommend that DPE

STAFF REPORTS - INFRASTRUCTURE SERVICES

commission animation graphic models of the 2022 flood event and provide to Council to assist in future community engagement for this project.

We anticipate that the Final report will be presented to the committee at the next scheduled meeting in May 2024.

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RECOMMENDATION:

That the Floodplain Management Advisory Committee:-

- 10 1. Note the update on the 'Community Education Strategy and Review of Flood Options' project which focusses on the Northern Byron Shire communities; and
 - 2. Recommend that the NSW Department of Planning & Environment (DPE) be requested to commission animation graphic models of the 2022 flood event and provide to Council to assist in future community engagement.

Attachments:

FLOOD Agenda

- 1 JBP-Review Of Flood Studies North Byron Study Region Draft Report Feb 2024, E2024/47658, page 22 12 12
- 20 2 JBP-Executive Summary-Review Of Flood Studies North Byron Region Draft March 2024, E2024/47660 , page 36 🖞 🖾

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This report provides an update to the Floodplain Advisory Committee requested in their recommendation of Report 4.2 tabled at the Friday 8 December 2023 committee meeting.

5 This recommendation has not been ratified with a council resolution. However, Council staff provide this report in good faith to keep the committee informed of the responses to these matters acknowledging that the Committee will end in September under this current Council term.

Background to this project is contained in the previous report table at the 8 December 2023 meeting – refer File I2023/1607.

Consultants JBP have progressed this assessment and project since the public meeting held on 6 December 2023 and the ensuing Christmas holiday period. Council staff have met with the Consultant JBP in late December 2023 and February 2024 to discuss ways of further engaging the community in relation to improved flood awareness to this region.

15 Attachments 1 & 2 are provided for the committee's information.

In addition, Council sought permission from the NSW Department of Planning & Environment (DPE) to provide and release the confidential 2022 Flood event review report that was presented to the committee late last year. DPE have agreed to that request in late December 2023, this information has been provided to JBP.

20 This project has budgetary constraints that are already committed with an agreed scope. Staff have negotiated with the consultant JBP to undertake a review of the DPE 2022 flood event review report and integrate outcomes where appropriate in this assessment. The report is well underway however too premature to release for this committee meeting.

Animation and graphical recreation of the flood event are supported, however that aspect is not included in the scope for this project. Given that DPE has commissioned this review by WMA Water and the fact that it is their report and work, we recommend that DPE commission animation graphic models of the 2022 flood event and provide to Council to assist in future community engagement for this project.

There are eight (8) interrelated flood related investigations in this study area that will be nearing completion. These other projects include: -

PM22_30091 - AGRN1012 - Local Government Recovery Grant Program

PM22_1486 - Flood Warning Systems (Gauges) Upgrade - Shire Wide

PM23_1513 - Flood Pump Generator Power Supply - South Golden Beach

PM23_1514 - Rear Drainage Easements Upgrade - South Golden Beach

35 PM23_1516 - Flood Pump Investigation for Western Levee - South Golden Beach

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PM23_1517 - Drainage Easement Maintenance Access Upgrade - Narooma Drive

PM23_1519 - Flood Gate Upgrade Options Investigation - South Golden Beach

PM23_##### - Sky Pump Feasibility Investigation - South Golden Beach Canal system

Once all these investigations are complete, there is an opportunity to report all of these projects in a consolidated and integrated manner to the community June/July 2024.

Next steps

The Floodplain Advisory Management Committee will be updated as the project progresses. Committee members will be provided an opportunity to be further involved during the later stage of the project at an options workshop (date not yet confirmed).

10 Strategic Considerations

Community Strategic Plan and Operational Plan

CSP Objective	CSP Strategy	DP Action	Code	OP Activity
3: Nurtured Environment	3.3: Protect the health of coastline, estuaries, waterways, and catchments	3.3.2: Floodplain management - Mitigate the impact of flooding on private and public property	3.3.2.3	Floodplain Risk Management Committee coordination

Legal/Statutory/Policy Considerations

The study will align with the framework established by the NSW Floodplain Development Manual and national best practice as outlined in the Australian Institute for Disaster Resilience Handbook 7: Managing the floodplain: best practice in flood risk management in Australia (AIDR, 2017).

Financial Considerations

This is a grant funded project comprising consultancy fees only of \$37,940 (excl. GST).

Consultation and Engagement

20 A Community and Stakeholder Engagement Plan (CSEP) has been developed for the project for implementation. The CSEP aims to collate community and stakeholder concerns and ideas and address all concerns after reviewing management options and data. The CSEP considers different approaches to communications and engagement,

STAFF REPORTS - INFRASTRUCTURE SERVICES

following the IAP2 Public Participation Spectrum. The key outcomes of the project is improved community and stakeholder understanding and education on flood risk and flood risk management, as such the below is proposed:

- Council Staff/DPE representatives are given a steering role (Empowered).
- 5 Council's Advisory Committees are *Involved*

• The community is *Involved* within the project. This is deliberately not at a level that would allow their request for new mitigation scenarios to be tested without checks from flood engineers to ensure they are viable; however, it will ensure they are a focus on this project.

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4.1 - ATTACHMENT 1



BYRON SHIRE COUNCIL STAFF REPORTS - INFRASTRUCTURE SERVICES

4.1 - ATTACHMENT 1



Document Status

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Revision	S3 P01
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	Director

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4.1 - ATTACHMENT 1



Contract

JBP Project Manager	Eoghain O'Hanlon
Address	Suite 46, 477 Boundary Street, Spring Hill, Brisbane, QLD 4000
JBP Project Code	2023s0843

This report describes work commissioned by Byron Shire Council, by an instruction dated 21 June 2023. The Client's representative for the contract was Chloe Dowsett of Byron Shire Council. Callan Schonrock and Eoghain O'Hanlon of JB Pacific carried out this work.

Purpose and Disclaimer

Jeremy Benn Pacific ("JBP") has prepared this Report for the sole use Byron Shire Council and its appointed agents in accordance with the Agreement under which our services were performed.

JBP has no liability for any use that is made of this Report except to Byron Shire Council for the purposes for which it was originally commissioned and prepared.

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4.1 - ATTACHMENT 1



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4.1 - ATTACHMENT 1



Abbreviations	
AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
ARR2019	Australian Rainfall and Runoff (2019 Version)
ARR87	Australian Rainfall and Runoff (1987 Version)
CL	Continuing Loss
FRMS	Flood Risk Management Study
FRMS&P	Flood Risk Management Study and Plan
FMP	Floodplain Management Plan
IL	Initial Loss
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation

Definitions

A la la seconda esta se

2022 Flood Event: 25th February - 5th of March 2022 Major Flood.

Australian Rainfall and Runoff: Australian Rainfall and Runoff Guidance, the present-day industry standard for several rainfall runoff estimation methods.

Antecedent Conditions: Properties of soil/ground before an event largely dictating storm rainfall losses and baseflow

Baseflow: The portion of stream flow sourced from below ground moisture flowing into waterways.

Continuing Loss: Rainfall depth that is estimated to be lost throughout an event primarily through soil infiltration.

Calibration: The process to adjust flood simulations to be consistent with real-world flood behaviour

Design Event: A constructed flood event typically simulated to estimate flood hazard.

Evacuation Routes: Drivable corridors that are assessed as critical for community/property evacuation.

Extreme Flood: A flood believed to be representing a near-maximum flood event.

Falling Limb: The tail end of a hydrograph typically following a flood peak, depicting duration of flooding

Flood Behaviour: The characteristics and properties of a flood in a catchment, being out of bank flow, flood wave progression/attenuation, rapid flood response or prolonged flooding.

Floodplain: The land where water flows or is stored in times of flood.

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STAFF REPORTS - INFRASTRUCTURE SERVICES



Hydraulic Controls: Real-world structures that modify flood behaviour.

Hydrograph: The rate of flow over time, typically depicting river flows.

Hydrologic Model: Typically, a numerical model to estimate water storage-discharge through a catchment.

Hydrodynamic Model: Typically, a numerical model to estimate hydraulic dispersion/conveyance used to define flood extents/depths/velocities.

Initial Loss: A depth of rainfall that is estimated to infiltrate ground and not convert to runoff at the beginning of a storm.

Isolated Properties: Properties that are considered isolated from communities, evacuation routes.

Mitigation Options: Controls/interventions adopted to reduce (flood) risk.

Modelling: Typically, a simulation of real-world events

Northern Rivers Region: The North Coast of New South Wales.

Hydraulic Roughness: A bed "friction" to hinder conveyance of flow.

Stakeholders: People, groups of people or organizations that have a vested interest in a project, plan or decision

Temporal Pattern: The pattern or distribution of a parameter over time, associated with rainfall over time.

Validation: The process to justify existing flood simulations to be representative of realworld

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Executive Summary

Byron Shire Council (BSC) engaged JB Pacific (JBP) to undertake a review of the previous flood studies, flood risk management plans, estuary and coastal studies and all the flood management options that were contained and assessed within them, that are applicable for the North Byron villages of New Brighton, Billinudgel, Ocean Shores and South Golden Beach. This report summarizes these assessments and their findings to support the Byron Shire Council's Community Education Strategy and Flood Review project.

The latest flood study the North Byron Floodplain Risk Management Study and Plan (WMA, 2020) has been the basis for Byron Shire Council's adopted flood risk management plan, from which several management actions have been progressed to varying stages of completion, including submission of grants, design development, construction or implementation underway or already completed.

The findings of this review will be used to confirm the accuracy and completeness previous flood management options assessments and/or identify new and revised options where further analysis may be warranted. The Community and Stakeholder involvement is planned to understand prioritise their concerns and management options, that their either are in favour of implementing and/or further investigation and those which they are not in favour of which should not progress to the next stage analysis or implementation.

This report also summarises investigation gaps for the North Byron flooding behaviour, outlined as in the North Byron Floodplain Risk Management Study and Plan (WMA, 2020).

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1 Introduction

Byron Shire Council (BSC) engaged JB Pacific (JBP) to undertake a review of the previously assessed flood mitigation options that are applicable for the North Byron villages of New Brighton, Billinudgel, Ocean Shores and South Golden Beach. This report summarises the works and findings undertaken of the existing flood, estuary and coastal studies for the region, to support the Byron Shire Council Community Education and Flood Review project.

The North Byron region has been subject to several flood risk and flood management studies that have assessed various flood mitigation options. The latest flood study, the North Byron Floodplain Risk Management Study and Plan (WMA, 2020) has been the basis for Byron Shire Council's adopted flood risk management plan, from which several management actions have been progressed to varying stages of completion, including submission of grants, design development, construction or implementation underway or already completed.

The findings of this review, in conjunction with community and stakeholder engagement and education activities, will be used to confirm the accuracy and completeness of previous management/mitigation options assessments and/or identify options where further analysis and/or refinement may be warranted. The Community and Stakeholder involvement is planned to understand their priority concerns and suggested management options. This will include their review of what they are in favour of implementing and their assessment of other options they do not want to progress to the next stage.

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2 Flooding in North Byron

2.1 Riverine Flood Risk

The 2022 flood event was estimated to render 837 properties with above floor flooding, and resulted in total tangible damages estimate of \$47 Million. Following this significant flooding, community concern has risen for the Northern Byron Community regarding their existing flood risk, concerns of local hydrology, and ongoing plans and works to reduce flood risk for the region. The North Byron community is built within the Marshalls Creek floodplain, with the creek having significant storage and "bathtub" behaviour during a storm event from the constricted Marshalls Creek drainage at the confluence with Brunswick River. This flood behaviour is observed to inundate significant area including parts of:

- Ocean Shores
- New Brighton
- Back Water causing elevated water levels at South Golden Beach

Billinudgel experiences predominant flood risk from riverine flooding, with significant constriction of Marshalls Creek at Billinudgel Bridge and the Pacific Motorway, however protection of Billinudgel from Marshalls Creek has been previously observed to still exhibit inundation from local overland flow.

2.2 Overland Flow Flood Risk

Further flood risk exists in the north Byron region from stormwater overland flow, particularly South Golden Beach and Ocean Shores.

South Golden Beach is protected from a levee up to the 1% AEP canal water level. However, from community consultation the South Golden Beach community experience significant local rainfall observed to inundate parts of the community. While a flood pump services the Western Side of South Golden Beach, to limit risk of elevated water levels within the South Golden Beach Canals preventing effective drainage, East South Golden Beach does not have this functionality. Ocean Shores is susceptible to coincident overland flow, and riverine flood risk. Several community members have testified of flooding from Water Lily Park, and elevated water levels within Marshalls Creek.

From community consultation these communities are extremely susceptible to stormwater network blockage.

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3 Reviewed Flood Studies

3.1 Overview

Several significant flood studies have been identified and reviewed as part of this detailed review including:

- North Byron Sky Pumps Study (JBPacific, 2024)
- Post 2022 Event Flood Behaviour Analysis Brunswick River (WMAwater, 2024)
- Characterisation of the 2022 Floods in the Northern Rivers Region (CSIRO, 2022)
- North Byron Floodplain Risk Management Study and Plan (WMAwater, 2020)
- North Byron Flood Study (BMT, 2016)
- Tweed Byron Coastal Creeks Flood Study (BMT, 2010)
- Marshalls Creek Floodplain Management Plan (Paterson Consultants, 1997)
- Brunswick River Flood Study (WMAwater, 1986)
- Brunswick Valley Flood Plain Management Study Hydrology Report (WMAwater 1984)

Other previous flood studies were identified from the latest North Byron Floodplain Risk Management Study and Plan (WMAwater, 2020). Several of these studies were summarized by the 2020 North Byron FRMS&P including:

- Marshalls Creek Flood Study (1986)
- Flood mitigation Options for Billinudgel (1988)
- Brunswick River Floodplain Management Investigation (1989)
- Proposed Levees and South Golden Beach (1989)
- Report on Feasibility of an EIS for North Ocean Shores Flood Outlet (1992)
- Mullumbimby Floodplain Management Plan (1993)

Additional reports were identified to exist; however, they are not summarized by the FRMS&P or this flood study review. These include:

- Brunswick River Tidal Data Collection (2008)
- Kallaroo Circuit Bund Culver Amplification Hydraulic Impact Assessment (1996)
- Marshalls Creek Dredging Investigations Stage 1 Report (1992)
- Mullumbimby Floodplain Management Study Re-evaluation of Options (1992)

3.2 Limitations

In 2020, flood risk management experts at WMAwater released the latest Flood Risk Management Study and Plan (FRMS&P) for the North Byron region, building on top of the 2016 BMT study. This study investigated the flood risk for the North Byron community by undertaking numerical modelling of simulated river and creek flood events. Notably this study had key limitations including:

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- It did not simulate overland flow flooding caused by intense rainfall across land.
- It builds upon and adopts dated industry modelling methodologies.

The existing study additionally utilized community consultation to provide several recommendations for drainage improvements where the modelling results were not practical for drainage assessment. Following the study, as an intermediate intervention, the Byron Shire Council has undertaken several works projects and plans to maintain and improve drainage in the North Byron community. However there remains a high-level of residual community concern about inadequate stormwater drainage and maintenance, which needs better planned and communicated to the community, along with undertaking a catchment wide overland flow path study to better understand the areas of concern.

Several mitigation options have been considered by the FRMS&P and Council to reduce the bathtub effect of Marshalls Creek including but not limited to:

- Marshalls Creek Ocean Outfalls
 - Simulated by carving coastal dunes out of the existing model, shown to reduce the 1-in-100 year peak flood level by 0.1m at Ocean Shores. Not greatly reducing flood risk for Marshalls Creek.
 - Ocean Outfalls are limited in their effectiveness by sizing (width) and through minimizing the risk of elevated ocean levels and waves flowing into Marshalls Creek. Additionally, they require significant clearing to construct and maintenance to ensure their conveyance capacity when needed.
- Pumping floodwater to the Ocean
 - This has been shown to be effective at reducing local and widespread peak flood levels, however there is limited technology to pump the required flow rates. This has also been used to provide a better understanding of the flow rate required for the ocean outfalls.
- Brunswick Heads Rock Wall Removal
 - Simulated by removing the Marshalls Creek Rock Walls out of the existing model, shown to not greatly reduce the 1-in-100 year peak flood level.
 - A limitation of this investigation is the increased tidal flushing of Marshalls Creek believed to increase sediment transport and reduce siltation in Marshalls Creek, having a similar but permanent effect that dredging provides.
 - The 1-in-100 year event was seen to significantly overtop the rock walls, however during more frequent events, the creek conveyance is believed to be a greater portion of total flow.
 - While this option could improve drainage of catchment dominated events, ocean dominated events are believed to propagate further upstream including wave setup, storm surge and peak tide levels. Low lying communities such as New Brighton and South Golden Beach and portions of Ocean Shores, would have to be investigated further for this option to be considered further.
- Brunswick Heads Training Walls Removal

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- Simulated by removing the Marshalls Creek Rock Walls out of the existing model, shown to not greatly reduce the 1-in-100 year peak flood level
- Marshalls Creek Dredging
 - Simulated by removing the Marshalls Creek Rock Walls out of the model, shown to not greatly reduce the 1-in-100 year peak flood level
- Billinudgel Levee
 - Simulated to assist keeping Marshalls Creek floodwaters out of the Billinudgel township, however Billinudgel was still observed to be flood affected from local catchment overland flow.
- South Golden Beach Levee Modifications
 - Following an audit several recommendations were made for South Golden Beach Levee modifications
- House Raising
 - o Proposed as part of the Voluntary House Raising Scheme
- House Purchasing Scheme
 - o Proposed as part of the Voluntary House Raising Scheme
- Kallaroo Circuit Bund Modification
 - Not simulated independently however modelled simultaneous to Dredging, dune openings, rock wall modifications, with lowering of the bund by 1m to -0.025mAHD. Simultaneous modelling indicated a reduction of 0.15m at South Golden Beach.

It was further identified that little previous studies have considered flood mitigation options for Water Lily Park and surrounds at Ocean Shores.

While the options assessment modelling to date, has not been able to exhibit great benefits in flood reduction for the region, Byron Shire Council has undertaken further community consultation of residents, seeking their opinions on the issues and potential mitigation that they are likely to support. It was identified at the latest community consultation that the support for particular mitigation options (ocean outfalls) varies across the region, with those who are potentially closest and likely to benefit the most, being against there installation.

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4 Summary

This review has identified several different mitigation options that have been assessed for their effectiveness and their cost to benefit ratio. Mitigation measures that have been suggested range from structural such as levees, dune openings, stormwater drainage upgrades and channel diversions, voluntary resumptions, planning scheme amendments and flood planning levels, to forecasting, flood warning and community education programs.

Council has implemented and is in the process of implementing several of the recommended measures. Measures that Council has already implemented include drainage and maintenance programs, flood forecasting and a flood forecasting and warning system, updates to the planning scheme and the flood planning levels, portal for individual property flood risk information.

Stormwater drainage has been identified as a major consideration for flood risk in the North Byron region it is recommended that future investigations consider flood risk sensitivity to near 100% structural blockage of stormwater infrastructure, siltation blockage of bridges (Orana Road, and Billinudgel Bridge), and alternatives/priority maintenance to be undertaken regularly to avoid blockage induced flood risk. It is expected that this will be assessed as part of the overland flow assessment.

Many of the major structural options were observed to reduce peak water level but were not found to be cost effective and/or resulted in impacts to other areas. However, strong community support for further investigation and to implement mitigation options has been observed at the several previous community consultations and during this study, particularly for ocean outfalls. It was however noted that community support is not unanimous for any mitigation option, with some people who would most benefit being the strongest opposed to the option. It is recommended that further investigation considers flood mitigation effectiveness for events more frequent than the 1% AEP.

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4.1 - ATTACHMENT 1



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4.1 - ATTACHMENT 2


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Contract

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This report describes work commissioned by Byron Shire Council, by an instruction dated 21 June 2023. The Client's representative for the contract was Chloe Dowsett of Byron Shire Council. Callan Schonrock and Eoghain O'Hanlon of JB Pacific carried out this work.

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Abbreviations

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
ARR2019	Australian Rainfall and Runoff (2019 Version)
ARR87	Australian Rainfall and Runoff (1987 Version)
CL	Continuing Loss
FRMS	Flood Risk Management Study
FRMS&P	Flood Risk Management Study and Plan
FMP	Floodplain Management Plan
IL	Initial Loss
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation

Definitions

2022 Flood Event: 25th February - 5th of March 2022 Major Flood.

Australian Rainfall and Runoff: Australian Rainfall and Runoff Guidance, the present-day industry standard for several rainfall runoff estimation methods.

Antecedent Conditions: Properties of soil/ground before an event largely dictating storm rainfall losses and baseflow

Baseflow: The portion of stream flow sourced from below ground moisture flowing into waterways

Continuing Loss: Rainfall depth that is estimated to be lost throughout an event primarily through soil infiltration.

Calibration: The process to adjust flood simulations to be consistent with real-world flood behaviour

Design Event: A constructed flood event typically simulated to estimate flood hazard.

Evacuation Routes: Drivable corridors that are assessed as critical for community/property evacuation.

Extreme Flood: A flood believed to be representing a near-maximum flood event.

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Falling Limb: The tail end of a hydrograph typically following a flood peak, depicting duration of flooding

Flood Behaviour: The characteristics and properties of a flood in a catchment, being out of bank flow, flood wave progression/attenuation, rapid flood response or prolonged flooding.

Floodplain: The land where water flows or is stored in times of flood.

Hydraulic Controls: Real-world structures that modify flood behaviour.

Hydrograph: The rate of flow over time, typically depicting river flows.

Hydrologic Model: Typically, a numerical model to estimate water storage-discharge through a catchment.

Hydrodynamic Model: Typically, a numerical model to estimate hydraulic dispersion/conveyance used to define flood extents/depths/velocities.

Initial Loss: A depth of rainfall that is estimated to infiltrate ground and not convert to runoff at the beginning of a storm.

Isolated Properties: Properties that are considered isolated from communities, evacuation routes.

Mitigation Options: Controls/interventions adopted to reduce (flood) risk.

Modelling: Typically, a simulation of real-world events

Northern Rivers Region: The North Coast of New South Wales.

Hydraulic Roughness: A bed "friction" to hinder conveyance of flow.

Stakeholders: People, groups of people or organizations that have a vested interest in a project, plan or decision

Temporal Pattern: The pattern or distribution of a parameter over time, associated with rainfall over time.

Validation: The process to justify existing flood simulations to be representative of realworld

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Executive Summary

Byron Shire Council (BSC) engaged JB Pacific (JBP) to undertake a review of the previous flood studies, flood risk management plans, estuary and coastal studies and all the flood management options that were contained and assessed within them, that are applicable for the North Byron villages of New Brighton, Billinudgel, Ocean Shores and South Golden Beach. This report summarizes these assessments and their findings to support the Byron Shire Council's Community Education Strategy and Flood Review project. ON outcome of this review is to determine whether any of the options that have previously been assessed require further assessment or if any options have been overlooked that should also be considered.

The latest flood study the North Byron Floodplain Risk Management Study and Plan (WMA, 2020) has been the basis for Byron Shire Council's adopted flood risk management plan, from which several management actions have been progressed to varying stages of completion, including submission of grants, design development, construction or implementation underway or already completed. Further investigation has been undertaken on the sedimentation of Marshalls Creek to inform future estuary management decisions and monitoring.

The findings of this review are used to confirm the accuracy and completeness previous flood management options assessments and/or identify new and revised options where further analysis may be warranted. The Community and Stakeholder involvement was undertaken to prioritise their concerns and management options, that their either are in favour of implementing and/or further investigation and those which they are not in favour of which should not progress to the next stage analysis or implementation.

Community engagement both undertaken historically and as part of this study, identified that there is strong community support to:

- Alleviate the bath tubbing effect of Marshalls Creek with increasing the capacity
 of ocean outfalls through new high flow openings and/or the removal of
 Brunswick Heads rock walls or increasing its capacity.
- Improvement of stormwater drainage networks (Particularly South Golden Beach and Ocean Shores) combined with increased maintenance of the networks.

