INFRASTRUCTURE POLICY COMMITTEE

AGENDA

3 FEBRUARY 2026

Notice is hereby given, in accordance with the provisions of the Local Government Act 1993 that an **INFRASTRUCTURE POLICY COMMITTEE MEETING of ORANGE CITY COUNCIL** will be held in the **COUNCIL CHAMBER, CIVIC CENTRE, BYNG STREET, ORANGE on Tuesday, 3 February 2026.**

Scott Maunder

CHIEF EXECUTIVE OFFICER

For apologies please contact Executive Support on 6393 8391.

AGENDA

1 INTRODUCTION 3

1.1 Apologies and Leave of Absence 3

1.2 Declaration of pecuniary interests, significant non-pecuniary interests and less than significant non-pecuniary interests 3

2 COMMITTEE MINUTES 5

2.1 Minutes of the Floodplain Risk Management Community Committee Meeting held on 8 December 2025 5

3 GENERAL REPORTS 131

3.1 Current Works 131

1 INTRODUCTION

MEMBERS

Cr J Whitton (Chairperson), Cr T Mileto (Mayor), Cr T Greenhalgh (Deputy Mayor), Cr K Duffy, Cr G Judge, Cr F Kinghorne, Cr D Mallard, Cr M McDonell, Cr S Peterson, Cr G Power, Cr M Ruddy, Cr J Stedman

1.1 Apologies and Leave of Absence

1.2 Declaration of pecuniary interests, significant non-pecuniary interests and less than significant non-pecuniary interests

The provisions of Chapter 14 of the Local Government Act, 1993 (the Act) regulate the way in which Councillors and designated staff of Council conduct themselves to ensure that there is no conflict between their private interests and their public role.

The Act prescribes that where a member of Council (or a Committee of Council) has a direct or indirect financial (pecuniary) interest in a matter to be considered at a meeting of the Council (or Committee), that interest must be disclosed as soon as practicable after the start of the meeting and the reasons given for declaring such interest.

As members are aware, the provisions of the Local Government Act restrict any member who has declared a pecuniary interest in any matter from participating in the discussion or voting on that matter, and requires that member to vacate the Chamber.

Council's Code of Conduct provides that if members have a non-pecuniary conflict of interest, the nature of the conflict must be disclosed. The Code of Conduct also provides for a number of ways in which a member may manage non pecuniary conflicts of interest.

RECOMMENDATION

It is recommended that Committee Members now disclose any conflicts of interest in matters under consideration by the Infrastructure Policy Committee at this meeting.

2 COMMITTEE MINUTES

2.1 Minutes of the Floodplain Risk Management Community Committee Meeting held on 8 December 2025

RECORD NUMBER: 2025/2725
AUTHOR: Jason Theakstone, Manager Engineering Services

EXECUTIVE SUMMARY

The Floodplain Risk Management Community Committee held a meeting on 8 December 2025 and the recommendations from that meeting are presented to the Infrastructure Policy Committee for adoption.

LINK TO DELIVERY/OPERATIONAL PLAN

The recommendation in this report relates to the Delivery/Operational Plan strategy "8.1 Identify and deliver essential water, waste and sewer infrastructure to service the community into the future".

FINANCIAL IMPLICATIONS

Nil

POLICY AND GOVERNANCE IMPLICATIONS

Nil

RECOMMENDATION

1 **That Council acknowledge the reports presented to the Floodplain Risk Management Community Committee at its meeting held on 8 December 2026.**

2 **That Council determine recommendations *3.1* and *3.6* from the minutes of the Floodplain Risk Management Community Committee meeting of 8 December 2026.**

3.1 – Floodplain Risk Management Community Committee - Charter

That the Charter for the Floodplain Risk Management Community Committee be updated with the following changes:

- ***Membership and Roles – add '(non-voting)' after NSW State Emergency Services;***
- ***Quorum – remove wording "Minimum of half voting members and one Councillor" and replace with "One (1) Councillor and one (1) community representative".***

3.6 – Update – Orange Ultimate Flood Modification Scheme – Feasibility and Design Project

1 That Council proceed with the detailed design and review of Environmental Factors for the following FMM's:

I. FMM1 – Cutcliffe Park Detention Basin
II. FMM7 – Ridley Oval Detention Basin
III. FMM8A – Glenroi Oval Detention Basin
IV. FMM9 – a modified project combining FMM9A and a portion of FMM9C required to mitigate FMM9A impacts:

a. FMM9A – East Orange Channel Works (between Icely Road and confluence with Blackmans Swamp Creek)
b. FMM9C – a reduced length of works to be revised through modelling - likely from Leeds Parade to McLachlan Street

2 That Council seek funding for the construction of the Flood Mitigation Measures.

3 **That the remainder of the minutes of the Floodplain Risk Management Community Committee from its meeting held on 8 December 2026 be adopted.**

2.1 Minutes of the Floodplain Risk Management Community Committee Meeting held on 8 December 2025

FURTHER CONSIDERATIONS

The recommendation of this report has been assessed against Council's key risk categories and the following comments are provided:

Service/Project Delivery	Nil with this recommendation.
Financial	Project funded from grant.
Reputation/Political	Nil with this recommendation.
Environment	Nil with this recommendation.
Compliance	Nil with this recommendation.
People & WHS	These works could save life and limb.
Information Technology/ Cyber Security	Nil with this recommendation.

ATTACHMENTS

1 Minutes of the Meeting of the Floodplain Risk Management Community Committee held on 8 December 2025, 2025/2673⇩

2 Agenda of the Meeting of the Floodplain Risk Management Community Committee held on 8 December 2025, 2025/2640⇩

Attachment 1 Minutes of the Meeting of the Floodplain Risk Management Community Committee held on 8 December 2025

ORANGE CITY COUNCIL

MINUTES OF THE FLOODPLAIN RISK MANAGEMENT COMMUNITY COMMITTEE

HELD IN COUNCILLORS WORKROOM, CIVIC CENTRE, BYNG STREET, ORANGE

ON 8 DECEMBER 2025

COMMENCING AT 5:00 PM

1 INTRODUCTION

ATTENDANCE

Cr Tammy Greenhalgh (Chairperson) (Deputy Mayor), Craig Ronan, Glenn Floyd, Kate Browning (DPIE), Manager Engineering Services, Works Manager, Manager Depot, Airport and Emergency Services, Manager City Presentation, Manager Development Assessments

1.1 APOLOGIES

RESOLVED **Cr T Greenhalgh/Mr G Floyd**

That the apologies be accepted from Mr R Kidd for the Floodplain Risk Management Community Committee meeting on 8 December 2025.

1.2 ACKNOWLEDGEMENT OF COUNTRY

The Chairperson conducted an Acknowledgement of Country.

1.3 DECLARATION OF PECUNIARY INTERESTS, SIGNIFICANT NON-PECUNIARY INTERESTS AND LESS THAN SIGNIFICANT NON-PECUNIARY INTERESTS

Nil.

2 PREVIOUS MINUTES

RESOLVED **Mr C Ronan/Mr G Floyd**

That the Minutes of the Meeting of the Floodplain Risk Management Community Committee held on 30 August 2023 (copies of which were circulated to all members) be and are hereby confirmed as a true and accurate record of the proceedings of the Floodplain Risk Management Community Committee meeting held on 30 August 2023.

3 GENERAL REPORTS

3.1 FLOODPLAIN RISK MANAGEMENT COMMUNITY COMMITTEE - CHARTER

TRIM REFERENCE: 2025/2621

RECOMMENDATION **Cr T Greenhalgh/Mr G Floyd**

That the Charter for the Floodplain Risk Management Community Committee be updated with the following changes:

Membership and Roles – add '(non-voting)' after NSW State Emergency Services;

Quorum – remove wording "Minimum of half voting members and one Councillor" and replace with "One (1) Councillor and one (1) community representative".

3.2 POST CONFERENCE REPORT - 2025 FLOODPLAIN MANAGEMENT AUSTRALIA NATIONAL CONFERENCE 13-16 MAY 2025

TRIM REFERENCE: 2025/2610

RECOMMENDATION **Cr T Greenhalgh/Mr G Floyd**

That the information provided in the attached report by Cr Tammy Greenhalgh be noted.

3.3 C2 BASIN UPDATE

TRIM REFERENCE: 2025/2599

RECOMMENDATION **Cr T Greenhalgh/Mr G Floyd**

That the Floodplain Risk Management Community Committee note the report on the C2 Basin Update.

3.4 C7 BASIN UPDATE

TRIM REFERENCE: 2025/2600

RECOMMENDATION **Cr T Greenhalgh/Mr G Floyd**

That the Floodplain Risk Management Committee note the report on the C7 Basin Update.

3.5 MARCH STREET BRIDGE

TRIM REFERENCE: 2025/2609

RECOMMENDATION **Cr T Greenhalgh/Mr G Floyd**

That the Floodplain Risk Management Community Committee note the report on the March Street Bridge.

3.6 UPDATE - ORANGE ULTIMATE FLOOD MODIFICATION SCHEME – FEASIBILITY AND DESIGN PROJECT

TRIM REFERENCE: 2025/2598

RECOMMENDATION **Cr T Greenhalgh/Mr G Floyd**

1 That Council proceed with the detailed design and Review of Environmental Factors for the following FMM's:

   I. FMM1 – Cutcliffe Park Detention Basin

   II. FMM7 – Ridley Oval Detention Basin

   III. FMM8A – Glenroi Oval Detention Basin

   IV. FMM9 – a modified project combining FMM9A and a portion of FMM9C required to mitigate FMM9A impacts:

      a. FMM9A – East Orange Channel Works (between Icely Road and confluence with Blackmans Swamp Creek

      b. FMM9C – a reduced length of works to be revised through modelling -likely from Leeds Parade to McLachlan St.

2 That Council seek funding for the construction of the Flood Mitigation Measures.

THE MEETING CLOSED AT 5.30PM.

ORANGE CITY COUNCIL

FLOODPLAIN RISK MANAGEMENT COMMUNITY COMMITTEE

AGENDA

8 DECEMBER 2025

Notice is hereby given, in accordance with the provisions of the Local Government Act 1993 that a **FLOODPLAIN RISK MANAGEMENT COMMUNITY COMMITTEE MEETING of ORANGE CITY COUNCIL** will be held in the **COUNCILLORS WORKROOM, CIVIC CENTRE, BYNG STREET, ORANGE on Monday, 8 December 2025** commencing at **5:00 PM.**

Barry Omundson
CHIEF EXECUTIVE OFFICER

For apologies, please contact Jason Theakstone on 6393 8505.

Attachment 2 Agenda of the Meeting of the Floodplain Risk Management Community Committee held on 8 December 2025

ORANGE CITY COUNCIL

FLOODPLAIN RISK MANAGEMENT COMMUNITY COMMITTEE

8 DECEMBER 2025

AGENDA

EVACUATION PROCEDURE

In the event of an emergency, the building may be evacuated. You will be required to vacate the building. The Committee Clerk will now identify the emergency muster point.

Under no circumstances is anyone permitted to re-enter the building until the all clear has been given and the area deemed safe by authorised personnel.

In the event of an evacuation, a member of Council staff will assist any member of the public with a disability to vacate the building.

1 INTRODUCTION 3
1.1 Apologies 3
1.2 Acknowledgement of Country 3
1.3 Declaration of pecuniary interests, significant non-pecuniary interests and less than significant non-pecuniary interests 3
2 PREVIOUS MINUTES 4
2.1 Minutes of the Meeting of the Floodplain Risk Management Community Committee held on 30 August 2023 5
3 GENERAL REPORTS 7
3.1 Floodplain Risk Management Community Committee - Charter 7
3.2 Post Conference Report - 2025 Floodplain Management Australia National Conference 13-16 May 2025 11
3.3 C2 Basin Update 15
3.4 C7 Basin Update 17
3.5 March Street Bridge 19
3.6 Update - Orange Ultimate Flood Modification Scheme – Feasibility and Design Project 21

1 INTRODUCTION

MEMBERS

Cr Tammy Greenhalgh (Chairperson) (Deputy Mayor), Craig Ronan, Reg Kidd, Glenn Floyd, CEO, Director Technical Services, Strategic Planning and Design Engineer, Works Manager, Transport Asset Engineer, Manager Development Assessments, Manager Engineering Services, Manager Depot, Airport & Emergency Services

1.1 Apologies

1.2 Acknowledgement of Country

I would like to acknowledge the Traditional Custodians of the land on which we meet today, the people of the Wiradjuri Nation. I pay my respects to Elders past and present, and extend those respects to Aboriginal Peoples of Orange and surrounds, and Aboriginal people here with us today.

1.3 Declaration of pecuniary interests, significant non-pecuniary interests and less than significant non-pecuniary interests

The provisions of Chapter 14 of the Local Government Act, 1993 (the Act) regulate the way in which Councillors and designated staff of Council conduct themselves to ensure that there is no conflict between their private interests and their public role.

The Act prescribes that where a member of Council (or a Committee of Council) has a direct or indirect financial (pecuniary) interest in a matter to be considered at a meeting of the Council (or Committee), that interest must be disclosed as soon as practicable after the start of the meeting and the reasons given for declaring such interest.

As members are aware, the provisions of the Local Government Act restrict any member who has declared a pecuniary interest in any matter from participating in the discussion or voting on that matter, and requires that member to vacate the Chamber.

Council's Code of Conduct provides that if members have a non-pecuniary conflict of interest, the nature of the conflict must be disclosed. The Code of Conduct also provides for a number of ways in which a member may manage non pecuniary conflicts of interest.

RECOMMENDATION

It is recommended that Committee Members now disclose any conflicts of interest in matters under consideration by the Floodplain Risk Management Community Committee at this meeting.

2 PREVIOUS MINUTES

RECOMMENDATION

That the Minutes of the Meeting of the Floodplain Risk Management Community Committee held on 30 August 2023 (copies of which were circulated to all members) be and are hereby confirmed as a true and accurate records of the proceedings of the Floodplain Risk Management Community Committee meeting held on 30 August 2023.

ATTACHMENTS

1 Minutes of the Meeting of the Floodplain Risk Management Community Committee held on 30 August 2023

ORANGE CITY COUNCIL

MINUTES OF THE

FLOODPLAIN RISK MANAGEMENT COMMUNITY COMMITTEE

HELD IN COUNCILLORS WORKROOM, CIVIC CENTRE, BYNG STREET, ORANGE

ON 30 AUGUST 2023

COMMENCING AT 5:00 PM

1 INTRODUCTION

ATTENDANCE

Cr G Floyd (Chairperson), Mr Robert Alford, Mr Craig Ronan, Ms Kathryn Read, Manager Engineering Services, Manager Depot, Airport & Emergency Services

1.1 Apologies and Leave of Absence

RECOMMENDATION **Cr G Floyd/Mr R Alford**

That the apologies be accepted from Cr J Evans and Manager Development Assessments for the Floodplain Risk Management Community Committee meeting on 30 August 2023.

1.2 Acknowledgement of Country

The Chairperson conducted an Acknowledgement of Country.

1.3 Declaration of pecuniary interests, significant non-pecuniary interests and less than significant non-pecuniary interests

Nil

2 PREVIOUS MINUTES

RECOMMENDATION **Cr G Floyd/Mr R Alford**

That the Minutes of the Meeting of the Floodplain Risk Management Community Committee held on 11 October 2022 (copies of which were circulated to all members) be and are hereby confirmed as a true and accurate record of the proceedings of the Floodplain Risk Management Community Committee meeting held on 11 October 2022.

MINUTES OF FLOODPLAIN RISK MANAGEMENT COMMUNITY COMMITTEE 30 AUGUST 2023

3 GENERAL REPORTS

3.1 ORANGE FLOOD MODEL AND VEGETATION MANAGEMENT PLAN

TRIM REFERENCE: 2023/1355

RECOMMENDATION **Cr G Floyd/Mr R Alford**

That Council:

1. Maintain its Lyall Australian Rainfall and Runoff (AR&R) 1987 model and flood mapping along with the current DCP controls borne from the mapping: and
2. Adopt the Vegetation Management Plan.

3.2 NEW FLOOD RISK MANAGEMENT MANUAL

TRIM REFERENCE: 2023/1367

RECOMMENDATION **Cr G Floyd/Mr R Alford**

That Council adopt the use of the Flood Risk Management Manual: the policy and manual for flood liable land (2023).

GENERAL BUSINESS

- Craig Ronan advised he is reviewing the Flood Plan for Orange City Council, looking at installing new gauges around Orange City Council and that Australia has adopted a new early warning system.
- Rob Alford shared his concerns over the accuracy and maintenance of the gauges, would like all river gauges accessible to the public and would like to see a weather station on top of Mt Canobolas. Jason Theakstone will pass on Mr Alford's wishes onto the Bureau of Meteorology.

THE MEETING CLOSED AT 6.13PM.

3 GENERAL REPORTS

3.1 Floodplain Risk Management Community Committee - Charter

RECORD NUMBER: 2025/2621
AUTHOR: Jason Theakstone, Manager Engineering Services

EXECUTIVE SUMMARY

Orange City Council has developed and adopted the Charter for the Floodplain Risk Management Community Committee.

The Community Committee structure was determined on 20 November 2024 and the draft Charters were reviewed at that time.

The Committee Charter sets out the operations and composition of the Committee and is presented for consideration and endorsement by the Committee.

The Committee members are asked to review the charter, make any necessary updates and refer the Charter to Council for Adoption.

The final approval lays with Council.

LINK TO DELIVERY/OPERATIONAL PLAN

The recommendation in this report relates to the Delivery/Operational Plan strategy "15.3 Ensure financial stability and support efficient ongoing operation".

FINANCIAL IMPLICATIONS

Nil

POLICY AND GOVERNANCE IMPLICATIONS

All Community Committee Charters have been updated to reflect Council's requirements and to comply with Council's Code of Meeting Practice.

RECOMMENDATION

That the Charter for the Floodplain Risk Management Community Committee me adopted.

FURTHER CONSIDERATIONS

The recommendation of this report has been assessed against Council's key risk categories and the following comments are provided:

Service/Project Delivery	Adoption of the charter will support positive engagement with the community, which in turn will assist in sound decision-making related to service and project delivery.
Financial	Nil.
Reputation/Political	Adoption of a charter in line with Council requirements for members to adhere to will mitigate and reputational or political implications.
Environment	Nil.
Compliance	Nil.
People & WHS	Nil.
Information Technology/ Cyber Security	Nil.

3.1 Floodplain Risk Management Community Committee - Charter

SUPPORTING INFORMATION

The Charter for the current term of the Committee is attached for consideration and endorsement by the Committee. The Committee may, if needed, recommend changes to the Charter be considered. Any such changes cannot be inconsistent with Council's Code of Meeting Practice.

Members should consider:

- Membership
- Quorum
- Meeting cycle
- Meeting Day/Time

The updated Committee Charter will be provided to the Council Policy Committee with the minutes for adoption.

ATTACHMENTS

1 Floodplain Risk Management Community Committee Charter 2024 - DRAFT, D24/120099

ORANGE CITY COUNCIL

COMMUNITY COMMITTEE CHARTER

FLOODPLAIN RISK MANAGEMENT

D24/120099

Community Committees play a vital role in helping Council to make informed decisions about the actions taken. The program is a key driver in Council's community engagement *'collaborate'* value, linking **to item 15.3 - provide opportunities for widespread and quality engagement, and where appropriate, shared decision making** of the Community Strategic Plan.

Purpose

To advise council and make recommendations in relation to the development and implementation of Orange City Council's Floodplain Risk Management Plan.

To strengthen engagement between Council and community as identified in Council's Community Strategic and Engagement Plans, and to support a consultative and collaborative approach in the decision-making processes that impact the City of Orange, its people and surrounds.

The Committee does not have a role in the operational function of Council, and any recommendations made may be adopted, amended or declined. Operational Activities are the responsibility of the Chief Executive Officer and staff. Equally, where Council has adopted a Strategic Policy or Strategic Planning document, the Committee must observe the Council position as set out in that policy, plan or document.

Reports To

Infrastructure Policy Committee.

Policy Committee are Council sub-committees designed to support increased engagement and ownership of Councillors in areas of interest and expertise, and to improve the decision making processes.

Responsibilities

To be aware of the needs of the community and ensure that this knowledge is reflected in its activities and recommendations to Council.

To develop and maintain a Community Committee Action Plan that is informed by the knowledge of members and the strategic priorities of Council to support recommendations made and activities undertaken.

The committee and its members must conduct themselves and their business in accordance with Orange City Council's Code of Conduct, Code of Meeting Practice and any procedures relating to Community Committees as approved by the Council.

Term

The Floodplain Risk Management Community Committee shall dissolve at the General Election of Orange City Council. Council may dissolve the Committee at any time by resolution of Council.

ORANGE CITY COUNCIL

D24/120099

Membership and Roles

- Chairperson – an elected Councillor
- Three Councillors including the Chairperson
- Department of Climate Change, Energy, the Environment & Water (non-voting member, advisory only)
- Local Land Services
- Business Orange
- State Emergency Service
- Committee Clerk (non-voting) – as nominated by the Chief Executive Officer
- Council staff (non-voting) – as nominated by the Chief Executive Officer
- Up to two (2) community representative(s) including from other relevant government or community agencies

Committee Clerk & Staff Members

The Chief Executive Officer will provide a Committee Clerk who is a sufficiently skilled Manager or Director who will be the representative of the Chief Executive Officer, and will exercise the functions of the Chief Executive Officer so far as they are relevant to the Committee and its Chairperson. The Committee Clerk will be responsible for the management of Committee correspondence, meetings, agendas & minutes.

Quorum

Minimum of half voting members and one Councillor.

Meeting Frequency

As required, with specific meeting dates and times to be determined by the Committee.

Voting

All members have one vote only, including the Chairperson. In circumstances of an equality of votes, the matter is to be referred to Council (via the Policy Committee) for determination.

Reports and Recording

Matters to be considered by the Committee must be included in the agenda for the meeting, and must be provided in writing to the Committee Clerk at least ten (10) business days before the scheduled meeting.

An agenda will be distributed electronically to members at least one (1) week before a scheduled meeting.

Formal minutes of meetings of the Committee will be produced in accordance with Council's Code of Meeting Practice and will be produced by nominated staff members via InfoCouncil – Council's dedicated software program for the production of local council business papers.

Vacancies

Vacancies may arise during the term of the Committee. If a vacancy does occur, the Committee may invite an individual to join the Committee, or seek expressions of interest to fill the vacancy.

Relevant Policies and Documents

Community Committee Member Information Pack	Orange Community Strategic Plan
Orange City Council Code of Conduct	Delivery/Operational Plan
Orange City Council Code of Meeting Practice	Asset Management Plan Strategy and Plans

Copies of these and other documents are available on Council's website at www.orange.nsw.gov.au, from the Committee Clerk or the Council's Governance team.

3.2 Post Conference Report - 2025 Floodplain Management Australia National Conference 13-16 May 2025

RECORD NUMBER: 2025/2610
AUTHOR: Jason Theakstone, Manager Engineering Services

EXECUTIVE SUMMARY

The 2025 Floodplain Management Australia (FMA) National Conference was held from 13-16 May 2025 in Melbourne. Cr Tammy Greenhalgh provided a report to the Council Meeting of 3 June 2025 and this report is provided to this Committee for information.

LINK TO DELIVERY/OPERATIONAL PLAN

The recommendation in this report relates to the Delivery/Operational Plan strategy "7.3 Plan for growth and development that balances liveability with valuing the local environment".

FINANCIAL IMPLICATIONS

Nil

POLICY AND GOVERNANCE IMPLICATIONS

Nil

RECOMMENDATION

That the information provided in the attached report by Cr Tammy Greenhalgh be noted.

FURTHER CONSIDERATIONS

The recommendation of this report has been assessed against Council's key risk categories and the following comments are provided:

Service/Project Delivery	Nil for this recommendation
Financial	Nil for this recommendation
Reputation/Political	Nil for this recommendation
Environment	Nil for this recommendation
Compliance	Nil for this recommendation
People & WHS	Nil for this recommendation
Information Technology/ Cyber Security	Nil for this recommendation

ATTACHMENTS

1 Report - 2025 Floodplain Management Australia National Conference - 13-16 May 2025, D25/145516

COUNCIL MEETING 3 JUNE 2025

4.4 NOTICE OF MOTION - POST CONFERENCE REPORT - 2025 FLOODPLAIN MANAGEMENT AUSTRALIA NATIONAL CONFERENCE - 13-16 MAY 2025

RECORD NUMBER: 2025/965

I, **CR TAMMY GREENHALGH** wish to move the following Notice of Motion at the Council Meeting of 3 June 2025:

MOTION

That Council note the contents of this report and continues to support Floodplain Management Australia.

BACKGROUND

The 2025 Floodplain Management Australia (FMA) National Conference, held from 13–16 May 2025 at Pullman Melbourne on the Park, marked a historic moment as it is the first time the event was hosted in Victoria. Themed "Flood Knows No Boundaries," the conference brought together over 400 delegates from across Australia and internationally, including engineers, planners, emergency managers, researchers, insurers and community leaders

FMA, established in 1961, plays a pivotal role in promoting sustainable floodplain development and reducing flood risk. The 2025 conference came at a critical time, as Australia continues to face increasing flood events due to climate change, urban expansion, and aging infrastructure.

The conference opened with a Welcome to Country and a keynote by a leading Indigenous water knowledge expert, who emphasized the importance of integrating First Nations perspectives into floodplain planning. This was followed by a series of plenary sessions that addressed:

- Climate change and flood risk: Presentations from CSIRO and the Bureau of Meteorology highlighted updated projections showing increased rainfall intensity and frequency of extreme events.
- National flood policy reform: Representatives from the Department of Climate Change, Energy, the Environment and Water (DCCEEW) discussed the evolving National Adaptation Plan and its implications for local governments.
- International perspectives: Experts from the Netherlands and the United States shared lessons from large-scale flood mitigation projects, including managed retreat and adaptive infrastructure.

These sessions set the tone for a conference focused on collaboration, innovation, and resilience.

The conference featured over 40 technical sessions across multiple streams. Key themes included:

1 Flood Modelling and Forecasting
- Advances in 2D hydraulic modelling using LiDAR and drone data.
- Real-time flood forecasting systems integrating machine learning and IoT sensors.
- Case studies from Queensland and New South Wales on model calibration and validation.

2 Urban Flood Management
- Challenges of managing stormwater in high-density developments.
- Use of green infrastructure (e.g. rain gardens, permeable pavements) to reduce runoff.
- Integration of flood risk into planning schemes and zoning codes.

3 Community Engagement and Risk Communication
- Innovative tools for visualising flood risk (e.g. virtual reality, interactive maps).
- Strategies for engaging culturally and linguistically diverse communities.
- Lessons from recent flood events on improving public trust and preparedness.