Support of particular options can be varying depending on the location of the residents in relation to the option, particularly the ocean outfall. With residents who live upstream and away from the actual outfall locations being more supportive than residents who live nearer to the outfalls. The residents who level nearest to the outfalls are the residents that are most likely to receive the greatest amount of benefit from the improved outfall capacity.

However, historical modelling results combined with cost benefit analyses, indicated that there was limited benefit from ocean outfalls and/or the removal of Brunswick Heads rock walls. As a result, this study recommends future studies consider flood mitigation benefit for more frequent events than the 1% AEP event. This study also recommends future studies consider sensitivity to stormwater network blockage to aid council maintenance priorities.

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1 Introduction

Byron Shire Council (BSC) engaged JB Pacific (JBP) to undertake a review of the previously assessed flood mitigation options that are applicable for the North Byron villages of New Brighton, Billinudgel, Ocean Shores and South Golden Beach. This report summarises the works and findings undertaken during the existing flood, estuary and coastal studies for the region, to support the Byron Shire Council Community Education and Flood Review project.

The North Byron region has been subject to several flood risk and flood management studies that have assessed various flood mitigation options. The latest flood study, the North Byron Floodplain Risk Management Study and Plan (WMA, 2020) has been the basis for Byron Shire Council's adopted flood risk management plan, from which several management actions have been progressed to varying stages of completion, including submission of grants, design development, construction or implementation underway or already completed.

The findings of this review, in conjunction with community and stakeholder engagement and education activities, will be used to confirm the accuracy and completeness of previous management/mitigation options assessments and/or identify options where further analysis and/or refinement may be warranted. The Community and Stakeholder involvement is planned to understand their priority concerns and suggested management options. This will include their review of what they are in favour of implementing and their assessment of other options they do not want to progress to the next stage.

Further investigation has been undertaken on the sedimentation of Marshalls Creek to inform future estuary management decisions and monitoring.

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2 Reviewed Flood Studies

2.1 Overview

Several significant flood studies have been identified and reviewed as part of this detailed review including:

- Post 2022 Event Flood Behaviour Analysis Brunswick River (WMAwater, 2024)
- Characterisation of the 2022 Floods in the Northern Rivers Region (CSIRO, 2022)
- North Byron Floodplain Risk Management Study and Plan (WMAwater, 2020)
- North Byron Flood Study (BMT, 2016)
- Tweed Byron Coastal Creeks Flood Study (BMT, 2010)
- Marshalls Creek Floodplain Management Plan (Paterson Consultants, 1997)
- Brunswick River Flood Study (WMAwater, 1986)
- Brunswick Valley Flood Plain Management Study Hydrology Report (WMAwater 1984)

Other previous flood studies were identified from the latest North Byron Floodplain Risk Management Study and Plan (WMAwater, 2020). Several of these studies were summarized by the 2020 North Byron FRMS&P including:

- Marshalls Creek Flood Study (1986)
- Flood mitigation Options for Billinudgel (1988)
- Brunswick River Floodplain Management Investigation (1989)
- Proposed Levees and South Golden Beach (1989)
- Report on Feasibility of an EIS for North Ocean Shores Flood Outlet (1992)
- Mullumbimby Floodplain Management Plan (1993)

Additional reports were identified to exist; however, they are not summarized by the FRMS&P or this flood study review. These include:

- Brunswick River Tidal Data Collection (2008)
- Kallaroo Circuit Bund Culver Amplification Hydraulic Impact Assessment (1996)
- Marshalls Creek Dredging Investigations Stage 1 Report (1992)
- Mullumbimby Floodplain Management Study Re-evaluation of Options (1992)

2.2 Brunswick Valley Flood Plain Management Study Hydrology Report (WMAwater Formerly Webb, McKeown & Associates, 1984)

2.2.1 Overview

This study was undertaken by WMAwater on behalf of Byron Shire Council. The scope of the study was limited to defining the hydrologic input parameters of the 20-year, 100-year and extreme floods within the Brunswick Valley for later use in hydraulic model development. A key limitation of this study included its timing. The study want conducted



almost 30 years ago, meaning it was conducted with less sophisticated industry standards resulting in limited storm pattern modelling, but also less available rainfall data for design rainfall estimation and now outdated modelling software.

2.2.2 Modelling Methodology

2.2.2.1 Hydrology Model

This study undertook development of a Boyd Hydrologic rainfall runoff model, similar to WBNM. Estimates of design rainfall depths were derived from ARR1977. "Extreme rainfall depths" were also provided by BoM for consideration in this study.

2.2.2.2 Calibration and validation

The hydrologic model was calibrated to several events. Calibration efforts included variation of "C" value for the Boyd Model to best fit historical events. IL and CL were identified from the rainfall and runoff volumes. The model parameters for each event identified are as shown in Table 2-1, where the 1972 event could not be accurately represented by available data and it is believed to be a localised event. Figure 2-1 and Figure 2-2 represent the hydrograph comparisons between the modelled and the recorded flood events for the March 1974 and March 1978 flood events respectively.

Table 2-1: Brunswick Valley FMS (1984) Calibration parameters

Event	"C" Parameter	IL	CL	Modelled Peak (m³/s)	Observed Peak (m³/s)	Comparison
October 1972	-	-	-	-	-	-
March 1974	2.2	0	4	296	299	Figure 2-1
March 1978	2.2	0	4	285	279	Figure 2-2





Figure 2-1: Brunswick Valley FMS (1984) 1974 Event Calibration Comparison at Durrumbul





Figure 2-2: Brunswick Valley FMS (1984) 1978 Event Calibration Comparison at Durrumbul

The parameters derived from the calibration were then validated for the 1976 event and achieved a reasonable comparison to the 1976 flood hydrograph at Durrumbul, shown in Table 2-2 and Figure 2-3. The modelled results, however, appear to have missed the initial peak and has the major peak lining up with the third peak, which was the second largest peak for the observed event and occurred several hours after the major observed peak.

Table 2-2: Brunswick Valley FMS (1984) Param	neter validation to the 1976 flood	FMS (1984) Parameter validation to the 1976 flood
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	Observed	Modelled	Percentage Difference
Volume (ML)	6300	5650	-10%
Peak (m ³ /s)	144	170	+18%

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2.2.2.3 Design Scenarios and Events

Rainfall depths were derived from local gauge analysis after identifying significant differences to generalised IFDs. A critical duration of 12 hours was identified for the study and a design temporal pattern was produced from observed storm behaviours. Following this the design hydrographs were produced for the 20, 100, and extreme events for the 12-hour critical duration. Resulting hydrographs for the 4.9%, 1% and "extreme" events are presented in Figure 2-4 to Figure 2-6

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2.3 Brunswick River Flood Study (WMAwater Formerly Webb, McKeown & Associates, 1986)

2.3.1 Overview

This study was undertaken by WMAwater on behalf of Byron Shire Council. The scope of the study was limited to determining flood behaviour in the Brunswick River and adjacent floodplain from the mouth at Brunswick Heads to a point approximately 3km upstream of Mullumbimby. Peak flood levels were also obtained in the main southern tributary, Simpsons Creek. Key limitations of this study included limited established industry standards, quasi-two-dimensional (one dimensional) hydraulic model.

2.3.2 Modelling Methodology

2.3.2.1 Hydrologic Inflows

This study adopted hydrologic inflows produced by the Brunswick Valley FMS Hydrology study (WMAwater, 1984).

2.3.2.2 Hydrodynamic Model

This study undertook development of a quasi-two-dimensional hydraulic model, consisting of four sources of hydrographic and topographic data of varying quality, as follows:

- 1:4000 orthophoto maps derived from photogrammetry
- Hydrographic survey (PWD, 1983)
 - A contour plan of the riverbed from the entrance to the Pacific Highway bridge
 - 50 Cross-sections on the Brunswick River between the Highway bridge and a point upstream of Mullumbimby
 - 27 cross-sections on Marshalls Creek
 - 18 cross-sections on Simpsons Creek
 - 6 cross-sections on Kings Creek
- A survey of the floodplain carried out by Council in 1983, specifically for this study.
- An additional survey carried out by Council in 1984, which defined areas in and to the south of Mullumbimby in more detail.

2.3.2.3 Calibration/Validation/Sensitivity

The hydrodynamic model was calibrated to the 1978 flood event. Calibration efforts included variation of manning's roughness. This resulted in adopting roughness by cross section, ranging from 0.020 - 0.130 Mannings 'n' values. Calibration efforts resulting in fair model calibration from the timing of the study, with results generally falling within $\pm 0.2m$ difference to observed flood markers.

2.3.2.4 Scenarios and Events

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Similarly, to the hydrology study, the 5%, 1% and "extreme" design storm events were modelled, these were paired with the 5% and 1% design ocean levels of 2.3mAHD and 2.6mAHD, from previous investigations. This produced peak water level contours and Brunswick River peak water level profiles shown in Figure 2-7.



Figure 2-7: Brunswick River FS (1986) Brunswick River Design Peak Level contours

2.4 Tweed-Byron Coastal Creeks Flood Study (BMT, 2009)

2.4.1 Overview

This study was undertaken by BMT on behalf of Tweed Shire Council, and due to the interactions of Yelgun/Marshalls Creek with Mooball Creek, Byron Shire Council took the opportunity to update Marshalls Creek Floodplain Management Plan as part of the study.

The primary objective of the study was to define flood behaviour of several coastal creeks, including the two creeks within the Byron Shire Council LGA, Yelgun Creek and Marshalls Creek. Key limitations of this study included the adoption of ARR87 methodology, outdated land-use, and limited data availability.



2.4.2 Modelling Methodology

2.4.2.1 Hydrology Model

This study undertook refinement of previously developed XP-RAFTS model developed by SMEC in 2006 for the Assessment of Flooding Behaviour in the Marshalls Creek Catchment Study. The hydrologic model extended over several local tributaries including, Burringbar, Sheens, Crabbes, Yelgun and Marshalls Creeks.

2.4.2.2 Hydrodynamic Model

This study undertook development of the Marshalls Creek TUFLOW hydraulic model. A two-dimensional model using a 15 metre grid resolution was adopted to represent the Marshalls Creek floodplain. The TUFLOW FV morphological model was utilized in the study to estimate bathymetry conditions at creek mouths.

2.4.2.3 Calibration/Validation/Sensitivity

The hydrodynamic and hydrologic models were calibrated to the June 2005 event and validated against the May 1987 event.

The calibration effort included the survey of several flood marks, undertaken by Council to provide peak water levels across the catchment, with the modelled peak water levels generally falling within 0.15m of the observed for the June 2005 event. Several recorded flood marks were located outside of the creek at relatively low levels such as 2.2mAHD at New Brighton, 2.6mAHD at Ocean Shores, and 3.9mAHD at Billinudgel, with the peak downstream level peaking at above 1.5mAHD catchment conditions are believed to account for only a portion of the resulting water levels. However, the available peak flood markers do generally support the peak flood levels observed.

A validation of the model was undertaken using the May 1987 event which had several flood markers, with the modelled results generally within 0.2m of the observed peak flood level.

The June 2005 event, had recorded water levels available for Billinudgel Gauge, and periodic recordings at Kallaroo Circuit culverts, the modelled results for the event are shown in Figure 2-8 and Figure 2-9. These indicate a fair calibration to flood peak level at Billinudgel, however falling limb indicates a misrepresentation of low storage-discharge relationships. Recorded water levels at the Kallaroo Circuit culverts were recorded at irregular and sparse intervals and are believed to not capture the timing of the peak, limiting the value of recorded results, however a comparison can be made to the progression of the flood wave, which indicates a fair validation for the falling limb.

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Figure 2-8: Tweed-Byron Coastal Creeks FS June 2005 Event Calibration at Billinudgel gauge





Figure 2-9: Tweed-Byron Coastal Creeks FS June 2005 Event Calibration at Kallaroo Circuit Culverts

2.4.2.4 Scenarios and Events

Several scenarios and events were modelled and have been summarized in Table 2-3.

Table 2-3: Tweed-Byron FS Modelled Scenarios and Events

Design Event	Catchment Inflow	Ocean Boundary	Ocean Boundary
	Rainfall Event	Storm Surge Event	Peak Tailwater Level (mAHD)
5 year ARI	5 year ARI	5 year ARI	0.8
10 year ARI	10 year ARI	10 year ARI	1.5
20 year ARI (envelope)	20 year ARI	10 year ARI	1.5
	10 year ARI	20 year ARI	2.2
50 year ARI (envelope)	50 year ARI	10 year ARI	1.5
	10 year ARI	50 year ARI	2.4
100 year ARI (envelope)	100 year ARI	20 year ARI	2.2
	10 year ARI	100 year ARI	2.6
500 year ARI	500 year ARI	100 year ARI	2.6
PMF	PMF	100 year ARI	2.6

2.4.3 Mitigation Measures

The report provided several recommendations to be assessed in the floodplain risk management plan, which was to be completed at a later stage. These recommendations included:

- Update Flood Planning Levels based on the results of this Flood Study, as well as Local Environmental Plans and Development Control Plans as appropriate.
- Update Councils GIS systems with the flood mapping from the Flood Study.
- Update S149 certificates for properties affected by flooding.
- Proceed to the preparation of the Floodplain Risk Management Study, to determine options to manage and/or reduce the flood risk taking into consideration social, ecological, and economic factors.
- The flooding interactions between Marshalls Creek and the Brunswick River should be considered prior to undertaking the Floodplain Risk Management Study for the area. The results of the Coastal Creeks Flood Study didn't consider coincident Brunswick River and Marshalls Creek flooding nor storm surge propagation.
- It was noted that the Floodplain Risk Management Study could be undertaken separately by each Council for their respective area. However, both Councils

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should ensure that management and mitigation options do not adversely impact on flooding behaviour where the floodplains are connected.

• On completion of the Floodplain Risk Management Study, a list of preferred options that were recommended by each Council would be presented in an overall Floodplain Risk Management Plan to be publicly exhibited for comment by the community and subsequently approved and implemented by Council.

2.5 Marshalls Creek Floodplain Management Plan (Paterson Consultants, 1997)

2.5.1 Overview

This study was undertaken by Paterson Consultants on behalf of Byron Shire Council. The scope of the study was limited to the development of the floodplain management plan for Marshalls Creek, and tributaries of Yelgun Creek and Billinudgel Creek, and did not undertake any modelling, at the timing of the study Council had adopted the Brunswick River Flood Study (Webb, McKeown & Associates, 1986). Key limitations of this study include the timing of the study as several new developments and changes in land use have occurred since the timing of the study, however many of the recommendations remain valid and are similar to present day council adopted floodplain risk management plans.

2.5.2 Identified Hazards/Risks

2.5.3 Mitigation Measures

Several floodplain management objectives were identified for this study including:

- Alerting the community to the extent and hazard of flood prone land in the Marshalls Creek area.
- Informing the community of Council's policies in relation to the development and use of flood prone land.
- Definition of a flood standard to be used for planning purposes.
- Reduction of the risk to human life and damage to property caused by flooding by appropriate works and measures and by controlling development on flood prone land.
- Adoption of requirements for development and for the use of land which is compatible with the land's flood hazard.
- Reduction of the impact of flooding on existing development by a series of works and measures.
- Prevention of flood losses in future development areas by application of effective planning and development controls.
- Provision of controls regarding flooding such that applications for development (including sub-division, rezoning development and building applications) can be assessed both consistently and on merit in accordance with the NSW Floodplain Development Manual (published by NSW Government, 1986)

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• Incorporation of plan provisions into planning policy provisions

The study proposed several general mitigation measures which are summarised in Table 2-4, as well as local mitigation measures summarised in Table 2-5.

Category	Controls
New sub-divisions of Flood-liable Lands	A moratorium for development of flood-liable land and filling of flood liable lands.
Development of Existing Lots and	A building application process
existing sub-divisions	Effluent disposal mounds where appropriate shall be located to provide minimal obstruction to local drainage and flood flows
Public Information and Education Programs	Byron Council and the SES should monitor the distribution of public information
	Public information should be reviewed after each major flood and amended where necessary
Flood Warning	Improvements to the warning system be investigated principally covering water level gauges to provide public information use of local area "Wardens" to assist in distribution of warnings
	Review of the Flood Plan be undertaken to ensure the consistency of damage and risk areas between all documents and the flood evacuation centres are located on flood free sites
	Investigation if established computer models can be used to improve flood prediction systems downstream of Billinudgel
	Funding to be sought to improve SES capacity to manage flood emergencies
Individual Lot Landscaping provisions	Building and development application provisions to be modified to promote open fencing and prevent traditional high "closed" style fencing
	Building and development controls such that flood protection measures on any particular block do not adversely affect the drainage and flooding characteristics on the surrounding blocks
Trunk Drainage Operations	A trunk drainage plan through the study area is required to identify works and measures to improve the efficiency of the system and to improve water quality
	Council's building and development conditions be reviewed to ensure they require and enforce the provision of overland flow

Table 2-4: Marshalls Creek FMP General Flood Mitigation Controls

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Category	Controls
	paths for safe discharge of runoff if the trunk drainage system should become blocked
Infrastructure Crossings	Byron Council should develop a set procedure for assessing the impacts of infrastructure crossings of the floodplain
	The established procedure should be applied to all works including those undertaken by Council
	Byron Council should notify the various government bodies authorities and construction groups of the intention to apply the principles of the Floodplain Management Plan to all land within the study area.
Integrated Catchment Management	Applications for development approval or change in land use shall be required to demonstrate that such development or change in land use will not increase runoff flowrates or pollution loadings within the Plan Area.

Table 2-5:	Marshalls Creek FMI	P Local Flood Mitigation Controls
Region	Control	e

Region	Controls
Billinudgel	Building controls allowing setting of minimum floor levels for new buildings, infill development and building extensions
	The storage of all toxic or hazardous substances or other products which in the opinion of Council may be hazardous or polluted flood waters, must be a minimum of 0.5m above designated flood level
	Development controls to allow filling of existing sub-divisions within the village
	Prohibition of further sub-division of flood liable land adjacent to the existing village boundaries
South Golden Beach	Building controls allowing setting of minimum habitable floor
and Ocean Shores North	extensions at RL 3.6m AHD
New Brighton	Building controls to be developed to
	Landscaping directions to be developed regarding fencing, flood access indicators, effluent disposal mounds

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	An interim measure was proposed to adopt the building material and detail guidelines in Appendix F of the NSW floodplain development manual
Ocean Shores	Building controls to set minimum floor levels flood compatible building materials and design of buildings to promote flood compatibility
	Prohibit subdivision or filling of undeveloped "High Hazard" areas.
Ocean Shores North/South Golden	Prohibit non-compatible development of "High Hazard - Flood Storage classed land
Beach/New Brighton Non-Urban Area	Prohibition of further fill or sub-division of the area
Yelgun/Wooyung Area	Building Controls to set minimum floor levels, Flood compatible building restraints, design of buildings to provide flood compatibility flood mounds to provide adequate flood refuge area

2.5.4 Other Findings

The study identified 28 houses in New Brighton and 1 house in Ocean Shores that would be suitable for house raising and a further 21 houses in New Brighton and 95 houses in Ocean Shores which would be appropriate for flood proofing. The study identified funding for house raising through joint Federal, State Governments and Council funded Flood Mitigation Programme to cover the full cost of house raising. The study estimated potential costs at the timing of the study for these works being:

- House-raising (29 Houses) \$ 1,015,000
- Flood Proofing (116 houses) \$ 342,000

There is some difference between number of houses suggested for flood proofing in the text and in the tables and summary.

2.6 North Byron Flood Study (BMT, 2016)

2.6.1 Overview

This study was undertaken by BMT on behalf of Byron Shire Council. It included the development of detailed hydrological and hydraulic models for Brunswick River to investigate flood risk for the catchment, for use in subsequent floodplain risk management studies.

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The scope of the study was limited to the Brunswick River, Simpsons Creek, and Marshalls Creek Catchments. Key limitations of this study included the poor calibration results to catchment response and the use of the ARR87 methodology.



2.6.2 Modelling Methodology

2.6.2.1 Hydrologic Model

This study undertook the development of an XP-RAFTS hydrological model for Brunswick River, Simpsons Creek, Marshalls Creek and Yelgun Creek. The XP-RAFTS model included several sub catchments to represent each of the major catchments, Brunswick River, Marshalls Creek, Simpson Creek and Yelgun Creek. Upstream sub catchments utilized an external routing methodology with no attenuation of peak flow and specification of travel time in attempt to minimize steep catchment's peak flow attenuation, remaining sub catchments utilized XP-RAFTS Muskingum routing methodology.

2.6.2.2 Hydrodynamic Model

This study undertook development of detailed TUFLOW hydrodynamic models that covered Ocean Shores, Brunswick Heads, Mullumbimby, and Brunswick River Estuary. In the upper areas of the floodplain a significant portion of major creeks and rivers were represented as one dimensional network, as shown in Figure 2-10. The Mannings' roughness values adopted for the design event modelling are presented in Table 2-6. Some of these roughness values are considered to be in the lower end of the range for roughness for typical the land use/vegetation types, however they are considered within reason.

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Figure 2-10: North Byron Flood Study (BMT, 2016) Model Schematization



	, 6
Land Use Type	Mannings' n Value
Pasture / Grass	0.04
Scattered Trees	0.05
Medium Trees	0.07
Thick Trees / Forest	0.09
Sandy River Bed	0.03
River Bed	0.04
Dams	0.07
Rock Walls	0.04
Urban Block	0.1
Golf Course	0.04
Sugar Cane	0.2
Bitumen Road	0.02
Gravel Road	0.025
Large Building Footprints	1.00

Table 2-6: North Byron Flood Study (BMT, 2016) Roughness Values

2.6.2.3 Calibration and Validation Overview

The hydrodynamic and hydrologic models were calibrated to the June 2005 and January 2012 flood events. Calibration efforts included hydrologic and hydrodynamic model calibration. Hydrologic model calibration included variation of; storm losses (IL and CL), roughness, and lag time for upstream sub catchments routing methodology as described in 2.6.2.1. Hydrodynamic model calibration included variation of roughness and structure losses. The calibration efforts results in a varying accuracy in the representation of the events throughout the catchment, the study identified that some of the discrepancies between the observed and the modelled results could be attributed to ever-changing catchment characteristics (including the Pacific Highway Upgrade) and data availability and accuracy, structure blockages and sub-daily rainfall data. Several observations were made on review of the resulting calibration comparisons.

2.6.2.4 Calibration results at Durrumbul

Model results of the Brunswick River Upstream of Durrumbul indicates that there is a misrepresentation of catchment response and falling hydrograph limbs, which is indicative of lower lag or attenuation and misrepresentative of storage - discharge relationships. Examples taken from the report of these comparisons of recorded data at Durrumbul to modelled data are provided in Figure 2-11, Figure 2-12, Figure 2-13, Figure 2-14.









Figure 2-12: June 2005 Calibration Results at Durrumbul











2.6.2.5 Calibration Results at Billinudgel

The hydraulic modelling results at Billinudgel gauge resulted in fair peak level comparisons, however a minor discrepancy was observed to the falling limb of the hydrograph shown in Figure 2-15. This discrepancy is relevant in assessing duration of inundation, which may be important to cropping lands or duration of closure to inundated roads.



Figure 2-15: North Byron Flood Study (BMT, 2016) Billinudgel Falling Limb

2.6.2.6 Calibration Results at Federation Bridge

Federation Bridge hydraulic model results indicate an overestimation of catchment volumetric response; however, the study believed a significant portion of the observed differences could be due to the data limitation of the sub-daily rainfall. Comparisons are shown in Figure 2-16 and Figure 2-17.









Figure 2-17: North Byron Flood Study (BMT, 2016) 1987 Event Comparison at Federation Bridge



2.6.2.7 Flood marks validation

Recorded flood marks are considered to generally align with model results, with relatively small absolute differences as shown in Figure 2-18 supporting the model calibration. However, it is believed that several recorded flood marks are believed to be located in shallow/sheet flow areas, which generally result in minor absolute differences and are not well related to the main flood flows, limiting the conclusions that can be drawn from these flood marks. It is noted that there is an approximately 1m difference between the recoded and the modelled for a flood mark near Mullumbimby.
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2.6.2.8 Scenarios and Events

Several scenarios and events were modelled, including both rainfall and ocean storm surge dominated flood events, for the 5, 10, 20, 50, 100, and 500 year Average Recurrence Interval (ARI), and the PMF events. In addition, climate change sensitivity scenarios were modelled which included, sea level rise and increased rainfall intensity.

Identified Hazards 2.6.3

The flood study undertook community engagement in aims to quantify hazards and concerns facing the community. Results from the community engagement are presented in Figure 2-19 and Figure 2-20



Figure 2-19: North Byron Flood Study (BMT, 2016) Community Identified Degree of Flooding

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2.6.4 Flood Risk Management Measures

From the conducted community engagement survey several flood risk management options were proposed by the community, presented in Table 2-7. From the community responses a significant portion of management options proposed were attributed to:

- Improve Road Drainage (26%)
- Increase maintenance (23%)
- Dredge creeks and river (19%)
- Remove vegetation/debris/silt (11%)

Similarly, responses to "Flooding issues that should be considered" were largely attributed to:

- Dredge river (25%)
- Restrict / Regulate development in floodplain (21%)
- Storm water drainage (12%)
- Brunswick River Mouth (10%)
- Clean and maintain drainage (7%)

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ľ	Table 2-7: North Byron Flood Study (BM	T, 2016	6) Community Management Options				
	Ideas to Improve Flooding	eas to Improve Flooding					
	Improve road drainage	26%	Dredge river	25%			
	Increase maintenance	23%	Restrict / regulate development in floodplain	21%			
	Dredge creeks and river	19%	Storm water drainage	12%			
	Remove vegetation/debris/silt	11%	Brunswick River mouth	10%			
	Open ocean outlets	3%	Clean and maintain drainage	7%			
	Levees / bunds	3%	Better flood warning / education	4%			
	Modify road/rail structures	3%	Modify road / rail structures	3%			
	Look at Marshalls Creek confluence with Brunswick River	2%	Other	3%			
	House Raising	2%	Substation at Waterlily Park	2%			
	Modify Waterlily Lake	2%	Tsunami alerts	1%			
	Raise causeways/keep clear of debris	2%	Increase in mosquitos	1%			
	Raise / monitor easements	1%	Sewage in Brunswick River	1%			
	Remove rock wall	1%	Climate change	1%			
	Fern Beach resulted in flooding of South Golden Beach	1%	Height of causeway on Main Arm Road	1%			
	Use wetland areas for mitigation	1%	Insurance	1%			
	Open flood gates on Golf Course	1%	Sand bar in Marshalls Creek	1%			
	Traffic management during flood	0%	Traffic management	1%			
			Extra span in bridge	1%			

Several actions were recommended following the adoption of this flood study including:

- Update the flood planning levels inclusive of the local environmental plans and DCP.
- Update Council's GIS systems with the flood mapping outputs from the flood study.
- Update S149 certificates for the properties affected by flooding.
- Undertake a condition survey of the gauge at Federation Bridge.
- Prepare a drainage strategy to reduce storm water flooding in Mullumbimby.
- Prepare a drainage strategy to reduce storm water flooding in Brunswick Heads.
- Proceed to the preparation of the Floodplain Risk Management Study and Plan to determine options to manage and/or reduce flood risk, taking into consideration social ecological and economic factors. This should consider the following:
 - o The flood risk and hazard for extreme events.

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- $\circ~$ The implications of the sensitivity tests on Flood Planning Levels and whether Council should change its current policy.
- Identification of areas in the floodplain that should not be 'filled' for the purpose of development.
- Review of past and potential future ocean outlets and the implications for flood mitigation. Such investigations should include:
 - Collaboration with Tweed Shire Council some outlets may have been within Tweed Shire.
 - Each historic ocean outlet should be modelled in unison and in combination with current catchment conditions.
 - A cost-benefit analysis to quantify the economic benefit that the ocean outlets may provide.
- Changes to the rock walls and the implications for flood mitigation. This investigation should include an assessment of removal of vegetation from the Readings Bay rock walls and cost-benefit analyses for the potential works.
- Model the dredging of each of the three creeks individually and in combination for the current catchment conditions. Assess the reduction in flooding these works provide, if any, and prepare a cost benefit analysis for the dredging works.

2.6.5 Other Findings

2.6.5.1 ARR87 Methodology

Due to the timing of the study the ARR87 methodology was adopted, which included ARR87 temporal patterns and the ARR87 IFD estimations. While the IFD estimations were investigated for validity, the quality of available data was not considered viable to support the adoption of locally derived IFD estimations.

2.6.5.2 Marshalls Creek Coastal Break Outs

The study found that there was supporting evidence through historic satellite imagery, of several breakout locations along Marshalls Creek. While no evidence was provided for the cause it was believed to be due to sand mining operations and subdivision works over several years. Flood level and inundation sensitivity due to these blocked outlets was not investigated in this study.

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2.7 North Byron Floodplain Risk Management Study and Plan (WMA, 2020)

2.7.1 Overview

This study was undertaken by WMAwater on behalf of Byron Shire Council. This study included an investigation of:

- Flood behaviour including hydraulic and hazard categorisation.
- Future development scenarios
- Review of potential climate change impacts on the flood behaviour and risks
- Flood damages assessment
- Emergency management

This study built on the North Byron Flood Study delivered in 2016. With the previous flood study using ARR87 methodologies, significant changes were made to this study by adopting of the ARR2019 update. The scope of this study was limited to the townships of Mullumbimby, Brunswick Heads, Ocean Shores, and villages of New Brighton, South Golden Beach and Billinudgel, and covers an approximate area of 55km². Key limitations of this study include resulting misrepresentation of catchment response from calibration.

2.7.2 Previous Study Overviews

The North Byron Flood Risk Management Study and Plan (WMA, 2020) included reviews of the following studies. These studies

2.7.2.1 Flood Mitigation Options for Billinudgel (Ray Sargent and Associates, 1988)

This report focused on flood mitigation options for Billinudgel. The 1987 Brunswick Valley Floodplain Management study showed minimal impacts on flood levels from filling. However, this report notes that increases in flood levels of 50mm could impact on existing properties and inundate previously dry properties, As the impact from filling land is very low, the report concludes the levees are likely to have minimal impact but while noting this, it does not continue to investigate this option further. To reduce the risk of flooding and prevent a deterioration of the flood problem, the following actions were recommended:

- Floodways blocked by vegetation growth should be cleared and maintained.
- The creek channel should be controlled by dredging, vegetation clearing and partial re-routing. However, some siltation at the downstream confluence of Marshalls Creek and Brunswick River is expected and the half-tide training wall at the creek mouth was considered as the likely contributing factor.

2.7.2.2 Brunswick River Floodplain Management Investigations (WMA, 1989)

The Brunswick River Floodplain Management Investigation was completed in November 1989 by Webb, McKeown & Associates in conjunction with the Brunswick River Floodplain Management Committee. The floodplain management investigation was in response to



requests to investigate flooding problems in the area and development applications to rezone and develop flood prone land in the Marshall Creek floodplain.

This investigation primarily looked at the Development Concept Plan put forward by the Ocean Shores Development Corporation (OSDC). Separate to the OSDC Development Concept Plan, the investigation also considered the future development of land owned by Crown Land and land owned by Mr J Mangleson. The investigation looked at flood mitigation options to both protect existing development and manage the impacts of possible future development.

The Floodplain Management Committee also requested the assessment of the several flood mitigation options. The study concluded that:

- To mitigate the impacts from the proposed development, a combination of flood mitigation works would be required and would need to include either the dredging of Marshall Creek or the North Ocean Shores flood outlet/opening.
- A levee around South Golden Beach would increase flood levels at new Brighton and would require a levee on the northern boundary.
- It is expected a levee around New Brighton without additional flood mitigation works would have impacts on upstream flood levels. For New Brighton, flood proofing measures were suggested.
- Should part of the development on Mr Mangleson's land proceed independently of the remainder of the proposal, a section of the floodway proposed opposite the land should be constructed.
- Development on Site B of the Mangelson land may have significant hydraulic impacts as the land is low-lying and forms part of the floodway. These impacts would not be easily mitigated.

2.7.2.3 Mullumbimby Floodplain Management Study (1989)

The Mullumbimby Floodplain Management Study was completed in December 1989 in consultation with the Brunswick River Floodplain Management Committee. The report focused on investigating flood mitigation options and assessing the potential impacts future development could have on flood levels. Considerable flood damage was caused during the May 1987 flood event. Residents put forward that the recently raised railway line had caused an increase in flood damages seen. However, study results showed that the changed railway level had no significant impact on flood levels.

Subsequently, the following flood management options were assessed, and the results are presented below:

- A diversion of floodwaters down Saltwater Creek provides no flood mitigation benefits and would have adverse impacts on other properties.
- Raising of houses or additional local flood protection would be not viable due to the number of houses affected and the cost. In combination with other options, house raising may be viable.

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- A flood warning system could reduce flood damages however, due to the short response time of the catchment was not considered a solution.
- Dredging of the Brunswick River would not eliminate the flood problem but in combination with other options could be more effective.
- Lowering or removal of the railway line would reduce flood levels on the upstream side of the railway line, as the line restricts flow across the floodplain at Mullumbimby. However, lowering of the line would increase flood levels on the downstream side and increase flow velocities at Station Street.
- Improved drainage through the railway line by adding culverts under the line would have a similar effect as the lowering of the line. A significant number of culverts (approx. 70) would be necessary to have a significant impact on flood levels upstream.
- A levee bank around the western part of the town would protect 30% of the flood prone properties but would have a negative impact on flood levels upstream of the levee. Associated drainage required with this option includes 4 culverts under the railway line and some additional culverts through the levee. Negative impacts caused by the levee could be mitigated by dredging of the Brunswick River, or stream clearing near the railway bridges to the south of Mullumbimby.
- Development of the proposed Industrial Estate located on Football Club Road would significantly increase flood levels downstream of the railway line. However partial development of the site may be possible.
- A levee bank around the eastern part of the town would protect 56% of the flood prone properties. While there were found to be no negative impacts on flood levels upstream of the railway line, a levee bank would cause a 10mm increase in flood levels downstream of the line. This option would require raising parts of Argyle Street and the construction of a 16-hectare storage basin inside the levee.
- Widening of the Main Road 524 bridge on Kings Creek by over double and lowering of Main Road 524 to ground level would reduce the 1% AEP flood levels by up to 20mm and 50mm respectively. Lowering of MR524 is expected to have impacts to trafficability during flood events. The report concludes neither option is cost efficient.

2.7.2.4 Proposed Levees around South Golden Beach (WMA, 1989)

This report was prepared by Webb McKeown & Associates and looks at managing flood risk in the residential development at South Golden Beach. This development is divided by Capricornia Canal and the proposal looked at a potential levee system around the eastern and western sections up to the 1% AEP event. The project considered the impacts of a 3.2m AHD levee. In comparison the May 1987 flood level was 2.7m AHD and the 1% AEP level is 3.2m AHD.

To manage the potential local drainage problems within the leveed area, the project investigated the effects of flap gated culverts. For operational and maintenance reasons, the use of flood pumps was not recommended here as a solution. While the flap gated

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culverts were found to be effective at preventing water entering the leveed area, ponding was still found to be a problem. Approximately 30 properties would experience worsening of a maximum afflux of 17mm. A flood compensation fund was suggested for those residents affected by the afflux.

2.7.2.5 Report on Feasibility of an EIS for North Ocean Shores Flood Outlet (WMA, 1992)

The construction of a flood outlet located in the North Ocean Shores area was proposed as possible flood mitigation measure in the Brunswick River Floodplain Management Investigations. Council subsequently commissioned Webb, McKeown and Associations to undertake further investigations into possible flood outlets at North Ocean Shores. The Floodplain Management Investigation found that while the outlet at North Ocean Shores provided flood mitigation benefits for floods of a greater magnitude than the 5% AEP, when this option is considered in conjunction with other mitigation measures such as dredging of Marshalls Creek and the levee at South Golden Beach benefits provided by the outlet are reduced.

This report concludes it is not feasible to undertake an EIS for a flood outlet at North Ocean Shores. This is primarily due to the potential economic and environmental impacts including a long-term financial commitment from Council to maintain the structure, potential impacts to dune stability, impact on the local flora and fauna from increased salinity levels in the connecting channel and Capricornia Canal and the relatively low benefit / cost ratio.

2.7.2.6 Draft Mullumbimby Floodplain Management Plan (BSC, 1993)

Following the completion of the Mullumbimby Floodplain Management Study, Byron Shire Council prepared the draft Mullumbimby Floodplain Management Plan. The Floodplain Management Committee considered mitigation options assessed in the Floodplain Management Study and concluded flood mitigation dams or catchment treatment were not viable options.

Recommendations made in the plan were:

- Advise the Roads and Traffic Authority (RTA) to consider effects of flood levels when investigating further works on Main Road 524
- RTA to improve drainage at Kings Creek bridge
- Remove obstructions in Saltwater Creek catchment and maximise the flows under the railway bridges
- Increase the capacity of the Myokum Street culverts
- Future buildings to have floor levels of the 1% AEP floor level plus 500mm
- A 15m floodway to the western and eastern side of the North Coast Railway Line
- A floodway over Hieronymus' property
- Installation of a flood warning system in the Brunswick River catchment

Recommended development Controls within floodways:

Maintain floodways ability to pass water

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- No works in the floodway that would decrease flow capacity,
- No building development within the floodway,
- No filling within the floodways,
- No fences within the floodway, as they may decrease flow capacity,
- · Land uses to be compatible with flood behaviour.

Recommendations for the eastern Mullumbimby floodplain:

- · Raise or flood proof all residential buildings impacted by a flood similar to the 1987 event or the 1% AEP event. Habitable floors should be 500mm above the 1% flood level.
- Filling is limited to the level created by a 1% grade line from the road centre line. It is considered this level of filling will not cause drainage problems for neighbouring properties.

Recommendations for Western Mullumbimby/Saltwater Creek Floodplain:

- Raise or flood proof all residential buildings impacted by a flood similar to the 1987 event or the 1% AEP event. Habitable floors should be 500mm above the 1% flood level.
- Habitable floors in new developments should be 500mm above the 1% flood level.
- Commercial and industrial floors should be the 1% flood level or higher,
- Residential properties that are raised should have floor levels 500mm above the 1% flood level.

2.7.3 Modelling Methodology

2.7.3.1 Hydrology Model

This study adopted of the previously developed XP-RAFTS hydrologic model developed from the 2016 study. However, several refinements were made to the existing XP-RAFTS model including:

- Catchments Slope Review
- Revised manning's roughness
- ARR2019 Storm Losses Applied
- Removal of sub-catchment storage factors
- Removal of Williams Bridge Basin

2.7.3.2 Hydrodynamic Model

This study adopted the TUFLOW hydrodynamic model developed for the 2016 study. However, several refinements were made to the existing TUFLOW model including:

- Inclusion of several significant hydraulic structures
- Topography amendments for recent developments:

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- \circ $\,$ Tallow Wood Estate Stage 4 $\,$
- Waterlily Park survey
- Shara Boulevard Sports field
- Orchid Place
- Rajad Road Subdivision
- River Bathymetry Update using bathymetric survey from November 2017
- Extended model extent
- Higher resolution of urban areas

2.7.3.3 Calibration/Validation/Sensitivity

The hydrodynamic and hydrologic models were calibrated to the March 2017 event, which was caused by ex-Tropical Cyclone Debbie. Calibration was to the recorded stream gauge data at five locations, for flood levels and for recorded streamflow, all modelled flows are believed to underestimate catchment and/or channel lags, with the model results showing all falling and rising limbs having faster runoff responses. While the study claimed a better representation was achieved the associated report figures indicate that a similar lag underestimation was encountered. The significance of the effect on floodplain estimation from the lag misrepresentation was not discussed. It does however have an impact on disaster response decisions and impacts on inundation timings (both time to inundation and duration of inundation. It is believed to be an underestimation of catchment roughness, affecting either channel or catchment lag, as the tidal gauges and catchment streamflow gauges both observe the discrepancy.

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Figure 2-21: North Byron FRMS March 2017 Level Calibration Brunswick River at Durrumbul Gauge





Figure 2-22: North Byron FRMS March 2017 Flow Calibration Brunswick River at Durrumbul Gauge









Figure 2-24: North Byron FRMS March 2017 Level Calibration Marshalls Creek at Billinudgel









Figure 2-26: North Byron FRMS March 2017 Level Calibration Brunswick River at Brunswick Heads









Figure 2-28: North Byron FRMS January 2012 Flow Calibration Brunswick River at Durrumbul Gauge

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Figure 2-29: North Byron FRMS January 2012 Level Calibration Brunswick River at Federation Bridge



Figure 2-30: North Byron FRMS January 2012 Level Calibration Marshalls Creek at Billinudgel

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Figure 2-32: North Byron FRMS March 2012 Level Calibration Brunswick River at Brunswick Heads



2.7.3.4 Scenarios and Events

Several oceanic and catchment scenarios were modelled and are summarized in Table 2-8. On review of the listed scenarios, events more common than the 1% AEP design event are thought to be conservative estimates from using join return periods for oceanic and catchment conditions.

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JBP scientists and engineers

Design Event	Oceanic Inundation	Catchment Inundation	
		Scenario	Duration
0.2EY	HHWS*	5 year ARI	12hr
			24hr
			36hr
10% AEP	HHWS	10% AEP	12hr
			24hr
			36hr
5% AEP	5% AEP Ocean Level	5% AEP	12hr
			24hr
			36hr
2% AEP	2% AEP Ocean Level	2% AEP	12hr
			24hr
			36hr
1% AEP	5% AEP Ocean Level	1% AEP	12hr
			24hr
			36hr
	1% AEP Ocean Level	5% AEP	12hr
			24hr
			36hr
	ISLW**	1% AEP	12hr
			24hr
			36hr
0.5% AEP	1% AEP Ocean Level	5% AEP	12hr
			24hr
			36hr
0.2% AEP	1% AEP Ocean Level	0.2%	12hr
			24hr
			36hr
PMF Event	1% AEP Ocean Level	PMF	12hr
			24hr
			36hr

Table 2-8: North Byron FRM Study (2020) Scenarios and Events

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2.7.4 Identified Risks

Several risks were identified from community engagement, the top three concerns among the community consultation were:

- Community Safety during floods
- Cost of floods
- Management options disadvantaging other parts of the community.

Several flood hazards were identified from the study that were used to assess flood risk including which were assessed for weighting specific to North Byron and are summarized in Table 2-9.

Criteria	Weight	Comment
Size of flood	3	While some residential properties are in unsafe areas for people / vehicles most properties are located in lower hazard areas for all events excluding the PMF.
Flood Awareness of the community	2	Recent flooding from Ex-Tropical Cyclone Debbie has elevated communities' awareness of flooding.
Depth and Velocity of flood waters	3	Already accounted for in the provisional hazard
Effective Warning and Evacuation Times	3	While the time available for flood warning varies across the North Byron Study area, a large proportion of the residents are located downstream, closer to the outlet (e.g. Mullumbimby and Brunswick Heads) providing opportunity for effective warning
Evacuation Difficulties	4	There are some identified pockets of the floodplain where evacuation routes are cut early, meaning residents may be trapped. Several residential areas were identified by the study as Low Flood Islands including Mullumbimby and a small area of Brunswick Heads.
Rate of Rise of floodwaters	2	While March 2017 exhibited characteristics similar to flash flooding and also showed the variable nature of flood events, flooding in North Byron typically progresses slowly provided people time to prepare
Duration of flooding	2	Duration of flooding varies across the catchment with Mullumbimby experiencing shorter durations of flooding than New Brighton and Billinudgel. However, these areas

Table 2-9: North Byron Flood Study Identified Flood Hazards

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Criteria	Weight	Comment
		are not expected to be isolated or flooded for substantial durations of time (e.g. longer than a day).
Effective Flood Access	4	Flood access is a concern for the catchment with several evacuation routes inundated in frequent flood events leaving some areas trapped.

In addition to this the study used modelling results to identify potentially isolated houses, the summary of number of isolated houses is shown in Table 2-10. The results indicate a significant proportion of the isolated houses are in Mullumbimby and may be sensitive to duration of inundation estimated from model results. It is noteworthy that the study indicates a decrease in isolated houses for events rarer than the 5% AEP event, this is believed to be due to a significant number of the isolated houses becoming inundated. Flood hazards, flood levels, and flow velocities were used to identified hotspot locations that were particularly vulnerable to flood risk, these included Mullumbimby, Riverside Crescent (Brunswick Heads), New Brighton, and Billinudgel.

Suburb	0.2EY	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Billinudgel	10	5	3	1	29	18	6	0
Brunswick Heads	0	3	0	0	13	3	0	51
Main arm	4	4	4	4	9	8	4	4
Middle Pocket	0	0	1	1	1	6	1	1
Mullumbimby	9	110	639	390	296	255	161	2
Myocum	1	1	0	0	0	0	0	0
New Brighton	20	20	15	2	1	1	0	11
Ocean Shores	0	0	3	10	11	25	63	2
South Golden Beach	0	0	0	0	0	0	26	0
The Pocket	1	1	1	0	0	0	0	0
TOTAL	45	144	666	408	360	316	261	71

Table 2-10: North Byron FRMS isolated houses

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2.7.5 Mitigation Measures

2.7.5.1 Existing Mitigation Measures

A levee exists along the eastern and western section of Capricornia Canal protecting the community at South Golden Beach, shown in Figure 2-33, which was constructed in 1989, with pumps installed in 2006 to reduce flooding behind the levee. The levee crest is currently set at a level of 3.2mAHD designed to protect South Golden Beach properties from the 1% AEP flood event. If the levee fails, during a 1% AEP event, an additional 272 properties were modelled to be impacted by flooding.



Figure 2-33: South Golden Beach Levee Location

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2.7.5.2 Management Options

The study categorizes flood management measures into three general categories: Flood modification measures, response modification measures and property modification measures. Several mitigation measures were analysed for their viability and recommended for more detailed assessment. This includes several mitigation options recommended by community, previously identified mitigation measures and other identified potential mitigation options. A summary of the options is provided in Table 2-11 and a spatial representation as in Figure 2-34, Figure 2-35, and Figure 2-36.