The keynote speakers were two Year 6 students from St Joseph's Catholic Primary School in Eugowra who had developed a flood early warning system. The project was awarded the "Making a Difference Award" at the 2024 STEM showcase in Brisbane.


St Joseph's Catholic Primary School, Eugowra NSW

A highlight of the conference was the field trips to key flood-prone areas in and around Melbourne, including:
- The Maribyrnong River floodplain, where participants examined recent flood impacts and mitigation works.
- The Moonee Ponds Creek corridor, showcasing integrated water management and community-led greening projects.
- Visits to stormwater harvesting sites and constructed wetlands demonstrating nature-based solutions.

These excursions provided valuable context for the technical discussions and highlighted the importance of place-based approaches to floodplain management.

The trade exhibition featured over 30 exhibitors including:
- Technology providers offering AI-powered flood prediction tools.
- Consulting firms showcasing integrated catchment management solutions.
- Government agencies presenting new guidelines and funding programs.

Notable innovations included:
- Smart flood sensors with satellite connectivity.
- Digital twin platforms for flood scenario planning.
- Community alert apps with multilingual support and geofencing.

The exhibition underscored the growing role of data, design, and digital tools in managing flood risk.

Several awards were presented including:
- Young Floodplain Manager of the Year.
- Excellence in Flood Risk Communication.
- Best Paper Presentation.

COUNCIL MEETING **3 JUNE 2025**

4.4 Notice of Motion - Post Conference Report - 2025 Floodplain Management Australia National Conference - 13-16 May 2025

Orange City Council currently has numerous projects in the feasibility, design and construction space, and the insights of this conference has added value to these projects. Council's Manager of Engineering is considering drafting a paper for next year's conference discussing the successes of C7, C2 and C6 basins along with the outcomes of the current feasibility and design of 8 flood mitigation projects.

Looking ahead, FMA announced that the 2026 conference will be held on the Gold Coast, with a continued focus on climate resilience, equity, and innovation. It is recommended that Council continue its support for the FMA.

Signed Cr Tammy Greenhalgh

3.3 C2 Basin Update

RECORD NUMBER: 2025/2599
AUTHOR: Jason Theakstone, Manager Engineering Services

EXECUTIVE SUMMARY
This report serves to update the committee on the construction of C2 stormwater retention basin.

LINK TO DELIVERY/OPERATIONAL PLAN
The recommendation in this report relates to the Delivery/Operational Plan strategy "7.3 Plan for growth and development that balances liveability with valuing the local environment".

FINANCIAL IMPLICATIONS
Nil

POLICY AND GOVERNANCE IMPLICATIONS
Nil

RECOMMENDATION

That the Floodplain Risk Management Community Committee note the report on the C2 Basin Update.

FURTHER CONSIDERATIONS
The recommendation of this report has been assessed against Council's key risk categories and the following comments are provided:

Service/Project Delivery	Nil with this recommendation
Financial	Nil with this recommendation
Reputation/Political	Nil with this recommendation
Environment	Nil with this recommendation
Compliance	Nil with this recommendation
People & WHS	Nil with this recommendation
Information Technology/ Cyber Security	Nil with this recommendation

SUPPORTING INFORMATION

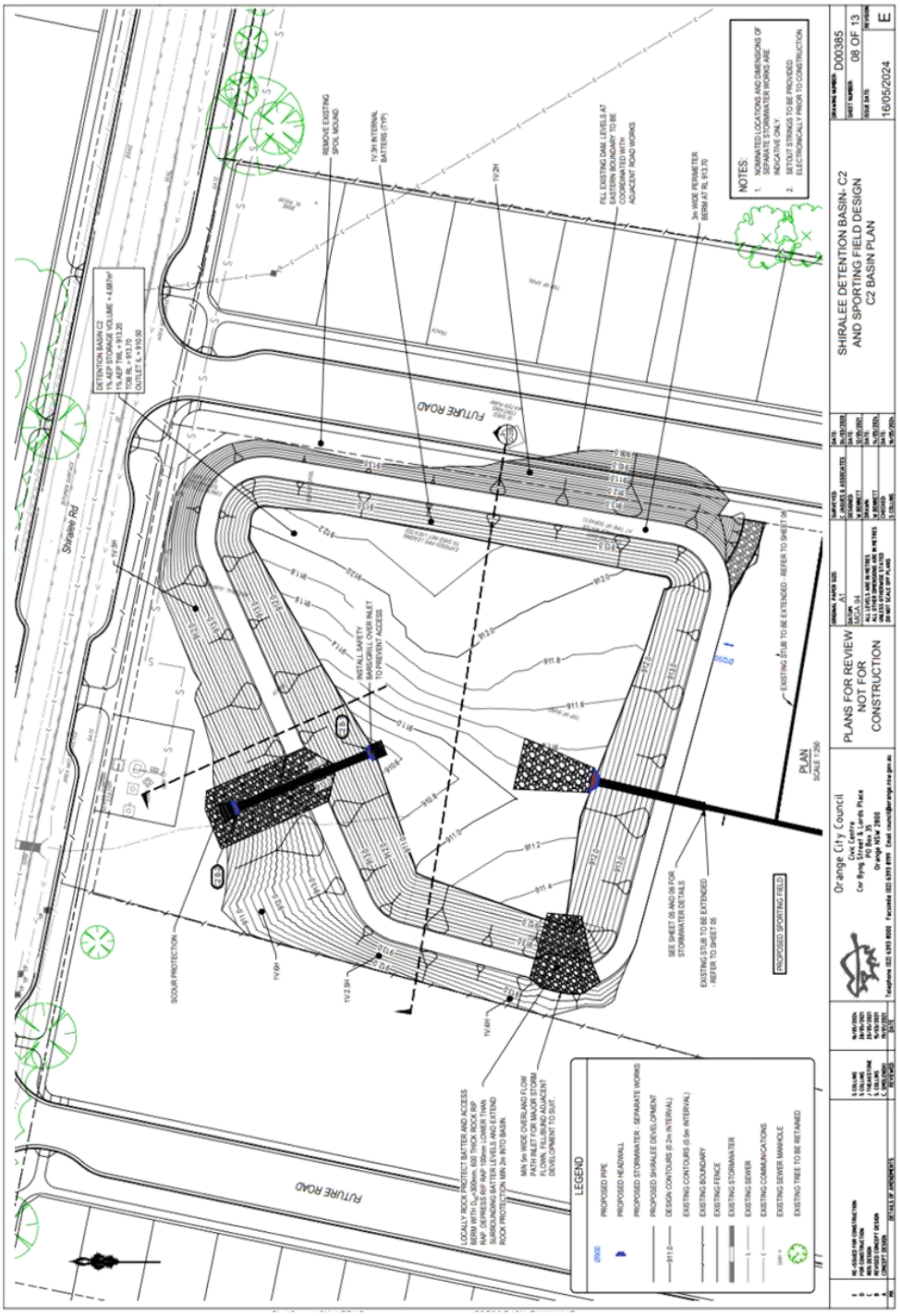
The Shiralee Development Control Plan (DCP) shows several stormwater retention basins throughout Shiralee. These basins are planned to mitigate the increase of peak flows downstream of Shiralee's development to pre-development flows.

Council was awarded part funding from the Disaster Recovery Fund 1 to construct C2 and part C6 basin in 2024. A tender to construct C2 basin was presented to Council 7 October 2025 where it was resolved to award a contract to Farra Civil Pty Ltd to construct the basin.

Farra Civil and Council have entered a contract for the construction of the basin and works are about to commence shortly.

The design of C2 basin is shown below:

3.3 C2 Basin Update



3.4 C7 Basin Update

RECORD NUMBER: 2025/2600
AUTHOR: Jason Theakstone, Manager Engineering Services

EXECUTIVE SUMMARY
This report serves to update the committee on the repair of C7 stormwater retention basin.

LINK TO DELIVERY/OPERATIONAL PLAN
The recommendation in this report relates to the Delivery/Operational Plan strategy "7.3 Plan for growth and development that balances liveability with valuing the local environment".

FINANCIAL IMPLICATIONS
Nil

POLICY AND GOVERNANCE IMPLICATIONS
Nil

RECOMMENDATION

That the Floodplain Risk Management Committee note the report on the C7 Basin Update.

FURTHER CONSIDERATIONS
The recommendation of this report has been assessed against Council's key risk categories and the following comments are provided:

Service/Project Delivery	Nil with this recommendation
Financial	Nil with this recommendation
Reputation/Political	Nil with this recommendation
Environment	Nil with this recommendation
Compliance	Nil with this recommendation
People & WHS	Nil with this recommendation
Information Technology/ Cyber Security	Nil with this recommendation

SUPPORTING INFORMATION
The Central West experienced a significant storm event 14 November 2022 that saw Eugowra experience the largest flood in living history that claimed 2 lives. The flood the Eugowra experienced was back calculated to a 1 in 5000-year event. Orange did not experience such an event due to its location within the catchment.

Orange did however experience significant storm damage from the 14 November 2022 event. C7 Stormwater Retention Basin located at Pines Lane, Shiralee was breached during the storm event rendering the basin unable to provide any protection to Orange during large storm events.

An aerial photograph showing the breached basin, taken 19 November 2022 is shown below:

3.4 C7 Basin Update

Council received funding from NSW Public Works to repair the breach early 2024 and a tender was presented to Council's 2 April 2024 meeting to remediate the basin.

A subsequent contract was awarded to Precision Civil Infrastructure Pty Ltd at a cost of $630,629 to repair the breach and a photo of the repaired basing wall is presented below:

It is recommended that Council note the body of this report and the basin's remediation.

3.5 March Street Bridge

RECORD NUMBER: 2025/2609
AUTHOR: Jason Theakstone, Manager Engineering Services

EXECUTIVE SUMMARY
This report serves to update the Committee on the construction of March Street Bridge.

LINK TO DELIVERY/OPERATIONAL PLAN
The recommendation in this report relates to the Delivery/Operational Plan strategy "7.3 Plan for growth and development that balances liveability with valuing the local environment".

FINANCIAL IMPLICATIONS
Nil

POLICY AND GOVERNANCE IMPLICATIONS
Nil

RECOMMENDATION

That the Floodplain Risk Management Community Committee note the report on the March Street Bridge.

FURTHER CONSIDERATIONS
The recommendation of this report has been assessed against Council's key risk categories and the following comments are provided:

Service/Project Delivery	Nil with this recommendation
Financial	Nil with this recommendation
Reputation/Political	Nil with this recommendation
Environment	Nil with this recommendation
Compliance	Nil with this recommendation
People & WHS	Nil with this recommendation
Information Technology/ Cyber Security	Nil with this recommendation

SUPPORTING INFORMATION
Council was awarded part funding in 2025 from the Disaster Recovery Fund 2 to remove the existing 3 x 1500mm stormwater pipes beneath March Street and construct a bridge. The construction of the bridge considerably increases the waterway area beneath March Street and will help alleviate flooding surrounding properties along the East Orange Channel.

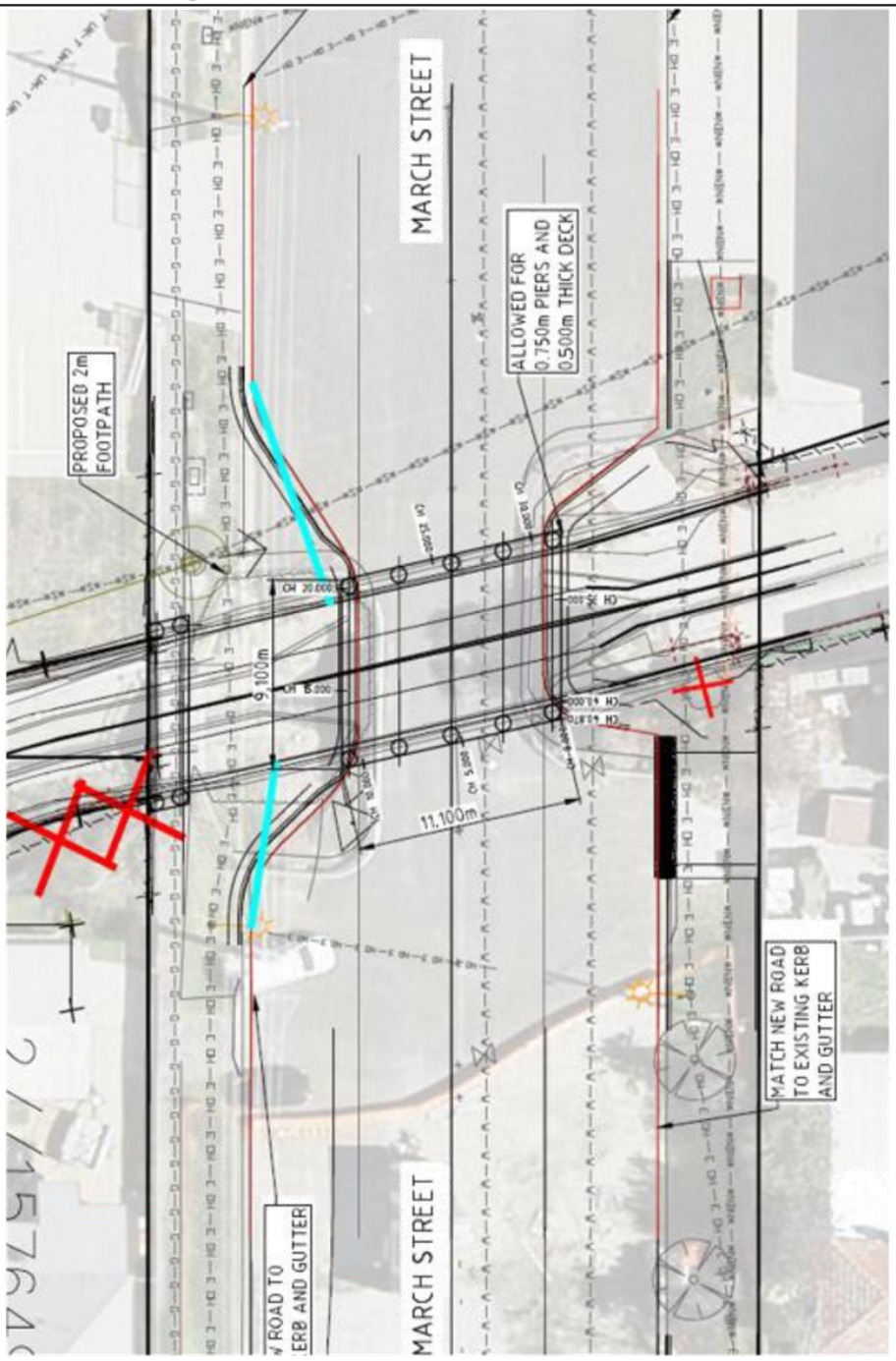
Council advertised a conceptual design in June 2025 and sought tenders for a design and construct tender for the replacement of the stormwater pipes with a bridge in July 2025.

Council's August 2025 meeting resolved *"That the Chief Executive Officer be authorised to enter into a standard contract with GC Civil Contracting Pty Ltd for the Design and Construction of March Street Bridge on East Orange Channel (F4358) for the amount of $1,124,637.00 (excl. GST)"*

A contract has been awarded to GC Civil Contracting Pty Ltd with design works being imminent.

A copy of the conceptual bridge design is shown below:

3.5 March Street Bridge



It is recommended that the Committee note the body of this report.

3.6 Update - Orange Ultimate Flood Modification Scheme – Feasibility and Design Project

RECORD NUMBER: 2025/2598
AUTHOR: Jason Theakstone, Manager Engineering Services

EXECUTIVE SUMMARY

This report serves to update the Committee on the feasibility outcomes of the F4291 Orange Ultimate Flood Modification Scheme – Feasibility and Design Project and resolve the measures to design from the feasibility.

LINK TO DELIVERY/OPERATIONAL PLAN

The recommendation in this report relates to the Delivery/Operational Plan strategy "7.1 Ensure best practice in climate change mitigation and adaption options for Council and community projects".

FINANCIAL IMPLICATIONS

Nil

POLICY AND GOVERNANCE IMPLICATIONS

Nil

RECOMMENDATION

1 **That Council proceed with the detailed design and Review of Environmental Factors for the following FMM's:**

   I. **FMM1 – Cutcliffe Park Detention Basin**

   II. **FMM7 – Ridley Oval Detention Basin**

   III. **FMM8A – Glenroi Oval Detention Basin**

   IV. **FMM9 – a modified project combining FMM9A and a portion of FMM9C required to mitigate FMM9A impacts:**

      a. **FMM9A – East Orange Channel Works (between Icely Road and confluence with Blackmans Swamp Creek**

      b. **FMM9C – a reduced length of works to be revised through modelling -likely from Leeds Parade to McLachlan St.**

2 **That Council seek funding for the construction of the Flood Mitigation Measures.**

FURTHER CONSIDERATIONS

The recommendation of this report has been assessed against Council's key risk categories and the following comments are provided:

Service/Project Delivery	Nil with this recommendation.
Financial	Nil with this recommendation.
Reputation/Political	Downstream property owners below FMM's with low BCR may not attract funding.
Environment	Only positive effect.
Compliance	Nil with this recommendation.
People & WHS	Nil with this recommendation.
Information Technology/ Cyber Security	Nil with this recommendation.

3.6 Update - Orange Ultimate Flood Modification Scheme – Feasibility and Design Project

SUPPORTING INFORMATION

Council may remember at its 8 August 2024 Council meeting resolving:

"That Council resolves to:

1 *Accept the tender from BG&E Pty Limited to the value of $876,565 for Items 1 – 6 within the Request for Tender, subject to concurrence from the Department of Climate Change, Energy, the Environment and Waters;*
2 *Accept any of the separable portions within the funding constraints dependant on the outcome of Items 1 – 6; and*
3 *Affix the Common Seal to any contractual documents for this tender."*

The Orange Ultimate Flood Modification Scheme (OUFMS) was created as an outcome of the Blackmans Swamp Creek and Ploughmans Creek FRMS&P. It seeks to provide considerable flood relief to some 129 properties affected by flooding in the 1% AEP event.

The aim of the OUFMS is:

- Reduction in above floor level inundation of public buildings, commercial/industrial developments and residential dwellings;
- Reduction in the prevalence of high hazard level flooding;
- Reduction in overland flow and nuisance flooding; and
- Removal of surcharge of the CBD Trunk Drainage Line at Kite Street during storms up to a 1% AEP intensity.

Geotechnical evaluation, conceptual design and flood modelling to determine the feasibility of the following projects have been undertaken:

- FMM1 – Cutcliff Park Detention Basin;
- FMM2 – Kenna Street Stormwater Drainage Upgrade Works;
- FMM5 – Rifle Range Creek Railway Detention Basin;
- FMM6 – Moulder Park Detention Basin;
- FMM7 – Ridley Oval Detention Basin;
- FMM8A – Glenroi Oval Detention Basin;
- FMM9A – East Orange Channel Works (between Icely Road and confluence with Blackmans Swamp Creek);
- FMM9C – Blackmans Creek Channel Widening.

A detailed flood modelling report is attached to this report describing:

- The updates to flood modelling;
- The concept design assessment;
- Any outcomes and recommendations.

The report further considers the viability of each project using flood damages assessment and a benefit cost analysis to determine a Benefit Cost Ratio (BCR) using present day costs for an ensemble of storm events.

A summary of each of the Flood Mitigation Measures (FMM), the Benefit/Cost Ratio and recommendation is listed below:

3.6 Update - Orange Ultimate Flood Modification Scheme – Feasibility and Design Project

FMM1 – Cutcliffe Park Detention Basin

Refer to Section 4 (PDF Pages 23-26).

FMM1 comprises a new basin at Cutcliffe Park. The concept design also includes capping an existing stormwater pipe which runs along the southern side of the park and diverting this through the basin to collect surcharging flows into the basin.

Table 4-3 – FMM1 BCA

Total Capital Cost	$ 642,000
Recurrent Cost	$ 0
Present Value Benefit	$ 996,450
NPV (5% Discount)	$ 354,450
BCR	1.55

Recommendation: FMM1 has good economic outcomes and is recommended for further design development.

FMM2 - Kenna Street Stormwater Drainage Upgrade Works

Refer to Section 5 (Page 27- 29).

Through the flood modelling FMM2 was refined to reduce the scale of works compared to the original FRMS&P concept option. Addition of existing pipes into the flood model, and other flood modelling updates, resulted in reduced above ground flood levels (refer section 2.2.4.4) which mean that the proposed works within 1-3 Moulder Street (160 m duplication of existing 1350 mm diameter RCP) is no longer required.

The FMM2 concept design proposes a stormwater network upgrade along Moulder Street, including the installation of twin 1050 mm diameter RCP stormwater pipes and upgraded junction pits. The system connects to a new 3.0 m x 0.9 m RCBC to replace the existing 3x 900 mm diameter culverts running beneath Woodward Street and increase the capacity of the system. The new RCBC will discharge to the tributary to Blackmans Swamp Creek channel in Elephant Park via an upgraded outlet.

Table 5-3 – FMM2 BCA

Total Capital Cost	$ 9,900,000
Recurrent Cost	$ 0
Present Value Benefit	$521,543
NPV	-$9,378,457
BCR	0.05

Recommendation: FMM2 does not provide an economic or social benefit, therefore will not proceed to detailed design.

3.6 Update - Orange Ultimate Flood Modification Scheme – Feasibility and Design Project

FMM5 – Rifle Range Creek Railway Detention Basin

Refer to Section 6 (Pages 30-33).

FMM5 considers a new embankment upstream of the rail embankment and footpath.

Table 6-3 – FMM5 BCA

Total Capital Cost	$ 1,860,000
Recurrent Cost	$ 5,000
Present Value Benefit	$ 0
NPV	-$1,936,862
BCR	0.00

Recommendation: Options considered for FMM5 progressed to the point that a new embankment would exacerbating existing flood conditions to the rear of James Shean Catholic High School, the public shared path and residential properties along Sundew Circuit. The option development was discussed with Council through the concept design process. As the options provide no flood benefit, do not significantly reduce ponding against the rail embankment and was shown to worsen the depths of flooding upstream, a decision was made to abandon consideration for further detailed design.

FMM6 – Moulder Park Detention Basin

Refer to Section 7 (Pages 34-37).

FMM6 comprises a detention basin within the eastern section of Moulder Park. The basin is designed to attenuate stormwater from upstream catchment before discharging into Blackman Swamp Creek to reduce the flood affection of properties on Lords Place and other areas downstream of Moulder Park before Kite Street. The spillway discharges to Anson Street near Torpy Street.

Table 7-3 – FMM6 BCA

Total Capital Cost	$ 2,840,000
Recurrent Cost	0
Present Value Benefit	$ 325,042
NPV (5% Discount)	-$ 2,514,958
BCR	0.11

Recommendation: FMM6 reduces flow in the channel downstream of the CBD truck drainage culvert, and while standalone provides no economic benefit.

FMM7 – Ridley Oval Detention Basin

Refer to Section 8 (Pages 38-41).

3.6 Update - Orange Ultimate Flood Modification Scheme – Feasibility and Design Project

The FMM7 final concept design proposes a detention basin spanning the Ridley Oval open space, including the dog park west of East Orange Creek. The basin aims to attenuate peak stormwater flows before discharging into the East Orange Creek culverts and to relieve flooding to properties on Warrendine Street. The embankment at the dog park was raised to ensure no overtopping in the 1% AEP event.

Table 8-3 – FMM7 BCA

Total Capital Cost	$ 1,500,000
Recurrent Cost	0
Present Value Benefit	$4,911,115
NPV (5% Discount)	$3,411,115
BCR	3.27

Recommendation: BCR indicated this design should proceed to detailed design

FMM8A – Glenroi Oval Detention Basin

Refer to Section 9 (Pages 42-45).

The FMM8A design involves an embankment around the west and north boundaries of the oval. A spillway discharges toward Moad Street. The outlet comprises a 375 mm diameter pipe connection to the existing twin 600 mm diameter stormwater pipes in Moad Street. The existing 1050 mm diameter stormwater pipe beneath the oval will remain in place.

Table 9-3 – FMM8A BCA

Total Capital Cost	$ 1,290,000
Recurrent Cost	$ 0
Present Value Benefit	$ 3,135,284
NPV	$ 1,845,284
BCR	2.43

Recommendation: A BCR based on a total cost of the option of approximately $1.29 million dollars comes out at 2.43. The option, over its estimated lifespan of 50 years, is estimated to provide sufficient reduction in damages to offset the cost of the project, with a good return on investment of approximately 250% of the construction costs. Therefore, this project will proceed to detailed design.

FMM9A – East Orange Channel Works (between Icely Road and confluence with Blackmans Swamp Creek)

Refer to Section 10 (Pages 46-49).

The FMM9A concept focuses on channel and culvert upgrades along East Orange Creek, from Icely Road through to Summer Street and William Street to the confluence of the two creeks.

3.6 Update - Orange Ultimate Flood Modification Scheme – Feasibility and Design Project

Table 10-3 – FMM9A BCA

Total Capital Cost	$ 7,975,000
Recurrent Cost	0
Present Value Benefit	$ 3,017,977
NPV (5% Discount)	-$ 4,957,023
BCR	0.38

Recommendation: A BCR based on a total cost of the option of approximately $8.0 million dollars comes out at 0.38. The option of completing the channel between McLachlan Street and March Street has obvious social benefit and will therefor proceed to detailed design.

FMM9C – Blackmans Creek Channel Widening

Refer to Section 11 (Pages 50-53).

The FMM9C concept design involves channel widening along Blackmans Swamp Creek between Leeds Parade and the Northern Distributor Road.

Table 11-4 – FMM9C BCA

Total Capital Cost	$ 9,250,000
Recurrent Cost	$ 5,000
Present Value Benefit	-$16,687
NPV (5% Discount)	-$9,343,549
BCR	0.00

Recommendation: Combined with FMM9A which causes increases in flood level in this area, FMM9C could work to reduce the impacts caused by FMM9A, therefore this FMM will proceed to detailed design due to its benefit to the scheme.

FMM9B – Blackmans Creek Channel Widening (bridge option)

Refer to Section 12 (pages 54-55).

The surveyed bridge has a larger cross-sectional area than the bridge modelled in the FRMS&P model. This, combined with the reduction in channel flows due to the ARR2019 updates, means that the bridge has capacity to convey the 1% AEP flows without overtopping. Therefore, the recommendation for replacement of the Leeds Parade Bridge (FMM9B), as documented in the FRMS&P, was considered unnecessary.

Recommendation: FMM9b not to proceed to detailed design.