Figure 2-34: Mitigation Options at Brunswick River Opening

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Figure 2-35: Mitigation Options at Billinudgel



Figure 2-36: Mitigation Options at Northern Beaches

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Table 2-11: North Byron Floodplain Risk Management Study potential mitigation measures

Category	Option	ID	Description	Recommended / Progress	Reasoning
Flood Modification Measures	Levee	BL	Billinudgel Levee	Yes	This option was investigated through modelling a levee 650m in length running from west to east along Gerald Street and O'Donnells Lane just south of Marshalls Creek. The levee level was set to 4.7mAHD (0.2-0.3m above 1% AEP peak flood level). The study claims a general reduction in flood levels of up to 0.38m, and existing increases are minor (~0.05m)
		SGBA	South Golden Beach Levee Audit Recommendations	Yes - Funding to be Sought	Several recommendations were made in the South Golden Beach Levee Audit
	Channel Modification	BP01	Kings Creek Bypass Floodway	No	This option was investigated through modelling an excavated 5m wide channel, 1m deeper than the existing Kings Creek, roughly 15,000m ³ of creek bed material. From considerable economic and environmental constraints and concerns for minor reduction of 0.08m in peak flood level this option was not recommended for further investigation.
		BP02	Saltwater Creek Upgrade	Yes - Part of Overland Flow Path Study	This option was investigated through modelling an excavated 5-10m wide channel, 1m deeper than the existing Kings Creek, roughly 20,000m ³ of creek bed material. This option also investigated increasing the capacity of the Jubilee and Myokum culverts for this scenario by lowering the invert level by 1m. While limited flood mitigation benefit was observed from modelling (0.05m lower peak flood level) other modifications options within Saltwater Creek were believed to have the potential for more significant benefits
		DO	Dune Openings	No	This option was investigated through modelling of four additional ocean outlets 20m wide by lowering the dune crest to the adjacent levels at each side of the dune (approximately 1.5mAHD), at Wooyung, North of South Golden Beach, South Golden Beach/New Brighton and South New Brighton. While widespread benefits were observed for catchment dominated events, the benefit was only minor (0.05 - 0.1m peak flood level reduction). It is believed that this mitigation option would result in different Ocean flooding behaviour and have several environmental considerations. From these findings this option is not recommended to be considered further.
		RW	Rock Wall Modifications	No	This option was investigated through modelling the lowering of the Western Brunswick River rock wall by 0.5m and the Marshalls Creek rock wall removal, and while the rock wall modifications were not recommended as a flood mitigation strategy, as the rock walls are significantly submerged in the 1% event, it was recommended that they be investigated for the potential to improve sediment transport
		TW	Removal of Brunswick River Training Wall	No	This option was investigated through modelling the removal of the training walls to the bed level. The resulting decrease in flood levels was observed to be minor (up to 0.1m at Brunswick Heads) but widespread, with the significance diminishing further upstream.
	Channel Maintenance	BRM0 1	Brunswick River Dredging at Mullumbimby	No	This option was investigated through modelling dredging a 3km stretch of Brunswick River at Mullumbimby by 0.5m depth across 20-30m width. This resulted in minor (0.05m) reduction in peak flood levels at Mullumbimby from this minor impact and significant economic considerations this option is not recommended to be considered further.
		BRM0 2	Brunswick River and Tributaries	No	This option was investigated through modelling an extended version of BRM01, extending into Mullumbimby and Saltwater Creeks. Results indicated a maximum decrease in flood levels of 0.12m at the Mullumbimby Community Garden an minor (0.05m) reduction in peak flood levels. From the limited impact on flood behaviour and considerable economic and environmental impacts this option is not recommended to be considered further,

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Category	Option	ID	Description	Recommended / Progress	Reasoning
		MC	Marshalls Creek Dredging at Ocean Shores	No	This option was investigated through modelling the dredging of a 7.5km stretch of Marshalls Creek to lower the riverbed by 0.5m at widths of between 10m-30m. Modelling results indicated minor (0.05m) reduction in peak flood levels were observed at Ocean Shores and New Brighton. Due to this limited reduction in peak flood levels this option is not recommended to be considered further.
	Drainage Modification	AC	Avocado Court	Yes - Part of Overland Flow Study	This option was investigated through DRAINS modelling of a formal flow path from the residential development along the Yoga Bera Gully pipeline to the Chinbible Avenue swale, as a 1m wide channel with a 0.5% slope. While modelling results of the 1% AEP event indicated low reduction of flood level (0.04m) it is believed other options could have the potential to reduce peak flood levels more significantly.
		NCD	Options identified in New City Road drainage assessment	Yes - Part of Overland Flow Study	The New City Road drainage assessment recommended several drainage modifications this was later considered to be a low priority mitigation measure
		CDM	Catchment wide drainage and overland flow model	Yes - Grant Submitted	Considerable community concern of effective drainage in the area has led to the recommendation to assess the Catchment wide drainage and overland flow.
	Drainage Maintenance	FDC	Debris Control Measures for Federation bridge and the Billinudgel Railway Bridge	Yes - Grant for design phase	While modelling results of 25% blockage sensitivity resulted in a minor increase on the peak flood levels (0.05m) substantial community concerns of maintenance and drainage led to the recommendation for further consideration
	Hydraulic Structures	GCW	Ocean Shores Golf Course Weir Lowering	No	This option was investigated by modelling a 1m lowering of the Gold Course Weir at Ocean Shores. Model results indicate negligible impact to peak flood levels (Up to a 0.01m reduction). From the negligible results it was not recommended to be considered further.
		BM	Billinudgel Infrastructure Improvements	Yes - Part of Overland Flow Study	This option was investigated by modelling of several drainage modifications for Billinudgel. Significant culvert capacity was added, and the 5m widening of the railway bridge north of Billinudgel. This was recommended for consideration in conjunction with Option BL, as minor reductions of peak water levels are observed in preliminary results for independent modelling (maximum of 0.22m at Wilfred Street), however it is believed that optimisation with the BL could result in more significant reduction in peak water levels.
	Flood Storage Areas	SW	Saltwater Creek Flood Storage Area	No	The current area adjacent to the railway line identified as a potential flood storage area is at approximately 3mAHD on the northern side of the wetland and 2-2.5mAHD on the southern side. The ground level was reduced to 2mAHD to investigate this option for flood mitigation. Results indicate minor reductions in flood level, however it may warrant further investigation as part of the Lot 22 assessment for water quality and storm water management
	Combined Option	CB01	Marshalls Creek Dredging (MC), Dune Openings (OO), Rock wall modification (RW) and Kallaroo Circuit Bund modification	No	These options were investigated by simultaneous modelling of previous options, MC, OO, RW and a lowering of the culvert at the Kallaroo Circuit bund to -0.025mAHD. Results indicate reductions in the peak flood levels are largely in areas with very few properties, however a reduction of 0.15m was observed in South Golden Beach, 0.06m at Ocean Shores, up to 0.08m in New Brighton, and 0.04m in Brunswick Heads.
		CB02	Billinudgel Infrastructure (BM) and Billinudgel Levee (BL)	No	These options were investigated by simultaneous modelling of previous options BM and BL. The combination of these options resulted in protection of properties behind the levee with a reduction of flood levels for the 1% AEP flood event up to approximately 0.5m. Some areas observed minor water level increases ranging from 0.02 to 0.05m. However detailed assessment estimated a resulting benefit cost ratio of 0.58.

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Category	Option	ID	Description	Recommended / Progress	Reasoning
	Fencing across waterways	WFG	Develop guidance on the design and installation of fencing traversing waterways and channels	Yes	Fencing in agricultural areas are known to having the potential to ob modelling was undertaken to investigate floodplain sensitivity fencing fencing is designed to not obstruct flood flow will generally improve to system.
Response Modification Options	Emergency Planning	RM01	Update Local Flood Plan based on outcomes of this report and collaboration between Council and the SES	Yes - Underway by SES	It is recommended to update the flood management plan with the fin
	Flood Warning	RM02	Byron Shire Council and SES to consider learnings and recommendations from this FRMS in the development of the Flood Warning Network for North Byron	Yes - Complete	The development of a flood warning network system was recommen
	Improving road access	RM03	Raising River Street to provide 1% AEP flood immunity and investigating a location for a new Evacuation Centre near Gaggin Street or Terrace Street	Yes - Part of Overland Flow Study	While this flood risk measure increases the peak flood level by up to there is a substantial risk to life for the properties trapped in the vicin River Street, with 13 properties experiencing above floor flooding with only evacuation route available.
		RM04	Raising Wilfred Street to provide 1%AEP flood immunity	No	While it is not recommended as a standalone measure, if included in mitigation options in the area it could be considered for re-assessme
	Road Closures	RM05	Identify key roads and implement automatic warning signs and depth indicators	Yes - Grant being Investigated	The investigation recommended the inclusion of automatic warning s for Pocket Road, Sherry's Bridge on Main Arm Road, Myocum Road Wilsons Creek Road, Gulgan Road, and Left Bank Road
	Community Education and Awareness	RM06	Community engagement to prepare an ongoing flood education program (and appropriate evaluation system)	Yes - Funding to be sought	Several recommendations for raising community awareness and edu such as historical flood markers, online flood awareness mapping (N action team group, letter/certificate/pamphlet from Council, informati school project, media releases, library displays, mobile displays, dist FloodSafe Guide, NSW SES Business FloodSafe Breakfast, Counci information signage at key locations, targeted evacuation planning e Beach local drainage education.
	Mullumbimby Evacuation Assessment	RM07	Undertake a detailed evacuation assessment for the Mullumbimby township for a range of design events.	Yes - Underway by SES	Mullumbimby was identified as being particularly vulnerable to flood was identified as a major concern. Development of an evacuation m of design events was recommended.
Property Modification Options	Voluntary House Raising	PM01	Assess raising eligible residential properties to reduce flood damages.	Yes - Grant submitted	A well-defined criteria that identifies eligible properties is believed to available from the NSW Flood Program, which makes house raising flood damages in North Byron.
	Voluntary House Purchase	PM02	Assesses purchasing eligible residential properties to remove residents from high flood risk areas and reduce floodway obstruction.	Yes - Grant Submitted	Similarly, to PM01, a buy back schemes is believed that to be a viab risk in North Byron, with developing appropriate criteria identify eligit susceptible to flood risk.

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struct flow. While no g blockages. Ensuring he conveyance of the
dings of the study
ded.
0.2m in New Brighton, ity of Casons Road and h River Street being the
e conjunction with other flood
signs and depth indicators , Coolamon Scenic Drive,
ucation were suggested, low available), community on packs for new residents, ribution of NSW SES I stall events, flood ducation, South Golden
risk, and that evacuation anagement plan for a range
satisfy grant funding, a viable program to reduce
le program to reduce flood ble properties that are

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Category	Option	ID	Description	Recommended / Progress	Reasoning
	Land Use Zoning	PM03	Changes to land use zoning should consider flood compatibility using outcomes from this report. Update flood hazard overlay based on the findings of this study	Yes - Complete	Flood hazard is a principal factor for planning land use zoning. It is recommended to update flood hazard overlay to reduce future development in high hazard areas.
	Flood Planning Levels	PM04	Revise Flood Planning Levels based on the findings of this study	Yes - Complete	The Byron Shire Council use several design event flood levels to define flood planning levels including, Present day 10%, 1%, and the 2050 and 2100 1% AEP peak flood levels. It is recommended to use the latest study's findings for flood levels to update the flood planning levels for more representative flood planning levels.
	Flood Planning Area	PM05	Updated FPA based on the findings of this study	Yes - Complete	The Flood planning areas are used to identify land prone to flooding. This study recommends defining the flood planning areas with conservative estimations of the 1% AEP event with 0.9m sea level rise, 20% increased rainfall and 500mm freeboard as defined from this study, this is recommended to increase understanding of flood prone areas, to help reduce development and increase mitigation strategies in these areas.
	Changes to Development Control Plan	PM06	DCP updated based on recommendations of this FRMS	Yes - Partially Complete	A review of the existing Byron Shire Council DCP (2014) by the study, identified some suggestions where further refinement may support the objectives of the intention of a DCP and the useability of the document by applicants.
	Flood Proofing	PM07	Provide more detailed guidance on the principles of wet proofing appropriate designs and materials with direct reference to available guidelines	Yes - Partially Complete	The purpose of flood proofing is to provide a permanent measure, which can be either wet proofing, to minimize damages from choice of materials or other measures or dry proofing, to exclude flood waters entering the building. Flood proofing is recommended for future investigation to reduce flood damages to the area.
	Property Level Protection	PM08	Undertake more detailed assessment of properties which may benefit from property level protection	Yes - Partially Complete	It is believed to be an alternative to retrofitting permanent flood proofing measures to existing properties, property level protection including temporary flood barriers like sandbags, plastic sheeting and other smaller barriers deployed before the onset of flooding could be considered as an effective, non-invasive flood damage control measure.
	S10.7 Certificates	PM09	Provide flooding info on Council's website, include up to date flooding info on future s10.7 (2) and (5) certificates requested	Yes - Complete	Several suggests have been made to improve flooding information available on the Council Website, it is believed that this could increase the understanding of flood risk for home and business owners in the region.
	Future Development Controls	PM10	Further investigation into appropriate controls to manage impacts from future development	Yes	It is believed that enforcing restrictions on future development effectively ensures the community's continuing flood resilience.

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A multicriteria assessment was undertaken to rank the mitigation options for North Byron, with the results of this assessment provided in Table 2-12:

Table 2-12: North Byron FRMS	WMA, 2020) Ranked Priority	v Flood Mitigation Options
			y i lood miligation optiono

ID	Option	Total	Overall
		Score	Rank
PM04	Flood Planning Levels revised based on the recommendations of the FRMS	20	1
PM09	Section 10.7 (5) certificates to provide further detail of flood behaviour. Consideration to providing property-level flood information via an online GIS platform	18	2
RM02	Byron Shire Council and SES to consider the findings and recommendations of the FRMS in the development of the Flood Warning Network for North Byron	18	2
RM05	Identify key roads and implement automatic warning signs and depth indicators	16	4
PM07, PM07, PM08 (part), PM10	Council to consider updating the DCP to incorporate the recommendations detailed in the FRMS; Provide more detailed guidance on the principles of wet proofing, appropriate designs and materials, with direct reference to available guidelines; include a requirement for an assessment to property level protection as part of the DCP2014 planning matrix criteria FL4; Implement the recommendations regarding appropriate fill areas in the DCP2014	16	4
CDM	Development of a whole of catchment drainage model and overland flow path investigation	16	4
PM08 (part)	Undertake more detailed assessment of properties which may benefit from property level protection	16	4
FDC	Implement debris control measures for Federation Bridge and Billinudgel Railway Bridge.	16	4
RM07	Undertake an Evacuation Assessment for Mullumbimby	16	4
PM03	Changes to land use zoning should consider flood compatibility based on the recommendations of the FRMS	16	4
PM01	Further investigate the raising eligibility of residential properties to reduce flood damages	15	11
SC	Further detailed assessments of Saltwater Creek mitigation options for Mullumbimby	15	11

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ID	Option	Total Score	Overall Rank
IC	Form a committee, comprising council, state, emergency services and community member representatives to oversee the implementation of the FRMP	15	11
RM01	Council and the SES to update the Local Flood Plan based on findings of the FRMS	15	11
PM05	Revise the Flood Planning Area based on the recommendations of the FRMS	14	15
RM06	Engage with the community to prepare an ongoing flood education program with appropriate evaluation by Council and SES following implementation	14	15
AC	Further consideration of Avocado Court drainage modification	14	15
PM11	Byron Shire Council compliance team investigate illegal builds south of North Heads Road	14	15
RW02	Develop a sediment transport model to investigate modification to the rock walls as part of the Coastal Management Program for the Brunswick Estuary	14	15
BM	Further consideration of Billinudgel infrastructure improvements	13	20
WFG	Develop guidance on the design and installation of fencing traversing waterways and channels	13	20
PM02	Consider establishing a Voluntary House Purchase scheme for eligible properties	13	20
RM03	More detailed assessment of potential raising of River Street to provide improved flood immunity and evacuation	11	23
SGBA	Implement the recommendations of the South Golden Beach levee audit	7	24
NCD	Further consider viable options to implement the recommendations of the New City Road drainage assessment	4	25

2.7.5.3 Community Engagement

The community engagement resulted in the community ranking several structural mitigation options. The top three structural mitigation options identified by the community were:

- Stormwater Pipes gutters and drain upgrades.
- Landscape management
- Dredging

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Several other mitigation options were proposed by the community including:

- Significant concern over drain blockages
- Respondents are generally supportive of alterations to the Marshalls Creek rock walls provided appropriate investigation is carried out prior.
- There is significant support for the consideration of openings through the dunes.
- Several respondents reported neighbours helping in past flood events.
- The community trust local knowledge and would look to key community members during events.
- Respondents are concerned about increasing insurance prices in the area.
- 12% of respondents would never evacuate their home.
- 63% of respondents have received conflicting information during an event in the past, with several comments from people who did not receive any information at all.
- 54% of respondents want flood information as early as possible and 81% of respondents would like this information via emergency SMS. Several comments requested accurate and timely information during a flood event.
- In addition to assistance during flood events, respondents have indicated they require the assistance to continue after the flood even has passed.
- Respondents want to see appropriate development within the floodplain there were a little under 50 comments relating to land use planning decision, with several comments specifically about the potential development of Lot 22.

This study included community consultation on Draft FRMS which resulted in several responses, priority concerns of the community were as follows:

- What the development of the South Mullumbimby Affordable Housing Precinct and the Mullumbimby Industrial Estate may do to the flood risk in Mullumbimby.
- Maintenance and improvements to the stormwater network. This is discussed in detail in Section 5.2.1, however was a consistent concern from all residents in the North Byron community irrespective of town or village.
- The Marshalls Creek rock walls and their potential environmental impact and contribution to increased siltation.
- Further investigation into environmental and flood mitigation benefits from dune openings.
- Improved environmental flows in Saltwater Creek; and
- Further investigation into areas that may be sensitive to future development.

Following this study, Byron Shire Council has subsequently undertaken works to improve local drainage including drainage upgrades and maintenance.

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2.7.6 Other Findings

2.7.6.1 Update to ARR2019

An assessment of sensitivity to ARR2019 methodology was undertaken for the study. It considered several significant changes in industry best practice of ARR2019 in comparison to guidelines from ARR87. The study considered that a full update in accordance with ARR2019 would not greatly assist in understanding flood risk in the catchment, however the report indicates that updates were made, but it is unclear in the report which ARR2019 methodologies were adopted over the developed ARR87 methodologies, other than an update of initial and continuing losses. IFD comparisons were undertaken for the 2016 IFDs, which indicated that the ARR87 estimations were observed to be higher and could be considered a conservative approach, but with the available reporting, which was Appendix C of the report, it is unclear whether the 2016 IFDS were adopted.

2.7.6.2 Legacy Model

Several modelling methodologies used for the development of the Hydrodynamic and Hydrologic model have become dated or inefficient, with usage of 1D river networks, no sub grid sampling, bridges not modelled as layered flow constrictions and no quadtree. Significance of effect to model results, and definition of flood planning levels was not undertaken as a part of this study.

2.7.6.3 Sandbag Blockages underneath railway line opposite Mill Street

Community comments were received that sandbags were placed in culverts underneath the railway line opposite Mill Street. This study modelled the hydraulic structure blockage sensitivity, however the 1% AEP scenario modelling indicated practically no impact for the 50% blocked scenario and impacts were restricted to a property when 100% blocked scenario.

2.7.6.4 Flow Constriction Hotspots

On review of the model results identification of major flow constrictions, causing increased water levels, were observed at several areas including areas at Billinudgel, Orana Bridge, and the junction of Marshalls Creek and Brunswick River.

The modelling indicated that there is a significant constriction at Billinudgel shown in Figure 2-37, where several hydraulic structures are observed to impede flow conveyance. The principle hydraulic structure observed in the modelling results is the railway embankment and bridge, where a greater than 1m head loss is observed across the railway embankment North of Mullumbimby. This is a resultant of the railway embankment being approximately 3m higher than the surrounding ground level. Several modelling methodologies were adopted to represent hydraulic controls at Billinudgel, which could misrepresent flood behaviour, if not representative of real-world conditions. A summary of hydraulic controls at Billinudgel are provided in Table 2-13.

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An additional constriction is located downstream at Orana Bridge is observed where a layered flow constriction is modelled with a pier blockage of 4.1 and a form loss coefficient of 0.07, which is standard losses for a typical bridge of this sizing, however the invert level of the deck is modelled at 2.218mAHD with a deck depth of 1.575m, it is believed this is a conservative estimate for the bridge deck invert, which significantly blocks the creek conveyance capacity by 40%.

Location	Method	Description	Blockage
Rail Embankment	Raised Crest Line	Heights Vary from 4.085 - 4.82 from North of Pacific Highway gully drainage at Billinudgel to Billinudgel	
Gully rail embankment cross drainage, 220m North of Marshall Creek	One- dimensional rectangular culvert	One 2x2m pipe with (US Invert Level higher than elevation data)	50%
Railway Bridge at Billinudgel/Marshalls Creek	One- dimensional form loss and increased Mannings Roughness, along with a one- dimensional Weir	The Weir is set to 3.801mAHD with 20m width, and the bridge is modelled with a Mannings 'n' roughness of 1.00, and a form loss coefficient of 1.75. This modelling approach results in a 0.45m head loss. However, following this bridge several one-dimensional river sections are modelled with a Mannings 'n' roughness factor of 2.677, Which results in a further head loss of 0.5m where channel storage is not used, and half the section leading up to the Pacific Motorway has a form loss coefficient of 0.4.	0%

Table 2-13: North Byron FRMS&P Hydraulic Controls at Billinudgel

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Road Embankments at Billinudgel	Raised Crest Lines	Several road embankments were used to represent the road levels at Billinudgel. Several roads were raised including Wilfred Street, Mogo Place, Lucky Lane and Bonanza Drive at varying heights typically between 3.2mAHD and 3.8mAHD, except for western Wilfred Street lowering to 2.0mAHD. Additionally, a smaller raised embankment was observed at a subsection of O'Donnells Lane continuing from Wilfred Street at 2.0mAHD to 9.39mAHD. These road embankments were identified to only cause conveyance issues along Wilfred Street, draining East, across the Pacific Motorway.	
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Figure 2-37: North Byron FRMS&P Flood Behaviour at Billinudgel





Figure 2-38: North Byron FRMS&P Flood Behaviour at New Brighton








Figure 2-40: North Byron FRMS&P Flood Behaviour at Brunswick Heads

2.8 Post Flood Discussion With South Golden Beach Community Members West of Capricornia Canal (BSC, 2022)

A Post-Flood discussion with South Golden Beach Community Members was undertaken to investigate and flooding concerns and comments from community. In total nine concerns were raised for the region including:

- Overland flow from catchment to the west (Palmer Avenue)
- Backyard Easements Project Revitalization
- Flap Gate Maintenance
- An additional flood pump serving the area West of Capriconia Canal under Elizabeth Street and a flood lifter pump stationed on the Council land opposite **Gloria Street**
- Collapsed Stormwater Inlet on Shara Boulevard near Palmer Avenue.
- Sewage Pump Failure near #13 Elizabeth Street during heavy rainfall
- Long Term stagnant water on the corner of Elizabeth and Clifford Street.
- Streets as overland flow paths for stormwater



 And two area-wide issues - Drainage from Palmer Avenue and backwater from Marshalls Creek

2.9 MAYDAY Community Flood Debrief and Disaster Preparedness Event Report (2022)

The MAYDAY flood debrief was undertaken to involve the community into collating experiences and proposal of possible solutions. A large portion of solutions proposed targeted response modifications. The list of issues and suggested solutions raised by the community is presented in Table 2-14.

Key Area	Issue	⊦req.	Suggested Solutions
Community Hub	Need for community led resilience network	3	 Develop the Community Resilience network throughout SGB, NB, OS - via street and neighbourhood areas and also maintain the CRT 'Key Area Working Groups' Volunteer training and incentive program (including CRT, Active Listening, trauma informed, volunteer ethics) Improve communications of community disaster preparedness network through the following: Facebook group (Adapt Flood Aftermath) Posters in key locations Echo Newsletter Email Database New Brighton Market Announcements/stall Street focal points

Table 2-14: MAYDAY Communit	y Suggested Solutions
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	Who do we get support from?	1	 Geographic groups/focal points needed for times of trauma/disaster Community Resilience Team - the CRT will be made up of the Team "Leaders" (Currently Bec and Bron), the key working groups (appoint a "leader" of each group) and the street/neighbourhood focal points/rep Rescue boat (SES/Marine Rescue) to check on residents Volunteer expenses reimbursed when stood up (e.g. SLSC, Marine Rescue) Community liaison person linking to broader government/recovery hub support options Powers delegated to resilience teams and clarity of roles, e.g. evacuation centres Need for multiple evacuation centres due to inability of SGB/NOS and some NB to reach OSCC
	Need templates and systems based on organic way resilience mob	1	 Develop electronic and hard copy forms including: Sensitive (vulnerable people) list - to check on Spreadsheet of people needing support (Name, Address, contact, issues, needs, people allocated, comments) List of tradespeople Volunteer timetable Daily log Equipment Register
	No support from enterprise businesses, old systems forgotten/ignored	1	 Improved relationships, self- sufficiency Make contact with OSCC and link to OSSDA Understand what skills we have in our community - build the skills and knowledge matrix through the CRT network
Preparedness Plan	Crisis Management plan ineffective	5	- Active community plan - where to go, how to get there, immediate support

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Key Area	Issue	Freq.	Suggested Solutions
	minimal visibility of it, minimal understanding of it Who do we listen to? What's the hierarchy of control / instruction / warnings? Who has what role after disasters? Need to confirm roles. Who does what? How to reach them? Not knowing how and when to leave. No community plan.		options, understanding vulnerable people - Need to confirm roles - Planning so that community awareness is developed ahead of time - Need to prioritise actions - Personal plan (Radio/cash/toilet paper/canned foods/When to leave/Switching power off) - Forum to support and assist individuals in making personal emergency plans Register of each street with a focal point who knows who the vulnerable people are - Holiday letting action plan (Holiday houses let by real estates, Stayz, AirBNB) provided localised info packs to keep at the property for guests to understand evacuation and preparedness procedures. - Protect the house beforehand (sandbag sourcing, council support, information flow, what is needed) - Kayaks available and in place - Community Resilience Team 'Newbie pack' for new residents to understand disaster preparedness in the local area.
	Evacuation centre coordination (who's in charge? Who's coordinating Resources)	1	 SES evacuation points predetermined and known Getting community up to date on an evacuation plan
	People hoarding scarce resources, no incoming supplies (Food/Fuel)	1	 Community based preparedness resources (Shipping container with resourced (at the school/church?) with procedures and how-to info Personal plan (e.g. radio/cash/toilet paper/canned foods and knowing when to leave)

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Key Area	ey Area Issue Freq.		Suggested Solutions	
Governance	Role and function of	1	- Duty of care for residents/rate payers	
	Council (obligations)		- Compassionate responses from Byron Shire Council and other flood services when residents present with concerns	
			- Town planners and water management people should get ideas from residents	
			- Stop particular communities gaining help first and needy groups being forgotten	
			- Waste management post flood (hazardous waste; salvage and repair)	
	Lack of response	3	- Improve emergency services capacity	
	from government services / emergency services capacity		 Powers given to people of the ground to act in the minute > single department, full autonomy (decentralisation of power) 	
	Development decisions	1	- Development moratorium for flood prone areas	
			- Review of "1 in 100 year" terminology as it relates to planning requirements (e.g. building heights, ban new slab on ground builds in floodplain, ban inappropriate fill on floodplain e.g. 1 Kallaroo Cct)	
			- Stop removing vegetation and building on top of the watersheds	
			- DA team capacity (upskill understanding good passive and resilient design) and timeframes need improving	
	SGB/NB/OS not considered priorities	1	- Remediation protocols and communication (post flooding)	
	in Byron Shire - lack of response from		- Improve relationship with ECHO to ensure greater coverage post flooding)	
	council, authorities,		- Councillors to engage across different	

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Key Area	Issue	Freq.	Suggested Solutions
	media coverage		community organisation and volunteer hubs to be holistic issues and context of area
			- Council disaster staff worked with volunteer hub during recovery - continue relationship with them and other relevant staff
			 Engage Councillors proactively in community events.
	Lack of master plan for SGB/NB/OS	1	-Advocacy required
Communications	SES SMS Alerts - How to receive? Not	2	- Instruction to turn on radio - to hear alerts
	early enough, mixed messages		- Local community member on SES team
			- Build relationships with SES to agree better notice
			 Warning system with more nuanced messages, not repeated messages
		- Map information flows (Community members, SES, resilience network, etc.) so that the right information is shared in both directions	
	Need for appropriate communication and	1	- Local community member on SES team
	warnings (Worried about "crying wolf"		 Build relationships with SES to agree better notice
	Sino.		- Community communication networks / Street focal points
			- Timely geographic pre-warning (during/post)
			 Communicate early; don't leave to too late to reach people (prioritise daylight)
			- Systematic door-to-door checks for preparedness (street focal points?)
	Localised	3	- Connecting the community - sign

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Key Area	Issue	Freq.	Suggested Solutions	
	communication back up (radio was only way)		boards to promote messages e.g. bad weather, signage directions to safety (see pics as example)	
			- Short wave radios - UHF/VHF units (also mesh network)	
			- UHF/CB radio - needs planning coordination)	
			- Emergency Channel at a local level	
			- Use community buildings to host infrastructure or become hub / meeting point	
	Lack of	6	Starlink/Sprint unit for emergencies	
	communication due to mobile, NBN, power out (people with dire needs unable to call for		- Provider co-op telcos	
			- Mesh Wi-Fi network	
			 Government grants to fund infrastructure needs 	
	emergency/medical help		- Exploration of Community Solar Project	

2.10 Characterisation of the 2022 floods in the Northern Rivers region (CSIRO, 2022)

2.10.1 Overview

After the flood event at the end of February and beginning of March 2022, many catchments in the Northern Rivers region saw rainfall totals and water levels exceed historical records significantly in several parts of the region. The Northern Rivers region consists of several Local Government Areas including, Clarence Valley Council, Kyogle Council, Richmond Valley Council, Lismore City Council, Tweed Shire Council, Byron Shire Council, and Ballina Shire Council. This study identified that the daily rainfall totals experienced in the Brunswick basin was the highest on record and was subsequently investigated for greater understanding of the flood event. This study did not undertake any hydrological or hydrodynamic modelling as part of the investigation, as it solely investigated the real-world observed flood behaviour.

2.10.2 Previous Events

This study summarized several major historical events for the Northern Rivers Region. The events are summarized in

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Table 2-15.

Table 2-15: List of Major flood events in the Northern Rivers region

Date	Event Maximum Daily Rainfall (mm/day)	Tropical Cyclone	Comment
February 1954	253	TC137	Reference flood for all basins. Often cited as the largest flood on record prior to the 2022 event
June 1967	109		Major Flood in the Clarence River
March 1974	243	Zoe	Major flood in the Clarence River, Richmond Basin including at Lismore and Tweed Basin
February 1976	202		Largest flood for most parts of the Clarence Basin and for the Wilsons River Upstream of Lismore. Significant flood in the Western part of the Richmond Basin. Major flood in Lismore.
March 1978	174		Major Flood in Lismore, Tweed and Brunswick Basin
April 1989	195		Major flood in the Clarence River, Lismore, and Tweed Basin
May 1996	129		Major flood in the Clarence River and River.
February 2001	314		Major flood in the Clarence River and Richmond basins including Kyogle and Lismore.
March 2001	92		Major flood on the Clarence
January 2008	130		Large flood affecting the Clarence and Richmond basins
May 2009	166		Major flood in the Clarence River and Richmond basins including at Lismore
January 2012	114		Large flood affecting the Brunswick and Tweed basins
January 2013	226	Oswald	Largest flood on record in the Lower Clarence
June 2016	246		Major flood in the Tweed Basin
April 2017	300	Debbie	Significant flood in the Richmond, Tweed and Brunswick basins. Major flood in Lismore.

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Date	Event Maximum Daily Rainfall (mm/day)	Tropical Cyclone	Comment
			Levee overtopped.
February 2022	482		Largest flood on record for most parts of Richmond Tweed and Brunswick basins. Major flood in Grafton and along the Clarence River further downstream
April 2022	165		Major flood in Lismore. Levee overtopped

2.10.3 2022 Floods

This study investigated the conditions and flood behaviour of the Feb/Mar 2022 flood event. This included investigation of antecedent conditions, rainfall conditions, frequency analysis, and river levels and flows.

2.10.3.1 Antecedent conditions

Several indicators are used to assess antecedent conditions. This study undertook rainfall conditions, water level analysis and AWRA-L simulations. The month leading up to the Feb/Mar 2022 flood event, experienced wet climate conditions. AWRA-L simulations have several antecedent conditions for several events provided as a comparison in Figure 2-41, with the root zone soil moisture available in Figure 2-42.



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Figure 2-41: AWRA-L event antecedent conditions



2.10.3.2 Rainfall Conditions and Frequency Analysis

The study undertook rainfall analysis using several gauges in the region, provided rainfall totals, daily rainfall maximums and date of daily rainfall maximums on record, in Figure 2-43 with associated Annual exceedance probability in Figure 2-44. While this is a good indicator for event size of larger catchments it is expected that the Brunswick River and Marshalls Creek experience shorter critical durations, than 24 hours from the sizing of the catchments. The rainfall gauge Brunswick River at Durrumbul (202001) provides rainfall data for the 2022 event, the gauge recorded a 24-Hour maximum of 696.5mm and a 72-Hour maximum of 1124.9mm, with the CSIRO study estimated these observed rainfall depths of having an equivalent frequency of a 0.1% AEP.

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Figure 2-44: CSIRO 2022 flood event rainfall Annual Exceedance Probability

2.10.3.3 Water Level and Frequency Analysis

Three gauges were used for water level analysis for the Brunswick River basin, including Durrumbul (202001), Mullumbimby (202402), and Brunswick Heads (H558063). The levels

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for the flood event are provided in Figure 2-45. While the water level gauge at Mullumbimby recorded a period of water levels exceeding the defined "Major Flood Level", no information was collected for flood level indication for Marshalls Creek, or its tributaries. Further analysis was undertaken for water levels at Brunswick Heads, the provided historical data is presented in Figure 2-46, which was observed to exceed the historical maximum water level, well exceeding the 95th percentile.







Figure 2-46: 2022 Water Levels against historic water levels at Brunswick Heads

2.11 Post 2022 Event Flood Behaviour Analysis - Brunswick River (WMAwater, 2024)

2.11.1 Overview

Following the 2022 flood event WMAwater undertook review of the resulting flood behaviour experienced in the Brunswick River Catchment. The objectives of the study included:

- Collecting sufficient flood debris information •
- Conduct a rapid infrastructure damage assessment
- Model the 2022 Flood Event
 - Determine Magnitude of event
 - o Describe flood behaviour
 - Extent of flooding
- Flood Damages Assessment



 Conclusions and Recommendations on the performance of the current modelling systems

2.11.2 2022 Flood Event

The flooding experienced on the 28th of February was widespread over the Brunswick River catchment, with significantly spatially varying observed rainfall with the peak water level observed to overtop the levee in South Golden Beach. Total tangible flood damages were estimated at \$47,000,000 with 837 properties estimated to experience above flood flooding. Several resulting surveyed flood peaks presented in Table 2-16. The recorded flood levels in comparison with surveyed flood levels generally indicate a fair comparison, however a 0.5m difference was observed within South Golden Beach, with a recorded peak of 3.6mAHD and a modelled peak of 3.1mAHD, with a significant real-world difference of levee overtopping (3.2mAHD).

Gauge	Recorded Peak Level (mAHD)	TUFLOW Modelled Peak Level (mAHD)	Difference (m)
Durrumbul	18.76	19.8	0.04
Federation Bridge	4.96	5.56	0.61
Yelgun Creek (Helen Street Bridge)	3.6	3.1	-0.5
Billinudgel	4.3	4.0	-0.3
Brunswick Heads	1.8	1.6	-0.2
Orana Bridge	2.8	2.6	-0.2

Table 2-16: 2022 Flood Event Peak Levels

2.11.3 Modelling Methodology

The 2022 event was modelled from the developed hydrologic and hydrodynamic model as part of the North Byron FRMS&P (2020). While the hydrologic model was observed to overattenuate flows a fair comparison was made for Brunswick River, however, some limitations of the modelling methodology were highlighted by this study such as:

- Over complication between hydraulic models at Ocean Shores, and South Golden beach. In these areas neither model performed well without feedback loops.
- · Outdated hydrologic modelling methods such as adoption of ARR87, and XP-RAFTs.
- No accounting for hydraulic linkage of the Tweed Shire Coastal Creeks
- One-Dimensional approaches to riverine modelling

2.11.4 Rainfall Flood Frequency Analysis



This study undertook FFA of at site IFD comparisons and stream gauge FFA. The report claims that BoM 2016 IFD estimates may be under-estimating the rainfall in some locations for longer duration, less frequent events. Although not stated in the report this appears to be from the findings of empirical AMS comparisons to BoM IFDs. Rainfall FFA was undertaken by comparison to 2016 BoM IFDs for Yelgun Creek at Helen St Bridge (558112), estimating up to 1 in 20-year rainfall conditions up to the 100-Hour duration, however at several other locations in the Brunswick River catchment, it was observed to exceed the 0.2% AEP IFD estimations, indicating that BoM rainfall estimations are potentially underestimating some design rainfall durations.



Figure 2-47: Yelgun Creek at Helen St Bridge (558112) - IFD Analysis

2.11.5 Stream Flood Frequency Analysis

From modelling undertaken as part of the study, several peak flows are compared are reported as in Table 2-17. While the 2022 event reports more frequent event than the 5% AEP at St Helen Bridge, all other location estimates range from 2% to 1% AEP. The levee at South Golden Beach was designed to withstand the 1% AEP peak water level, however the 2022 event was observed to overtop the levee, it is believed a localised storm could account for the discrepancy between the observed and model results, the study also

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identified limitations of the modelling methodology to represent the South Golden Beach, with the hydraulic model extending to the Kallaroo circuit bund.

	Table 2 17. Compansion of Design Flows at Locations with 2022 Event Flows						
Location	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	2022 Event	
Brunswick Heads	911	1,193	1,441	1,782	2,000	1,797	
Orana Bridge	249	328	393	472	560	423	
St Helen Bridge	68	91	107	129	150	86	
Billinudgel	163	215	259	312	370	358	

Table 2-17: Comparison of Design Flows at Locations with 2022 Event Flows

2.12 North Byron Sky Pumps Study (JBPacific, 2024)

2.12.1 Overview

With previous studies finding limited benefit of flood mitigation options for Marshalls Creek, such as ocean outfalls, Rockwall removal and dredging, and residual community support for ocean outfalls, a need was identified to quantify the volume of floodwater extraction required for the following different levels of floodplain benefit:

- 1% AEP event peak water level reduction of 200mm
- 1% AEP event peak water level reduction of 400mm
- 1% AEP event peak water level reduction of 600mm

This resulted in the undertaking modelling of "Sky Pumps" as a flood mitigation option, where floodwater is extracted out of the system. While installing flood pumps were identified to likely be unrealistic for cost-benefits, this study was undertaken to identify flow rates required at the three locations, North of South Golden Beach, immediately South of South Golden Beach, and immediately North of New Brighton shown in Figure 2-48 to remove flood waters through ocean outfalls to achieve the same benefit.

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Figure 2-48: Sky Pumps Configuration

2.12.2 Modelling Methodology

This study adopted the existing North Byron flood model developed by the North Byron Floodplain Risk Management Study and Plan (WMA 2020), with minor modifications. The existing model configuration extended up to the Kallaroo Circuit Bund Culverts, so the model domain was extended upstream so that the pump North of South Golden Beach could be modelled.

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2.12.3 Sky Pump Extraction Volume Rates

From an iterative modelling process the following required pump operational rates were required. A summary of configuration flood behaviour is provided as below, and are presented in Figure 2-50, Figure 2-51, and Figure 2-52.

• 200mm

The modelling results indicated that there would be widespread reductions to the North of South Golden Beach, upstream of Kallaroo Circuit Bund of 150-200mm, downstream of this location it appears to be impacted by backflow. The two pumps located immediately South of South Golden Beach and immediately North of New Brighton appear to have coincident effects of Marshalls Creek flood behaviour. Widespread reductions in peak water level of the range of 150-200mm were shown to extend the entire length of the Southern Levee at South Golden Beach and some of the Northern end of New Brighton. New Brighton, Ocean Shores and South Golden Beach were shown to have a reduction of peak water levels between 100-150mm. With minor reductions shown downstream of Ocean Shores, with the exception of Brunswick Heads Nature Reserve with a significant reduction of water overtopping of Tweed Street.

• 400mm

Widespread reduction was shown to the North of South Golden Beach, upstream of Kallaroo Circuit Bund indicated a reduction of 380mm, downstream of this location was observed to have backflow dominated water levels. The two pumps located immediately South of South Golden Beach and immediately North of New Brighton are shown to result in peak level reductions immediately adjacent to the pump location, resulting in a reduction of peak water levels near 250mm at Ocean Shores, 150-300mm at New Brighton and 180mm within South Golden Beach. Minor reductions in peak water level were shown to occur at Brunswick River at Brunswick Heads of up to 80mm, with Brunswick Heads Nature Reserve benefiting with up to 180mm reduction in peak water level.

• 600mm

Widespread reduction was observed North of South Golden Beach, upstream of Kallaroo Circuit Bund to 550mm, downstream of this location was shown to be impacted by backflowing water levels. The two pumps located immediately South of South Golden Beach and immediately North of New Brighton were shown to have immediate reduction in water level near to the pump location, resulting in a reduction of peak water levels of 300mm at Ocean Shores, 150-300mm at New Brighton and 220mm within South Golden Beach. Minor reductions in peak water level were shown at Brunswick River at Brunswick Heads of up to 80mm, with Brunswick Heads Nature Reserve benefiting with up to 180mm reduction in peak water level.

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Table 2-16. Required Operational Fump Rates (Cumecs)						
Pump operational	Pump Immediately	Pump Immediately	Pump Immediately			
below 1% AEP peak	North of New	South of South	North of South			
water level	Brighton	Golden Beach	Golden Beach			
200mm	75	50	25			
400mm	120	55	40			
600mm	130	60	40			

Table 2-18: Required Operational Pump Rates (Cumecs)

2.12.4 Conclusions

The modelling results indicated that widespread peak water level reductions for Ocean Shores, New Brighton, and South Golden Beach, with some alleviation on peak water levels for Brunswick Heads for each of the sky pumps scenarios. While the bath tubbing affect observed in Marshalls Creek is not eliminated, it is believed that the reduction in peak water level could be significantly impact in areas currently experiencing drainage issues exacerbated by elevated riverine water levels, particularly in South Golden Beach, which is protected by a levee. It is recommended that future overland flow studies consider the flooding benefit of well-maintained stormwater drainage networks.

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Figure 2-50: 1%AEP Afflux 600mm Sky Pump Configuration

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Figure 2-51: 1% AEP Afflux 400mm Sky Pump Configuration

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3 Reviewed Estuary Studies

3.1 Overview

Several estuary studies have been identified for review for this project, as they included potential mitigation options and community consultation engagements, the reviewed studies included:

- Marshalls Creek Dredging Investigation (1992)
- Brunswick River Estuary Study (2002)
- Brunswick Estuary Management Study and Plan (2007)
- Brunswick Estuary Management Plan (2008)
 - o Brunswick River Estuary Study Public Exhibition Report

3.2 Marshalls Creek Dredging Investigation (Planning Workshop and Web McKeown Associates, 1992)

3.2.1 Scope

This study was undertaken to prepare an Environmental Impact Statement (EIS) for the dredging of Marshalls Creek for flood mitigation purposes. As it was believed that the Marshalls Creek Floodplain potentially provides the greatest relief to all flood prone properties and could be undertaken at minimal cost to Council. While the study did not undertake any numerical modelling or flood estimation assessment many ecological considerations were provided for five distinct dredging options.

3.2.2 Dredging Options

- Dredging would extend from 1km upstream of the Marshalls Creek training walls to about 0.3km downstream of the confluence with Yelgun Creek. The volume of sediment removed would be 330, 000m³. Options 1a-1c accommodate a setback from both sides of the creek bank over length of the creek proposed for dredging of 5m, 10m, or 15m, respectively. The amounts of sand removed would be 280,000m³, 175,000m³, and 100,000m³ for options 1a, b, and c, respectively.
- Dredging would extend from about 2.3km upstream of the training walls. It would avoid dredging adjacent to seagrasses which fringe the edge of the creek and are located about 0.6km downstream of Orana Bridge. Some 220,000m³ of sand would be removed under this option.
- 3. This option is similar to the previous one, except that no dredging would occur near to seagrass beds located 0.5km upstream of Orana Bridge. Moreover, a 5m offset would be taken from both creek banks over the length of the dredged portion. The volume of sand removed under this option would be 135,000m³.
- 4. This option is similar to Option 3, but the upstream extent of dredging would be reduced by 1.4km to a point about 0.6km upstream of Casons Road. As with the

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previous option a 5m offset would be employed. The volume of sand removed would be $90,000 \text{m}^3$

5. Dredging would extend from 1km upstream of the Marshalls Creek training walls to about 0.3 km downstream of the confluence with Yelgun Creek. It would occur to a maximum depth of -2.5mAHD with 1:5 batters. Measures would be incorporated to maintain bank stability and protect biological resources in designated areas, in all other areas the dredge batter would start from the edge of the creek. The volume of sediment which would be extracted would be 130,000m³.

3.2.3 Constraints

The study identified several ecological constraint considerations for dredging Marshalls Creek. The NSW Fisheries guidelines, provides guidelines relevant to the dredging of Marshalls Creek including:

- Buffer Zones must be maintained around oyster leases, seagrass beds, saltmarshes and mangrove stands.
- Settlement ponds adjacent to the waterway must be constructed above the mean high-water mark and secure from 1 in 10 year flood levels to ensure that entrained silt from dredging operations is not returned to the waterway.
- Silt curtains must be used where high turbidity levels are likely as result of dredging or reclamation.
- Dredging in shallow areas generally must not exceed a depth of 2m at mean low water to facilitate mixing and ensure that the substratum remains in the euphotic zone. The bottom must be even, battered to a slope of 1 in 7 and free of holes (which allow build up of stagnant waters).
- The applicant must undertake to pay compensation to oyster farmers if investigations by responsible authorities establish that operations carried out during dredging have adversely affected oyster leases due to siltation or any deterioration in water quality.
- Existing public access to the estuary foreshore must be maintained or, where possible, enhanced.
- Existing flora and fauna must be maintained in their natural undisturbed states in areas which are not designated for dredging and in areas adjacent to the dredging. In particular, this applies to vegetated foreshore, saltmarsh, mangrove and seagrass areas.

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3.3 Brunswick River Estuary Study (MHL, 2002)

3.3.1 Scope

This study undertook investigation of Brunswick River Estuary, including the main arm of the Brunswick River, Marshalls Creek and Simpsons Creek, to support the Byron Shire Council in development of the estuary management plan.

3.3.2 Identified Issues of Concern

Several primary issues of concern were identified from this study including Ecological Health, Erosion, sedimentation, protection of aquatic habitat, riparian vegetation, acid sulphate soils, flooding, fishing, alteration to natural flows, waterway usage, and development.

3.3.3 Flooding

This study identified the primary sources of flooding in the Brunswick River Estuary as eastcoast lows and tropical cyclones, typically associated with longer duration storms in comparison to frontal convective storms. It was also identified that the Capricornia Canal and Marshalls Creek are affected by the ocean levels including the spring/neap range and flow constrictions within the canals at Kallaroo Circuit. It was identified that the spring and neap cycles peak levels range between 0.70mAHD and 1.23mAHD at the entrance, 0.68mAHD and 1.16mAHD at Mullumbimby and the tidal limit extends to the Coral Avenue ford. Along Marshalls Creek at New Brighton the range was identified as 0.23mAHD and 0.37mAHD while upstream of the Kallaroo Circuit resulted in a negligible 0.01m difference. The tidal prism for the estuary varies between about 1,200 and 4,000 ML between the spring and neap tides, which was identified as marginally larger than the 1,300ML estuary volume.

3.3.4 Recommendations

The study recommended that floodplain management should be integrated with recommended estuary management strategies recommended from this study including implementation of planning controls on flood prone land.

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3.4 Brunswick Estuary Management Study and Plan (Patterson Britton, 2007)

3.4.1 Scope

This study was undertaken to develop an estuary management strategy and plan for the Brunswick River Estuary including the Marshall Creek and Simpsons Creek Estuaries. This study builds upon the findings of the Brunswick River Estuary Study (MHL, 2002).

3.4.2 Identified Issues of Concern

Several primary issues of concern were identified from this study including water quality management, wastewater management, estuarine sediment quality management, acid sulfate soil management, estuarine flushing, estuarine sedimentation and Erosion, catchment management, terrestrial vegetation management, aquatic habitat management, ecological health, fishery management, waterway usage, cultural values and tourism. This study identified flood risk as a lower priority concern for the estuary and did not adopt flood mitigation as a priority management objective for the Brunswick Estuary.

3.4.3 Community and Stakeholder Engagement

Three committee workshops were undertaken, where the first targeted whether the findings of the Brunswick River Estuary Study reflected the current concerns of the community. The second workshop was held with members of the Brunswick Estuary Management Committee at the Byron Shire Council to discuss the outcomes of the first workshop and to establish an agreed list of management objectives and strategies for the Brunswick Estuary, A list of potential management strategies and works was provided to council with council feedback being given before the third workshop where the preferred management strategies were presented to the Committee. A public exhibition of the draft estuary management plan was presented for 3 months seeking feedback from community and key stakeholders.