The committee should note that the result of more than one Flood Mitigation Measure combined can have a positive result. The combination of the FMM's are described as Flood Mitigation Schemes (FMS).

3.6 Update - Orange Ultimate Flood Modification Scheme – Feasibility and Design Project

The following schemes were modelled and economically assessed similar to the FMM's above:

FMS1 comprises:

- FMM1 – Cutcliffe Park Detention Basin;
- FMM2 – Kenna Street Stormwater Drainage Upgrades;
- FMM6 – Moulder Park Detention Basin.

Table 13-2 – FMS1 BCA

Total Capital Cost	$ 13,382,000
Recurrent Cost	$ 0
Present Value Benefit	$1,758,340
NPV (5% Discount)	-$11,623,660
BCR	0.13

Recommendation: While FMM6 delivers localised benefits, its combination with FMM1 and FMM2 in the FMS1 scheme does not demonstrate significant additional flood mitigation downstream. Therefore, it is recommended that the combined FMM1 and FMM2 configuration be investigated further as a more efficient and cost-effective option. However, noting the poor BCR of FMM2 due to high cost and practicability of construction this should be considered with regard to other social and environmental issues.

FMS2 comprises:

- FMM6 – Moulder Park Detention Basin;
- FMM9A – East Orange Creek Channel Works;
- FMM9C – Blackmans Creek Channel Widening.

Table 14-2 – FMS2 BCA

Total Capital Cost	$ 20,065,000
Recurrent Cost	$ 0
Present Value Benefit	$4,377,128
NPV (5% Discount)	-$15,687,872
BCR	0.22

Recommendation: Given the higher cost of FMM6 compared to other basins, its limit benefit on properties upstream of the CBD trunk drainage culvert and the reduced freeboard it causes on properties on National Avenue an assessment of the flood benefits of FMM9A and FMM9C without FMM6 would be beneficial. This could improve the benefit-cost-ratio.

FMS3 comprises:

- FMM7 – Ridley Oval Detention Basin;
- FMM9A – East Orange Creek Channel Works;
- FMM9C – Blackmans Creek Channel Widening.

3.6 Update - Orange Ultimate Flood Modification Scheme – Feasibility and Design Project

Table 15-2 – FMS3 BCA

Total Capital Cost	$ 18,725,000
Recurrent Cost	$0
Present Value Benefit	$ 7,404,212
NPV (5% Discount)	-$ 11,320,788
BCR	0.40

Recommendation: It is recommended to review for the options for the full range of enable storms before progressing to detailed design.

There may be opportunities to reduce the scale of works in FMM9C if this reduced costs as there are significant decreases in the channel water levels. Addition of FMM8a to this scheme may also enhance the BCR.

Post review of the flood modelling it became apparent there are synergies between,

- FMM7 – Ridley Oval Detention Basin
- FMM8A – Glenroi Oval Detention Basin and
- FMM9A – East Orange Creek Channel Works

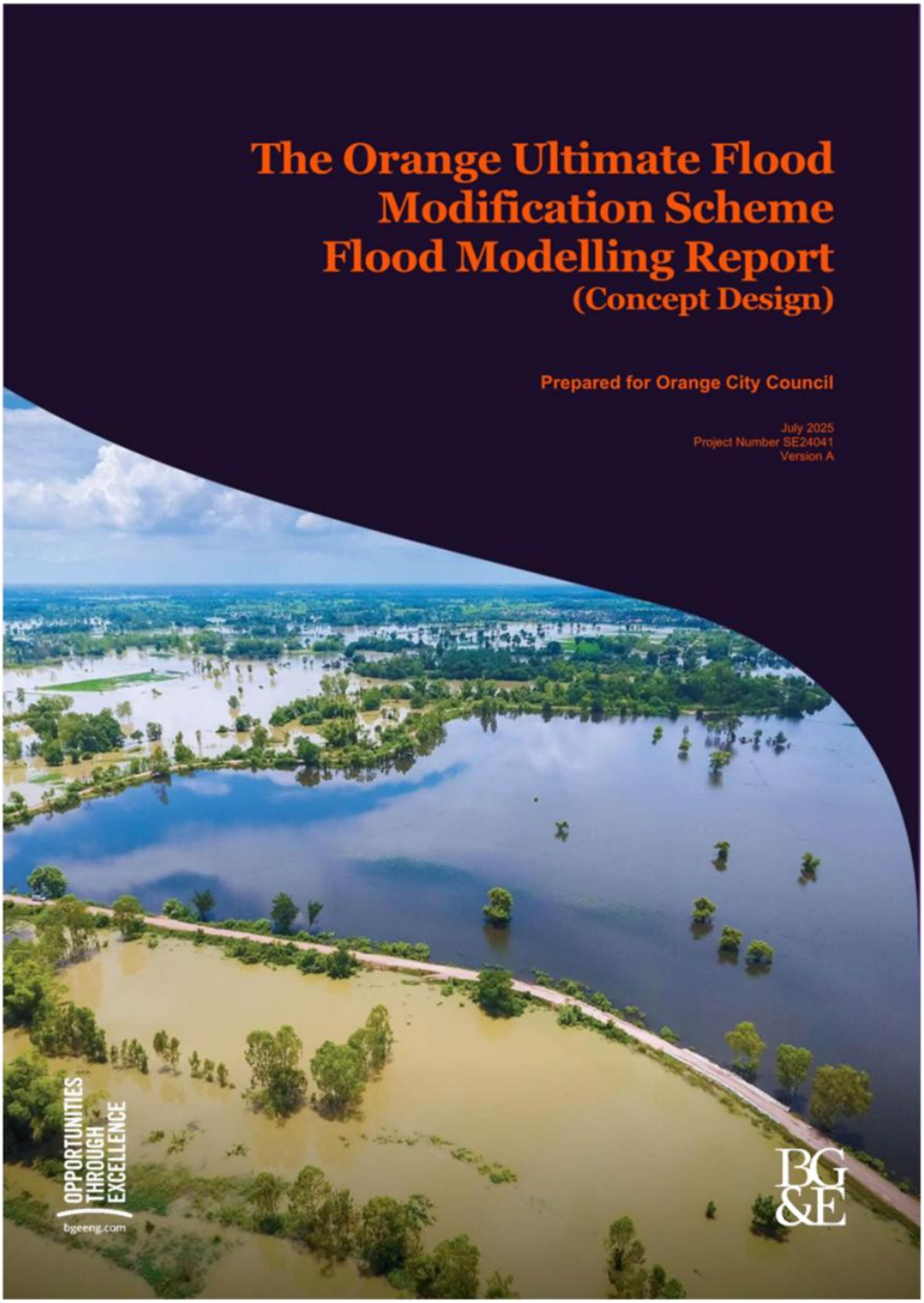
As both Glenroi Oval and Ridley Oval are directly upstream of East Orange Channel and the retention of stormwater within basins upstream of East Orange Channel would help capacity issues within the channel. Council has sought a variation to the contract to have this scheme looked at with a hope that the combined interaction will bolster the BCR of East Orange Channel for grant funding purposes.

It is recommended:

1 That Council proceed with the detailed design and Review of Environmental Factors for the following FMM's,
   I. FMM1 – Cutcliffe Park Detention Basin
   II. FMM7 – Ridley Oval Detention Basin
   III. FMM8A – Glenroi Oval Detention Basin
   IV. FMM9 – a modified project combining FMM9A and a portion of FMM9C required to mitigate FMM9A impacts
      a. FMM9A – East Orange Channel Works (between Icely Road and confluence with Blackmans Swamp Creek
      b. FMM9C – a reduced length of works to be revised through modelling -likely from Leeds Parade to McLachlan Street.
2 That Council seek funding for the construction of the Flood Mitigation Measures.

ATTACHMENTS

1 Flood Modelling report, D25/80016


The Orange Ultimate Flood Modification Scheme Flood Modelling Report
(Concept Design)
Prepared for Orange City Council
July 2025
Project Number SE24041
Version A
OPPORTUNITIES THROUGH EXCELLENCE
bgeeng.com
BG&E

Contents

Executive Summary 1
Scope of project 1
Updates to flood modelling 1
Concept design assessment 2
Outcomes and Recommendations 2
1. Introduction 4
1.1 The Orange Ultimate Flood Mitigation Scheme 4
1.2 Baseline flood model updates 4
1.3 Concept design 4
2. Flood Modelling 6
2.1 Available data 6
2.2 Updates to FRMS&P Model 7
2.3 Australian Rainfall and Runoff 2019 11
2.4 Updated baseline flood modelling 12
2.5 Concept Design flood modelling 13
2.6 Climate change sensitivity assessment 14
3. Flood Damages Assessment and Benefit-Cost Analysis 16
3.1 Assessment of flood damages 16
3.2 Existing (present day) flood damages 17
3.3 FMM flood damages 21
3.4 Benefit-Cost Analysis (BCA) 21
4. FMM1 – Cutcliffe Park Detention Basin 23
4.1 Existing conditions 23
4.2 Summary of option 24
4.3 Flood assessment 24
4.4 Flood damages and benefit-cost ratio 25
4.5 Recommendations 26
5. FMM2 – Kenna Street Stormwater Drainage Upgrade Works 27
5.1 Existing conditions 27
5.2 Summary of option 28
5.3 Flood assessment 28
5.4 Flood damages and benefit-cost ratio 29
6. FMM5 – Rifle Range Creek Railway Detention Basin 30
6.1 Existing conditions 30
6.2 Summary of option 31
6.3 Flood assessment 32
6.4 Flood damages and benefit-cost ratio 32
6.5 Recommendations 33
7. FMM6 – Moulder Park Detention Basin 34
7.1 Existing conditions 34
7.2 Summary of option 35
7.3 Flood assessment 35
7.4 Flood damages and benefit-cost ratio 36
7.5 Recommendations 37
8. FMM7 – Ridley Oval Detention Basin 38

BG&E

Report for Orange City Council | Project Number SE24041
SE24041-WAT-RPT-001-A Flood Modelling Report | Version A

8.1 Existing conditions 38
8.2 Summary of option 39
8.3 Flood assessment 39
8.4 Flood damages and benefit-cost ratio 40
8.5 Recommendations 41

9. FMM8A – Glenroi Oval Detention Basin 42

9.1 Existing conditions 42
9.2 Summary of option 43
9.3 Flood assessment 44
9.4 Flood damages and benefit-cost ratio 44
9.5 Recommendations 45

10. FMM9A – East Orange Channel Works (between Icely Road and confluence with Blackmans Swamp Creek) 46

10.1 Existing conditions 46
10.2 Summary of option 47
10.3 Flood assessment 47
10.4 Flood damages and benefit-cost ratio 48
10.5 Recommendations 49

11. FMM9C – Blackmans Creek Channel Widening 50

11.1 Existing conditions 50
11.2 Summary of option 50
11.3 Flood assessment 51
11.4 Flood damages and benefit-cost ratio 52
11.5 Recommendations 53

12. FMM9B – Blackmans Creek Channel Widening (bridge option) 54

12.1 Summary of option 54
12.2 Assessment of option 54

13. FMS1 – Flood Modification Scheme 1 56

13.1 Summary of option 56
13.2 Flood assessment 56
13.3 Flood damages and benefit-cost ratio 56
13.4 Recommendations 57

14. FMS2 – Flood Modification Scheme 2 58

14.1 Summary of option 58
14.2 Flood assessment 58
14.3 Flood damages and benefit-cost ratio 58
14.4 Recommendations 59

15. FMS3 – Flood Modification Scheme 3 60

15.1 Summary of option 60
15.2 Flood assessment 60
15.3 Flood damages and benefit-cost ratio 60
15.4 Recommendations 61

16. The Orange Ultimate Flood Modification Scheme 62

16.1 Summary of option 62
16.2 Flood assessment 62
16.3 Flood damages and benefit-cost ratio 62
16.4 Climate change sensitivity 63
16.5 Recommendations 63

BG&E

17. Preliminary Dam Break Analysis 64
17.1 Dam break approach 64
17.2 Dam break outcomes – proposed basins 65
17.3 Dam break outcomes – Rifle Range Creek rail embankment 65
18. Summary and Recommendations 66
18.1 Benefit-cost ratio summary 66
18.2 Recommendations 67
19. References 69

Appendices

Appendix A - Rifle Range Creek Underpass Assessment
Appendix B - Flood Mapping – Model Updates and Baseline Conditions
Appendix C - Flood Mapping – Flood Modification Measure Concept Design
Appendix D - Flood Mapping – Flood Modification Schemes and Ultimate Modification Scheme
Appendix E - Flood Mapping – Dam Break

Document Control				
Revision	**Date**	**Prepared**	**Reviewed**	**Approved**
A – Draft for Client Review	4 July 2025	A Mokal N Bannigan D Wood	L Baxter B Collyer	L Baxter

Report for Orange City Council | Project Number SE24041
SE24041-WAT-RPT-001-A Flood Modelling Report | Version A

Executive Summary

Scope of project

As part of the Blackmans Swamp Creek and Ploughmans Creek Floodplain Risk Management Study and Plan (FRMS&P) (Lyall and Associates, 2020) commissioned by Orange City Council, a number of potential flood modification measures (FMMs) were identified for the town of Orange. These measure sought to reduce the frequency of inundation and results flood damage and cleanup costs to residential dwellings and commercial premises in Orange . The Orange Ultimate Flood Modification Scheme (the Ultimate Scheme) was created as an outcome of the FRMS&P and combines eight of the FMMs into one larger scheme. Three smaller flood modification schemes (FMSs), each being a combination of the FMMs were also identified.

The aim of the Ultimate Scheme is to:

- Reduce above floor level inundation of public buildings, commercial /industrial developments and residential dwellings;
- Reduce the prevalence of high hazard level flooding;
- Reduce overland flow and nuisance flooding; and
- Reduce surcharge of the CBD trunk drainage culvert Line at Kite Street during storms up to a 1% AEP intensity.

Preliminary concepts were developed in the FRMS&P and Council identified several measures for further investigation and concept design.

This report forms the flood modelling assessment undertaken to inform the concept design and should be read in conjunction with the Civil Design Report (SE24041-CIV-RPT-001-A). It includes:

- Outcomes of flood model updates to incorporate catchment changes and updates to Australian Rainfall and Runoff (ARR) hydrology approaches (ARR 4.1) and refine baseline flood estimates; and
- Flood modelling assessment of potential concepts including cost-benefit analysis of the concept measures and schemes and interdependency of the measures.

Updates to flood modelling

The FRMS&P flood model was updated to incorporate detailed survey at each of the FMM locations. Changes within the catchment since the time the FRMS&P modelling was completed were also incorporated into the baseline modelling including representation of the soon to be constructed Orange Water Harvesting Scheme and the pedestrian and cycleway underpass though the rail embankment at Rifle Range Creek including the associated earthworks. Hydrology was also updated to Australian Rainfall and Runoff 2019 (ARR2019 4.1) methods which were not released at the time of the FRMS&P modelling.

As the FMMs are all located within the Blackmans Swamp Creek catchment only this catchment was updated. The Ploughmans Creek model was not updated from the FRMS&P but it is expected that the overall outcomes to the baseline flood behaviour would be similar.

The updates to the baseline modelling resulted in some changes in predicted flood behaviour. Generally the change to ARR2019 hydrology leads to reduced rainfall intensity and overland flows and therefore lower flood levels in most areas. The greatest change in flood levels is noted in the Blackmans Swamp Creek and East Orange Channel channels. The updated baseline modelling was used to inform the concept designs.

It should be noted that ARR 4.2 was released subsequent to agreement of this current concept design scope of works and therefore the IFD data has not been adjusted for "present day" as per ARR 4.2. ARR 4.2 results in higher present day flood estimates that ARR2019 (known also as ARR 4.1) adopted for this study.

Concept design assessment

Concept design development was undertaken through an iterative approach between the flood modelling and civil design. Design constraints and considerations are detailed within the Civil Design Report (SE24041-CIV-RPT-001-A) and should be read in conjunction with this flood modelling assessment report.

Concept designs were first hydraulically assessed for the 10% and 1% annual exceedance probability (AEP) storm events and the design iterated to obtain a practicable reduction in flood impact where possible. A final assessment was run for the 20%, 10%, 1%, 0.05%, and Probable Maximum Flood (PMF) events. Flood impact mapping was prepared for each AEP to visually assess the flood benefits of each FMM, the three FMSs and the Ultimate Scheme. A benefit-cost analysis (BCA) was undertaken based on the change in flood damages and estimated costs for each option and each option ranked by benefit-cost ratio (BCR) and flood benefits.

A preliminary dam break analysis to assess Population at Risk (PAR) was undertaken for the proposed basins to understand potential residual risks of the concept design and if further detailed dam break consequences assessment would be required.

Outcomes and Recommendations

The findings of the flood assessment feed into the overall outcomes of the Civil Design Report (SE24041-CIV-RPT-001-A). With regard to flooding:

- The Ultimate Scheme scored a BCR of 0.39. As a result of the Ultimate Scheme about 190 properties benefit from a reduction in peak flood levels or are no longer inundated in the 1% AEP event. The Ultimate Scheme has a very good economic benefit, however the high cost of implementation results in a poor outcome with regards to economic value.
- When considered in isolation of other options, the three basins FMM7, FMM1 and FMM8a, provide the best reduction in flood damages for cost of construction and ongoing maintenance.
- FFM7 results in the best BCR as reductions in peak flood levels extend downstream as far as the confluence of the East Orange Channel with Blackmans Swamp Creek. However, it is recommended that the assessment consider additional critical durations in the downstream channel here to confirm the BCR.
- The two basins FMM1 and FMM8a result in a high BCR as both provide benefit in frequent AEP events and reduction is peak flood levels extend a considerable distance downstream. It is recommended that the assessment consider additional critical durations in the downstream areas to confirm the BCR.
- Preliminary dam break assessment indicates that FMM7 and FMM8a increase PAR by only 3 in the 1% AEP event. The dam break PAR increases PAR by 20 at FMM1.
- FMS3 (FMM6, FMM9A and FMM9C), scores higher than the other schemes and is the only option that reduced flooding at the Transgrid Orange 132kV Substation (ES3).
- FMS1 and FMS2 provide flood damage reduction but the cost of the option results in poor economic value. Removal of FMM6 may improve BCR.
- FMM6 provides only a small reduction in flood damages as most reduction in flood levels occurs in open space areas. As the critical duration storm for the Blackmans Swamp Creek and the flooding that occurs at Lord Street are different, it provides no benefit to properties on Lord Street. It is the most expensive of the basin options due to the additional work for creek realignment. Preliminary dam break for FMM6 is to be completed should the option be pursued.
- FMM2 results in reasonable flood reductions at multiple residential properties, however the high cost of the option means a poor BCR. Many properties benefitted by FMM2 are also benefitted by FMM1 though not as effectively.
- FMM9C is not economically viable in terms of reduction in flood damages when considered in isolation, however does reduce the increase in flood levels in the downstream reach of Blackmans Swamp Creek caused by FMM9A. The option should only be considered with FMM9A.
- Following flood model updates FMM9B was found unnecessary as the existing bridge at Leeds Parade has capacity in the 1% AEP event.

- FMM5 provides no flood benefit, nor improves ponding of water against the rail embankment. Failure of the rail embankment during flooding would have significant consequences to residential properties downstream. Flood behaviour, including inundation of the pedestrian underpass, is also sensitive to the blockage of the rail culverts.
- Addition of FMM8a to FMS3 may enhance the BCR and would provide benefit to additional properties.
- A revised Ultimate Scheme without FMM6 and FMM2 may result in a better economic outcome due to the high-costs of FMM6 and FMM2.
- Further recommendations include:
  - Consultation with rail maintenance authority regarding rail culvert blockage and maintenance on Rifle Range Creek;
  - Review of proposed low level bund near the Transgrid Orange 132kV Substation (ES3);
  - Assessment of preferred options to be progressed to detailed design with ARR 4.2 (not formally adopted at time of project commencement) which is expected to increase flow volumes and peak flood levels; and
  - For options to be progressed to detailed design, undertake a detailed review of the flood damages using lots and survey points for the assessment.

1. Introduction

1.1 The Orange Ultimate Flood Mitigation Scheme

The Blackmans Swamp Creek and Ploughmans Creek FRMS&P identified a number of potential flood modification measures (FMMs) comprising of detention basins, stormwater drainage upgrades and channel upgrade works. Eight of these are grouped together to form Orange's Ultimate Flood Modification Scheme (the Ultimate Scheme) as per Figure 1-1. All FMMs are within the Blackmans Swamp Creek catchment.

The location of each of the FMMs is shown Figure 1-2. The approach of basins in the upper catchment areas and channel augmentation in the lower catchment aims to reduce flows by increasing attenuation upstream while allowing lower catchment flows to discharge faster to Blackmans Swamp Creek and downstream of the main urban area of Orange.

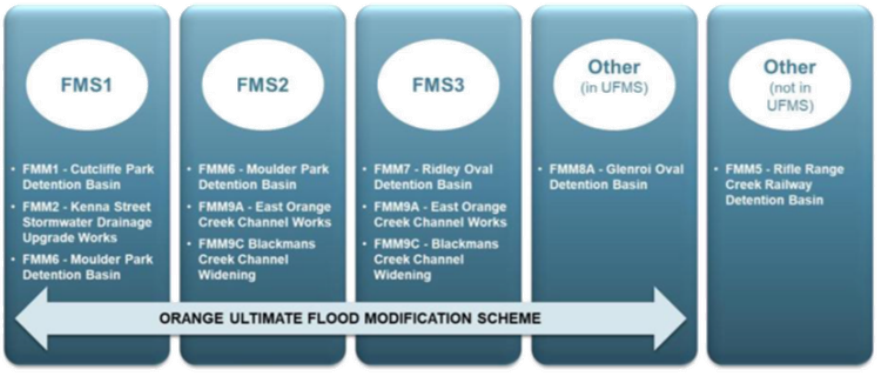


Figure 1-1: Flood modification options

1.2 Baseline flood model updates

The baseline flood modelling was updated to incorporate detailed survey at the FMM locations, changes to the catchment since the FRMS&P modelling was complete including the East Orange Harvesting Wetland (EOHW) and pedestrian and cycleway underpass of the rail embankment near Rifle Range Creek. Hydrology was also updated to ARR2019.

1.3 Concept design

This report documents hydrology and hydraulic modelling updates to the FRMS&P model and the flood modelling undertaken to inform the Concept Designs. It should be read in conjunction with the Civil Design Report (SE24041-CIV-RPT-001-A). This report also includes the flood damages assessment used to inform the benefit-cost assessment.

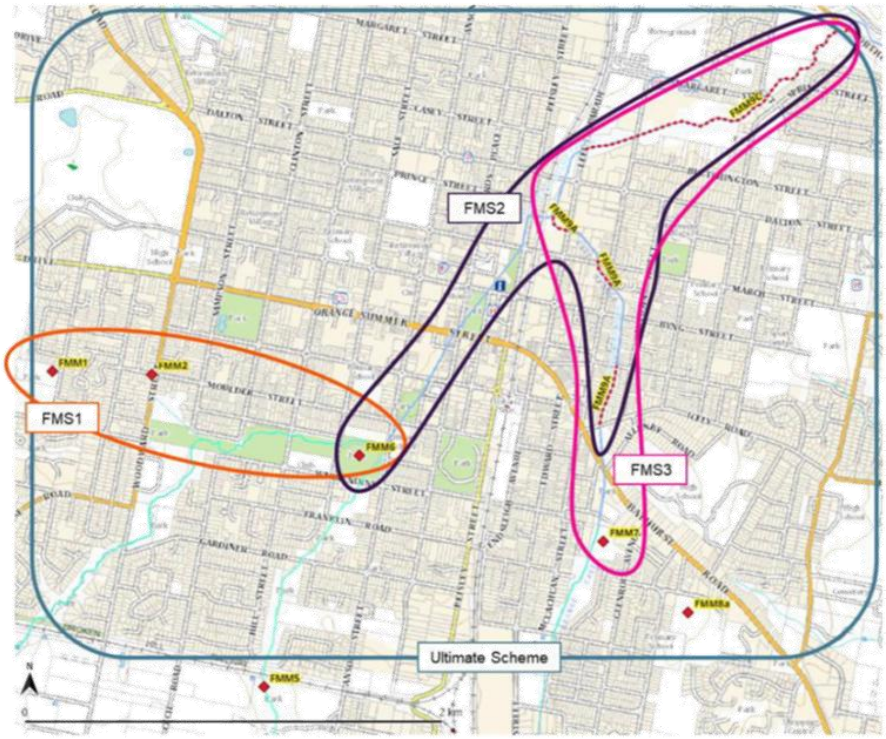


Figure 1-2: Location of FMMs and FMS

2. Flood Modelling

2.1 Available data

Table 2-1 – Available Data

Data	Supplied By	Purpose	Comment
Black Swamp Creek DRAINS hydrology model and TUFLOW hydraulic model developed as a part of Blackmans Swamp Creek and Ploughmans Creek Flood Study and subsequent FRMS&P (December 2020).	Council	Used to inform the baseline flood modelling and updated as detailed in this report.	DRAINS model was amended to update the hydrology to ARR2019. Only Blackmans Swamp Creek catchment model was used as all FMMs are within this catchment.
Survey (obtained December 2024 to March 2025) - Detailed survey was obtained at each of the FMM locations including surface levels, channel sections, culverts and bridges and drainage pits and pipes network.	Usher and Company	Used to refine detail in flood model in areas of the proposed FMMs	A check of surface levels from survey against LiDAR was undertaken and the survey found to be within 50 mm of the LiDAR in open areas as such giving reasonable confidence to surface elevations across the flood model.
Floor level survey	Council (from FRMS&P) Usher and Company	Used to assess over floor flooding to inform the flood damages assessment and BCA.	Additional floor level survey was combined with the floor level information extracted from the FRMS&P. An additional 105 properties in the PMF extent were estimated from LiDAR data and Streetview observations.
As-Builts / Work as Executed Drawings • Railway underpass at FMM5 (Rifle Range) • bridges on East Orange Creek	Council	Survey was available at all these locations so WAE drawings were used to validate detailed survey.	Drawings for the railway underpass and the pedestrian bridges were used to validate the geometry and invert levels of the underpass survey.
GIS data • Existing Stormwater Network • Critical/Vulnerable Infrastructure	Council	Stormwater data used for modelling checks. Critical infrastructure layer used in assessment of concept design option hydraulic outcomes.	Council's pit and pipe database was already incorporated into the FRMS&P model which has made assumptions around missing data as documented in the Flood Study report (L&A, 2019). These assumptions were retained for the concept design flood modelling.
Detailed design drawings and plans for the McLachlan to March Street - East Orange Channel and Bridge upgrade.	Council	Incorporated into design for FMM9A.	Following the FRMS&P, Council developed a design of the channel and culvert upgrades from McLachlan Street to March Street which is incorporated in FMM9A.
East Orange Harvesting Wetland – Digital Elevation Model (DEM) and DWG design file (Received March 2025)	KBR	Used to update the flood model surface near East Orange to represent the East Orange Harvesting Wetland.	The harvesting scheme basin was assumed to be empty at the commencement of the rainfall event.
Site inspection / Site observation	BG&E	Used to validate the model assumptions, confirm structure locations and identify any additional drainage features not captured in the FRMS&P modelling.	Site inspections undertaken over three days in October 2024 with BG&E and Council staff.
Costing information	Vasey QS	Inform likely cost of construction of each option to inform cost-benefit assessment.	Costings are included as an attachment to the Concept Design report.

2.2 Updates to FRMS&P Model

2.2.1 Modelling approach

For the FRMS&P, hydrology modelling was undertaken using DRAINS (ILSAX and RAFTS sub-model) for input of hydrographs into the TUFLOW model. The DRAINS model did not include drainage links and represents subcatchment hydrology only. Outputs from DRAINS model were input into the TUFLOW hydraulic models as flow hydrographs within each sub-catchment.

2.2.2 Hydrology review

Table 2-2 – Hydrology model review and updates

Review	Location	Comment
Catchment delineation and application to TUFLOW	All FMM locations	Hydrology for the FRMS&P was assessed using a DRAINS model with 2630 subcatchments. Catchment delineation is to the street block scale and was retained as per the FRMS&P. Minor changes were made to the location of inflows in the TUFLOW model to suit modelling of the FMMs.
Adopted parameters	Total catchment	Parameters were maintained for consistency with the calibrated Flood Study and FRMS&P models.
Australian Rainfall and Runoff 2019 (ARR2019)	Total catchment	Previous modelling in the FRMS&P used ARR87 techniques. KBR (2023) undertook a preliminary assessment of the impact of ARR2019 on flood behaviour for the 1% AEP event noting that rainfall intensities are some 7% to 15% lower under ARR2019 than ARR87. Rainfall was updated to use ARR2019 (4.1) approaches – refer section 2.2.3.

2.2.3 Hydraulic modelling review

Table 2-3 – Hydraulic model review and updates

Item for Review	Model Updates and Review Outcomes
TUFLOW version	The TUFLOW model version 2018-03-AB was retained to be consistent with the version used in the FRMS&P modelling, which was developed and calibrated using this version. The model was run in double precision to improve mass balance stability and produce acceptable model performance.
Model health - The model was found to be unstable in the downstream reaches of the Blackmans Swamp Creek channel which caused mass balance errors to propagate upstream affecting the area from Northern Distributor Road bridge upstream to Byng Street bridge near East Orange Creek.	A review area of "influence of error" caused by the boundary conditions indicated that the issue was significant enough that it would have considerable impact on the assessment of the effectiveness of the proposed flood modification measures (FMMs) and could cause costly unnecessary design. The following modelled adjustments reduced the error to acceptable and within typical modelling tolerances: • Change model from single to double precision calculation. • Modification of connection from 1d channel to 2d channel at near the Northern Distributor Road bridge, where Black Swamp Creek crosses the road. • Refinement of the 1D channel networks (including incorporating survey)
Application of hydrology to TUFLOW model – 2D BC, 1D BC in Pit and 2D SA inflow application	Inflow locations were reviewed and adjusted to aligned with low points, particularly near the East Orange Channel where surface modifications were introduced as part of the water harvesting scheme. Inflow locations were reviewed and refined based on updated survey data. Where appropriate, inflows were relocated to reflect actual surface low points and pit locations.

Item for Review	Model Updates and Review Outcomes
Topographic data - the FRMS&P model is based on LiDAR data flown in 2017. 2019 LiDAR is available. Detailed site survey was obtained at the location of the FMMs.	The FRMS&P model Digital Elevation Model (DEM) was validated against spot heights undertaken during detailed survey and found to be a good match typically within 50 mm. Therefore, the more recent LiDAR was not incorporated into the modelling. The urban nature of the catchment means it is unlikely there are significant changes to the surface elevations over this time period. Significant changes, such as the works near Rifle Range Creek, and the East Orange Harvesting Wetland are known and incorporated into the flood model (refer section 2.2.4). At each of the FMM locations the detailed survey was incorporated.
Typical model assumptions - Typical model assumptions such as roughness, drainage losses, pit blockage, and application of hydrology were reviewed throughout the project	Generally, assumptions from the FRMS&P model were retained to maintain consistency. Minor amendments made local to the FMM locations where necessary. • Adjusted pit locations and inflow points at FMM2, FMM6, and FMM8a based on updated survey data. • No changes to roughness values were made, roughness values from FRMS&P were retained. • Blockage assumption updated to 50% at the rail culvert near FMM5 based on site inspection (previously unblocked in FRMS&P)
Drainage network - data based on Council's asset GIS database has limited accuracy for detailed design.	Detailed survey of drainage network, kerb and gutter and roadway at the FMM locations was incorporated into the flood model to improve the accuracy of the design outcomes. Generally the survey resulted in minor refinements such as culvert size or inverts. However significant changes to the modelling were made at FMM2 and FMM5 (refer section 2.2.4).
Blockage assumptions - Assumptions can influence of flood levels and thus the flood damages and benefit-cost analysis.	Blockage assumptions from the FRMS&P were generally retained for consistency. A sensitivity analysis was undertaken at the FMM5 location, where the rail embankment culvert was revised to assume a 50% blockage in the baseline conditions following site observations and discussions with Council. The FRMS&P had adopted a zero blockage at the rail culverts. The outcome of this assessment is documented in Appendix A. Confidence in model outcomes was improved at FMM5 location, where blockage was found to have impact on downstream flood behaviour.

2.2.4 Flood model geometry updates including catchment changes post FRMS&P model development

Detailed survey was obtained at each of the FMM locations including surface levels, channel sections, culverts and bridges and drainage pits and pipes network. This was used to refine the baseline flood model in areas of the proposed FMMs. In addition, the baseline flood model was updated to incorporate catchment changes since the original FRMS&P model development.

Notable changes are summarised in the following sections.

2.2.4.1 East Orange Water Harvesting Scheme

KBR (2023) assessed the impact of the proposed East Orange Harvesting Wetland (EOHW) on flood behaviour for the 1% AEP event. The EOHW is designed to extract stormwater flows from Blackmans Swamp Creek via inlet control weirs that control water flow along Blackmans Swamp Creek into the wetland. The wetland is an off-line wetland that is split into different zones for stormwater harvesting and water quality treatment, a water reticulation pond. Outlet structures consisting of a box inlet pit with 450 mm diameter and control valve, and rock-lined overflow spillway discharge flows back to Blackmans Swamp Creek.

A design surface for the wetland was provided by KBR and incorporated into the baseline flood model to inform the spill level into the wetland and ground levels within the harvesting basin. The harvesting scheme was assumed to be empty for all model runs.

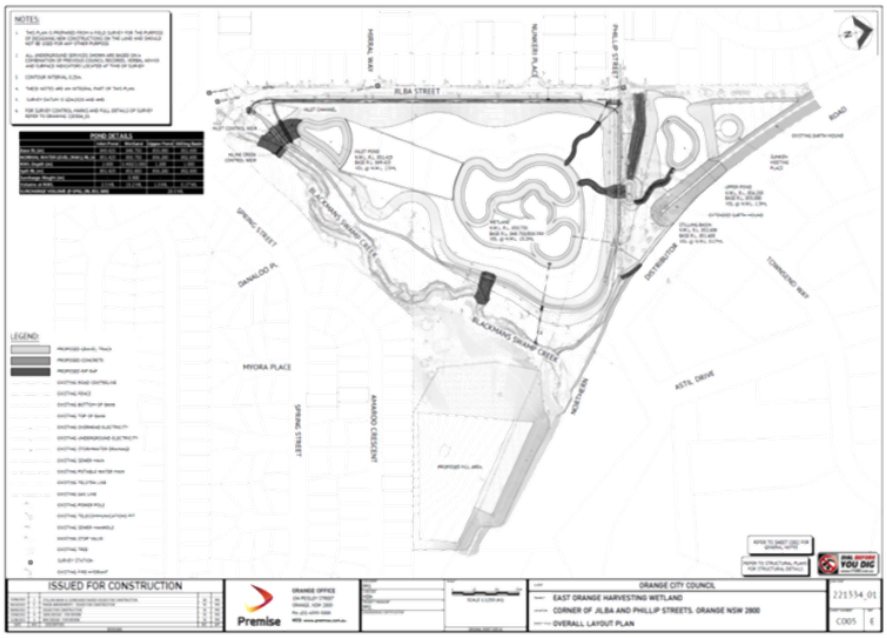


Figure 2-1: East Orange Harvesting Wetland

As the basin discharges during low flows, the outlet was not incorporated into the updated modelling. KBR (2023) noted that under 1% AEP event conditions the state of the outlet valve does not significantly influence the amount of flood storage within the wetland and the EOHW closed outlet scenario has the most influence on existing 1% AEP flood behaviour.

KBR found that the EOHW resulted in localised changes in flood behaviour in the lower reaches of Blackmans Swamp Creek. The additional flood storage provided by the proposed wetland results in reduction in peak flood levels within Blackmans Swamp Creek and minor benefits to some private properties immediately upstream of the wetland. They noted that the 1% AEP peak flood levels and flood extent increased due to changes in topography within the EOHW and along Northern Distributor Road though hazard remained low (H1).

2.2.4.2 Cycle and pedestrian underpass through Orange-Broken Hill railway corridor near to Rifle Range Creek (near FMM5)

The pedestrian underpass, footpath and associated earthworks were constructed in 2018. The baseline modelling was updated to incorporate the detailed survey of the as constructed earthworks, cycle path and the underpass. The project-specific survey was validated against works-as-executed drawings of the underpass.

Figure 2-2: Photographs taken 15 October 2025 showing blockage at the railway culverts

2.2.4.3 Rifle Range Creek rail culverts (near FMM5)

Survey of the rail culverts was not possible due to access constraints, however through site observation and Council data the culverts were assumed 1.5 m diameter culverts as agreed with Council. The culverts are likely to be brick arches given the age and typical construction of the rail corridor. However circular conduits were opted for in the modelling for simplicity. Given the high blockage and standing water this is unlikely to have a significant impact on modelled flood levels.

The blockage applied to the rail embankment culverts on Rifle Range Creek was assumed as zero in the FRMS&P modelling. Site observations indicate that the culverts were considerably blocked and therefore blockage was revised to 50% for updated baseline modelling. Sensitivity on the rail culvert blockage was also undertaken (refer Appendix A).

Figure 2-3: Blockage at the railway culverts (15 October 2025)

2.2.4.4 Stormwater drainage near FMM2 location

Survey investigations at the FMM2 location identified stormwater pipes that were not included in the FRMS&P modelling. These were added to the updated baseline model as it was prudent to include all local stormwater drainage to provide more certainty to the flood assessment outcomes used to inform the design of FMM2.

One 300 mm diameter circular pipe and one 375 mm diameter circular pipe collect stormwater from the rear of properties at 1-3 Moulder Street and connect to the system draining Moulder Street and eventually to the channel

downstream of Woodward Street. A 375 mm diameter pipe drains the front of properties and the roadway within 1-3 Moulder Street connecting into 1025 mm diameter pipe, which discharges into three 900 mm diameter circular pipes located along Woodward Street, before entering the downstream channel.

The invert levels of three 900 mm diameter circular pipes that connects the stormwater network in Moulder Street to the stormwater network in Woodward Street were amended based on updated survey data.

2.3 Australian Rainfall and Runoff 2019

The Orange FRMS&P adopted ARR1987 procedures as current at that time. Subsequently a ARR 2019 sensitivity assessment was undertaken. The *Orange Ultimate Flood Modification Scheme: Feasibility & Design Project – Phase A: ARR19 Update Memorandum (KBR, 2023)* concluded that while there are changes in the 1% AEP flood as a result of the revised IFDs and ARR2019 procedures, the ARR 2019 flood modelling results show levels are generally lower than the ARR 1987 methods. However, only the 1% AEP event was assessed with the ARR2019 methodology and no other AEPs were assessed, and while adopting the ARR87 mapping may be acceptable and conservative for flood planning purposes, it is considered that for design of the flood management options it would be prudent to assess the full ensemble of design temporal patterns under ARR2019.

There are a number of benefits to updating the flood modelling fully to ARR2019 and designing to this standard:

- ARR2019 is the most recent standard for hydrology assessment in Australia (at the time of this current concept design study ARR2019 (now known as ARR4.0 was the most recent) and is based on additional records of historical data.
- Studies have shown that the scale of difference in flooding between ARR 1987 and ARR 2019 methodologies can vary with AEP event.
- The functionality, and therefore design, of detention basins is sensitive the temporal patterns of rainfall and the resulting hydrograph shape. ARR87 adopts a single unit hydrograph, however the ARR2019 ensemble approach considers multiple temporal patterns. With the introduction of a detention basin into a catchment, the mean temporal pattern (as well as mean duration) can vary from pre-basin conditions. In basin design it can be important to test front-loaded and rear-loaded patterns to understand basin performance. This is particularly important in urban areas with populations present in the immediate vicinity of the basin.

The DRAINS model for Blackmans Swamp Creek was updated to incorporate the ARR2019 IFDs and DataHub information and run for the full ensemble of design events. Point rainfall was used uniformly as the catchment is < 75 km^2. The ensemble included 14 storm durations from 10 minutes to 24 hours, each with 10 temporal patterns, for the 20% AEP, 10% AEP, 1% AEP, 0.05% AEP events.

The PMF approach adopted in the FRMS&P was maintained. This approach included an ensemble of 24 PMF storms between the 15 minutes to three hours for each of the three spatial patterns across the catchment.

2.3.1 Losses

2.3.1.1 Previous modelling

For the 2019 Flood Study, the DRAINS model used the ILSAX (Horton) method for most of the catchment and RAFTS I Initial Loss / Continuing Loss sub-model (IL/CL model) for the rural areas. The model was calibrated to the 2002 and 2010 events. These same calibrated losses were adopted for the subsequent FRMS&P. KBR (2023) undertook a model validation for the 2022 event and retained the IL/CL and ILSAX loss parameters as per the Flood Study model. They found that simulated flood levels correlate well with the Council surveyed flood levels along the mainstream channel of Blackmans Swamp Creek though limitations of modelling in urban environments meant that some other areas did not calibrate so well. Overall they concluded that the model is fit for purpose for the majority of the catchment and that adopted calibrated losses from the 2019 Flood Study are considered appropriate to be maintained for future modelling.

2.3.1.2 ARR2019 losses

Orange sits between the reconciled loss catchments of Cudal No.2 (G01) and Molong (G15), both of which indicate that the standard ARR method losses considerably underestimate greenfield flows due to high initial losses (but

noting both catchments have a poor fit to the Flood Frequency Analysis (FFA) and calibration undertaken as part at the ARR reconciled losses project).

The ARR2019 hierarchy for application of losses in NSW recommends using the calibration losses from an actual study on the catchment if available over the NSW reconciled losses or standard ARR datahub losses.

2.3.1.3 Loss sensitivity

KBR (2023) assessed the sensitivity of the ARR2019 standard losses (not reconciled) and the calibrated losses noting that the ARR2019 standard losses resulted in higher peak flood levels. The ARR standard initial and continuing losses are reduced compared to the Flood Study model losses.

Noting that the ARR loses refer to rural areas and are not suitable or urban areas, KBR adjusted the ILSAX model to a IL/CL model with an initial loss of 1 mm and a continuing loss of 0 mm/hr. The urban ILSAX catchments comprise 95 % of the Blackmans Swamp Creek subcatchments and therefore the losses applied to urban areas would have great impact on flood behaviour than losses applied to rural area. While KBR found that the revised losses cause an increase in the peak flood levels, this is likely to be most influenced by the change from the ILSAX IL/CL model in urban areas than the ARR standard losses for rural areas.

Both the ILSAX and IL/CL models are recognised in ARR2019 as suitable hydrologic modelling approaches.

2.3.1.4 Adopted losses

The combined ILSAX and Initial/Continuing hydrologic losses adopted in the Flood Study and FRMS&P were maintained as it maintains consistency with calibrated flood modelling and is in keeping with the ARR2019 hierarchy for application of losses in NSW.

2.3.2 ARR 4.2

It should be noted that ARR 4.2 was released subsequent to agreement of this current concept design scope of works and therefore the IFD data has not been adjusted for "present day" as per ARR 4.2. ARR 4.2 results in higher present day flood estimates that ARR2019 (known also as ARR 4.0) adopted for this study.

2.4 Updated baseline flood modelling

The full storm ensembles were run through the TUFLOW model. Using the ARR2019 ensemble approach the median values for the peak water level was identified from ten temporal patterns for each storm duration. The maximum of these medians was then selected to identify the critical storm duration and develop the flood mapping.

Flood mapping of the baseline conditions, including depth, levels and hazard is included in Appendix B.

2.4.1 Comparison of updated flood model and FRMS&P model

Mapping of the difference in flood behaviour in the existing case at each of the FMM locations (assuming baseline conditions) is shown in Figure B 1 for the 10% AEP event and Figure B 2 for the 1% AEP event.

Overall, peak water levels across most locations in the updated model are lower when compared to the FRMS&P model. This is consistent with the KBR ARR2019 assessment findings. The greatest decreases in flood level occur in flood storage areas and the downstream catchment.

The most notable differences are at the following locations:

2.4.1.1 FMM5 / Rifle Range Creek

The updated model shows increased water levels upstream of the railway embankment from 877.72 mAHD in the FRMS&P model to 878.10 mAHD in the updated baseline model. The increases are driven by the updated blockage assumptions and inclusion of surveyed features (refer sections 2.2.4.2 and 2.2.4.3) and further discussion on the impacts of this is included in Appendix A.

The model revisions result in a reduction in total peak flow at the rail culverts from about 8.7 m^3/s in the western culvert and 5.2 m^3/s in the eastern culvert in the FRMS&P model to about 4.2 m^3/s in the western culvert, 3.4 m^3/s

in the eastern culvert and 2.14 m³/s in the underpass in the updated flood model. Downstream of the rail embankment the inclusion of the pedestrian underpass into the flood model allows flow to be redirected downstream in response to blockage of the culvert beneath the rail embankment. The underpass is expected to first convey water downstream between the 5% AEP and 2% AEP events.

2.4.1.2 Leeds Parade bridge and Black Swamp Creek lower reaches

Considerable reductions in predicted peak levels occur in this area of over 200 mm. The maximum reduction within the Black Swamp Creek is up to 620 mm. The reduction is a result of the improved model stability and reflects the hydrology update to ARR2019 with reduced flows across the catchment arriving at the lower reaches of the creek.

2.4.2 Critical storm durations and temporal patterns

The critical duration ranges from about 10 minutes in the urban upper catchment areas to between one and six hours in the creeks and channels as shown in Figure B 3 and Figure B 4. The updated model indicates a wider distribution of critical durations from ten minutes up to six hours across the catchment when compared to the FRMS&P model. This is as to be expected as the ARR87 methodology adopted in the FRMS&P modelling was known to typically result in the 60 minutes to 90-minute storm in similar catchments.

Shorter critical durations (15 to 90 minutes) dominate the more urban catchment areas consistent with more rapid runoff response. The less developed upper catchment areas are characterised by mid-duration events (one to six hours) as flow routes through the greenfield areas. In the creeks and channels, durations range from one hours to nine hours. Upstream of the CBD trunk drainage culvert at Kite Street, the limited capacity of the culvert causes longer critical durations flooding.

2.5 Concept Design flood modelling

Concept designs are detailed in the Civil Design Report (SE24041-CIV-RPT-001-A) which should be read in conjunction with this flood assessment report. Detailed drawings of the concept designs are included the Civil Design Report.

The flood models were used to inform the concept design and an iterative approach to design undertaken to optimise design to give best possible flood outcomes while considering design constraints. The flood outcomes are detailed in the later sections of this report. Constraints and further details of the design is provided in the Civil Design Report.

For the concept design development models were run for the 10% AEP and 1% AEP events. A representative ensemble of storms was selected to avoid the need to run the full ensemble and to accelerate the design program. The representative storms were considered on a location-by-location basis and selected on a review of the flood behaviour including water level, flows, and volume observed at each FMM location. The selected storms for the representative ensemble were chosen at the location itself but also considered areas that might be sensitive to the design outcomes for example downstream areas, location of detention basin inflows and outflows. Three representative temporal patterns were selected for each storm duration and design location, based on the distribution of rainfall intensity, specifically to represent front, mid and rear loaded patterns. This approach ensure critical hydraulic response at sensitive location were captured without requiring simulation of the full ensemble set.

The adopted representative storm durations for the 10% AEP and 1% AEP events at each FMM location are summarised in Table 2-4.

Table 2-4 – Adopted representative storms for Concept Design

Location	10% AEP	1% AEP
FMM1	30 min – TP06, TP08, TP10 24 hr – TP05, TP06, TP10 45 min – TP01, TP06, TP09	30 min – TP06, TP07, TP09 02 hr – TP02, TP04, TP10 45 min – TP03, TP05, TP10
FMM2	90 min – TP01, TP05, TP06 45 min – TP06, TP07, TP10 30 min – TP03, TP08, TP10	90 min – TP02, TP06, TP08 45 min – TP02, TP05, TP07 30 min – TP03, TP07, TP08
FMM5	09 hr – TP01, TP05, TP06 24 hr – TP03, TP08, TP10 02 hr – TP01, TP06, TP10	03 hr – TP07, TP08, TP09 24 hr – TP02, TP06, TP07 270 min – TP01, TP06, TP10
FMM6	06 hr – TP01, TP03, TP05 09 hr – TP03, TP08, TP10 15 min – TP06, TP08, TP10	270 min – TP02, TP05, TP09 12 hr – TP01, TP05, TP09 30 min – TP05, TP07, TP10
FMM7	90 min – TP02, TP08, TP07 02 hr – TP01, TP08, TP10	45 min – TP02, TP06, TP08 03 hr – TP02, TP06, TP10
FMM8a	30 min – TP04, TP06, TP09 90 min – TP02, TP03, TP10 45 min – TP01, TP04, TP09	45 min – TP01, TP06, TP07 90 min – TP01, TP02, TP10 30 min – TP03, TP06, TP09
FMM9a	01 hr – TP01, TP05, TP07 02 hr – TP01, TP02, TP08	90 min – TP02, TP04, TP07 02 hr – TP02, TP04, TP08
FMM9bc	02 hr – TP02, TP08, TP10 90 min – TP04, TP05, TP07	90 min – TP02, TP07, TP09 01 hr – TP01, TP04, TP05 45 min – TP01, TP06, TP08

Following completion of the concept design, the flood models were used to assess the impact of the designs on the 20% AEP, 0.05% AEP and PMF events and feed into the benefit-cost analysis (refer section 3). The representative ensembles selected for the 10% and 1% AEP events were applied to other AEPS and the representative ensemble assessed rather than the full ensemble. This approach was adopted to reduce modelling run and processing time without losing the detailed outputs to inform the flood damages and cost-benefit analysis.

2.6 Climate change sensitivity assessment

Two climate change scenarios were adopted for sensitivity testing; application of a 10% and 30% multiplier to inflows in the 1% AEP event in keeping with the approach adopted in the FRMS&P. While an increase in rainfall intensity does not directly correlate to the same increase in flows, the flow increases are used as a proxy for future climate conditions for sensitivity to flow increases and do not represent any given future climate horizon. A reduced ensemble of the 30 minute, 45 minute, 90 minute and 270 minutes storms was used being those durations that are typically dominant across the majority of catchment.

Subsequent to the modelling for this project, the release of ARR 4.2 has altered the way in which climate change is applied to the IFD data. It is recommended that the hydrologic modelling be reviewed in light of the latest ARR 4.2 release for the detailed design of any options.

2.6.1 Impacts of climate change – baseline conditions

Mapping of the increases in peak flood levels for the baseline conditions are shown in Figure B 20 and Figure B 21.

A 10% increase in flow leads to increases typically within the range of 10 mm to 50 mm in the channels and main overland flow paths. Flood levels in the upper catchment areas subject to shallow overland flows are less sensitive to increases in flow. Greater impacts on flood levels as a result of the flow increase are seen in flood storage areas

such as update of the rail embankment on Rifle Range Creek where increases of about 175 mm are likely to occur and at the basin at McNeilly Avenue where increase of about 125 mm occur. Large increases also occur in the channel downstream of the confluence due to the accumulation of increased flow.

A 30% increase in flows leads to a similar pattern with increases in peak flood level of 50 mm to 100 mm in main overland flow paths and increases of up to 250 mm Blackmans Swamp Creek. At Rifle Range Creek a 490 mm increase in water levels ponding upstream of the rail embankment is predicted. As the capacity of the CBD trunk drainage is exceeded increased overland flows occur through the CBD area with depths in roadways predicted to increase by about 200 mm to 350 mm which would be likely to increase over floor flood affectation.

2.6.2 Impacts of climate change Ultimate Flood Modification Scheme

The impacts of climate change on the Ultimate Scheme are addressed in section 16.4.

3. Flood Damages Assessment and Benefit-Cost Analysis

3.1 Assessment of flood damages

Flood damages have been assessed using the *NSW Flood Damage Assessment TOOL (DT01) and NSW Flood risk management guideline Flood risk management measures MM01*. This supersedes the flood damages tool used in the 2019 Flood Study. The DT01 Tool is based on more recent flood damage and also allows for a more robust estimate of non-residential flood damages compared to the previous tool.

3.1.1 Input data

A property database from the 2019 Flood Study was updated with the additional surveyed information and points within the PMF (refer section 2.1).

Damages were inflated by the Consumer Price Index by 133.7 and regional cost adjustment factors were applied for 10% Central Land Division. For residential buildings default residential building curves were utilised. The actual potential damages ratio for contents was kept as the default 0.9. The short duration storms in Orange do not warrant using a lower ratio. For commercial and industrial buildings the floor area was taken from the 2019 Flood Study database or estimated from GIS mapping.

Properties identified in Council's Critical Infrastructure GIS layer were classified as public buildings for the purposes of the damage assessment. For the purposes of damage assessment, child care facilities have been considered as educational facilities. Aged care facilities were considered to be "hospitals". A number of other features including sewerage systems, highlighted road crossings and other features, were not included in the flood damages in keeping with the Flood Study and FRMS&P approach.

Two substations (Transgrid Orange 132kV Substation (ES3) and the substation at Leeds Parade (ES2) have been incorporated into the assessment as a specific unit cost. In the event the sites are identified flooded, a unit cost of $15 million has been applied to the total event damages cost within the structural damages total. The $15 million is an estimate of the cost associated with the development of a 132 kV substation.