The first committee workshop delivered a rank-ordered list of key issues shown in Table 3-1. Where the concern of flooding was ranked last from the committee out of all 31 key issues within the estuary, notably even losing out to "Reduced Estuary navigability", at rank 29. As the latest major flood before the study was undertaken had occurred in 1987 (some 20-years), which was known as the "Mother's Day Flood", and that no major floods had occurred close to the timing of the study could have affected the perceived relevance of flood risk to the community. The study also claims that concern for flooding was reduced in the community due to the draft floodplain management plan for Mullumbimby being released at the timing of the study.

Ranking	Key Issue
1	Water quality - sewer overflows and effluent
2	Riparian Vegetation - loss of habitats
3	Protection and rehabilitation of riparian vegetation

Table 3-1: Ranking of key issues from committee member responses

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Ranking	Key Issue
4	Protection of aquatic habitat
5	Fishing - fauna and habitat
6	Water quality - pollutants
7	Water quality - agricultural runoff
8	Education - Improve awareness
9	Development - infrastructure development
10	Cultural values - Aboriginal sites
11	Development - Urban expansion
12	Tourism - maintaining a balance
13	Foreshore access - pedestrian and cycle pathway on public land
14	Water Quality - accidental spillage
15	Sediment quality - nutrients and trace metals
16	Fish Kills
17	Fish stocks
18	Bank erosion - failure of remedial measures
19	Sedimentation - fisheries habitat
20	Effect of pollution incidents on aquatic habitat
21	Increased bank erosion
22	Waterway usage - boating impacts
23	Waterway usage - conflicts between users
24	Waterway usage - facilities
25	Acid Sulfate soils - acid runoff
26	Alteration to natural flows - training walls and breakwaters
27	Sedimentation - navigation
28	Water quality - low estuarine flushing
29	Waterway usage - reduced navigability
30	Sedimentation - tidal exchange
31	Flooding - flooding behaviour

3.4.4 Flooding

The study recommended the undertaking of several studies, including the preparation of floodplain management plans for Brunswick Heads, and Mullumbimby and a review of the existing Marshalls Creek Floodplain Management Plan, and to incorporate climate change investigation into these studies and plans.

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3.5 Brunswick Estuary Management Plan (Byron Shire Council, 2008)

This Brunswick Estuary Management Plan built upon the Brunswick Estuary Management Study and Plan (Patterson Consultants, 2007), to produce an estuary management plan for adoption of council. It included several estuary management options which were ranked in priority, including several flood risk mitigation options adopted from the Brunswick Estuary Management Study and Plan (Patterson Consultants, 2007).



4 Reviewed Coastal Studies

4.1 Overview

Similar to the estuary management studies and plans Coastal studies were reviewed to assess any flood management options, activities, planning and community consultation outcomes. Studies that were reviewed included:

- Byron Shire Coastline Hazards Assessment Update (BMT, 2013)
- Coastal Zone Management Plan (BSC, 2018)
- Byron Shire Coastal Hazards Assessment (2022) ONGOING

4.2 Byron Shire Coastal Hazards Assessment Update (BMT, 2013)

This study builds on top of Byron Coastline Hazard Definition study (WBM Oceanics Australia, 2000), in accordance with updates to the Coastal Protection Act, 1979 and new guidelines from "Guidance for preparing Coastal Zone Management Plans" in 2010, including new planning horizons of 2050 and 2100. This study investigated several coastal processes including oceanic inundation from storm tide and sea level rise. Several extents of oceanic inundation are available for the North Byron region and are presented within the study. From the report it is unclear which approach was undertaken to result in the inundation extents from either bathtub or numerical modelling approaches.

4.3 Coastal Zone Management Plan for the Brunswick Estuary (Byron Shire Council, 2018)

4.3.1 Purpose

This study and its associated report investigated several coastal zone management options for the Brunswick Estuary.

Some recommendations were made for further investigation into flood mitigation including:

- Incorporation of climate change impacts in the North Byron Coastal Creeks Flood Study and Marshalls Creek Flood Study
- Preparation of a water-sensitive urban design policy for the Byron Shire
- Undertake drain mapping of the North and South of Brunswick River and Marshalls Creek
- Control and manage development.

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5 Marshalls Creek Sedimentation

5.1 Introduction

JB Pacific have been commissioned by Byron Shire Council to undertake an analysis of sedimentation in Marshalls Creek. The sediment analysis includes a range of historic and contemporary sources, including:

- Available aerial imagery/photogrammetry
- Available data (LiDAR, Bathymetry, Sonar, sediment sampling etc)
- Previous studies

5.1.1 Background

Marshalls Creek originates approximately 1.5 km east of the village of Main Arm, situated in the northeastern part of the state of New South Wales. It flows in an eastward direction, meandering through a valley that is bound by ridges to the north and south. The creek covers a total distance of 23 km before it joins the Brunswick River.

Lacks Creek is a significant tributary that joins Marshalls Creek upstream of Billinudgel. Other contributing water sources include Strike-a-Light Creek and a large modified tidal lake near Balemo Drive. In addition, there is the Capricornia Canal, constructed in 1974, is a large artificial canal that facilitates drainage from elevated terrain within the Ocean Shores and low-lying areas, directing water into Marshalls Creek.

The lower part of Marhsall Creek from the Pacific Highway bridge to Brunswick Heads is tidal in nature. The hydrology of Marshalls Creek, NSW, has undergone significant changes over the decades, influenced by various factors:

- Urbanization and Runoff: The adjacent urban landscape has expanded, leading to increased runoff into Marshalls Creek. Urban development contributes to higher volumes of stormwater discharge, carrying sediment and pollutants into the watercourse.
- Land Use Changes: Changing catchment conditions, including deforestation, • farming practices, and ongoing urban development, have likely increased runoff and suspended sediment loads. The alteration of land use patterns affects the natural hydrological balance of the creek.
- Infrastructure Development: The construction of extensive drainage canals and levees near the reserve, dating back to the 1920s and 1930s, has been a notable factor. These structures were designed to drain wetland areas and enhance the viability of the land for agricultural and residential uses. The development of such infrastructure has altered the natural flow patterns and groundwater levels, impacting the creek's hydrology.
- Structural Interventions: The addition of training walls at the entrance of Marshalls Creek, implemented since the late 1960s, has influenced sand accretion in the lower estuary. The original purpose of these walls was to prevent



Brunswick River from silting up, ensuring a deep channel for the fishing fleet to access the ocean. Capricornia Canal was constructed in the early 1970s, linking Yelgun Creek to Marshalls Creek.

• Natural Events: Natural storm events have contributed to changes in channel conditions. These include alterations to the creek's course, sediment deposition, and erosion, all of which impact the overall hydrological dynamics. Marshalls Creek has experienced several significant flood events, including notable occurrences in May 1987 (commonly known as "the Mothers Day Flood"), March 1974, June 2005, March 2017 and March 2022.

5.1.2 Available Data

A range of datasets are available at a regional scale as well as specific to the study area.

5.1.2.1 Height datums

All height data is relative to Australian Height Datum (AHD), unless otherwise specified.

5.1.2.2 Elevation data

Topographic data has been sourced from the ELVIS (Elevation Information System) data portal¹:

- 1m NSW LiDAR data (2010): High resolution (1m) LiDAR survey of the Byron shire region. This data is available in 1km-by-1km tiles.
- 5m Coastal marine topographic and bathymetric data (2018): Medium resolution (5m) LiDAR and bathymetric survey of Point Danger to Cape Byron.

5.1.2.3 Aerial and satellite imagery

Historical aerial imagery was downloaded from NSW Government Spatial Services website and georeferenced in QGIS. There were 7 dates in total: 1958, 1966, 1971, 1987, 1991 and 1997. In addition, this has been supplemented by satellite imagery from Google Earth and Sentinel Hub. Selected examples are shown in Figure 5-1. High temporal Setinel-2 imagery covering 2016 to 2024 has been assessed to identify broad-scale post-flood changes in creek morphology.

1 https://elevation.fsdf.org.au/

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Figure 5-1: Selected historical aerial and satellite imagery. Historical images 1958-1997 available on <u>https://portal.spatial.nsw.gov.au/</u>. Satellite images 2009-2022 available from Google Earth.

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5.1.2.4 Published literature

- Marshalls Creek near Brunswick Heads, Northern New South Wales: A preliminary study of bed sediments and stability (Warner, 1988)
- Marshalls Creek Floodplain Management Plan. (Paterson Consultants, 1997)
- Brunswick River Estuary Study (2002). Appendix E Physical Processes
- North Byron Floodplain Risk Management Study and Draft Plan (2019)

5.2 Sediment Dynamics

5.2.1 Sources of bed material

Marshall Creek has been the subject of several studies over the years. A previous investigation by Warner (1988)², which included sediment sampling, suggested three sources of channel bed material in the lower tidally influenced part of Marshalls Creek; fluvial sediments, reworked coastal sands and marine sands.

Warner found that the upper part of the estuary, between the Pacific Highway bridge at Billinudgel and lake entrance at Ocean Shores Golf Club, comprised predominately fluvial sediments. Downstream from the lake to about Orana Bridge, Warner described the bed material as reworked coastal sands of mainly fine- to medium-grain size which have been well rounded and well sorted by marine processes. This material is believed to have been derived from eroded barrier systems and dunes formed during the Holocene period after sea level rise. From Orana Bridge to the training walls, Warner found the bed material comprised predominately of marine sands, having been deposited in a flood-tide delta environment. Marine sand and reworked sand are very similar in terms of composition, distribution, shape and sorting, the main discerning traits being marine sand is pale orange (iron staining) and contains more shell fragments.

5.2.2 Channel morphology

The reaches of Marshalls Creek vary from the wide, shoaled region of Readings Bay at the confluence of the Brunswick River, to more meandering further upstream towards New Brighton.

5.2.3 Historical changes in creek morphology

The aerial imagery of 1958, prior to the construction of the training walls, shows extensive shoaling in the lower estuary and Readings Bay (Figure 5-1) formed by sand transported in on the flood tide.

Although the 1988 study by Warner suggested much of the marine sand had been introduced since the near closure of the estuary by the training walls in the 1960s. As noted

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² Warner, R. 1988. Marshalls Creek near Brunswick Heads, Northern New South Wales: A preliminary study of bed sediments and stability.

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in the 1997 Marshalls Creek Floodplain Management Plan3 and 2002 Brunswick River Estuary Study, historical oblique photographs of the estuary show siltation of the Readings Bay pre-dated training wall construction (Figure 5-2).





1961 - Before Construction of River Walls 1967 - After Construction of River Walls

Figure 5-2: Oblique photographs of Marshalls Creek entrance pre- and post-training wall construction (source: 1997 Marshalls Creek Floodplain Management Plan).

In most tide-dominated estuaries, the peak tidal current is generally stronger during flood than during ebb; this promotes import of marine sediment in periods of low or medium river runoff. Historical conditions in the early to mid-1900s, marked by a drier Marshalls Creek catchment with fewer floods, likely facilitated the introduction of a significant amount of marine sand during that period². Aerial imagery shows a large sand shoal on the eastern side of Readings Bay with Marshalls Creek forming a number of braided channels.

The east-west training wall across the entrance to Marshalls Creek was built in the early 1960s. It originally has an opening at the eastern end only (see 1966 image in Figure 5-1). Between 1967 and 1971 modifications were made to the training walls. The channel to the boat harbour kept silting up so a second opening was made at the western end, a wall was constructed perpendicular to the original training wall cutting off the eastern opening built, and a curved spur constructed projecting into the main Brunswick River channel (see 1971 image in Figure 5-1). The perpendicular wall was lowered in 1973 after concerns about its effects on flooding. The eastern opening is 42 m wide, however, the north-east rock wall at an elevation of circa 0.4 m AHD limits its operability to large, infrequent events. The western opening is 37 m wide and is free flowing.

The training walls have trapped sand in the Readings Bay with aerial imagery highlighting the rapid accumulation of sediment on the northern side of the wall soon after construction. By 1979, vegetation had started colonising this accumulation above high-water levels. Calculations of the surface area of this accumulation, as depicted in

Figure 5-3, demonstrate a general increase over time, with some fluctuations, and a recent trend suggesting stabilization. Bathymetric data exists for 2018, however, no newer data is available to allow volumetric comparisons within the bay.

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³ Paterson Consultants. 1997. Marshalls Creek Floodplain Management Plan. Byron Shire Council.





Since construction of the training walls tidal flow in Readings Bay has been constrained to a single deep channel.

Figure 5-3: Timeseries plot showing surface area of sand accumulation on the northern side of the training wall.

Further upstream, there is also evidence for natural channel changes in the recent past. A cutoff meander is discernible in the wetlands of New Brighton (Figure 5-4), exemplifying the typical evolution of meandering rivers where a curved section is abandoned in favour of a more direct route. South of New Brighton, the ongoing evolution of meandering is evident through the erosion of bank material on the outer bends, where the flow is swifter, and the deposition of sediment on the inner bends. Figure 5-5 shows the evolution of this meander through recent aerial and satellite imagery. Bank erosion along this stretch of the creek is measured at a rate of approximately 1 metre per year. This meander is anticipated to progress towards a more sinusoidal form until a cutoff event eventually transpires. These observations underscore the dynamic nature of Marshalls Creek and emphasize the importance of continued monitoring and adaptive management strategies to address its evolving geomorphology.

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Figure 5-4: Cutoff meander in New Brighton (1997 NSW historical imagery).



Figure 5-5: Evolution of meander south of New Brighton (NSW historical imagery).

The 2002 Brunswick Estuary Study compared cross sections in Marshalls Creek from 1983 and 1991 finding a general accretion of the creek bed upstream of the Orana Bridge. The study found that downstream of Orana Bridge increases in depth of up to 0.5 m were documented while upstream of Orana Bridge a decrease of 0.5 m was documented.

5.2.4 **Bedload changes**

The movement of sediment in the study area is affected by tides and river discharges which can cause notable changes over relatively short periods, such as during a storm. These processes mobilise sand from the bed and transport it from one area to another, resulting in areas of erosion and accretion.

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Much of the sand in the lower part of the estuary, even up to New Brighton is very mobile in the upper layers, as is evident from low amplitude, ebb-dominated shoals/dunes with secondary bedforms (i.e. ripples and mega-ripples) partially superimposed on the larger dunes. The dunes retain their shape and asymmetry for extended periods of time while secondary bedforms appear to reverse in response to the changing flow direction. Tidal flows have also formed ebb and flood barbs along the lower reaches as shown in Figure 5-6.





Figure 5-6: Tidal flows have formed ebb and flood barbs.

Timeseries of satellite images show the differential migration and merging of dunes. Tracing the crests of dunes between successive satellite imagery makes it possible to estimate average migration rates of ebb-dominated dunes. It is surprisingly difficult to characterise this downstream movement, partly because the bed forms change their profiles with time but also because any given bed form has a finite lifetime. When imagery was more than a year apart it was difficult to track individual

Figure 5-7 shows migration of bedload sediment upstream of Orana Bridge following the March 2022 floods. Five crests can be tracked between June 2022 and March 2023 with those crests migrating at circa 30-40 m/year in a downstream direction.

Figure 5-8 shows the evolution of shoals in Readings Bay between June 2021 and 2022. The eastern side of Reading Bay appears relatively immobile. Along the western side, dunes migrate downstream at circa 20-30 m/year. It is not clear what occurs as the shoals

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get closer to the creek entrance. Imagery suggests some sediment can migrate through the entrance; the rest likely gets reworked during larger flood tides.



Figure 5-7: Migration of ebb-dominated dunes in New Brighton.



Figure 5-8: Migration of ebb-dominated dunes in Reading Bay.

5.2.5 Influence of Storms

During storms, soil and debris are washed off the land into the river turning it brown and transported to the ocean. This is typical of most large rain events in the Marshalls Creek catchment. Figure 5-9 shows the changes in Marshalls Creek pre and post a storm event

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on the 29-30 March 2022 where circa 295 mm of rain was recorded at Mullumbimby. The images show it takes several days for the suspended sediment to clear with most of the fine sediment transported to the ocean.



Figure 5-9: Impact of 29-30 March 2022 rainfall event on water quality (SentienI-2 imagery).

The interplay between storm surges and increase river flows due to rainfall create a complex dynamic in a tidal river such as Marshalls Creek. Following storm events, bedload and dune patterns suggest both downstream pulses of sand and upstream entrainment of sand with the flood tide. The low resolution of SenitenI-2 imagery and temporal gaps in available high-resolution satellite imagery makes it difficult to identify storm-induced changes.

5.3 Summary

Previous studies identified three sources of channel bed material: fluvial sediments, reworked coastal sands, and marine sands.

Historical imagery indicates that Marshalls Creek entrance had a high volume of sedimentation with significant shoaling prior to the construction of the training walls in the 1960s. Following construction, the Brunswick River was straightened, and siltation increased on the north side of the Marshalls Creek entrance training wall. This accumulation appears to be stabilising in recent years suggesting the majority of sediment in Readings Bay is immobile. It is evident from historical imagery that around Ocean Shores and New Brighton, there are ongoing natural channel changes and meander evolution of the creek, with ~1 m/year of bank erosion occurring on the outside of meander beds and deposition of sand on the inside.

Tidal flows and river discharges influence sediment movement, causing erosion, accretion, and migration of sandy shoals. Larger dunes are ebb-dominant and migrate downstream at 30-40 m/year with storm events potentially exacerbating these processes. The high frequency of events and low temporal resolution of imagery mean it is difficult to track dune



migration over several years. Storm events significantly affect sediment transport and water quality in Marshalls Creek, leading to changes in bedload dynamics and dune migration patterns. There is also evidence of sediment reworking during flood tides with occasional upstream movement of shoals.

Marshalls Creek experiences dynamic sedimentation influenced by various factors, including human interventions and natural processes. Continued monitoring using available data sources is recommended for informed decision-making and sustainable environmental management.

6 Identified Investigation Gaps

The North Byron Floodplain Risk Management Study (WMA, 2020) identified several potential gaps in assessing flood management and mitigation options, which it recommended for further investigation, including:

- A review of Simpsons Creek Sedimentation Study
- Catchment Drainage Model
- Undertake a Mullumbimby Evacuation Assessment
- Dredging assessments were done for Brunswick River and Marshalls Creek in isolation however a recommendation was that it also be done in combination.
- Further detailed modelling assessments of Saltwater Creek mitigation options for Mullumbimby.
- Undertake more detailed assessments of properties, which may benefit from property level protection.
- Further investigate the eligibility of raising residential properties to reduce flood damages.
- More detailed assessment of potentially raising River Street to provide improved flood immunity and evacuation:
 - This was modelled in the study but was recommended that further detailed investigation be undertaken to better understand the impacts and benefits of this option.

Additional alternative modification approaches to flood mitigation options were identified on review of the adopted modelling approaches in the North Byron FRMS (WMA, 2020), including:

• Dredging/Channel Modification: Flow path widening, connecting South Golden Beach canals with Marshalls Creek, in addition to dredging extent modification. The reporting for the Marshalls Creek Dredging suggests that the dredging extended to the West end of the Marshalls Creek junction with Brunswick River, it is thought that with the rock wall removal at the Eastern end of the junction that flow conveyance will improve further, increasing the drainage from Marshalls Creek out to the ocean. Additionally, as part of this FRMS&P only the 1% AEP event was modelled to assess the flood mitigation impact of dredging where the



creek banks were observed to overtop significantly, it is believed more frequent events, or shorter duration events would have a larger portion of flood water flow within the creek banks increasing the effectiveness as a flood mitigation option.

- Rock Wall modification: While preliminary modelling was undertaken as part of the North Byron FRMS, the investigation only modelled the 1% AEP event, which was observed to submerge the existing rock wall structure resulting in minimal flood mitigation. It could be investigated for flood mitigation impact to more frequent events where the creek blockage would be more significant. Additionally, it was also noted that while the enforcement of the hydraulic structure existed in the model, few sections of the hydraulic enforcement were believed to incorrectly represent the maximum rock wall crest and could be improved, however it is believed to result in minimal modelling impact.
- Dune Openings Modelling Modification
 - While this was modelled as a flood mitigation option in the North Byron FRMS&P, further lowering of the dune crest lower than the modelled (~1.5mAHD) at the South Golden Beach Openings is expected to potentially increase catchment release. However, lower dune crest levels have potential to result in oceanic backflow due to high tides and/or storm surge.
 - Dune openings were modelled with a 20m width, however with significantly flood water extent widths, a wider modelled channel has the potential to increase flow conveyance, as the estuary area enclosed by South Golden Beach, Ocean Shores and New Brighton, are observed to bathtub inundate from limited outflow drainage.
 - An alternative dune opening is suggested to be investigated for viability 100m North of New Brighton Beach. This alternative location would be subject to investigation of disruption to either indigenous heritage sites and dune and environmental health.
 - An additional opening immediately south of New Brighton was identified that could be investigated to improve Marshalls Creek immediate drainage before the junction with Brunswick River, consideration of possible increased sedimentation at the Marshalls Creek junction with Brunswick River must be considered if not in conjunction with dredging.
 - The preliminary modelling undertaken did not investigate impacts of tidal inundation/coincidental tidal and catchment conditions.
 - Previous modelling has not considered flood benefit to stormwater drainage systems with lowered tailwater levels.



- Drainage Infrastructure at Billinudgel
 - While several drainage infrastructure improvements were suggested a Billinudgel no infrastructure improvements were identified for improving the rail embankment cross drainage immediately North of Billinudgel
- Drainage Improvement at Strand Avenue
 - A significant constriction is observed at Strand Avenue Bridge, modelled as a 2.218mAHD deck level with a 1.575m depth.

6.1 Community Perception and Communications

It is noted throughout the various studies and community consultation that several options were regularly put forward by the community that were shown to not significantly decrease flood levels and the number of properties that were affected. It may be considered as part of future studies for reconsideration of flood alleviation affects for more frequent events than the 1 in 100-year flood event.



7 Community Consultation

7.1 Community Survey

A community survey was undertaken in November 2023, to gauge community awareness and support for flood mitigation options. The survey asked about the respondent's:

- Supported Mitigation Options
- Priorities for flood mitigation
- And any comments on floodplain management in North Byron

The community survey received 90 responses; a summary of supported mitigation options is shown in Figure 7-1. Where 65 of 90 respondents were in support of the Ocean Outfalls. The magnitude of the support is believed to be sourced from the historical ocean openings and previous investigation of the ocean outfalls as a flood mitigation option.





Figure 7-1: Community Survey Supported Mitigation Options (Multiple Choice)

From the responses stormwater was identified a prominent issue mentioned several times by a significant number of respondents. A following summary is provided regarding number of mentions of stormwater concerns, ranked by percentage of mentions from respondents.

- 1. Maintenance/Improvement of drainage (20% of respondents)
- 2. Prevention of fill areas with adverse effects (11%)
- 3. Easement Flow Path Blockage (8%)
- 4. Kallaroo Circuit Bund Constriction (8%)
- 5. Flooding from Water Lily Park (5%)
- 6. Hydraulic Linkage with Tweed-Byron Coastal Creeks (3%)
- 7. Vegetation Flow Path Blockage (2%)

Responses with attributed locations are provided for Billinudgel, South Golden Beach, Ocean Shores, New Brighton and Brunswick Heads in Figure 7-2, Figure 7-3, Figure 7-4, and Figure 7-5.

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Figure 7-2: Billinudgel Community Survey Responses



Figure 7-3: Ocean Shores and New Brighton Community Survey Responses

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Figure 7-4: South Golden Beach Community Survey Responses



Figure 7-5: Brunswick Heads Community Survey Responses



7.2 **Community Workshop**

7.2.1 Overview

A community engagement workshop was undertaken to further explore community support for flood mitigation options following the community survey. The workshop identified several considerations for future flood studies and flood modelling. Findings from the workshop, with recommendations for investigation have been broken down by locality below.