3.1.1.1 Limitations of approach

The approach adopted is consistent with the Flood Study and FRMS&P and uses point data to represent properties. As a limitation of this approach, the flood damages calculated at the property is based only on the flood behaviour at this single point. Therefore where a property is partially inundated, or there is variation in the flood behaviour across the lot such as from local overland flows and mainstream channel flooding, this may not be represented in the flood damages assessment. In addition, this approach would also impact the reporting of changes in flood behaviour in the BCA as shown in Figure 3-1. It should be noted that while the approach may miss some properties from the assessment, others would be included where the overall flood affectation on a lot is minor and not necessarily at the dwelling such as those where points were placed on the street frontage.

A combined lot and point approach can increase the certainty of flood damage estimation and therefore BCA outcomes though require a manual review in areas sensitive to flood behaviour changes as a result of the FMMs.

The current approach is suitable for an overall assessment and it is only recommended to refine the approach where options are to be pursued further for detailed design, or the outcomes of the BCA may influence the overall decision to progress or not with an option.

Figure 3-1: Example of limitation of point data for flood damages assessment

3.2 Existing (present day) flood damages

3.2.1 Total catchment

The total catchment flood damages have been developed for Blackmans Swamp Creek and are reported in Table 3-1.

Figure 3-2 presents a heatmap of the 1% AEP total damages. Figure 3-3 presents the damages present on residential properties only. Of note:

- Significant damages are present at the commercial properties along Palmer Street and Glenroi Avenue.
- Another area of significant damage is the area between Peisley Street and Byng Street.
- Within the residential areas, the area bounded by Coronation Drive, Wentworth Lane and Woodward Street presents a location of significant damages, as does the corner of March and McLachlan Streets.

Figure 3-2: Total flood damages heat map – 1% AEP event – all properties

Figure 3-3: Total flood damages heat map – 1% AEP event – residential properties only

Table 3-1: Flood damages – baseline flood modelling - $2025

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	No. Allotment Affected	No. dwellings affected above floor level	Damages ($ Millions)	No. Allotment Affected	No. dwellings affected above floor level	Damages ($ Millions)	No. Allotment Affected	No. dwellings affected above floor level	Damages ($ Millions)
20%	226	1	0.51	27	4	0.98	4	0	0.00
10%	369	5	1.39	49	9	2.74	8	1	0.00
1%	1098	77	10.83	182	40	8.20	17	5	0.53
0.05%	1766	234	36.14	298	185	44.09	38	17	2.58
PMF	3070	1580	356.00	721	603	369.23	58	42	69.89
AAD ($ Millions)			1.17			1.42			0.39
Total AAD (Including Substations)									3.80

3.2.2 Comparison with 2019 Flood Study flood damages

Differences between the 2019 Flood Study baseline flood damages which was used to inform the FRMS&P options and this current study are expected due to the updated flood modelling and the revised flood damages tool.

- The number of properties inundated above floor level in a 1% AEP has slightly reduced. This is due to the change in modelling approach from ARR87 to ARR2019 which results in slightly lower peak flood levels
- Allotments affected in the revised damages assessment are any property that is inundated in the relevant AEP event at the assessment point. Damages however are not applied until depth exceeds 300 mm. In the previous assessment, affected allotments were considered where depth on the property was greater than 100 mm or if the flood level is within 0.5 m of the floor level. Due to the substantially different methodology the values in the tables presented are not directly comparable.
- For residential dwellings this has resulted in a reduction in damages in the 1% AEP event. At higher depths, the damages curve for residential dwellings in the DT01 Tool is higher than the now superseded Flood Damages guidelines adopted for the 2019 Flood Study. This results in a significant increase in the total damages for the PMF event. This is increase is consistent across all building types.
- For commercial uses, while less properties are impacted under the revised flood damages assessment, there is a significant increase in the damages. This is due to a large change in the cost per m^2 associated with commercial damages between the older and newer flood damages calculation approach. For example the maximum damage in the previous damages approach was $650 per m^2 which has increased to $2,000 per m^2 in the DT01 tool.

As none of the FMMs are within Ploughmans Creek Catchment this has not been included, however the difference in flood damages between 2019 Flood Study assessment and the updated model and damages approach is likely to be of a similar scale.

Table 3-2: Residential flood damages – comparison with 2019 Flood Study

Flood Event (AEP)	2019 Flood Study			Updated Damages Assessment		
	No. Allotment Affected	No. dwellings affected above floor level	Damages ($ Millions)	No. Allotment Affected	No. dwellings affected above floor level	Damages ($ Millions)
20	20	1	0.4	226	1	0.51
10	80	9	1.7	369	5	1.39
5	175	32	4.2	Not assessed		
2	316	72	8.5	Not assessed		
1	447	129	14.0	1098	77	10.83
0.5	572	176	19.1	Not assessed		
0.2	720	261	26.4	Not assessed		
0.05	Not assessed			1766	234	36.14
PMF	2291	1581	170	3070	1580	356.00

*note – number of affected allotments is different due to change in how they are considered between the damages assessments.

Table 3-3: Commercial and industrial flood damages – comparison with 2019 Flood Study

Flood Event (AEP)	2019 Flood Study			Updated Damages Assessment		
	No. Allotments Affected	No. buildings affected above floor level	Damages ($ Millions)	No. Allotments Affected	No. buildings affected above floor level	Damages ($ Millions)
20	7	4	0.6	27	4	0.98
10	16	9	1.0	49	9	2.74
5	34	21	1.6	Not assessed		
2	61	35	2.7	Not assessed		
1	118	66	4.5	182	40	8.20
0.5	181	119	7.7	Not assessed		
0.2	242	189	12.4	Not assessed		
0.05	Not assessed			298	185	44.09
PMF	615	588	156	721	603	369.23

*note – number of affected allotments is different due to change in how they are considered between the damages assessments.

Table 3-4: Public flood damages – comparison with 2019 Flood Study

Flood Event (AEP)	2019 Flood Study			Updated Damages Assessment		
	No. Allotments Affected	No. buildings affected above floor level	Damages ($ Millions)	No. Allotments Affected	No. buildings affected above floor level	Damages ($ Millions)
20	2	0	0.03	4	0	0.00
10	2	1	0.03	8	1	0.00
5	4	3	0.1	Not assessed		
2	10	5	0.5	Not assessed		
1	18	9	0.8	17	5	0.53
0.5	22	14	1.1	Not assessed		
0.2	29	19	1.6	Not assessed		
0.05	Not assessed			38	17	2.58
PMF	46	39	26.3	58	42	69.89

*note – number of affected allotments is different due to change in how they are considered between the damages assessments.

3.3 FMM flood damages

Flood damages were estimated for each FMM, FMS and the Ultimate Scheme using the representative ensembles used to assess the option (refer section 2.5). To ensure consistency in the benefit-cost ratio, the representative ensembles were for the baseline conditions were also used for the benefit-cost analysis.

Damages for each FMM are reported in the following sections specific to each FMM.

3.4 Benefit-Cost Analysis (BCA)

A BCA has been undertaken using the DT01 Tool. Outcomes are discussed in the following sections for each FMM, FMS and the Ultimate Scheme and assumptions summarised below.

For the benefit-cost analysis (BCA), a 5% discount rates was assumed as the recommended default as per the *NSW Flood Damage Assessment TOOL (DT01)*.

All options were assessed for a 50 year horizon assuming a least a 50 year design life. Increasing the design life would increase the benefit outcomes of the benefit-cost-ratio (BCR).

Costs for construction of each FMM, FMS and the Ultimate Scheme were developed by a Quality Surveyor and are included in the Civil Concept Design report.

For ongoing annual maintenance costs, the following was assumed, as agreed with Council:

- FMM1, FFM6, FMM7, FMM8a are on Council owned land with maintenance provision around the same levels pre and post (maintained sports field that will largely retain the same mowing intervals etc.). Therefore no additional maintenance costs were included.
- For FMM5 a maintenance cost of $5000 was applied. It is not currently Council land.
- For FMM2 costs are not likely to differ significantly from existing costs to maintain the Council drainage network. Therefore no additional maintenance costs were included.

- For the length of FMM9A, the proposed concrete lined channel is likely to reduce some of the maintenance costs. A reduction in mowing of the channel, as well as less risk of blockages and easier clearing at some structures (McLachlan Street culverts, March Street Bridge) should make this section easier to maintain reducing costs. Therefore no additional maintenance costs were included.
- For FMM9C, a maintenance cost of $5000 was applied to allow for mowing of the embankment. Costs are anticipated to slightly increase form existing due to embankment access and constraints.

4. FMM1 – Cutcliffe Park Detention Basin

4.1 Existing conditions

FMM1 is located at Cutcliffe Park in a residential area. Calare Public School is located immediately south of the park (refer Figure 4-1).

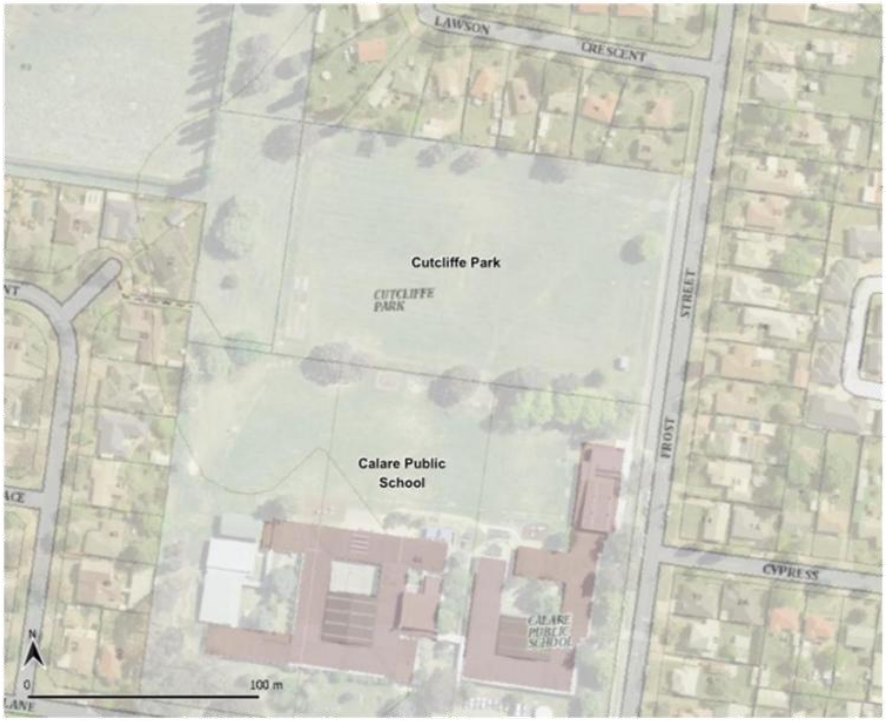


Figure 4-1: Location plan – FMM1

Existing flood behaviour mapping is presented in Appendix B.

Overland flows enter Cutcliff Park from the residential catchment to the west and flow from the park across Frost Street across Covent Close and Yulanta Place. The hazard of the overland flows path in the 1% AEP is generally H1 (generally safe for people, vehicles and buildings).

Nine properties on Lawson Cresent which back on to Cutcliffe Park are affected by shallow flows typically less than 50 mm in events up to and including the 1% AEP event.

Properties on Frost Street are affected by shallow overland flows in as little as the 20% AEP event but are not expected to exceed 50 mm until events larger than the 10% AEP storm. In the 1% AEP event, the overland flow path from Cutcliffe Park affects seven residential properties on Frost Street, 16 properties on Covent Close and eight properties on Yulanta Place. Flood depths on properties in Frost Street are considerable. Five properties are

predicted to experience flooding over 200 mm and two of these could experience 1% AEP flood depths of 400 mm to 550 mm. Four properties are predicted to be flooded above floor.

Depths and properties on Covent close are up to 420 mm with general depths observed between 50 mm to 350 mm including three properties likely subjected to over floor flooding. Properties on Yulanta Place may be subject to flood depths between 150 mm to 350 mm and one is flooded above floor.

In the 10% AEP event, the overland flow path affects five properties on Frost Street, eight on Convent Close and nine on Yulanta Avenue. Three properties on Frost Street experience shallow flooding (<150 mm) and two experience flood depth ranging from 200 mm to 400 mm. Shallow flooding is experienced by properties on Yulanta Place typically less than 50 mm.

Ponding occurs upstream of Cutcliffe Park to the southeast at a sag point on Burreburry Crescent. Once depths exceed the kerb and gutter, flows pass thorough a residential property and into the school grounds. A shallow flow path forms at Calare Public School between the 10% AEP and 1% AEP events as flows move towards Cutcliffe Park. Depths in the school grounds area are less than 100 mm and typically less than 50 mm in the 1% AEP event.

4.2 Summary of option

FMM1 comprises a new basin at Cutcliffe Park. The concept design also includes capping an existing stormwater pipe which runs along the southern side of the park and diverting this through the basin to collect surcharging flows into the basin.

Table 4-1 – FMM1 concept design

Design	Detail
Embankment	Length = 215 m Top level = 879.30 m AHD (260 mm above 1% AEP)
Spillway	Length = 15 m Spill level = 879.0 m AHD Spillway immunity = < 1% AEP (nominal overtopping in 1% AEP)
Outlet	1 x 600 mm diameter pipe to existing stormwater network in Frost Street Downstream invert level = 876.46 m AHD
Volume	To 10% AEP level = 922 m^3 To 1% AEP level = 2,650 m^3 To spillway = 2,455 m^3
Flood levels in basin	10% AEP = 878.58 mAHD 1% AEP = 879.04 mAHD (nominal overtopping spillway)
Other features	Existing 600 mm diameter stormwater line along southern boundary of park to be diverted through the basin.

4.3 Flood assessment

Flood impact mapping for option FMM1 is presented in Figure C 1 and Figure C 2 for the 10% AEP and 1% AEP events.

FMM1 generally results in reduction in flood levels from Frost Street to Woodward Street in all AEP events. The spillway is engaged near the peak of the 1% AEP event where the depths of overtopping of the spillway is 50 mm with peak flows of 0.04 m^3/s.

In the 20% AEP event, properties on Frost Street and the north side of Covent Close which previous would have experience shallow overland flows are no longer inundated. Reductions of up to 200 mm occur in the 10% AEP event the number of affected properties on Frost Street is reduced to three which are typically affected by shallow overland flows less than 50 mm from local catchment runoff. A ponding depth of 190 mm occurs at one property at a trapped low point in the DEM however this is a considerable reduction from the existing situation.

At Frost Street reductions in the region of 100 to 150 mm mean only one property is expected to be subject to over floor flooding in the 1% AEP event, a reduction of three properties. Up to 175 mm reductions are likely at the rear of affected properties on Convent Close though flooding at the front of properties is not reduces significantly. Flood levels at properties on Yulanta Place reduce between 150 and 160 mm at the rear of properties.

In the 1% AEP event FMM1 provides benefits downstream to Woodward Street including properties on Kenna Street and Moulder Street in the FMM2 location. Flood level reductions between 80 mm and 140 mm are observed at eight properties at Kenna Street and 20 mm to 80 mm reduction in flood depths on ten properties on Moulder Street, suggesting that greater overall benefits could be achieved if FMM1 is implemented in conjunction with FMM2.

In the 0.05% AEP and PMF event reductions are typically not more than 50 mm as the basin spillway is fully engaged. The water level in the basin of 879.19 remains below the embankment crest. By the peak of the PMF the crest of the embankment is expected to overtop.

The cricket field within Cutcliffe Park is incorporated into the basin footprint and will be inundated as frequent as the 20% AEP event (events more frequent than the 20% AEP event were not assessed). This is a deliberate design approach that maintains a similar frequency of inundation as recommended in the FRMS&P, delivering flood mitigation benefits for downstream properties.

4.4 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMM1 is shown in Table 4-2. Only residential properties are affected.

A BCR based on a total cost of the option of approximately $0.64 million dollars comes out at 1.55. The high BCA is influenced by the significant improvement in property flood affectation seen in the 1% AEP and more frequent events.

The option, over its estimated lifespan of 50 years, is estimated to provide sufficient reduction in damages to offset the cost of the project, with a moderate return on investment of approximately 50% of the construction costs.

Table 4-2 – FMM1 change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)
20%	6	0	$0.17	0	0	$-	0	0	$-
10%	7	0	$0.41	0	0	$-	0	0	$-
1%	8	8	$6.56	0	0	$-	0	0	$-
0.05%	5	4	$10.12	0	0	$-	0	0	$-
PMF	0	0	$2.88	0	0	$-	0	0	$-
Reduction in AAD ($ 100,000's)									0.54

Table 4-3 – FMM1 BCA

Total Capital Cost	$ 642,000
Recurrent Cost	$ 0
Present Value Benefit	$ 996,450
NPV (5% Discount)	$ 354,450
BCR	1.55

4.5 Recommendations

FMM1 has good economic outcomes and is recommended for further design development.

5. FMM2 – Kenna Street Stormwater Drainage Upgrade Works

5.1 Existing conditions

FMM2 is located in a predominantly residential area of Orange (refer Figure 5-1). Under typical rainfall events, stormwater drainage network collects runoff and conveys it to the open channel at Elephant Park. The channel joins Blackmans Swamp Creek about 350 m downstream.

Figure 5-1: Location plan – FMM2

Existing flood behaviour mapping is presented in Appendix B.

Properties along Kenna Street experience overland flow during the 10% AEP event. Flooding first occurs on Moulder Street in events between the 10% AEP and 1% AEP. Properties on the south side of Moulder Street are not affected in the 1% AEP. Front yard flooding occurs and two properties in the 0.05% AEP event and across the lot at a third property although above floor level flooding is not expected.

In the 20% AEP event shallow flood typically less than 50 mm may affect some lots on Kenna Street. 10% AEP event 29 dwellings on Kenna Street experience flooding on the lot of which none experience above floor level inundation. In the 1% AEP event about 94 properties between Woodward Street, Coronation Drive, Kenna Street and Moulder Street experience flooding on the lot of which seven dwellings are inundated above floor.

FMM2 seeks to reduce flooding to affected properties, particularly those on Kenna Street subjected to more frequent inundation.

5.2 Summary of option

Through the flood modelling FMM2 was refined to reduce the scale of works compared to the original FRMS&P concept option. Addition of existing pipes into the flood model, and other flood modelling updates, resulted in reduced above ground flood levels (refer section 2.2.4.4) which mean that the proposed works within 1-3 Moulder Street (160 m duplication of existing 1350 mm diameter RCP) is no longer required.

The FMM2 concept design proposes a stormwater network upgrade along Moulder Street, including the installation of twin 1050 mm diameter RCP stormwater pipes and upgraded junction pits. The system connects to a new 3.0 m x 0.9 m RCBC to replace the existing 3x 900 mm diameter culverts running beneath Woodward Street and increase the capacity of the system. The new RCBC will discharge to the tributary to Blackmans Swamp Creek channel in Elephant Park via an upgraded outlet.

Table 5-1 – FMM2 concept design

Design	Detail
Stormwater Network	Addition of 2 x 1050 mm RCP pipes placed beneath Moulder Street Multiple upgraded junction pits New 3.0 m x 0.9 m RCBC under Woodward Street replacing existing 3x 900 mm diameter

5.3 Flood assessment

Flood impact mapping for option FMM2 is presented in Figure C 5 and Figure C 6 for the 10% AEP and 1% AEP events.

In the 10% AEP event, FMM2 provides benefit at 23 of the 29 flood affected properties on Kenna Street. Reduction in peak flood levels at buildings is typically about 50 mm though reductions at the rear of seven properties that back on to 1-3 Moulder Street are over 100 m. The flood extent is reduced meaning four buildings previous affected by flood waters are no longer inundated at the building location.

In the 1% AEP event five properties on the east side of the driveway at 1-3 Moulder Street are no longer affected by flooding. A reduction in peak flood levels of 50 mm to 100 mm provides benefit to about 60 properties on Kenna Street and Moulder Street.

The additional overland flow captured and conveyed by the upgraded stormwater network is discharged downstream into the existing channel, causing flood level increases of 40 mm and 90 mm in the channel in the 10% and 1% AEP events respectively. In both events, increases in peak flood levels continue downstream through Moulder Park (FMM6 location) and to Matthews Park upstream of the CBD trunk drainage culvert. In the 10% AEP event, most increases are contained within the channel or adjacent open space areas with the exception of one property on Moulder Street near the Orange Netball Complex that is subject to a 10 mm increase. In the 1% AEP event, increases are again typically contained to open space areas and there is no significant increase in flood extent affecting property or infrastructure. Minor increases of 15 mm affect National Avenue between Hill Street and Sale Street and a similar increase occurs at the Orange Netball Complex near Moulder Park however the frequency of inundation is not likely to increase considerably.

5.4 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMM2 is shown in Table 5-2.

A BCR based on a total cost of the option of approximately $9.9 million dollars comes out at 0.05. The extremely high construction cost of the option does not result in commensurate damages reductions, resulting in the option having a poor economic argument for its continued development.

Table 5-2 – FMM2 change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)
20%	1	0	$0.01	0	0	$-	0	0	$-
10%	3	0	$0.13	0	0	$-	0	0	$-
1%	13	2	$4.78	-1	0	$-	0	0	-$1.26
0.05%	4	3	$7.81	0	0	$4.38	0	0	$-
PMF	0	0	$3.32	0	0	$0.11	0	0	$-
Reduction in AAD ($ 100,000's)									0.34

Table 5-3 – FMM2 BCA

Total Capital Cost	$ 9,900,000
Recurrent Cost	$ 0
Present Value Benefit	$521,543
NPV	-$9,378,457
BCR	0.05

6. FMM5 – Rifle Range Creek Railway Detention Basin

6.1 Existing conditions

FMM5 is located on Rifle Range Creek upstream of the Orange-Broken Hill railway corridor. The creek flows northwards. Orange Christian School is located west of the option and can be accessed at the rear by a footpath between the railway corridor and the potential FMM5 embankment. James Sheahan Catholic School is located east of FMM5. The school buildings are on higher ground at the Anson Street frontage with school sport facilities including the private oval backing on to Rifle Range Creek floodplain. A pedestrian link and cycle way runs east of Rifle Range Creek at the rear of James Sheahan Catholic School and connects to residential properties to the north via an underpass through the rail embankment.

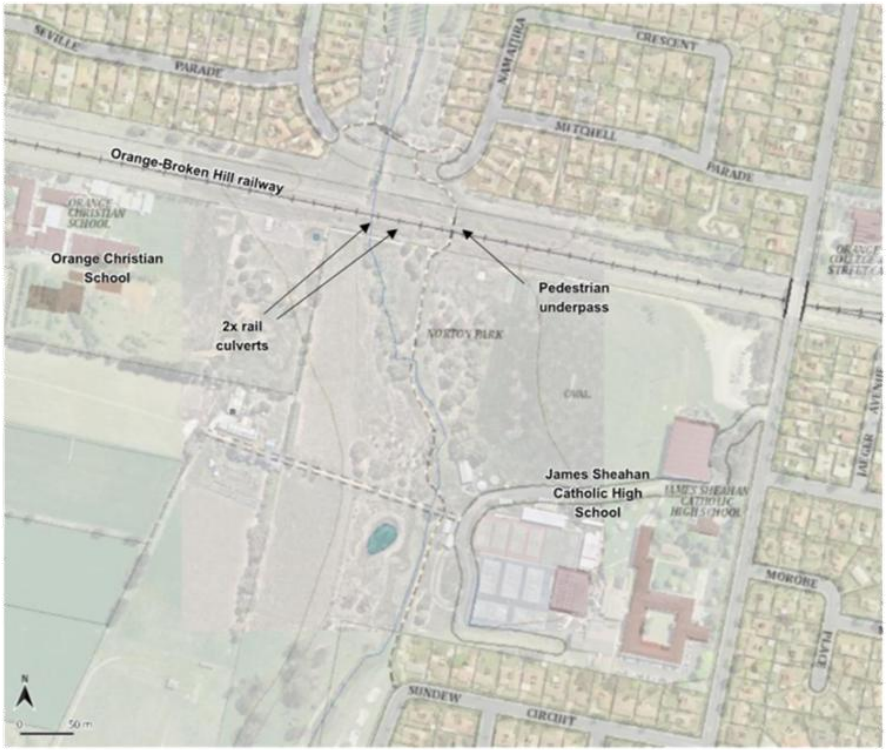


Figure 6-1: Location plan – FMM5

Existing flood behaviour mapping is presented in Appendix B.

The rail embankment acts as a dam to flows from the Rifle Range Creek catchment. Flood behaviour in this area is sensitive to the assumed blockage of the rail culverts. A sensitivity analysis on the culvert blockage and assessment of flooding at the pedestrian underpass is presented in Appendix A.

Upstream of the rail embankment no dwellings are affected by the ponding water levels in events up to an including the 1% AEP event. Upstream of the rail embankment ponding to 878.10 in the 1% AEP event causes inundation of a shed in the back corner of James Shean Catholic School and the entirety of the public shared path. The PMF level of 882.24 mAHD is shown to inundate properties along Sundew Circuit. A shallow flow path starts to form through James Sheahan Catholic in rarer AEP events from local catchment runoff exceeding the local drainage network but depths remain shallow.

The rail embankment is expected to overtop between the 0.05% AEP and PMF events (refer Figure 6-2). The embankment will be subject to depths of upstream ponding of 4 m in the 1% AEP event and 5 m in the 0.05% AEP event.

Flows through the pedestrian underpass are likely to occur at events rarer than the 5% AEP event and the modelling analysis show they drain away from property though parkland directly to the creek. Downstream of the rail embankment shallow flooding of less than 50 mm is shown to occur in the 1% AEP on properties on Namatjira Crescent. This is from local catchment runoff exceeding the drainage system and not from Rifle Range Creek or flows through the pedestrian underpass.

Properties adjacent to the creek are not typically inundated from creek flows in the 1% AEP event until Talinga Place about 600 m downstream of the rail embankment, where five properties are flood affected. A review of the flood model indicates that the channel is poorly defined in this area where local catchment inflow is applied. The mapped flood patterns and property affectation may be subject to increased uncertainty in this area.

6.2 Summary of option

FMM5 considers a new embankment upstream of the rail embankment and footpath. The FRMS&P indicated that this option would possibly reduce flooding downstream of the embankment. In addition, the purpose of considering this option is to reduce the reliance on the rail embankment which is not designed as a flood retention structure.

Table 6-1 – FMM5 concept design

Design	Detail
Embankment	Length = 130 m Top level = 878.00 m AHD (180 mm below 1% AEP)
Spillway	Length = 15m Spill level = 877.50 m AHD (10% AEP immunity, 680 mm overtopping in 1% AEP)
Outlet	3 x 1200 mm diameter pipe and precast headwall system to existing 1500 mm diameter culvert running under railway with adequate scour protection between
Volume	To 10% AEP level = 12,690 m^3 To 1% AEP level = 34,660 m^3 To spillway = 18,020 m^3
Flood levels in basin	10% AEP = 877.20 mAHD 1% AEP = 878.18 mAHD
Flood level between FMM5 basin embankment and rail embankment	10% AEP = 876.96 mAHD 1% AEP = 878.16 mAHD

6.3 Flood assessment

Flood impact mapping for option FMM5 is presented in Figure C 9 and Figure C 10 for the 10% AEP and 1% AEP events.

During concept design development, flood model iterations considered several alternatives of embankment heights and outlet structure dimensions to respond to the site constraints identified (refer Civil Design Report). The concept design finished at an embankment height of 878 mAHD, approximately 2 m lower than the height nominated in the FRMS&P.

Flood modelling indicated overtopping of the embankment height in the 1% AEP event and increased water levels upstream in all AEP events assessed. Options to raise the design height of the new embankment resulted in further increases in water levels upstream compared with the baseline attributed to the loss of storage compared with the baseline conditions as the new embankment was placed upstream of the railway.

In the 1% AEP and rarer events, the increase in water level on the upstream side of the embankment drove an increase flow through the rail culverts having some minor downstream impacts. In the 10% AEP and 5% AEP events some minor decreases in flood levels are noted downstream but do not benefit any properties. Further raising the embankment or restricting flows was shows to have adverse impacts on the flood behaviour affecting James Sheahan Catholic School. Therefore further design attention for a basin upstream of the rail corridor was abandoned, in discussions with Council, given the negligible benefit downstream and the increased flooded depths upstream.

The reporting on FMM5 further in this report and in the Civil Design Report is based on the latest state of the design.

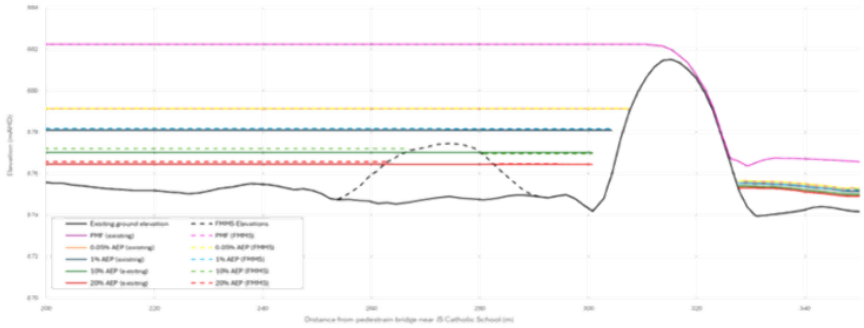


Figure 6-2: Flood levels and embankment overtopping at FMM5

6.4 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMM5 is shown in Table 7-2.

A BCR based on a total cost of the option of approximately $1.9 million dollars comes out at 0.00. The option results in a no reduction in flood damages and therefore has no economic benefit.

Table 6-2 – FMM5 change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)
20%	0	0	$-	0	0	$-	0	0	$-
10%	0	0	$-	0	0	$-	0	0	$-
1%	0	0	$-	0	0	$-	0	0	$-
0.05%	0	0	$-	0	0	$-	0	0	$-
PMF	0	0	$-	0	0	$-	0	0	$-
Reduction in AAD ($ 100,000's)z`									0.00

Table 6-3 – FMM5 BCA

Total Capital Cost	$ 1,860,000
Recurrent Cost	$ 5,000
Present Value Benefit	$ 0
NPV	-$1,936,862
BCR	0.00

6.5 Recommendations

As outlined in Section 6.3 above, attempts were made to revise the design to provide a benefit downstream whilst minimising negative effects upstream. Options considered for FMM5 progressed to the point that a new embankment would exacerbating existing flood conditions to the rear of James Shean Catholic School, the public shared path and residential properties along Sundew Circuit. The option development was discussed with Council through the concept design process. As the options provide no flood benefit, do not significantly reduce ponding against the rail embankment and was shown to worsen the depths of flooding upstream, a decision was made to abandon consideration for further detailed design.

Given the impact of rail culvert blockage on predicted flooding though the underpass and the impact on flood levels affecting the rear of James Sheahan Catholic School (refer Appendix A), it is recommended that Council consider engagement with the rail maintenance authority to minimise risk of further blockage of the culverts.

7. FMM6 – Moulder Park Detention Basin

7.1 Existing conditions

Moulder Park is located at the confluence of Rifle Range Creek with Blackmans Swamp Creek. The area is used for recreation uses. Orange Public School (Junior campus) is located east of the park on Anson Street.

At the northeast corner of Moulder Park the two creeks flow into three 1800 mm circular culverts which cross Anson and Moulder Street and flows into open channel in Matthews Park. The Blackmans Swamp Creek channel enters the CBD trunk drainage culvert at Kite Street and continues about 900 m downstream to where it daylights at the rear of commercial industrial properties on Peisley Street and joins with the East Orange Channel.

Figure 7-1: Location plan – FMM6

Existing flood behaviour mapping is presented in Appendix B.

In as frequent as the 10% AEP event minor flooding occurs downstream of Moulder Park at the corner of Anson Street and Moulder Street. Depths of up to more than 250 mm affect Orange Public School and impact the smaller school building to the north. Depths increase to over 400 mm in the 1% AEP event though at buildings is generally less than 100 mm.

By the 10% AEP event three properties on Moulder Street are flood affected. Depths increase to maximum between 300 mm and 500 mm at these properties in the 1% AEP event. However floor levels are above 1% AEP flood levels[1].

[1] *Floor levels were obtained from the FRMS&P and additional survey is recommended at detailed design or for refinement of the benefit-costs analysis to check.*

Above floor flooding has been previously reported at commercial properties on Lords Place. In the 1% AEP event depths of 100 mm to localised areas of 200 mm occur though priorities are not inundated above floor level though some are very close to over floor flooding.

Upstream of Moulder Park on Black Swamp Creek, minor flooding occurs in the open space area between Hill Street and Sale Street in the 20% AEP and is expected to spill onto National Avenue by the 10% AEP event. In the 1% AEP event depths on National Avenue of up to about 250 mm are predicted but do not affect dwellings and lots generally grade up from the road.

In the Rifle Range Creek catchment local overland flood occurs at residential properties draining to the creek in the 1% AEP event but is generally shallow being less than 100 mm.

7.2 Summary of option

FMM6 comprises a detention basin within the eastern section of Moulder Park. The basin is designed to attenuate stormwater from upstream catchment before discharging into Blackman Swamp Creek to reduce the flood affection of properties on Lords Place and other areas downstream of Moulder Park before Kite Street. The spillway discharges to Anson Street near Torpy Street.

The concept design includes an east-west direction embankment north of Blackmans Swamp Creek extending southwards between Rifle Range Creek and Anson Street. Options to raise the spillway to reduce frequency of overtopping are limited by the water level in the basin and increased flood levels on National Avenue. The existing stormwater drainage along Anson Street is redirected to the existing culverts at Anson Street. A portion of Rifle Range Creek would be realigned to provide increased storage capacity within the basin footprint.

Table 7-1 – FMM6 concept design

Design	Detail
Embankment	Length = 310 m Top level = 864.00 m AHD (390 mm freeboard to 1% AEP)
Spillway	Length = 60 m Spill level = 863.50 m AHD Spillway immunity = < 10% AEP (nominal overtopping in 10% AEP)
Outlet	3x 1800 mm pipes connecting to existing culvert at Anson Street
Volume	To 10% AEP level = 16,867 m^3 To 1% AEP level = 18,310 m^3 To spillway = 16,867 m^3
Flood levels in basin	10% AEP = 863.50 mAHD (nominal overtopping of spillway) 1% AEP = 863.61 mAHD
Other features	Realignment of the stormwater network along Anson Street Realignment of Rifle Range Creek

7.3 Flood assessment

Flood impact mapping for option FMM6 is presented in Figure C 13 and Figure C 14 for the 10% AEP and 1% AEP events.

FMM6 has minor benefit is the 20% AEP event as flows are generally contained within channels or open space areas and few properties are flood affected. The basin spillway engages in the 10% AEP event although flows are

nominal at 0.05 m³/s. While there are minor increases in flood levels on the west side on Anson Street as a result, the flood hazard remains as H1 and the opposite side of the road remains trafficable.

In the 10% AEP event flood levels at Orange Public School are reduced by about 100 mm. There is between 100 mm and 180 mm reduction in flood levels affecting the properties on Moulder Street which benefits two dwellings. All other decreases in flood level are within open space of the channel.

In the 1% AEP event flood levels at the school are reduced between 30 mm at the northern building to 70 mm in the open space areas. Decreases of about 70 mm affect one commercial/industrial property which backs on to Matthews Park and is accessed from Moulder Street. However the building is not flooded over floor in existing conditions. Similar reductions occur at the carpark at the intersection of Kite Street and Lords Place. All other reductions are contained mainly within open space areas and provide little property benefit. At properties on Moulder Street reductions of up to 130 mm occur but the properties are not flooded above floor in existing conditions anyway.

The option also results in decreases in flood levels in the channel downstream of the CBD trunk drainage culvert. In the 10% AEP event, reductions as much as 100 mm occur as far as The Council Depot and reduction in water levels are predicted to continue as far as near the East Orange Harvesting Wetland. Therefore FMM6 would assist in mitigating impacts from FMM2 and FMM9A which increase water levels in this area (refer sections 5.3 and 0).

In the 1% AEP event minor reductions of about 20 mm occur in the same area. It should be noted that the changes are noted for the storm events assessed in the representative ensemble. From the representative storm ensemble 270 minute is critical here in the 1% AEP event and results in peak flood levels lower than the 90 minute storm which is critical storm when assessing the full ensemble.

Upstream of the FMM6 basin, flood levels on National Avenue are increased in the 10% AEP event and larger caused by the restricted discharge from the basin. Increases of up to 140 mm in the 10% AEP to 230 mm in the 1% AEP are predicted however as properties grade up from the street no impact occurs at the dwellings themselves and no properties are affected by over floor flooding. This does however reduce the freeboard available to habitable floor levels.

At Lords Place there is no notable benefit in terms of reduction in peak flood levels. Noting that the FRMSP&P design found option FFM6 offered benefit here and the area has flooded historically, the difference between the FRMS&P and the updated assessment is likely caused by:

- Differences in the flood modelling hydrology between ARR87 and ARR2019. The ARR2019 modelling predicts reduced flood levels compared to the FRMS&P up to 230 mm.
- The representative ensemble included the 15 minute and 30 minute storm in the 10% and 1% AEP event, which is the critical duration storm at Lords Place. This is different to the critical duration storm in the Blackmans Swamp Creek at the area downstream of the proposed basin and upstream of Kite Street which is subject to longer critical duration storms. Therefore, while the basin provides benefit in some duration storms, it provides no benefit to Lords Place in the short duration storms critical for flooding in that area.
- Flooding that occurred at Lords Place in October 1999 was noted to be exacerbated by debris blockage accumulated on a grated structure at the CBD trunk drainage culvert entrance which has since been removed. The FMS&P model and parameters adopted for this concept design assessment assume the culvert is unblocked.

7.4 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMM6 is shown in Table 7-2.

A BCR based on a total cost of the option of approximately $2.8 million dollars comes out at 0.11. The option has little to no economic benefit, resulting in the option having a poor economic argument for its continued development. The options is the most expensive of the basin options to construct due to the additional works for channel diversion and drainage in Anson Street.

Table 7-2 – FMM6 change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)
20%	0	0	-$0.01	1	0	$-	0	0	$-
10%	0	0	$-	0	0	$-	0	1	$0.07
1%	0	0	$-	1	0	$1.98	0	0	$1.33
0.05%	0	0	$-	0	2	$1.71	0	0	$-
PMF	1	2	$10.31	0	0	$0.96	0	0	$0.90
Reduction in AAD ($ 100,000's)									0.17

Table 7-3 – FMM6 BCA

Total Capital Cost	$ 2,840,000
Recurrent Cost	0
Present Value Benefit	$ 325,042
NPV (5% Discount)	-$ 2,514,958
BCR	0.11

7.5 Recommendations

While the option provides little economic benefit there are flood improvements at Orange Public School (Junior Campus) and to three dwellings on Moulder Street. Detailed floor level survey of these properties may show some minor economic benefit (floor levels were adopted from the Flood Study data).

FMM6 reduces flow in the channel downstream of the CBD truck drainage culvert, and while standalone provides no economic benefit, could be beneficial with other options (refer sections 13 and 14). The option may need assessment for the critical duration flows in the lower catchment to more accurately assess any benefit. FMM6 would also assist to mitigate impacts from FMM2.

If the option is pursued to detailed design, refinement to the concept could consider relocating the spillway to the northeast corner of Moulder Park so that flows are not released directly towards Anson Street.

8. FMM7 – Ridley Oval Detention Basin

8.1 Existing conditions

East Orange Creek flows through open space from Churchill Avenue and adjacent to Riddley Oval into two 1350 mm culverts which daylight downstream of Bathurst Road into Memory Park. The oval and parkland is bounded by residential properties on all sides and sports facilities and the Orange Function Centre are located above the downstream culverts. A dog park is located on the west side of the creek access by Caroline Street and Warrendine Street. A bridge crossing of the creek provides access between Caroline Street eats of the creek and parkland west of the creek.

Figure 8-1: Location plan – FMM7

Existing flood behaviour mapping is presented in Appendix B.

As the channel capacity is exceeded flows first spill to lower ground to the west at the rear of properties on Warrendine Street. In the 20% AEP event flows exceeding the capacity of the channel encroach into the rear of four properties however flows are shallow and the fence line is likely to restrict most water. In the 10% AEP event flood mapping shows one property is likely to be inundated to the building footprint however the floor level is more than 1 m above the flood levels. Flood extents encroach further into properties in the 1% AEP event but again are not are expected to be flooded above floor level. By the peak of the PMF, properties here are surrounded by floodwaters, however only six of the nine properties are expected to suffer over flood flooding.

The Totally Tennis building on Palmer Street immediately downstream of Ridley Oval is flooded over floor in as frequent as 20% AEP event. In the 10% AEP event flood level are likely to reach the floor level of the Orange Function Centre. Further downstream Eyles Street some shallow flooding occurs. Depths of 350 mm are predicted in the 1% AEP event at the Orange Function Centre. Seven properties on the west side of the road would be subject to yard inundation.

8.2 Summary of option

During the concept design process, a number of options were considered to minimise the embankment footprint in Ridley Oval to maintain a suitable cricket field size. However, each of the options investigated did not provide sufficient flood benefit and therefore the final concept design option selected though consultation with Council limits the function of the cricket pitch.

The FMM7 final concept design proposes a detention basin spanning the Ridley Oval open space, including the dog park west of East Orange Creek. The basin aims to attenuate peak stormwater flows before discharging into the East Orange Creek culverts and to relieve flooding to properties on Warrendine Street. The embankment at the dog park was raised to ensure no overtopping in the 1% AEP event.

The basin layout includes a 370 m long embankment from end or Warrendine Street, across the East Orange Creek and wrapping around the oval east of the East Orange Creek and toward the oval access at Palmer Street. The spillway discharges directly to the creek. Additional storage is created by excavation the dog park area. Two 900 mm RCPs will convey creek low flows through the embankment where it crosses the creek. A grated inlet pit in the proposed basin will drain the basin to East Orange Creek via a 600 mm diameter pipe.

Table 8-1 – FMM7 concept design

Design	Detail
Embankment	Length = 370 m Top level = 871 m AHD around Ridley Oval (30 mm freeboard to 1% AEP) Top level = 871.8 m AHD near dog park (700 mm freeboard to 1% AEP)
Spillway	Length = 30 m Spill level = 870.5 m AHD (overtopped by 180 mm in 1% AEP) Spillway immunity = between 10 and less than a 1% AEP
Outlet	Grated inlet pit at a low point near the northwest corner of the basin to drain via 600 mm diameter pipe to East Orange Creek upstream of the existing culvert
Volume	To 10% AEP level = 935 m^3 To 1% AEP level = 9,320 m^3 To spillway = 6,780 m^3
Flood levels in basin	Ridley Oval: 10% AEP = 869.54 to 870.43 mAHD 1% AEP = 870.70 mAHD Dog Park: 10% AEP = 870.73 mAHD 1% AEP = 871.10 mAHD
Other features	3,808 m^3 excavation in the dog park to increase flood storage. 2 x 900 mm diameter culvert through the embankment where is crosses East Orange Creek

8.3 Flood assessment

Flood impact mapping for option FMM7 is presented in Figure C 17 and Figure C 18 for the 10% AEP and 1% AEP events.

Flooding of the oval is expected between a 20% AEP and 10% AEP event. The two 900 mm diameter pipes where the embankment crosses the creek cause increases creek levels upstream though no properties are impacted.

Decreases in peak flood level of about 70 mm occur in the 20% AEP event in the channel downstream and decreases of about 90 mm in the 10% AEP event however there is no significant change to the flood extent. The Orange Function Centre and Totally Tennis building benefit from a reduction in levels of about 50 mm on the south side of the buildings.

In the 1% AEP event decreases of 160 mm occur immediately downstream of the two proposed 900 mm diameter pipes reducing to a 35 mm benefit at the pedestrian footbridge. Rear yards of properties on Warrendine Street are benefitted but there is no significant reduction in flood event.

Further downstream, properties on Eyles Street benefit average decreases of about 20 mm to 40 mm in front yards although no properties are affected by over floor flooding in the baseline or FMM7 scenario. Minor reductions benefit the Totally Tennis and Orange Function Centre but there is no change to the over floor flooding that occurs at both properties.

In the 10% AEP and larger magnitude events (up to 0.05% AEP), decreases in peak flood levels continue as far as the confluence of East Orange Creek with Blackmans Swamp Creek with significant benefits. In the 1% AEP event:

- about an 80 mm to 90 mm reduction in peak flood levels to residential properties between Icely Road and Summer Street;
- 20 mm to 60 mm reduction at residential properties on the east side of McLachlan Street south of March Street; and
- 10 to 25 mm reduction at residential properties on McLachlan Street north of March Street.

These downstream benefits are noted in the representative storm ensemble for FMM7. This FMM7 representative ensemble does not include the critical storm in the East Orange Channel at the location of all the decreases which is 90 minutes in the 1% AEP event. The flood levels in the FMM7 representative ensemble are lower (by up to 100 mm in some areas) than the critical storm and thus benefits may be overestimated. It is recommended that the 90 minute storm is added to the representative ensemble should the option progress to detailed design.

Upstream of the embankment one property on McLachlan Street experiences increases in backyard flood depths, with flood levels increasing by up to 70 mm but remaining 700 mm below floor level.

In the PMF event the basin results in some redirection of flows leading to an increase in flood depths at properties in Warrendine Street of 70 to 440 mm and some minor increases of less than 30 mm at McLachlan and Palmer Streets. Two properties become flooded over flood (refer Table 8-2). These increases are not shown to occur in the 0.05% AEP event. While there are increases in the PMF, the probability of this impact occurring is extremely low and the benefit of FMM7 in all other AEPS is considered to outweigh the PMF impacts.

8.4 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMM7 is shown in Table 8-2.

A BCR based on a total cost of the option of approximately $1.5 million dollars comes out at 3.27. This strong BCR is largely due to the continued downstream benefits of the option downstream to as far as the confluence of the two creeks. Benefits may be slightly overestimated due to the selection of the representative ensemble of durations and temporal patterns in the FMM7 assessment (refer section 8.3).

The option, over its estimated lifespan of 50 years, is estimated to provide sufficient reduction in damages to offset the cost of the project, with a good return on investment of approximately 330% of the construction costs.

Table 8-2 – FMM7 change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)
20%	0	0	$-	0	0	$4.09	1	0	$-
10%	3	1	$1.22	1	2	$3.00	0	0	$-
1%	12	0	$2.76	1	1	$4.74	1	0	$-
0.05%	6	5	$5.72	1	1	$3.50	0	0	$-
PMF	0	-2	-$4.85	0	0	-$0.80	0	0	$-
Reduction in AAD ($ 100,000's)									2.69

Table 8-3 – FMM7 BCA

Total Capital Cost	$ 1,500,000
Recurrent Cost	0
Present Value Benefit	$4,911,115
NPV (5% Discount)	$3,411,115
BCR	3.27

8.5 Recommendations

Given the flood impacts seen downstream, it would be prudent to assess additional storm durations and temporal patterns to confirm the BCR. It is recommended that the 90 minute storm is added to the representative ensemble should the option progress to detailed design.

The embankment at the dog park has a 700 mm freeboard above the 1% AEP level and could be reduced to reduce construction costs and visual impacts.

9. FMM8A – Glenroi Oval Detention Basin

9.1 Existing conditions

Glenroi Oval is located within in a residential area with housing to the west and north. The oval itself is mainly used for cricket. Orange Hockey Centre, which includes two hockey pitches, is located to the south including carpark to the east of the oval. A pre-school and Masonic Centre are located on Moad Street to the north and Glenroi Heights Public School and another pre-school are located to the south of the oval.

Existing flood behaviour mapping is presented in Appendix B.

Figure 9-1: Location plan – FMM8A

During heavy rainfall events, overland flows pass from south to north through the open grounds of Glenroi Heights Public School and into Glenroi Oval. Flood modelling outputs show some ponding occurring at the southeast corner of the oval occurring in frequent AEP events. At the southern end of the oval an existing 525 mm pipe is shown in Council GIS data with the upstream pit located in the tree line. This pit and pipe was not picked up during survey however for the purpose of the flood modelling the pit and pipe was retained as per the Council GIS which indicates it connects to the existing 1050 mm diameter pipe that crosses the oval from south to north.

In the 1% AEP event and larger magnitude flood, the flood modelling indicates that shallow flows are concentrated along the eastern side of the oval and shallow flows pass into the rear of properties on Maxwell Avenue ponding at a trapped low point shown in the DEM. Shallow over floor flooding is predicted at four dwellings.

The 1050 mm diameter pipe through the site connects to two 600 mm diameter pipes as it crosses Moat Street and back into a 1050 mm diameter pipe as it continues downstream through an easement at the rear of properties on Elizabeth Street and Nunns Avenue. Properties on Moad Street are generally flood free in the 1% AEP event. An overland flow path affects properties in the Elizabeth Street and Nunns Avenue area. In the 10% AEP event, depths can exceed 150 mm though properties in this area not expected to be inundated over floor level. By the 1% AEP event one dwelling on Nunns Avenue and five dwellings on Elizabeth Street are predicted to be inundated above floor level.

The overland flow paths continues downstream to the west between Garden Street and Bathurst Road following the alignment of the 1050 mm diameter pipe drainage and affecting a car parking area, The Ophir Hotel and commercial properties on Glenroi Avenue before joining flows from East Orange Creek near Orange Indoor Tennis Centre (near FMM7).

9.2 Summary of option

The FMM8A concept design comprises a detention basin within the Glenroi Oval to reduce downstream flood risk and overland flow conveyance through residential areas. The design involves an embankment around the west and north boundaries of the oval. A spillway discharges toward Moad Street. The outlet comprises a 375 mm diameter pipe connection to the existing twin 600 mm diameter stormwater pipes in Moad Street. The existing 1050 mm diameter stormwater pipe beneath the oval will remain in place.

Table 9-1 – FMM8A concept design

Design	Detail
Embankment	Length = 290 m Top level = 878.5 m AHD
Spillway	Length = 17 m Spill level = 878.3 m AHD Spillway immunity = < 1% AEP (1% AEP overtopping by 10 mm)
Outlet	Circular 375 mm pipe discharging into existing 2 x 600 mm diameter pipe at the northwest of the basin.
Volume	To 10% AEP level = 3,529 m^3 To 1% AEP level = 14,260 m^3 To spillway = 14,071 m^3
Flood levels in basin	10% AEP = 877.70 m AHD 1% AEP = 878.31 m AHD
Other features	New 375 mm dia pipe and pit to collect local ponding in south-west corner of oval (at location of possible 525 mm dia in Council's GIS).

Council records indicate a 525 mm diameter low-flow pipe aligned on the southern edge of the oval draining to the 1050 mm pipe, however the recent survey indicated that this pipe does not exist. The civil design shows a new 375 mm diameter pipe to restore this asset.

9.3 Flood assessment

Flood impact mapping for option FMM8A is presented in Figure C 21 and Figure C 22for the 10% AEP and 1% AEP events.

In the 1% AEP event, the overland flows affecting properties on Elizabeth Street and Nunns Avenue are reduced by 100 mm to 250 mm. Only two dwellings are inundated above floor compared to the six under current conditions.

Further downstream, decreases of 50 to 90 mm occur at commercial properties and decreases of about 60 mm affect the rear of properties on Autum Street which back on to the East Orange Channel. Residential properties near the East Orange Channel on McLachlan Street are benefitted by reductions in peak flood levels of around 30 mm. Decreases of 10 to 20 mm benefit residential properties in the area between March Street and the confluence of Blackmans Swamp Creek and the East Orange Channel. Decreases in peak water levels about 10 mm to 15 mm continue downstream as far as Ngumbadal / Unity Bridge downstream of the confluence of Blackmans Swamp Creek and the East Orange Channel although do not benefit any properties.

The basin prevents the overland flows which under existing conditions encroached onto properties on Maxwell Avenue. As a result, the affected properties on Maxwell Avenue are now flood free in events up to an including the 0.05% AEP event.

In the PMF event, the option worsens flooding for properties on Maxwell Avenue and Moad Street by 100 mm to 300 mm due to diversion of flows caused by the embankment and an additional two properties are likely to be subject to overflood flooding in the PMF compared to the existing conditions scenario. These impacts are not noted in the 0.05% AEP event and the chance of this PMF impact is low compared to the benefit brough by the basin for more frequent AEP flood events. This is reflected in the BCR that the annual financial benefit of flood level reduction at these properties in all other AEP events exceeds the increase in the PMF.

9.4 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMM8A is shown in Table 9-2.

A BCR based on a total cost of the option of approximately $1.29 million dollars comes out at 2.43. The option, over its estimated lifespan of 50 years, is estimated to provide sufficient reduction in damages to offset the cost of the project, with a good return on investment of approximately 250% of the construction costs.