7.2.2 South Golden Beach

South Golden Beach has several concerns predominantly regarding stormwater flooding, as South Golden Beach is protected from Yelgun Creek and backwater from Marshalls Creek from a 1% AEP levee level. Concerns raised during the workshop included:

- The development at Palmer Avenue/Player Parade was observed to have • inadequate drainage during the 2022 flood event, a local resident testified that a worrying volume of water was flowing down Palmer Avenue and believed to have little stormwater network conveyance. The stormwater network is recommended to be further investigated for adequacy as part of an overland flow flood study.
- Blockage of stormwater pits and kerb inlets, concern was raised for the maintenance of the existing stormwater infrastructure. It is recommended that hydraulic structure blockage sensitivity is to be conducted up to 100% blockage.
- Concerns of easement flow path blockage were raised, including overgrown vegetation. It is recommended that easement roughness sensitivity is to be undertaken as part of future modelling.
- Some uncertainty for cause of flooding was raised, it was believed that flooding • for significant portions of South Golden Beach was from inadequate stormwater drainage, however it was unknown if this was due to elevated water levels in the canals, preventing drainage.
- Changes to the floodplain are believed to affect sugar cane agriculture North of South Golden Beach, along with the floodplain in Tweed Shire Council. This concern has been identified from previous studies and it is recommended that mitigation options are to be investigated for impact to the Tweed Shire Council.

7.2.3 Billinudgel

Billinudgel had concerns predominantly regarding Marshalls Creek flood behaviour. Thoughts raised during the workshop included:

Billinudgel has significant flow path blockage at Billinudgel Bridge (Railway Line) and the Pacific Motorway. Residents expressed concern of siltation in Marshalls Creek, where historically it was deep flowing it is now observed to be shallow flow. It is identified that the debris control measure currently under investigation may improve conveyance capacity.

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 From the survey, concern was raised for vegetation blockage of the drainage flow path running parallel to Billinudgel immediately West of the township. It is recommended that this flow path undergoes roughness sensitivity checks as part of future modelling.

7.2.4 Ocean Shores

Varying responses were provided regarding Ocean Shores.

- Some responses regarded flooding sourced from Water Lily Park. It was noted that limited stormwater mitigation options, and investigations have been proposed for Ocean Shores. It is believed that the planned catchment wide overland flow study will provide a foundation for mitigation options. Including stormwater infrastructure upgrades.
- Strong support for ocean outfalls were expressed to increase Ocean Shores flood resilience, however a few community members expressed concern over the considerations of costing, sea level rise and tidal inundation.
- There exists concern of the Ocean Shore's Golf Course impact to flood behaviour due to its significant flood storage. While Ocean Shores Golf Course weir lowering has been modelled before it is suggested to be further investigated for any additional flood alleviation potential.

7.2.5 New Brighton

- A community member raised concern about the existing open drainage channel running along Brunswick Street, claimed to have still water, and during a flood event carries a significant volume of water at a hazardous velocity. It is recommended to investigate an underground stormwater network along Brunswick Street as part of the planned Overland Flow Study.
- Strong support for ocean outfalls were expressed to increase New Brighton's flood resilience.

7.2.6 Brunswick Heads

Brunswick Heads had concerns predominantly regarding Marshalls Creek Constriction at the conjunction with Brunswick River. All mitigation options suggested during the workshop had been investigated by the North Byron Floodplain Risk Management Study (2021), however all the options were observed to have limited alleviation for the North Byron Communities. The options raised for Brunswick Heads included:

- Brunswick Heads Rock Wall Removal / Lowering
- Brunswick Heads Dredging
- Brunswick River Training Wall Removal
- Combination options, with ocean openings, dredging and rock wall removal.



While the previous modelling was discussed several community members insisted further investigation. Key limitations of previous modelling included only the investigation of the 1% AEP event and 20m wide outfalls. It is suggested that further investigation explores flood mitigation benefit for more frequent events, or modification of outfall setup.

8 Options Review

8.1 Overview

From the reviewed of the studies detailed in the previous sections, many flood mitigation options for the North Byron Beaches/Townships have been assessed and are summarised into the below list and detailed in the following subsections:

- 1. Billinudgel Levee
- 2. South Golden Beach Levee Audit Recommendations
- 3. Dune Openings
- 4. Rock Wall Modifications
- 5. Removal of Brunswick River Training Wall
- 6. Marshalls Creek Dredging at Ocean Shores
- 7. Catchment Wide Drainage and Overland Flow Model
- 8. Debris Control Measures for Billinudgel Bridge
- 9. Ocean Shores Golf Course Weir Lowering
- 10. Billinudgel Infrastructure Improvements
- 11. Marshalls Creek Dredging, Dune Openings, Rock wall Modification and Kallaroo Circuit Bund Modification
- 12. Billinudgel Infrastructure and Billinudgel Levee
- 13. Develop Guidance on the design and installation of fencing traversing waterways and channels
- 14. Update Local Flood Plan Based on outcomes of the North Byron FRMS&P and collaboration between Council and the SES
- 15. Byron Shire Council and SES to consider learnings and recommendations from the North Byron FRMS&P (2020) in the development of the Flood Warning Network for North Byron
- 16. Raising River Street to provide 1% AEP flood Immunity and Investigating a location for a new Evacuation Centre near Gaggin Street or Terrace Street
- 17. Raising Wilfred Street to provide 1% AEP flood immunity
- 18. Identify key roads for the implementation of automated warning signs and depth indicators
- 19. Community engagement to prepare and ongoing flood education program (and appropriate evaluation system)
- 20. Assess raising eligible residential properties to reduce flood damages
- 21. Assess purchasing eligible residential properties to remove residents from high flood risk areas and reduce flood way obstruction



- 22. Changes to land use zoning should consider flood compatibility using outcomes from this report. Update flood hazard overlay based on the findings of the North Byron FRMS&P (WMA, 2020)
- 23. Revise Flood Planning Levels based on the findings of this study
- 24. Updated FPA based on the findings of the North Byron FRMS&P (WMA, 2020)
- 25.DCP updated based on recommendations of the North Byron FRMS&P (WMA, 2020)
- 26. Provide flooding info on Council's website, include up to date flooding info on future s10.7 (2) and (5) certificates requested
- 27. South Golden Beach Flood Pump Generator
- 28. South Golden Beach Flood Gate Upgrade
- 29. South Golden Beach and Fern Beach Flood Levee Upgrade
- 30. Investigate Flood Levee for Western South Golden Beach
- 31. Post Event Shire-wide Flood Planning Levels Review
- 32. Formation of a committee to oversee the completion of the FRMP
- 33. Investigation of illegal builds south of North Heads Road

8.2 Detailed Option Assessment

Item	Findings
Synopsis	This option proposes a Levee protecting the township of Billinudgel with several buildings currently at risk of flooding.
Potential Impacts	While Levees can be an effective flood mitigation option to protect a township, the design and construction often has considerable economic consideration. Additionally, while levees may render portions of townships flood free, levees typically elevate flood waters within the creek adjacent to the levee and potentially increasing water levels upstream due to the restriction in flow.
Coastal Impacts	This option is believed to have minimal effect outside flood events and any coastal impacts were considered negligible.
Key Constraints	The North Byron Floodplain Risk Management Study (2021) identified risks of residual overland flow flooding with modelling of a preliminary Levee design, this would have to be investigated further to assess drainage options for Billinudgel.
Potential Approval Pathways and barriers	While the North Byron Floodplain Risk Management Study (2021) indicated that the community are generally neutral about building flood levees in the North Byron catchment, it is believed that the construction and maintenance costs would be substantial.

8.2.1 Billinudgel Levee

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Item	Findings
Synopsis	In 2014 the NSW Department of Works undertook a visual audit of the South Golden Beach levee; this audit identified several recommendations for implementation which were predominantly linked to vegetation management and ongoing maintenance.
Potential	The recommendations to come out of the audit are believed not to
Impacts	deterioration of the levee.
Coastal Impacts	The maintenance of the South Golden Beach Levee is believed to have minimal coastal impacts
Key Constraints	While the North Byron Floodplain Risk Management Study
	recommended for these suggestions to be implemented, funding remains to be sought.
Potential	Levees typically have low maintenance costs after implementation if
Approval Bathways and	properly and regularly maintained, it is not expected to be a substantial
barriers	
Flood mitigation Effectiveness	The items identified from the Audit are believed to have no immediate impact to flood hazard.

8.2.2 South Golden Beach Levee Audit Recommendations

8.2.3 Dune Openings

Item	Findings
Synopsis	The North Byron Beaches have historically had dune openings, since the dune closures, several floods have occurred, and the flood mitigation options assessing dune opening/s have been subsequently investigated to relieve catchment flows upstream of Brunswick River.
Potential Impacts	While dune openings do relieve downstream catchment flows there are environmental and ecological considerations to consider, biodiversity impacts due to increased salinity, tidal inundation, and possible increase in siltation.

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Item	Findings
Coastal Impacts	Dune openings have potential to cause significant short term coastline erosion over catchment events, and effects to longitudinal shoreline recession.
Key Constraints	Significant concerns of community include disruption to the community, ecological concerns and increased tidal propagation within the estuary. There are significant regulatory concerns and requirements in relation to clearing and works undertaken in a marine zone. All these concerns would have to be addressed before implementation.
Potential Approval Pathways and barriers	Further evidence through Sky Pumps investigations provide evidence of widespread potentially impactful benefit. Through further investigation as part of future overland flow path studies it is recommended to be investigated for impact to drainage networks.
Flood mitigation Effectiveness	Existing pre-liminary modelling has been undertaken by the North Byron Floodplain Risk Management study and plan, indicating limited reduction in peak water levels of approximately 0.05m at Brunswick Heads and 0.1m at Ocean Shores. However further options have been identified for consideration for catchment flood mitigation and further investigation of tidal inundation.

8.2.4 Rock Wall Modifications

Item	Findings
Synopsis	Major rock wall structures exist at the Brunswick River opening and at the Marshalls Creek Brunswick River junction. The rock walls are a hydraulic structure built up across a section of Marshalls Creek, which limits flow conveyance. A modification of these rock walls has been considered as a potential option to reduce flood risk.
Potential Impacts	By increasing conveyance into Brunswick River and immediately discharging catchment flows through the ocean outlet, it is believed to lower water levels at the rock walls and upstream of the rock walls. Coincident flooding from Brunswick River and Marshalls Creek may cause increased water levels and water velocity at Brunswick Heads, this would also need to be considered before implementation.
Coastal Impacts	Modification/Reduction of structure flow path blockage is believed to have an impact to sediment transport within Marshalls Creek, with expected higher velocities immediately upstream of the Rock Walls. It is also believed to have increased saline intrusion as coastal dominated events are expected to have improved conveyance as well, impacts to risks of breakthroughs is not considered as part of this

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Item	Findings
	review.
Key Constraints	Rock wall modifications are expected to have significant financial considerations, ecological considerations as well as potentially significant community concerns. Modification of the rock walls will also have to consider Marine Estate legislation due to the increase in flow velocities into the opposite Brunswick Heads Boat Harbour.
Potential Approval Pathways and barriers	Potential approval could be sought through demonstration of improved flood mitigation from previously modelled scenarios. This could include improved rock wall DEM enforcement in the model, modelling of more frequent events, or modification of combined mitigation options, predominately modification of dredging options.
Flood mitigation Effectiveness	Preliminary modelling of rock wall modifications was undertaken by the North Byron Floodplain Risk Management Study and Plan (2020), however only the 1% AEP event was assessed, and it observed the rock walls were significantly overtopped during this event. More frequent events are expected to show a more significant flood risk mitigation due to the proportion of blockage compared to the flow conveyance.

8.2.5 Removal of Brunswick River Training Walls

Item	Findings
Synopsis	The removal of the Brunswick River Training Walls was proposed to better convey catchment flows.
Potential Impacts	As a flood mitigation option, the removal of the Brunswick River Training Walls is expected to increase conveyance of catchment through the river mouth. This has the potential to change outlet morphology and shoaling.
Coastal Impacts	Increased shoaling and morphological changes could result in an unexpected reduction of catchment discharge, which would also result in an increase in wave propagation into the estuary increasing the estimated wave setup height.
Key Constraints	Removal of the Brunswick River training walls is expected to have significant economic and community usage implications importantly the navigability, this is a major concern with a small Boat Harbour located immediately upstream. Additionally key fish habitat and marine estate legislation would have to be considered before implementation.
Potential Approval	Approval for the removal of the Brunswick River training walls is expected to be challenging with the limited flood mitigation benefit,

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Item	Findings
Pathways and barriers	potentially increased tidal inundation risk and significant impact to navigability and morphology. These would all have to be addressed prior to the seeking approval.
Flood mitigation Effectiveness	The North Byron FRMS&P (2020) undertook preliminary modelling investigating the potential flood mitigation. Results indicated a minor reduction of catchment peak flood water levels. The study did not undertake a detailed assessment of tidal inundation, nor the changes of morphology on flood behaviour.

8.2.6 Marshalls Creek Dredging at Ocean Shores

Item	Findings
Synopsis	The dredging of Marshalls Creek was proposed to improve flow conveyance through Marshalls Creek extending from Billinudgel to Brunswick River
Potential Impacts	Dredging increases the flow conveyance of in bank flows, potentially reducing out of bank inundation.
Coastal Impacts	No identified coastal impacts were identified from the dredging of Marshalls Creek
Key Constraints	Upstream Marshalls creek, at Billinudgel, exists a bridge believed to hinder accessibility for dredging this is suggested to be investigated further if a modification to the proposed dredging option is considered.
Potential Approval Pathways and barriers	Approval for the Marshalls creek dredging option could be sought through demonstration of improved flood mitigation through modification of the modelling dredging approach or through demonstration of improved flood resilience through more frequent events.
Flood mitigation Effectiveness	While preliminary modelling was undertaken by the FRMS&P (2020), this modelling only undertook the modelling of the 1%AEP event, where the flood waters overtopped the creek banks significantly, resulting in minimal reduction in peak water levels of 0.05m. The flood mitigation effectiveness for more frequent events is unknown.



Item	Findings
Synopsis	A large community concern was identified for North Byron of drainage and overland flow. The development of a catchment wide drainage and overland flow model is proposed and is currently pending grant approval.
Potential Impacts	The development of a detailed hydraulic model will improve understanding of overland flow behaviour at North Byron identifying hotspots for which further investigation can be undertaken. The development of the detailed hydraulic model also would allow further usage of the model to investigate other flood mitigation options.
Coastal Impacts	The development of this detailed hydraulic model would allow further investigation of tidal impacts, with increased wave setup into the estuary, which could be further used to assess mitigation options.
Key Constraints	The usage and adoption of this hydraulic model would be subject to validation and calibration results, as two recent comparable hydraulic models would exist, so substantial evidence would have to be supplied for reasoning of Council adoption.
Potential Approval Pathways and barriers	There are a number of grant opportunities for the region as a result of the flooding that occurred in 2022. Potential issues with assessing the overland flow is that residents may not appreciate their properties being identified as being within an overland flow path as it may result in increased insurance premiums and reduction in the viable uses of their property, which may reduce its value.
Flood mitigation Effectiveness	Community feedback indicates that the North Byron community experiences significant overland flow flood risk. Definition of the communities' overland flow flood risk would aid mitigation options appraisal and approval pathways.

8.2.7 Catchment Wide Drainage and Overland Flow Model

8.2.8 Debris Control Measures for Billinudgel Bridge

Item	Findings
Synopsis	Billinudgel modelling results indicate a significant head loss experienced at the constriction of Billinudgel Bridge, leading to the proposal of debris control measures as a flood mitigation option. This option has a current grant for design phase.
Potential Impacts	This option would improve flow conveyance through Billinudgel believed to reduce peak water levels experienced at Billinudgel.

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Item	Findings
Coastal Impacts	This flood mitigation option was not identified to have any significant coastal impact
Key Constraints	While debris control measures would increase flow conveyance the Billinudgel bridge piers block a portion of the creek cross section, so it is believed there will be consistent head loss at Billinudgel Bridge.
Potential Approval Pathways and barriers	A grant has already been approved for design phase; however further investigation of flood mitigation affects should be investigated.
Flood mitigation Effectiveness	While the North Byron FRMS&P undertook preliminary modelling of Billinudgel Bridge sensitivity to blockage, modelling results indicated a minor increase in flood levels (0.05). Several concerns were raised on review of the modelling methodology at Billinudgel, however as discussed in section 5, limiting the interoperability of the modelling results. Real world flood mitigation for blockage controls is unknown and is recommended to be investigated further.

8.2.9 Ocean Shores Golf Course Weir Lowering

Item	Findings
Synopsis	The option of the Ocean Shores Golf Course Weir Lowering was proposed to reduce peak flood levels
Potential	The lowering of the Golf Course weir was believed to have the
Impacts	at Ocean Shores.
Coastal Impacts	No coastal impacts were identified for this flood mitigation option
Key Constraints	The Golf Course Weir acts a dam for an upstream pond of the golf course, this would require approval for modification of private property.
Potential	The lowering of the Ocean Shores Golf Course Weir is expected to be
Approval Pathways and	challenging due to the negligible modelled impact.
barriers	
Flood mitigation	The North Byron FRMS&P undertook preliminary modelling of the
Effectiveness	Ocean Shores golf course weir lowering, results indicate a negligible impact to flood levels experienced at ocean shores with a reduction of 0.01m



8.2.10 Billinudgel Infrastructure Improvements

Item	Findings
Synopsis	Billinudgel infrastructure improvements was proposed to reduce flooding observed at Billinudgel. These improvements are aimed to be considered as part of the development of the Overland Flow Study.
Potential Impacts	Infrastructure improvements such as improved cross drainage and stormwater networks could result in a reduction of overland flood risk.
Coastal Impacts	No coastal impacts were identified for this flood mitigation option.
Key Constraints	Existing hydraulic structures at Billinudgel would either have to be replaced or improved for improved drainage infrastructure.
Potential Approval Pathways and barriers	Approval for Billinudgel Infrastructure improvements could be sought through detailed hydrodynamic modelling undertaken as part of the Overland Flow Study.
Flood mitigation Effectiveness	The North Byron FRMS&P undertook preliminary modelling of infrastructure improvements at Billinudgel indicating minor reduction of peak water levels with a maximum of 0.22m lowering at Wilfred Street. Flooding at Billinudgel experiences is sourced from major constriction caused from the Railway embankment and bridge, with the 1% AEP event overtopping the creek banks, infrastructure improvements at creek cross drainage are not observed to greatly improve flow conveyance.

8.2.11 Marshalls Creek Dredging, Dune Openings, Rock wall Modification and Kallaroo Circuit Bund Modification

Item	Findings
Synopsis	A combination of options were proposed as flood risk management options including dune openings rock wall modification and Kallaroo Circuit bund.
Potential Impacts	These options in combination have potential to increase conveyance through Marshalls Creek, reducing peak water levels
Coastal Impacts	This option has greatest coastal impact from dune openings, having potential to cause significant short term coastline erosion over catchment events, and effects to longitudinal shoreline recession.

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Item	Findings
Key Constraints	Similarly, to the Dune openings option there is a significant concern of community disruption, ecological concerns and increased tidal propagation within the estuary. All these concerns and others related to the combination of flood mitigation would have to be addressed before implementation.
Potential Approval Pathways and barriers	While individual approval pathways could be sought for each mitigation option this could take a significant amount of time, a coincidental combination of mitigation options could be investigated for effectiveness and cost-benefit. A coincidental investigation like dredging and rock wall modification are believed to magnify flood mitigation effectiveness. Additionally, more frequent events could demonstrate that the out of bank inundation could be conveyed by the in-bank flow capacity with a combination of these mitigation options as the 1% AEP event well overtops the creek banks.
Flood mitigation Effectiveness	Preliminary modelling was undertaken of these of flood mitigation events, resulting in widespread flood mitigation benefit up to 0.15m at South Golden Beach, 0.06m at Ocean Shores and up to 0.08m in New Brighton, however only the 1% AEP event was modelled, which significantly overtops the creek banks. It is believed a more significant reduction of inundation extent could be observed for more frequent events.

8.2.12 Billinudgel Infrastructure and Billinudgel Levee

Item	Findings
Synopsis	A combination of the flood mitigation options including the Billinudgel Levee and Billinudgel Infrastructure upgrades were proposed to mitigate the overland flow flood risk for the areas behind the Billinudgel Levee.
Potential	While the Billinudgel Levee solely resulted in residual overland flow
Impacts	infrastructure was proposed to drain the overland flow and protect the township.
Coastal Impacts	No coastal impacts were identified for this mitigation option
Key Constraints	The Pacific Motorway as well as the residential area East and downstream of Billinudgel limit the drainage options for Billinudgel, as any options is to not adversely impact downstream or other urban areas.
Potential	The North Byron FRMS&P investigated the viability of these flood

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Item	Findings
Approval Pathways and barriers	mitigation options, while the levee and infrastructure protected the buildings of Billinudgel, a more detailed investigation estimated that the option would result in a CBR of 0.58.
Flood mitigation Effectiveness	The North Byron FRMS&P undertook modelling of the Billinudgel Levee and infrastructure as a flood mitigation option, a widespread reduction of flooding in Billinudgel was observed with minor increases in flood levels ranging from 0.02-0.05 in Marshalls Creek. However, there are concerns of modelling methodology, see Section 2.7.6.

8.2.13 Develop Guidance on the design and installation of fencing traversing waterways and channels

Item	Findings
Synopsis	Fencing that traverses' waterways and channels are known to cause blockage, the development of guidance for the design and installation was proposed as a flood mitigation option.
Potential	Providing advice on fencing that traverses' waterways that results
Impacts	minimal blockage, allows greater flow to convey through channels.
Coastal Impacts	No coastal impacts were identified from this flood mitigation option.
Key Constraints	As this would be development of guidance and not policy, difficulty in
	enforcement or removal of inappropriate fencing would be a constraint.
Potential	Identification of properties with fencing traversing waterways would
Approval Bothways and	assist in identifying of potentially interest properties which council
harriers	sensitivity modelling could be undertaken for key properties to aid
barners	explanation of effects to property owners.
Flood mitigation	No modelling was identified as being undertaken it is suggested that
Effectiveness	sensitivity modelling runs could be undertaken as part of the Overland



8.2.14	Update Local Flood Plan Based on outcomes of the North Byron FRMS&P ((2020)
	and collaboration between Council and the SES	

Item	Findings
Synopsis	Recommendations were given for flood mitigation options in the North Byron FRMS&P, it was proposed for these options to be considered further for adoption by the Council and SES. These have subsequently been adopted with minimal modifications as part of Council's FRMP
Potential Impacts	Further investigations into mitigation options have been recommended by the study, as well as providing the best practice flood risk estimation for the North Byron Community as of present day.
Coastal Impacts	The existing coastal structures have been assessed for modification by this study as well as other coastal mitigation options including Dune openings.
Key Constraints	While this study undertook detailed modelling, it was not within the scope of the project to assess overland flow drainage and flooding. Some concerns of modelling methodology are discussed in Section 2.7.6.4
Potential Approval Pathways and barriers	While minimal hard structural mitigation options were recommended for further investigation, the study summarised a list of many mitigation options regardless of their effectiveness. The findings of this study can be used as evidence to educate the community that some of their preferred options aren't effective, whilst alternatives more effective and viable mitigation measures.
Flood mitigation Effectiveness	This flood study undertook widespread mitigation measures catchment wide. While improvements could be made to the investigations, the preliminary modelling undertaken has exhibited either flood mitigation effectiveness or inefficiencies, for many options during the 1% AEP event.

8.2.15 Byron Shire Council and SES to consider learnings and recommendations from the North Byron FRMS&P (2020) in the development of the Flood Warning Network for North Byron

Item	Findings
Synopsis	As the townships in North Byron are in lower portion of the catchment, it is believed that a flood warning network could be an effective response measure and is proposed as a mitigation option.
Potential Impacts	A flood warning network could reduce property and vehicular flood damages and population at risk during flood events.
Coastal Impacts	No coastal impacts were identified for this mitigation option

JBP

Item	Findings
Key Constraints	Flood warnings provided from the findings of the North Byron FRMS&P (2020) would be limited to the quality of the modelling in the flood study, as some concerns were raised over catchment lag in the hydrologic model, which a flood warning network is heavily reliant on.
Potential Approval Pathways and barriers	The development of the flood warning network was completed for North Byron as per the recommendation of the North Byron FRMS&P (2020)
Flood mitigation Effectiveness	As a great majority of buildings in the North Byron Community are located lower portion of the catchment and could potentially benefit significantly from a properly implemented flood warning network.