Table 9-2 – FMM8A change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)
20%	3	1	$0.27	2	1	$0.76	0	0	$-
10%	16	1	$1.82	2	1	$2.67	0	0	$-
1%	17	5	$7.84	0	0	$4.43	0	0	$-
0.05%	6	12	$12.74	5	4	$16.94	0	0	$-
PMF	-5	-2	-$7.39	-2	0	-$3.11	0	-1	-$11.85
Reduction in AAD ($ 100,000's)									1.72

Table 9-3 – FMM8A BCA

Total Capital Cost	$ 1,290,000
Recurrent Cost	$ 0
Present Value Benefit	$ 3,135,284
NPV	$ 1,845,284
BCR	2.43

9.5 Recommendations

The spillway is located opposite a pre-school and may put the school at risk should dam failure occur. Relocation existing pipe exists that is suitable for use of if a new drainage connection is required. This is unlikely to significantly impact flood levels as the pit drains allow point to the main trunk drainage.

10. FMM9A – East Orange Channel Works (between Icely Road and confluence with Blackmans Swamp Creek)

10.1 Existing conditions

The reach of the East Orange Channel from Icely Road pedestrian bridge to Summer Street is a concrete lined drain with grassed banks. The existing channel north of Summer Street to Byng Street was widened by Council in 2014 and these works included converting the existing v-shaped channel to a concrete-lined trapezoidal channel with a base width of approximately 7m.

The channel typically passes through residential areas until March Street where is passes through an industrial area and adjacent to the Transgrid Orange 132kV Substation before joining Blackmans Swamp Creek. At McLachlan Street flows are conveyed through two 1800mm diameter culverts. Flows continue in open concrete lined channel with bridge crossings at March Street and William Street until the confluence with Blackmans Swamp Creek.

Figure 10-1: Location plan – FMM9A

Existing flood behaviour mapping is presented in Appendix B.

Between Icely Road and Summer Street, all properties that back on to the East Orange Creek channel are subject to yard inundation in the 10% AEP event though none are expected to be inundated above floor from creek flooding. By the 1% AEP event the rear of properties on McLachlan Street are also affected, however no properties are subject to over floor flooding from creek flows.

From downstream of Summer Street flows typically reman in channel to Byng Street for all events up to and including the 1% AEP event. This section was previously widened by Council in 2014. In the 10% AEP event and larger magnitude events, properties on the east side of McLachlan Street are subject to inundation from creek flows as the channel capacity is exceeded at the McLachlan Street crossing. The property nearest the creek would be subject to some over floor flooding in the 10% AEP event. In the 1% AEP event, depths of flooding at the road crest are up to about 130 mm as flows from the channel overtop the road. Properties in the area between McLachlan Street and March Street are subject to depths of inundation up to 500 mm and 12 properties here are likely to experience above floor flooding.

In the 10% AEP event, some inundation is shown at properties on McLachlan Street north of March Street which is largely due to the application of local catchment inflows. As the magnitude of a flood event becomes larger, flooding at these properties becomes more dominated by out of creek flows exceeding the channel upstream of McLachlan Street. Six properties are affected by over floor flooding in the 1% AEP event.

The Transgrid Orange 132kV Substation is predicted to become inundated between the 10% AEP and 1% AEP events with depth up to 375 mm in the 1% AEP event. The flooding occurs as a result of the limited capacity of the culvert at William Street causing out of bank flows to will over the road and into the substation.

10.2 Summary of option

The FMM9A concept focuses on channel and culvert upgrades along East Orange Creek, from Icely Road through to Summer Street and William Street to the confluence of the two creeks. Council have developed a design for McLachlan Street and March Street which was incorporated into the flood modelling of FMM9A.

Survey determined that the channel width between Summer Street and Byng Street are at least 7 m wide and therefore no further works is proposed in this area. Summer Street bridge has pedestrian bridges on either side which creates a hydraulic pinch point in the channel reducing the channel width to between 2.4 m and 4.4 m.

Key design updates include:

- Channel cross-section from Icely Road to Summer Street adopted from FRMS&P preliminary concepts, with top of bank levels updated to match recent survey;
- Replacement of pedestrian bridges at Summer Street
- Adoption of Council's detailed design between McLachlan Street and March Street including replacement of:
  - 2 × 1.8m diameter pipes under McLachlan Street with a new 2 × 3.6 m × 1.8 m box culvert; and
  - Upgraded bridge structure under March Street;
- Revised channel cross-section downstream of William Street to increase flow capacity; and
- A new 150mm high earth bund near the TransGrid substation to minimise upstream overflow from spilling into the site due to insufficient capacity at William Street Bridge.

Table 10-1 – FMM9A concept design

Design	Detail
Channel Works	Channel widening and realignment between Icely Road and Summer Street Channel widening from McLachlan Street to March Street Channel widening downstream of William Street
Culverts	Replace 2 x 1.8m pipes with 2 x 3.6m x 1.8m box culvert (McLachlan Street)
Bridges	March St upgrade (Council design) Summer Street bridge pedestrian bridges to be replaced
Other	150 mm high bund to minimise overland flows entering the substation (in events between 10% AEP event and event which first overtops the bund).

Through the flood modelling and concept design development it was found that the option would increase flood levels on the substation in the 1% AEP event in the order of 60 mm. To minimise impact on the substation a 150 mm bund was incorporated into the design. The maximum 150 mm height was determined to maintain driveway accessibility to the substation and to tie into existing terrain. At 150 mm the bund would be overtopped in the 1% AEP event as depths in William Street reach 450 mm in the FMM9A scenario, however the bund does reduce the increase in water levels on the substation compared to the no bund scenario by reducing flow into the

substation. Flood modelling showed that a higher bund could further reduce impact on the substation but would have adverse impacts on properties on the opposite side of William Street.

10.3 Flood assessment

Flood impact mapping for option FMM9A is presented in Figure C 25 and Figure C 26 for the 10% AEP and 1% AEP events.

In events up to and including the 1% AEP event, option FMM9A decreases flood levels upstream of March Street. Property inundation between Icely Road and Summer Street is reduced significantly. Out of bank flooding no longer occurs in the 20% AEP event and flood depths in the 1% AEP event are reduced in the region of 300 mm to 500 mm with four properties on McLachlan Street no longer inundated.

Properties in the east side of McLachlan Street where the channel crosses the street are subject to decreases in peak flood levels. In the 20% AEP event, four previously inundated properties are now shown as flood free and eleven properties in the 10% AEP event with a further eight now flood free properties on the west side of McLachlan Street north of March Street.

Downstream of March Street increased flow causes increases predicted peak flood levels in the channel downstream of March Street. Increases continue downstream to beyond the Northern Distributor. No properties are impacted in the 20% AEP and 10% AEP and increases remain in channel or open space areas. In the 1% AEP event, flooding occurs at William Street as in channel flow exceeds the capacity of the bridge. Flows spill over Wiliam Street and into the substation. Although this flood behaviour already occurs under the existing conditions, flood depths on the road and at the substation are exacerbated by the increased channel flow. At the substation depths increase by about 34 mm from the existing depths of about 150 mm to 370 mm.

10.4 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMM9A is shown in Table 10-2.

A BCR based on a total cost of the option of approximately $8.0 million dollars comes out at 0.38. The option has good economic benefit, however the high cost of implementation results in a poor outcome with regards to economic value.

Table 10-2 – FMM9A change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)
20%	4	0	$0.06	0	0	$0.38	0	0	$-
10%	16	0	$0.97	1	0	$-	0	0	$-
1%	41	9	$15.55	9	6	$6.62	1	0	$-
0.05%	14	18	$26.61	2	0	$2.56	-1	0	$-
PMF	4	4	$24.24	0	0	$2.48	0	0	$0.39
Reduction in AAD ($ 100,000's)									1.65

Table 10-3 – FMM9A BCA

Total Capital Cost	$ 7,975,000
Recurrent Cost	0
Present Value Benefit	$ 3,017,977
NPV (5% Discount)	-$ 4,957,023
BCR	0.38

10.5 Recommendations

The bund at the substation was agreed as 150 mm high in consultation with Council and assessment of possible tie in locations and accessibility for the substation access. At 150 mm the bund is shown to provide minor benefit in the 1% AEP event and only likely to provide betterment when spilling into the substation occurs (between a 10% AEP and 1% AEP event). Flood modelling showed that a higher bund would provide more benefit for the substation however can increase inundation to properties on the opposite side of William Street. At detailed design, review of the bund design, incorporating survey data and including flood modelling, is recommended to assess if there is opportunity to raise the bund.

11. FMM9C – Blackmans Creek Channel Widening

11.1 Existing conditions

Downstream of Leeds Street, Blackmans Swamp Creek passes through open space which is backed on to by industrial properties to the south and the Leeds Street substation (ES2) to the north. Council's depot, including the NSW SES and RFS Stations is located immediately downstream of the McLachlan Street crossing and the creek continues through open spaces backed on to by residential properties.

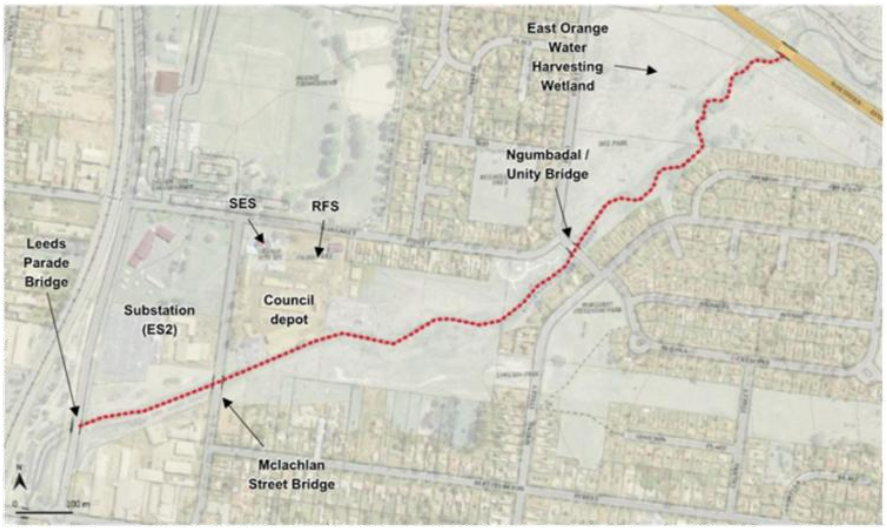


Figure 11-1: Location plan – FMM9C

Existing flood behaviour mapping is presented in Appendix B.

In events more frequent than the 1% AEP event an out of bank flows remain in the open space area. In the 1% AEP event overland flows paths draining toward the creek cause inundation at one property on Spring Street and two properties on Margaret Street near Ngumbadal / Unity Bridge. Peak flow in the channel is about 80 m^3/s to 90 m^3/s in the 1% AEP event increasing downstream.

The deck level of Ngumbadal / Unity Bridge is overtopped by 570 mm in the 1% AEP event. Modelling shows that the bridge is soffit is exceeded in the 20% AEP and 10% AEP events but not overtopped. This bridge has been designed to be overtopped.

11.2 Summary of option

The FMM9C concept design involves channel widening along Blackmans Swamp Creek between Leeds Street and the Northern Distributor Road. Channel widening will occur on alternative sides of the creek and features a 10 m wide bench with 2% cross-fall to the main channel and 1V:4H batter to natural as per the typical section in Figure 11-2. The FRMS&P suggests that the widening is required to offset the impacts caused by FFM9A.

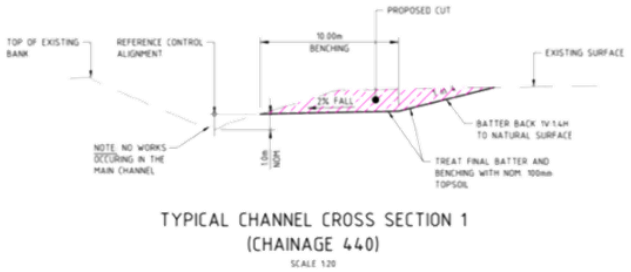


Figure 11-2: Typical section for channel widening FMM9C

11.3 Flood assessment

Flood impact mapping for option FMM9C is presented in Figure C 29 and Figure C 30 for the 10% AEP and 1% AEP events.

As a standalone option FMM9C works to reduce peak flood levels in the channel downstream of the confluence of Blackmans Swamp Creek and the East Orange Creek channel. There are some minor increases in flow downstream of the Northern Distributor in the more frequent AEP events due to the increased conveyance of the widened channel however there is negligible impact to property.

In the 1% AEP upstream of the option channel reduction of about 100 mm to 200 mm occur as results of the increased flow capacity of the channels downstream. Modelling results show a reduction in peak flood levels of 10 mm at the Transgrid Orange 132kV Substation (ES3).

As no properties along this reach of the creek are significantly impacted by flooding in events up to and including the 1% AEP event, there is little property benefit however the option has benefit in reducing the flood frequency at Ngumbadal / Unity Bridge.

Combined with FMM9A which causes increases in flood level in this area (refer section 0), FMM9C could work to reduce the impacts caused by FMM9A as shown in Table 11-1.

Table 11-1 – Channel flows – existing baseline conditions, FMM9A and FMM9C

Location	10 % AEP peak flow (m^3/s) *(and level (mAHD))*			1% AEP peak flow (m^3/s) *(and level (mAHD))*		
	Existing	FMM9A	FMM9C	Existing	FMM9A	FMM9C
Leeds Parade Bridge	40.56 *855.05*	41.89 *855.08*	40.66 *854.88*	78.56 *856.04*	82.94 *856.140*	78.67 *855.77*
Adjacent to substation ES2	40.51 *854.90*	41.79 *854.93*	40.90 *854.66*	79.68 *855.92*	83.37 *856.017*	79.52 *855.59*
McLachlan Street Bridge	40.36 *854.79*	41.434 *854.83*	40.59 *854.54*	79.45 *855.86*	83.18 *855.96*	79.42 *855.52*
Ngumbadal / Unity Bridge	48.48 *853.16*	49.61 *853.17*	48.82 *852.91*	87.97 *853.69*	90.58 *853.73*	93.27 *853.54*
Near Amaroo Crescent*	30.10 *851.73*	30.42 *851.92*	39.35 *851.65*	45.29 *852.55*	46.54 *852.58*	65.22 *852.32*
Downstream of Northern Distributor	32.98 *850.15*	33.23 *850.16*	36.90 *850.22*	94.79 *850.90*	98.58 *850.93*	88.92 *850.80*

**Flows are impacted by the offtake for the East Orange Harvesting Wetland*

Table 11-2 – Flood behaviour at Blackmans Swamp Creek bridges – 1% AEP event

Bridge Location	Soffit level (m AHD)	Top of deck (m AHD)	Baseline Conditions			FMM9C Scenario		
			Flows (m^3/s)	Water level u/s (m AHD)	Overtopped	Flows (m^3/s)	Water level u/s (m AHD)	Overtopped
Leeds Parade	856.04	856.70	76.98	856.01	No	77.53	855.76	No
McLachlan Street	855.40	856.19	77.94	855.83	No but soffit exceeded	78.42	855.50	No but soffit exceeded
Ngumbadal / Unity Bridge	852.59	853.49	86.8	854.06	Yes 0.43 m3/s	92.07	854.01	Yes 0.009 m^3/s

11.4 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMM9c is shown in Table 11-3.

A BCR based on a total cost of the option of approximately $ 9.3 million dollars comes out at 0.00. As the benefits are mainly contained within the open land and creek corridor, the option has no economic benefit, with a minor increase in damages identified in rarer flood events.

Table 11-3 – FMM9C change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)
20%	0	0	$-	0	0	$-	0	0	$-
10%	0	0	$-	0	0	$-	0	0	$-
1%	0	0	$-	1	0	-$0.05	0	0	$-
0.05%	0	1	$0.03	0	2	$0.17	0	0	$-
PMF	0	3	$1.04	0	0	$0.23	0	0	$0.17
Reduction in AAD ($ 100,000's)									0.0

Table 11-4 – FMM9C BCA

Total Capital Cost	$ 9,250,000
Recurrent Cost	$ 5,000
Present Value Benefit	-$16,687
NPV (5% Discount)	-$9,343,549
BCR	0.00

11.5 Recommendations

As a standalone option FMM9C provides little benefit. However combined with FMM9A which causes increases in flood level in this area FMM9C could be more feasible. This has been assessed as part of FMS2 and FMS3 (refer section 14 and section 15).

12. FMM9B – Blackmans Creek Channel Widening (bridge option)

12.1 Summary of option

The FMM9B option is option FMM9C (channel widening) with the inclusion of a bridge widening at Leeds Parade.

The FRMS&P recommended this option to increase the capacity at the bridge on Leeds Parade to gain maximum benefit from the proposed widening downstream.

Figure 12-1: Leeds Parade Bridge

12.2 Assessment of option

The Leeds Parade bridge was updated in the flood modelling based on the detailed survey. A summary of the changes and modelled hydraulic behaviour at the bridge is provided in Table 12-1.

The surveyed bridge has a larger cross-sectional area than the bridge modelled in the FRMS&P model. This, combined with the reduction in channel flows due to the ARR2019 updates, means that the bridge has capacity to convey the 1% AEP flows without overtopping. Therefore the recommendation for replacement of the Leeds Parade Bridge (FMM9B), as documented in the FRMS&P, was considered unnecessary.

Table 12-1 – Comparison of FRMS&P modelled bridge at Leeds Parade and updated flood modelled bridge

	FRMS&P model	Updated baseline model (updated from survey)	Channel downstream of Leeds Parade – Existing	Channel downstream of Leeds Parade – FMM9C
Number of spans	Single span	Single span	n/a	n/a
Bridge / channel width (direction of flow) (m)	13.5	15.48	Top of bank: 18m Bottom of bank: 7m	Top of bank: 29m Bottom of bank: 12m
Channel invert level (mAHD)	853.01	853.17	852.81	852.81
Bridge soffit level (mAHD)	855.73	856.04	n/a	n/a
Bridge deck level (mAHD)	857.0	856.7	n/a	n/a
Top of bank level (mAHD)	n/a	n/a	856.2	855.8
Waterway cross section area to soffit of bridge or **top of channel bank** level (m^2)	33.73	39.03	36.11	43.97
1% AEP flood level (mAHD)	856.64 (existing) 856.47 (with FMM9C)	856.01 (existing) 855.76 (with FMM9C)	856.00	855.74
1% AEP overtops bridge deck?	No	No	n/a	n/a
1% AEP flood exceeds top of bank?	Yes	Yes	Yes	Yes
1% AEP Peak flows (critical storm) (m^3/s)	83.4	78.1 (existing) 79.5 (with FMM9C)	78.1	79.5
Critical storm	120 minutes	90 minutes, temporal pattern 02	90 minutes, temporal pattern 02	90 minutes, temporal pattern 02

13. FMS1 – Flood Modification Scheme 1

13.1 Summary of option

FMS1 comprises:

- FMM1 – Cutcliffe Park Detention Basin
- FMM2 – Kenna Street Stormwater Drainage Upgrades
- FMM6 – Moulder Park Detention Basin

13.2 Flood assessment

Flood impact mapping for option FMS1 is presented in Figure D 1 and Figure D 2 for the 10% AEP and 1% AEP events.

The combination of FMM1 and FMM2 provides additional benefit on Kenna Street and Moulder Street than when the options are considered in isolation. In the 5% AEP and 10% AEP, the additional benefits are negligible and typically within 10 mm of the options when considered alone. However, larger benefits of combining FMM1 and FMM2 are noted in the 1% AEP event.

In the 1% AEP event, the combination of FMM1 and FMM2 provide additional benefit at properties on Kenna Street and Moulder Street. Further improvement to properties of between 30 mm to 80 mm compared to the FMM2 scenario alone are shown in the modelling results. One property on Kenna Street sees reduction in flood levels of around 170 mm however is not subject to over floor flooding in the existing case scenario.

National Avenue is subject to increases in the road corridor and at the frontage of property boundaries as a result of FMM6 (refer section 7.3) and also as result of FMM2 (refer section 5.3). Combined under FMS1, there are further increases on National Avenue to a maximum of about 270 mm. As dwellings are raised from road level no floor level are affected however this indicates that the frequency of inundation on National Avenue would be increased and freeboard to dwelling floor levels reduced.

The combined benefits of the three FMMs in the 1% AEP event decrease inundation at Orange Public School Junior Campus by 25 mm to 75 mm and the northern building is benefitted by a reduction of 30 mm. This is similar to when considering FMM6 in isolation and FMM1 and FMM2 provide no significant benefit here. No other properties downstream are significantly benefited. Decreases in the channel downstream of the confluence are about 60 mm.

In the 0.05% AEP event, flood impacts represent the combined impacts of the three FMMs. Decreases of up to about 30 mm occur in the channel downstream of the confluence of the creeks similar to the impacts seen in FMM6.

In the PMF decreases of about 10 mm to 20 mm occur at properties around 1-3 Moulder Street and Kenna Street around the FMM2 location and decreases of 10 mm to 30 mm in the area around FMM6.

13.3 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMS1 is shown in Table 13-1.

A BCR based on a total cost of the option of approximately $13.4 million dollars comes out at 0.13. The option has good economic benefit, however the high cost of implementation results in a poor outcome with regards to economic value.

Table 13-1 – FMS1 change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($100,000's)
20%	7	0	$0.21	0	0	$-	0	0	$-
10%	11	0	$0.54	0	0	$-	0	1	$0.07
1%	19	8	$10.57	1	0	$1.70	0	0	$-
0.05%	7	7	$19.10	0	2	$4.18	0	0	$0.09
PMF	2	1	$7.56	0	0	$1.74	0	0	$0.55
Reduction in AAD ($ 100,000's)									0.96

Table 13-2 – FMS1 BCA

Total Capital Cost	$ 13,382,000
Recurrent Cost	$ 0
Present Value Benefit	$1,758,340
NPV (5% Discount)	-$11,623,660
BCR	0.13

13.4 Recommendations

While FMM6 delivers localised benefits, its combination with FMM1 and FMM2 in the FMS1 scheme does not demonstrate significant additional flood mitigation downstream. Therefore, it is recommended that the combined FMM1 and FMM2 configuration be investigated further as a more efficient and cost-effective option. However, noting the poor BCR of FMM2 due to high cost and practicability of construction this should be considered with regard to other social and environmental issues.

14. FMS2 – Flood Modification Scheme 2

14.1 Summary of option

FMS2 comprises:

- FMM6 – Moulder Park Detention Basin
- FMM9A – East Orange Creek Channel Works
- FMM9C – Blackmans Creek Channel Widening

14.2 Flood assessment

Flood impact mapping for option FMS2 is presented in Figure D 5 and Figure D 6 for the 10% AEP and 1% AEP events.

The pattern of flood level impacts is consistent with those seen for each of the individual options. FMS2 provides a decrease in peak flood levels across a significant portion of the catchment. About 130 lots are benefited by a reduction in water levels or considered no longer flooded in the 1% AEP event.

Changes in flood behaviour to properties between Icely Road and Summer Street, and around the McLachlan Street and March Street intersection are the same in FMS2 as they are in FMM9A. Any change is typically less than a few mm. At FMM6 impacts are as per the FMM6 option.

Decreases in the Blackmans Swamp Creek Chanel downstream of the confluence occur in the FMS2 scenario as the combined effect of FMM6 and FMM9C is greater than the increases caused by FFM9A.

Increases in water level on National Avenue occur as a result of the FMM6 basin. Properties are not affected above floor, however freeboard is reduced.

Additional increases occur in the channel from March Street towards Wiliam Street due to the increased flows from the FMM9A works. These are mitigated by FMM9C from downstream of William Street however the additional flow over William Street cause 27 mm increase in water level on the substation in the 1% AEP event. This is a reduced impact when compared to FMM9A alone and due to the less than 10 mm decreases at the substation from FMM6 and FMM9C. There is an increase of 40 mm at the property east of William Street adjacent to the channel which is reduced by about 10 mm from FMM9A alone due. This impact would need to be managed should FMS2 go ahead.

Generally, while FMS2 mitigates the downstream increases caused by FMM9A, it provides little extra benefit to properties as the impacts of FMM9A are typically contained within the channel and adjacent open space areas in events up to and including the 1% AEP event.

14.3 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMS2 is shown in Table 14-1.

A BCR based on a total cost of the option of approximately $20.0 million dollars comes out at 0.22. The option has good economic benefit, however the high cost of implementation results in a poor outcome with regards to economic value.

Table 14-1 – FMS2 change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)
20%	4	0	$0.04	0	0	$0.38	0	0	$-
10%	26	2	$2.53	3	2	$1.64	0	1	$0.07
1%	39	10	$15.71	13	7	$11.30	1	0	$1.33
0.05%	16	24	$33.19	4	6	$14.52	0	0	$0.09
PMF	10	8	$39.45	0	0	$7.13	0	0	$2.35
Reduction in AAD ($ 100,000's)								2.39	

Table 14-2 – FMS2 BCA

Total Capital Cost	$ 20,065,000
Recurrent Cost	$ 0
Present Value Benefit	$4,377,128
NPV (5% Discount)	-$15,687,872
BCR	0.22

14.4 Recommendations

Given the higher cost of FMM6 compared to other basins, its limit benefit on properties upstream of the CBD trunk drainage culvert and the reduced freeboard it causes on properties on National Avenue an assessment of the flood benefits of FMM9A and FMM9C without FMM6 would be beneficial. This could improve the benefit-cost-ratio.

15. FMS3 – Flood Modification Scheme 3

15.1 Summary of option

FMS3 comprises:

- FMM7 – Ridley Oval Detention Basin
- FMM9A – East Orange Creek Channel Works
- FMM9C – Blackmans Creek Channel Widening

15.2 Flood assessment

Flood impact mapping for option FMS3 is presented in Figure D 9 and Figure D 10 for the 10% AEP and 1% AEP events.

The pattern of flood level impacts is consistent with those seen for each of the individual options. FMS3 results in a decrease in peak flood levels across a significant portion of the catchment. About 135 lots are benefited by reduced flood levels or become flood free in the 1% AEP event as a result of FMS3.

Upstream of Icely Road impacts are comparable to the outcomes of FMM7. Between Icely Road and Summer Street the combination of FMM7 and FFM9C does not considerably improve reductions in flood level when compared to FMM9C alone despite FFM7 showing an 80 mm to 90 mm reduction in peak flood levels to residential properties between Icely Road and Summer Street. This is likely due to the difference in critical duration assessed in the representative ensembles as noted in section 8.3.

Around the McLachlan Street and March Street intersection almost all properties on McLachlan Street south of March Street are shown to be no longer flood affected in the 1% AEP event for the representative ensemble of storms assessed. This is an improvement in flood benefit compared to option FFM9A in isolation and FMS2 which reduced flood levels in this area.

At the Transgrid Orange 132kV Substation (ES3), the option decreases peak flood levels by about 13 mm as the bund acts to reduce the volume of stormwater runoff from William Street entering the substation.