8.2.16 Raising River Street to provide 1% AEP flood Immunity and Investigating a location for a new Evacuation Centre near Gaggin Street or Terrace Street

Item	Findings					
Synopsis	River Street was identified as an evacuation route for the township of New Brighton. Due to this the raising of River Street to provide 1% AEP flood immunity was proposed.					
Potential	The raising of River Street for flood immunity would provide the					
Impacts	residents of New Brighton an evacuation route to reduce risk of loss of life.					
Coastal Impacts	No coastal impacts were identified for this flood mitigation option					
Key Constraints	The North Byron FRMS&P (2020) modelling results indicate that the raising of River Street would result in localised increases of peak water levels.					
Potential Approval	It is proposed that these impacts and design options be further investigated as part of the Overland Flow Study, and potential control					
Pathways and barriers	measures to minimize impact.					
Flood mitigation Effectiveness	While this flood mitigation option is estimated to raise local water levels at New Brighton, 13 properties were identified to experience above floor flooding with River Street being their only evacuation route.					

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Item	Findings
Synopsis	With other mitigation options potentially changing the flood behaviour at Billinudgel, the raising Wilfred Street to provide the road with 1% AEP flood immunity was considered as a flood mitigation option to further increase resilience at Billinudgel.
Potential Impacts	While raising roads can hinder conveyance of overland flow increasing water levels, with adequate cross drainage, this mitigation option can result in a flood free evacuation route.
Coastal Impacts	No coastal impacts were identified for this flood mitigation option
Key Constraints	Raising Wilfred Street holds back overland flow drainage and is only recommended as a flood mitigation option in conjunction with other flood mitigation options. The existing drainage for overland flow runs North to Marshalls Creek immediately adjacent to Billinudgel, the raising of Wilfred Street is expected to exacerbate the overland flow inundation.
Potential Approval Pathways and barriers	Similar to the raising of River Street, this option could be considered in conjunction with other mitigation options such as the Billinudgel Levee, and drainage infrastructure improvements
Flood mitigation Effectiveness	The North Byron FRMS&P undertook preliminary modelling investigating the impacts of raising Wilfred Street, involving raising of Wilfred Street by 0.5m, while this did not provide 1% AEP flood immunity, the raising of 0.5m increased time available for evacuation during a flood event. This modelling resulted in widespread impacts of 0.05m and up to 0.2m increased water levels. This modelling did not incorporate improved drainage infrastructure to facilitate the raising, and it is believed improved drainage infrastructure would provide additional benefits for evacuation of Billinudgel.

8.2.17 Raising Wilfred Street to provide 1% AEP flood immunity



8.2.18 Identify key roads for the implementation of automated warning signs and depth indicators

Item	Findings					
Synopsis	North Byron experiences several flooded roads, which present a risk to life for motorists and pedestrians. It is recommended that the usage of road closures early notifications and creek crossing deterrents are used to discourage the crossing of floodwaters.					
Potential Impacts	While this option does not improve flood behaviour several flooded roads were identified, where deterrents could be used to reduce attempts of crossing floodwaters.					
Coastal Impacts	No coastal impacts were identified for this flood mitigation option.					
Key Constraints	Two options were presented from the North Byron FRMS&P including automatic road closures/boom gates and automatic warning signs and depth indicators.					
Potential Approval Pathways and barriers	The North Byron FRMS&P (2020) identified some key road crossing locations for consideration, where this mitigation option could be employed, a significant majority of these locations were for Mullumbimby, a few locations were identified for the Northern Beaches community including Orana Road, Shara Boulevard, Red Gate Road, New Brighton Road, Brunswick Street and The Pocket Road.					
Flood mitigation Effectiveness	Floodwater crossing deterrents and indicators typically reduce risk to population, with identification of at-risk roads and crossings in North Byron this implementation could reduce flood risk in North Byron.					

8.2.19 Community engagement to prepare and ongoing flood education program (and appropriate evaluation system)

Item	Findings
Synopsis	The North Byron community have indicated concern of the lack in local knowledge and understanding of flood risk. This was identified in many of the previous study surveys regarding drainage upgrades/maintenance and channel modification. A plan for community engagement and ongoing flood education program was suggested as an outlet for the community to express concerns of flooding in the local area, while also being educated on the potential options for flood mitigation in North Byron and the findings of previous studies.



Item	Findings
Potential Impacts	This mitigation option has several benefits including community awareness and preparedness for flooding, but also for increased opportunity for community expression and subsequent Council evaluation of options for further consideration.
Coastal Impacts	This mitigation option is expected to result in several community comments and feedback on coastal mitigation options.
Key Constraints	Many attempts at community engagement have been undertaken before including the North Byron Flood Study (2016) and the North Byron Flood Risk Management Study and Plan (2020), each of which indicating high community concern and lack in the level of understanding of mitigation option investigations, and the impacts.
Potential Approval Pathways and barriers	A community and stakeholder engagement plan is underway as part of this project.
Flood mitigation Effectiveness	Many potential outcomes are possible because of the community engagement plan including identification of investigation gaps, increased community flood risk understanding, increased flood preparedness and potential support for future flood mitigation options.

8.2.20 Assess the raising of eligible residential properties to reduce flood damages

Item	Findings				
Synopsis	Many houses experience above floor flooding in North Byron, raising the floor level to above defined flood level was proposed to potentiall reduce flood damages.				
Potential	This mitigation option would result increasing flood resilience of many				
Impacts	at risk properties adjacent to Marshalls Creek.				
Coastal Impacts	No coastal impacts were identified for this mitigation option				
Key Constraints	Many instances exists where house raising may not be viable,				
	including, cost of house raising in comparison to relocation or building				
	a new house, and community willingness.				
Potential	Further detailed assessment of properties viable for house raising can				
Approval	be undertaken to investigate approval pathways. Council has proposed				
Pathways and	this option as a part of the VHR/VHP scheme.				
barriers					

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Item	Findings
Flood mitigation Effectiveness	House raising eligible properties would likely consist of properties adjacent creeks/major flow paths, whilst house raising for 1% AEP flood immunity results in a decrease of damages for events up to the 1% AEP. It results in a substantial increase for rarer events, or climate change considerations could be a residual risk to these properties. 20 properties were identified as potentially eligible for house raising in New Brighton, with an additional building in Billinudgel. It is recommended these properties be considered for detailed investigation of raising eligibility.

8.2.21 Assess purchasing eligible residential properties to remove residents from high flood risk areas and reduce flood way obstruction

Item	Findings					
Synopsis	Many properties may be not viable for house raising due to extreme water levels, velocities, or material of building. Voluntary purchases involving the acquisition of high-risk flood affected properties was proposed to reduce the flood risk of these properties.					
Potential Impacts	Voluntary house purchasing removes these properties from flood risk the property is also rezoned to a use that can't be developed. It does however remove housing stock. Properties need to be fairly and consistently selected. Can lead to neighbourhoods having a gappy appearance as the uptake is voluntary.					
Coastal Impacts	Some of these properties could be located adjacent to the coast, and the house purchasing of these properties could reduce coastal risk for North Byron simultaneously or provide further reasoning for voluntary house purchasing.					
Key Constraints	As the house purchasing is voluntary a significant community education program would have to be pursued targeted to eligible properties of their flood/coastal risk. Significant funds required to purchase and remove buildings.					
Potential Approval Pathways and barriers	The Byron Shire Council has indicated that this plan has had a Grant Submitted in May 2022, for further investigation of this program.					
Flood mitigation Effectiveness	This mitigation option immediately removes properties from high flood risk areas, in attempt to relocate residents to lower risk areas and repurposes land use for North Byron to increase the communities flood resilience.					



8.2.22 Revise Flood Planning Levels based on the findings of the North Byron FRMS&P (WBM 2020)

Item	Findings		
Synopsis	Flood planning levels are used extensively for development and flood risk assessments. It was proposed that council update FPL to the recommendations of the North Byron FRMS&P.		
Potential Impacts	As a result of the adoption of the new flood levels future development would be based on the revised flood planning levels. Decreasing overdesign and potentially increasing flood resilience of new developments.		
Coastal Impacts	No coastal impacts were identified as part of this mitigation option.		
Key Constraints	The updated flood planning levels are only used to control new developments, it is not within the scope of the DCP to control existing developments.		
Potential Approval Pathways and barriers	Byron Shire Council has indicated that the flood planning levels have been updated to those recommended in the North Byron FRMS&P (WBM, 2020).		
Flood mitigation Effectiveness	Development controls for new developments, provide resilient future developments and control impact to neighbouring and existing properties with best practices.		

8.2.23 Changes to land use zoning should consider flood compatibility using outcomes from this report. Update flood hazard overlay based on the findings of the North Byron FRMS&P (WBM, 2020)

Item	Findings
Synopsis	The flood hazard zoning in North Byron was improved by the North Byron FRMS&P, changing defined flood levels for flood hazard overlays for the North Byron developers and community. This mitigation option was proposed to re-evaluate land use areas to aide development areas, and property purchase schemes.
Potential Impacts	Re-zoning land to land-uses that are appropriate for the flood classification provides the benefit that future development minimises
	additional people being placed in at risk areas.
Coastal Impacts	Flood planning areas in North Byron can be adjacent to coastal areas, changes to land use at coastal areas could result in potential changes for coastal hazards.

JBP scientists and engineers

Item	Findings
Key Constraints	Changes to land use zoning, including community relocation have high community involvement and considerations. May include compensation to those affected by the changes (devaluing the property/reducing usage)
Potential Approval Pathways and barriers	The Byron Shire Council has indicated that the Land Use Zoning has been updated for flood compatibility in North Byron. Considerations for future studies including the planned Overland Flow Study, or implementation of flood mitigation options may result in changes to flood planning areas.
Flood mitigation Effectiveness	This flood mitigation measure exists primarily as a preventative measure for future developments, but also for consideration for existing developments.

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0.Z.Z4	Updated FPA	based on the	e iinaings o	n the North	BYION FRIVISAP	(VVDIVI,	2020)

Item	Findings
Synopsis	The North Byron FRMS&P undertook review and improvement of the existing flood model developed by BMT in 2016, changing North Byron's design flood estimates. It was proposed that the council update flood planning areas based on the findings of the North Byron FRMS&P (2020).
Potential Impacts	Improvements to flood estimation and the resultant flood planning areas would assist in prioritising mitigation strategies and planning for priority areas.
Coastal Impacts	Changes to flood planning areas can coincide with coastal hazard areas, and potentially increase coastal hazards.
Key Constraints	The flood planning areas identified in the North Byron FRMS&P exclude coastal inundation modelling and might not represent all mechanics of inundation (Coastal, Catchment and Coincidental flooding). The North Byron region and specifically Marshalls Creek are coastal adjacent estuaries and could be sensitive to tidal conditions.
Potential Approval Pathways and barriers	The Byron Shire Council has indicated that the Flood Planning Areas have been updated in North Byron. Considerations for future studies including the planned Overland Flow Study, or implementation of flood mitigation options may result in change to flood planning areas.
Flood mitigation Effectiveness	The improved flood risk estimation further increases understanding of flood behaviour in North Byron, leading to greater confidence in designating planning zones and the design and assessment of mitigation options.



8.2.25 DCP updated based on recommendations of this North Byron FRMS&P (WBM, 2020)

Item	Findings
Synopsis	The Development Control Plan (DCP) provides guidelines to support the planning controls in the Local Environmental Plan developed by council. It was proposed to update the local DCP based on the findings of the review of the existing DCP within the North Byron FRMS&P (WBM, 2020). Suggested amendments included more detailed guidance on the principles of wet proofing, appropriate design and materials, with direct reference to available guidelines, a requirement for an assessment of property level protection as part of the DCP2014 planning matrix criteria and implement the recommendations regarding appropriate fil areas in the DCP2014.
Potential Impacts	The amendments proposed for the Byron Shire Council DCP, are aimed to improve community flood resilience, through guidance for new developments.
Coastal Impacts	No coastal impacts were identified for this mitigation option.
Key Constraints	While the suggested amendments improve flood resilience for future developments, it does not reduce flood risk for existing structures.
Potential Approval Pathways and barriers	Byron Shire Council indicates that the proposed amendments are partially complete and still ongoing.
Flood mitigation Effectiveness	The review of the DCP by (WBM, 2020) generally found the existing DCP consistent with current best practice, with the proposed amendments suggesting minor improvements to increase flood resilience and improve useability and guidance of the DCP.

8.2.26 Provide flooding info on Council's website, include up to date flooding info on future s10.7 (2) and (5) certificates requested

Item	Findings
Synopsis	Flooding impacts are widespread in the North Byron region, with several properties experiencing different and varying levels of flooding. It was proposed that council provide further detailed information regarding flood behaviour as property level flood information via an online, easy to access, GIS platform.
Potential Impacts	As flood behaviour varies property to property this platform would provide residents and home/business owners guidance of their flood risk specific to their property.

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Item	Findings
Coastal Impacts	The implemented GIS platform provides catchment inundation for events up to the PMF extent, no mapping is provided for tidal inundation.
Key Constraints	This property level information is currently available for "flood prone areas" this information is provided as PMF inundation extents. While this is a conservative estimation of flood risk, it may benefit properties near the fringe of the PMF extent to observe more frequent events. Additionally, it is further recommended to assess community knowledge of this flood information portal.
Potential Approval Pathways and barriers	The Byron Shire Council have finished developing the online GIS platform for property level flood risk.
Flood mitigation Effectiveness	The mapping portal has provided property owners/dwellers a method to assess their flood risk, which may improve residents support for mitigation options, such as voluntary house raising/purchasing scheme. Additionally, for properties within the flood risk zone, residents become more aware of their flood risk potentially increasing the community's preparedness.

8.2.27 South Golden Beach Flood Pump Generator

Item	Findings
Synopsis	Residents west of Capricornia Canal are aware of the flood pump serving the area East of the Canal. It was proposed that a flood pump for the Residents on the West side of Capricornia Canal could benefit from an additional flood pump under Elizabeth Street.
Potential Impacts	Flood pumps provide improved floodwater drainage, however they would not protect West South Golden Beach from creek flooding from Marshalls Creek.
Coastal Impacts	No coastal impacts were identified as part of this mitigation option.
Key Constraints	The existing pump on the East side of Capricornia canal has a large drain used for the collection of stormwater directing a substantial volume to the central pump. The East of Capricornia canal has a smaller catchment of overland flow, and is expected to have reduced effectiveness.
Potential	Further investigation of capability and storm water flood risk for
Approval	residents West of Capricornia Canal could be undertaken to further

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Item	Findings
Pathways and barriers	justify an additional flood pump. It is proposed to be investigated as part of the planned Overland Flow Study.
Flood mitigation Effectiveness	While a flood pump would reduce the risk of overland flow inundation, it could be investigated in conjunction with the Western South Golden Beach Levee investigation to provide additional flood risk immunity for the residents.

8.2.28 South Golden Beach Flood Gate Upgrades

Item	Findings
Synopsis	South Golden Beach experiences overland flow drainage to the Capricornia Canal. It was proposed that alternate solutions like flood gates with automated knife valve for full closure would increase the flood resilience of South Golden Beach.
Potential Impacts	An automated system for the flood gates could further ensure the protection of South Golden Beach from back water while maintaining overland flow drainage systems.
Coastal Impacts	No coastal impacts were identified from this mitigation option.
Key Constraints	No existing hydraulic model exists for identifying South Golden Beach's capacity for drainage and susceptibility for back water flooding
Potential Approval Pathways and barriers	It is recommended to use the findings of the planned overland flow study to help guide cost-benefit analysis due to the existing flood gates at South Golden Beach.
Flood mitigation Effectiveness	While no modelling has been undertaken to investigate potential operational controls, it is believed that operational controls could increase the resilience of the South Golden Beach township.

8.2.29 South Golden Beach and Fern Beach Flood Levee Upgrades

Item	Findings
Synopsis	It was identified that the levy was overtopped in the 2022 flood event. Subsequently it was proposed that a raising of this levee would be warranted.
Potential	Raising the levee could result in the protection of several properties
Impacts	behind the Levee in South Golden Beach, however it is known that
	levees typically increase water levels within the channel.
Coastal Impacts	No coastal impacts were identified as part of this mitigation option.

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Item	Findings
Key Constraints	Raising this flood levee further would be a considerable financial cost, it is estimated that the existing level provides protection up to the 1% AEP event. While the levee provides protection for riverine flooding, it does not provide protection for overland flow.
Potential Approval Pathways and barriers	Byron Shire Council has indicated that it is currently under investigation by Public Works. Raising the flood levee to provide further protection beyond the 1% AEP event could be justified through a cost benefit analysis.
Flood mitigation Effectiveness	While raising the flood levee would provide further protection beyond the current design, similarly, increasing the design capacity overland flow drainage infrastructure to improve the flood immunity of the township.

8.2.30 Investigate Flood Levee for W	Vestern South Golden Beach
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Item	Findings
Synopsis	A flood levee exists for the Capricornia Canal protecting residents east of the canal. However, it is observed that significant flood waters travel to the western side of the canal, and it was proposed a Flood Levee for Western South Golden Beach could reduce flood risk for the township.
Potential	A flood levee designed to provide flood immunity for flood events
Impacts	protects properties behind the levee, however levees often increase
	levee may reduce the level of protection that the existing eastern levee
	provides.
Coastal Impacts	No coastal impacts were identified as a part of this study.
Key Constraints	Flood levees are associated with a considerable financial cost, where few properties are currently observed to be impacted by the 100 year flood event from the modelling results developed by the North Byron FRMS&P (WMA, 2020).
Potential Approval Pathways and barriers	Modelling to be undertaken by the Catchment Wide overland flow study could result in different flood levels potentially further justifying the investigation of a flood levee for West South Golden Beach.

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Item	Findings
Flood mitigation Effectiveness	As very few properties are observed to be impacted by the 1% AEP event is expected to have limited effect on the protection of properties for Western South Golden Beach, as it is unknown if the residents West of South Golden Beach experience significant overland flow flooding.

8.2.31 Post Event Shire-wide Flood Planning Level Review

Item	Findings
Synopsis	The CSIRO undertook post-event analysis for the Northern Rivers Region in the "Characterisation of the 2022 floods in the Northern Rivers Region. It was proposed to use the findings of this study, along with the MAYDAY Flood debrief held on 15th May 2022, with any additional region-specific information to review flood planning levels with the observed flood event.
Potential Impacts	By undertaking a post-event review of the unprecedented floods in 2022 and comparison to the flood planning levels, discrepancies could be identified and reviewed for observed rare flood behaviour and estimated design event rare flood behaviour.
Coastal Impacts	Identification of any extreme short-term erosion during the observed event could be an indication of erosion risks.
Key Constraints	As a significant time has passed since the event, flood markers and debris markers to indicate flood levels would be scarce. Community testimonials with supporting evidence of photographs could be a valid alternative. However, timing is a critical constraint to this option as community interest will dissipate over time.
Potential Approval Pathways and barriers	Understanding of the 2022 flood event could result in greater understanding of flood behaviour and increase potential for validation/calibration efforts for the development of the planned Catchment Wide overland flow study, and it recommended to be undertaken as part of the study.
Flood mitigation Effectiveness	An improved representation of extreme flood events by future flood studies from having well characterized event behaviour of the 2022 flood event could increase accuracy/confidence of future model results and any mitigation assessments.



Item	Findings
Synopsis	Many recommendations were made from the North Byron FRMS&P (WMA, 2020). It was proposed that a formation of a committee would better ensure progression and quality of works undertaken towards implementation of the recommendations.
Potential Impacts	Ensuring the progression of recommended mitigation options could result in improved timeliness of completion and comprehensive evaluation of works undertaken.
Coastal Impacts	Flood mitigations with potential of coastal impact could be further assessed from mitigation option implementation as part of this committee obligations.
Key Constraints	Further investigations are planned and are likely to result in further recommendations for flood mitigation options, notably the planned Catchment Wide overland flow study, the findings of this study could result in contradiction or identification of more effective flood mitigation options.
Potential Approval Pathways and barriers	Byron Shire Council has indicated that this has been completed.
Flood mitigation Effectiveness	The North Byron FRMS&P (WMA, 2020) undertook preliminary modelling to investigate many of these flood mitigation options, however, the preliminary modelling undertaken was limited to the 1% AEP event. Further modelling may be undertaken as part of the planned Catchment Wide Overland Flow Study to assess flood mitigation effectiveness.

8.2.32 Formation of a committee to oversee the implementation of the FRMP

8.2.33 Investigation of illegal builds south of North Heads Road

Item	Findings
Synopsis	Illegal builds were identified south of North Heads Road, further investigation of these builds is proposed to assess impact to flood behaviour.
Potential	Private builds typically go through development assessments, to raise
Impacts	any issues of flood behaviour impact including levees and fill pads.
Coastal Impacts	No coastal impacts were identified as part of this mitigation option.
Key Constraints	Further investigation of the illegal builds and their effect on flood behaviour will have to be investigated to identify constraints.
4.1 - ATTACHMENT 2



Item	Findings
Potential Approval Pathways and barriers	The removal of illegal builds is expected to have push back from the property owner, as the builds may increase flood resilience for the single property but may worsen downstream water levels.
Flood mitigation Effectiveness	The developments can be further investigated for flood mitigation by identification if the developments are outside the flood planning area, or above the flood planning level.

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9 Summary

This review has identified several different mitigation options that have been assessed for their effectiveness and their cost to benefit ratios. Mitigation measures that have been suggested range from structural such as levees, dune openings, flood pumps, stormwater drainage upgrades and channel diversions, voluntary resumptions, planning scheme amendments and flood planning levels, to forecasting, flood warning and community education programs.

Council has implemented and is in the process of implementing several of the recommended measures. Measures that Council has already implemented include drainage and maintenance programs, flood forecasting and warning systems, updates to the planning scheme and the flood planning levels portal for individual property flood risk information.

Stormwater drainage has been identified as a major concern for flood risk in the North Byron region, it is recommended that future investigations consider flood risk sensitivity to near structural blockage of stormwater infrastructure, siltation blockage of bridges (Orana Road, and Billinudgel Bridge), to assist in developing priority maintenance plans for regular maintenance to avoid blockage induced flooding.

Many of the major capital works options which although were seen to be effective at mitigating flooding were not found to be cost effective and/or resulted in impacts to other areas. Numerous options were seen to reduce flooding from creek flooding but resulted in impacts due to overland flooding. Strong community support for further investigation/implementation has been observed from several previous community consultations and as that undertaken as part of this study, particularly for ocean outfalls. Further investigation through the North Byron Sky Pumps study has further quantified the localised impact for flood level alleviation and is recommended to be used to assist in community consultation. The Sky Pumps have been used to quantify the flow rates required to by potential ocean outfalls to reduce peak flood level by the designated amounts.

It is noted that any structural option that is found to provide a reduction to flooding is going to be subject to significant regulatory approval due to the environment that it will need to be constructed, as most of the North Byron region is nature reserve.

As has been identified during several studies the community has some awareness of flood mitigation and potential options, however technical understanding of the mechanisms and reasons why the options may or may not work and their effectiveness remains a challenge for the North Byron Community. As part of this project simplified examples and explanations of the key concepts needs to be provided to the community to improve their understanding and to enable them to relinquish their desire for measures that have been shown in the past to provide little to no effective reduction in flood risk. Many of the major structural options were observed to reduce peak water level but were not found to be cost effective and/or resulted in impacts to other areas.

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There is strong community support for further mitigation option investigation and implementation, particularly for ocean outfalls, it is recommended for re-consideration for more frequent events than the 1% AEP subject to community tolerability.

The community has a strong desire to fix/alleviate nuisance flooding. This type of flooding occurs frequently and is regularly in the community's perspective. This can mostly be alleviated through improved drainage and maintenance of stormwater drainage systems.

It is noted that support for different structural mitigation measures can be varying across the region with certain areas being strongly for the mitigation and other areas being strongly against. The outfalls option was strongly suggested and recommended by parts of the community, while at the same time residents who lived nearest to the proposed outfall locations were seen to be against the option. Having a community that is significantly divided on whether a option should go ahead will likely mean that there will be significant rejection of the option even if it is shown to provide a benefit to the community.

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BYRON SHIRE COUNCIL

STAFF REPORTS - INFRASTRUCTURE SERVICES

4.1 - ATTACHMENT 2







FLOOD Agenda