15.3 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of FMS3 is shown in Table 15-1.

A BCR based on a total cost of the option of approximately $18.7 million dollars comes out at 0.40. The option has good economic benefit, however the high cost of implementation results in a poor outcome with regards to economic value. Of the three FMSs assessed this has the best net benefit and the best BCR.

Table 15-1 – FMS3 change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)
20%	4	0	$0.06	0	0	$4.47	0	0	$-
10%	25	1	$2.18	4	2	$3.00	0	0	$-
1%	52	10	$16.08	11	7	$7.79	1	0	$-
0.05%	18	20	$30.32	3	2	$8.48	0	0	$0.06
PMF	7	5	$33.51	0	0	$4.84	0	0	$1.97
Reduction in AAD ($ 100,000's)								4.06	

Table 15-2 – FMS3 BCA

Total Capital Cost	$ 18,725,000
Recurrent Cost	$0
Present Value Benefit	$ 7,404,212
NPV (5% Discount)	-$ 11,320,788
BCR	0.40

15.4 Recommendations

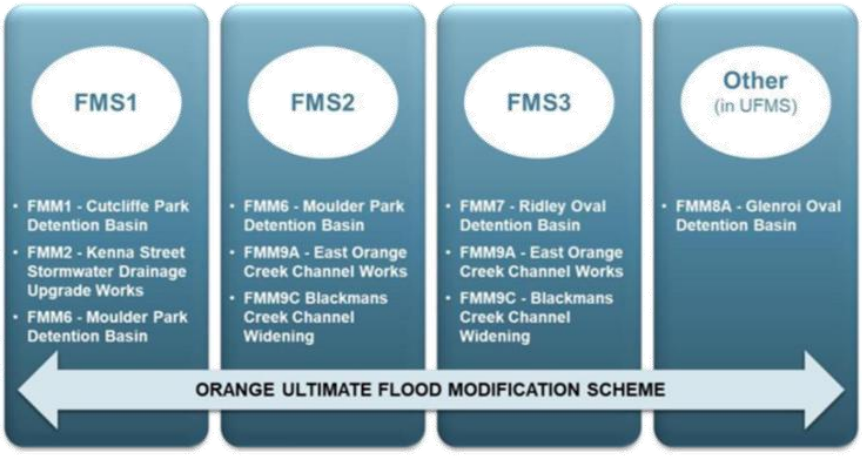
It is recommended to review for the options for the full range of enable storms before progressing to detailed design.

There may be opportunities to reduce the scale of works in FMM9C if this reduced costs as there are significant decreases in the channel water levels. Addition of FMM8a to this scheme may also enhance the BCR.

16. The Orange Ultimate Flood Modification Scheme

16.1 Summary of option

The Ultimate Scheme comprises all of the FMMs with the exception of FMM5.



16.2 Flood assessment

Flood impact mapping for the Ultimate Scheme is presented in Figure D 13 and Figure D 14 for the 10% AEP and 1% AEP events.

The Ultimate Scheme generally decreases peak flood levels access the catchment. Increases in flood levels are seen at National Avenue upstream of FMM6 and the channel updates of FFM7 as per the impacts of those option is insolation.

About 190 properties benefit from a reduction in peak flood levels or are no longer inundated as a result of the Ultimate Scheme in the 1% AEP event.

Flood modelling results show decreases in the channel downstream of the confluence of Blackmans Swamp Creek and the East Orange Channel of up to 250 mm in the 1% AEP event indicating that the Ultimate Scheme may not need the inclusion of FMM9C here.

Likewise, the benefit of FMM6 may not be worth the higher cost of this basin, given the upstream impact on National Avenue and the limited benefit to properties downstream.

16.3 Flood damages and benefit-cost ratio

A summary of the change in total event flood damages and AAD as a result of the Ultimate Scheme is shown in Table 16-1.

A BCR based on a total cost of the option of approximately $33.4 million dollars comes out at 0.39. The option has a very good economic benefit, however the high cost of implementation results in a poor outcome with regards to economic value.

Table 16-1 – Ultimate Scheme change in flood damages from baseline

Flood Event (AEP)	Residential			Commercial & Industrial			Other / Public Buildings		
	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)	Reduction in no. lots affected	Reduction in no. buildings affected above floor level	Reduction in damages ($ 100,000's)
20%	17	1	$2.08	1	0	$4.47	0	0	$-
10%	49	3	$5.46	5	2	$4.56	0	1	$0.07
1%	74	20	$32.43	16	9	$17.12	1	0	$-
0.05%	29	29	$55.53	6	12	$30.15	1	0	$0.06
PMF	8	5	$39.78	0	0	$5.44	0	0	$2.35
Reduction in AAD ($ 100,000's)									7.17

Table 16-2 – Ultimate Scheme BCA

Total Capital Cost	$ 33,397,000
Recurrent Cost	$ 5,000
Present Value Benefit	$ 13,097,799
NPV (5% Discount)	-$ 20,376,063
BCR	0.39

16.4 Climate change sensitivity

The change in peak flood levels as a result of a 10% increase end 30% increase in flows is shown in Figure D 17 and Figure D 18. The greatest increases occur in the main channels and storage areas due to the accumulation of flows. A compassion of the existing and Ultimate Scheme climate sensitivity indicated that the Ultimate Scheme will still provide benefit under future climate conditions though this may warrant further investigation as the future climate causes changes to critical duration storms.

16.5 Recommendations

Considering the Ultimate Scheme without FMM6 and FMM2 and/or a modified version of FMM9C to may improve the BCR.

17. Preliminary Dam Break Analysis

17.1 Dam break approach

A preliminary dam break analysis was undertaken for the proposed basins to assess the need for detailed dam break assessments. The assessment considered the 1% AEP flood failure scenario. A consequence category was established for each dam break scenario in accordance with *Guidelines on the Consequence Categories for Dams (2012)* and *Guidelines on Selection of Acceptable Flood Capacity for Dams (2000)*.

Dam break was undertaken for the following flood modification basins:

- FMM1 Cutcliffe Park
- FMM6 Moulder Park *(FMM6 has been affected by some model instabilities and will be provided in the next revision of the report).*
- FMM7 Ridley Oval
- FMM8a Glenroi Oval

As it was agreed with Council that FMM5 is unlikely to progress, a dam break assessment was undertaken for the existing rail embankment rather than the FMM5 basins embankment.

Within TUFLOW the dam breaks were modelled using time variable shape layers which allow for the elevation of the surface elevations in the model to vary over the course of the simulation, simulating the erosion of a dam break. The following assumptions were made when implementing the dam break scenarios into TUFLOW:

- Dam failure was a result of flood failure and occurred at the time the spillway overtopped.
- Erosion of the embankment occurs as a trapezoidal shape
- Average side slope ratio of the failure shape was 1
- The breach occurred at either the peak flood level or when the flood level started to overtop the dam, whichever occurred sooner.

The geometry and timing of each dam break was calculated with reference to Froehlich (2016) '*Empirical model of embankment dam breaching*'. Key modelling parameters for a trapezoidal approximation of the final eroded opening in the embankment, and the formation time of the breach included:

- Height of the breach (Hb)
- Average width of the breach (Bavg)
- Average side slope ratio (m) assumed as being equal to 1
- Mean erosion coefficient (Km), given as 1.5 for overtopping failures
- Reservoir volume above breach bottom (Vw)

In order to determine the Population at Risk (PAR) for each basin, a PAR assessment in accordance with ANCOLD *Guidelines on the Consequence Categories of Dams (2012)* was undertaken. This provides an approach to determine total PAR and dam break PAR. Non-breach PAR has been calculated based on if the dwelling point is affected by the natural (i.e. no dam break) flood. Properties are only considered in the assessment if over floor flooding occurs. The number of dwellings affected is multiplied by 2.5, which is the average number of occupants per residential dwelling (ABS, 2021). It is noted that commercial and other sites may have a different population however for a preliminary assessment this assumption is considered valid at this stage. The dam break PAR is considered in the same manner, with it calculated based on the number of dwellings experiencing over floor flooding in the event multiplied by the average number of occupants (2.5).

The assessment was undertaken on the 1% AEP event, with the storm event from the representative ensemble that generates the largest water level in the basins during a non-failure event considered critical. This approach is conservative as it the worst case scenario of flooding due to a basin breach.

17.2 Dam break outcomes – proposed basins

Table 17-1 presents the outcomes of this analysis. Dam break mapping showing the difference in water level between with non-failure and failure scenario is provided in Appendix E.

Table 17-1 – Preliminary dam break assessment

Option	AEP	Non-Breach PAR	Summary of change in flood behaviour	Dam Break PAR	Difference in PAR
FMM1	1% (120 min TP04)	215	Water level increases immediately downstream of the basin of up to 250 mm for a distance of approx. 400 m.	235	20
FMM6	To be completed				
FMM7	1% (180 min TP10)	150	Very minor increases downstream to the main channel (< 50 mm). Minor increases (<100 mm) between Byng and March Street.	153	3
FMM8a	1% (90 min TP01)	185	Impacts of up to 400 mm immediately downstream for approx. 100 m. Minor Impacts present for another 650 m downstream.	188	3

The analysis identifies that FMM1 basin presents a significantly elevated risk to persons downstream. If the option is progressed the preliminary analysis should be furthered and potential mitigative measures to reduce the impact of a dam breach investigated.

17.3 Dam break outcomes – Rifle Range Creek rail embankment

Failure of the rail embankment during a flood could cause significant flood impact to properties near to Rifle Range Creek and Blackmans Swamp Creek including Orange Public School Juniors Campus.

Table 17-2 – Rifle Range Creek rail embankment failure assessment

Option	AEP	Non-Breach PAR	Summary of change in flood behaviour	Dam Break PAR	Difference in PAR
Rifle Range Creek Embankment	1% (24 hour, TP02	370	Significant Increases (> 300 mm) for the area downstream until the rail crossing	475	105

18. Summary and Recommendations

18.1 Benefit-cost ratio summary

A summary of the benefit-cost analysis outcomes is shown in Table 18-1.

Table 18-1 – Benefit-cost ratio summary

FMM	Total Capital Cost	BCR	Comment
FMM7	$ 1,500,000	3.27	Very good benefit-cost ratio due to continued downstream reduction in flood levels. Note option is recommended to be assessed with additional critical duration storm from downstream which may reduce the BCR.
FMM8a	$ 1,290,000	2.43	Very good benefit-cost ratio due to number of properties benefits downstream particularly in frequency AEP events.
FMM1	$ 642,000	1.55	Provides good flood reduction benefits in frequent AEP events targeting damages hotspots immediately downstream and also on Kenna Street and Moulder Streets near FMM2 location).
FMS3	$ 18,725,000	0.40	FMM7, FMM9A, FMM9C The only option which reduced flood levels (but does not prevent flooding) at the Transgrid Orange Substation
Ultimate Scheme	$ 33,397,000	0.39	All FMMs excluding FMM5. Removal of FMM6 may improve BCR.
FMM9A	$ 7,975,000	0.38	Large benefit to property flood reduction (41 properties in 1% AEP event) however cost of option results in a low BCR.
FMS2	$ 20,065,000	0.22	FMM6, FMM9A, FMM9C Removal of FMM6 may improve BCR.
FMS1	$ 13,382,000	0.13	FMM1, FMM2, FMM6 Removal of FMM6 may improve BCR.
FMM6	$ 2,840,000	0.11	Provides only a small reduction in flood damages as most reduction in flood levels occurs in open space areas.
FMM2	$ 9,900,000	0.05	Reasonable flood reductions at multiple residential properties including in frequent AEP events, however the high cost of option means poor BCR. Results in increase sin downstream peak water levels which could be reduced by FMM6, however increases in events up to an including the 1% AEP are generally within channel open space areas.
FMM9C	$ 9,250,000	0.00	Few properties benefited and high cost. Not recommended as a standalone option however does reduce downstream impacts from FMM9A.
FMM5	$ 1,860,000	0.00	No reduction in flood damages or flood risk.
FMM9B	n/a	n/a	Option was discounted based on revised baseline modelling that shows bridge has capacity for 1% AEP flows.

- The Ultimate Scheme scored a benefit-cost ratio of 0.39. As a result of the overall scheme about 190 properties benefit from a reduction in peak flood levels or are no longer inundated in the 1% AEP event. The Ultimate Scheme has a very good economic benefit, however the high cost of implementation results in a poor outcome with regards to economic value.
- When considered in isolation of other options, the three basins FMM7, FMM1 and FMM8a provide the best reduction in flood damages for cost of construction and ongoing maintenance.
- FFM7 results in the best BCR as reductions in peak flood levels extend downstream as far as the confluence of the East Orange Channel with Blackmans Swamp Creek. It is recommended that the assessment consider additional critical durations in the downstream channel to confirm the BCR.
- The two basins FMM8a and FMM1 result in a high BCR due to lower cost of construction compared to other basins. It is recommended that the assessment consider additional critical durations in the downstream areas to confirm the BCR.
- FMS3 (FMM6, FMM9A and FMM9C), scores higher than the other schemes and is the only option that reduced flooding at the Transgrid Orange 132kV Substation.
- FMS1 and FMS2 provide flood damage reduction but the cost of the option results in poor economic value. Removal of FMM6 may improve BCR.
- FMM6 provides only a small reduction in flood damages as most reduction in flood levels occurs in open space areas. As the critical duration storm for the Blackmans Swamp Creek and the flooding that occurs at Lord Street are different, it provides no benefit to properties on Lord Street. It is the most expensive of the basin options due to the additional work for creek realignment.
- FMM2 results in reasonable flood reductions at multiple residential properties, however the high cost of option means poor BCR. Many properties benefitted by FMM2 are also benefitted by FMM1 though not as effectively.
- FMM9C is not economically viable in terms of reduction in flood damages when considered in isolation, however does reduce the increase in flood levels in the downstream reach of Blackmans Swamp Creek caused by FMM9A. The option should only be considered with FMM9A.
- Following flood model updates FMM9B was found unnecessary as the existing bridge has capacity in the 1% AEP event.
- FMM5 provides no flood benefit, nor improves ponding of water against the rail embankment. Failure of the rail embankment during flooding would have significant consequences to residential properties downstream. Flood behaviour, including inundation of the pedestrian underpass, is also sensitive to the blockage of the rail culverts.

18.2 Recommendations

- While the outcomes of this flood modelling report include a cost-benefit analysis, many of the options have significant social, environmental, amenity and other impacts. The decision to progress options should consider a holistic approach.
- The assessment has been undertaken with ARR2019 (4.1) current at the time of project commencement. ARR 4.2 introduces additional consideration for the changing climate including a requirement to update rainfall inputs to account for changes in climate since intensity-rainfall-frequency data was developed and allow for the non-stationarity of the climate. The impacts of ARR 4.2 are likely to increase predicted flood levels for a given AEP. As such, to assess the long-term viability of the measures it would be recommended to check their performance against ARR 4.2. As ARR 4.2 could results in a prediction of increased frequency of inundation this could lead to better performing benefit-cost-ratios.
- A 150 mm bund was incorporated into FMM9a to reduce the flood impact of the option on the Transgrid Orange 132kV Substation (ES3). The height of the bund was assumed as 150 mm based on site observations and possible tie in points however flood modelling showed the bund would need to be higher to fully mitigate impacts to the substation in a 1% AEP event. A detailed survey and review of the possible bund height is recommend including flood modelling should it be possible to increase the bund height without having adverse impacts on property on the opposite side of William Street. Should FMS2 or FMS3 progress in full, the bund may not be required however it is recommended the options be assessed in the flood modelling without the bund to ensure no unwanted impacts on the substation.

- The flood damages assessment based on point data from the Flood Study. The location of the points means that in some cases the flood behaviour is not well represented eg where points are at the front of the property, but the rear of the property is subject to inundation first. Damages assessment may benefit from a detailed review, particularly for those options where the cost-benefit analysis has a large influence on the detailed design decision.
- The assessment assumes the East Orange Harvesting Wetland is empty at the commencement of the flood event. Sensitivity on this assumption and the implications on FMM9C, FFM9A, FMS2, FMS3, and the Ultimate Scheme is recommended if the options are to be considered further for detailed design.
- At Rifle Range Creek the flood behaviour is sensitive to the assumed blockage on the railway culverts. It is recommended that Council engage with the rail maintenance authority to maintain the culverts. Full clearance is unlikely, but culverts should be maintained so they are not more than 50 – 70% blocked.
- FMM6 has localised benefits but mainly in open space areas. Combined with FMM1 and FMM2 as part for FMS1 is provides little additional benefit. There would be value in assessment of FMM1 and FMM2 without FMM6 as this would provide a higher benefit-cost-ratio.
- Given the higher cost of FMM6 compared to other basins, its limit benefit on properties upstream of the CBD trunk drainage culvert and the reduced freeboard it causes on properties on National Avenue an assessment of the flood benefits of FMM9A and FMM9C without FMM6 would be beneficial.
- For FFM7, FMM8a and FMM1 which result in increases as far as the downstream channel it is recommended that the assessment consider additional critical durations in the downstream channel to confirm the BCR before detailed design.
- Addition of FMM8a to FMS3 may enhance the BCR and would provide benefit to additional properties.
- A revised Ultimate Scheme without FMM6 and FMM2 may result in a better economic outcome due to the high-costs of FMM6 and FMM2.

19. References

ANCOLD, 2012, Guidelines on the Consequence Categories for Dams

ANCOLD, 2000, Guidelines on Selection of Acceptable Flood Capacity for Dams

Babister, M., Trim, A., Testoni, I. & Retallick, M., 2016, The Australian Rainfall & Runoff Datahub, 37th Hydrology and Water Resources Symposium Queenstown NZ

Ball J. et al., 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia (now known as ARR4.0)

Froehlich, February 2017, Empirical model of embankment dam breaching, Third National Dam Safety Conference, Roorkee.

KBR, 3 July 2023, Technical Memorandum: The Orange Ultimate Flood Modification Scheme: TUFLOW Validation Using November 2022 Historical Event.

KBR, 3 July 2023, Technical Memorandum: The Orange UFMS: Feasibility & Design Project – Variation: East Orange Harvesting Wetland Flood Modelling

KBR, 3 July 2023, Technical Memorandum: The Orange Ultimate Flood Modification Scheme: Feasibility & Design Project – Phase A: ARR19 Update Memorandum

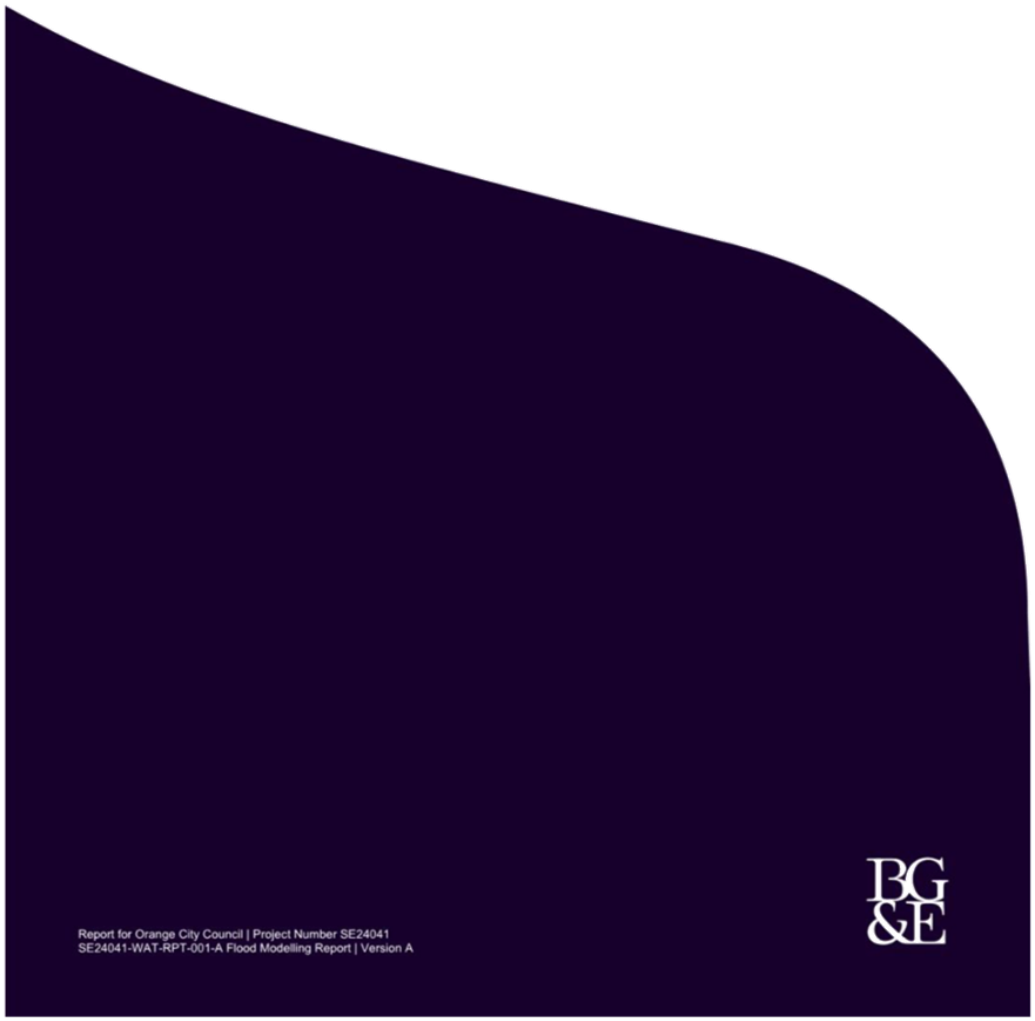
Lyall and Associates, 2019, Blackmans Swamp Creek and Ploughmans Creek Flood Study.

Lyall and Associates, 2020, Blackmans Swamp Creek and Ploughmans Creek Floodplain Risk Management Study and Plan.

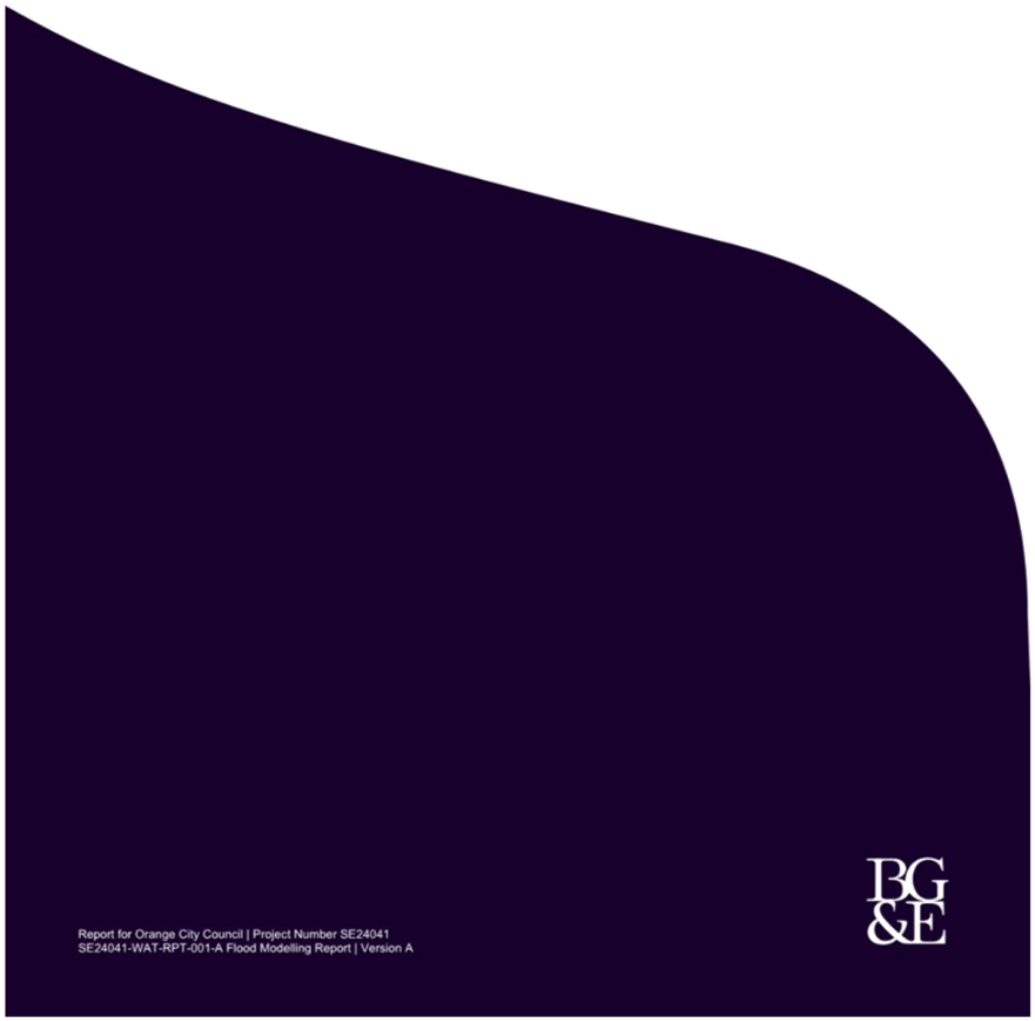
Department of Planning and Environment, NSW Government, 2023, Flood risk management guideline MM01: Flood risk management measures.

Department of Planning and Environment, NSW Government, 2023, NSW Flood damage Assessment Tool DT01

Appendices


Report for Orange City Council | Project Number SE24041
SE24041-WAT-RPT-001-A Flood Modelling Report | Version A
BG&E

Appendix A - Rifle Range Creek Underpass Assessment



A.1 Technical Note – Orange UFMS – Rifle Range Creek Underpass and Rail Culvert Blockage Sensitivity

Client	Orange City Council
Document Number	SE24041_WAT_TechNote_002_Rifle Range Rail blockage and underpass
Revision and Date	A - 26 May 2025
Prepared By	N. Bannigan
Approved By	L. Baxter

A.1.1 Introduction

A flood modelling assessment has been undertaken to:
1) understand the implications of the recently constructed pedestrian underpass on flood behaviour
2) understand the sensitivity of flood behaviour to the existing rail culvert blockage

The assessment used the updated baseline model which incorporated the following changes in the area around Rifle Range Creek underpass:

- Hydrology updated from ARR1987 to ARR2019
- Detailed survey incorporated for ground levels on upstream of rail line including the cycleway
- Pedestrian underpass added based on site survey
- Rail culvert dimensions and blockage amended based on site inspection

A.1.2 Flood model updates

A.1.2.1 Structure dimensions

Rail culverts were sized through site inspection and data provided by Council and modelled as per Table A.1.2.1-1. The culverts are likely to be brick arches, however circular conduits were opted for simplicity in modelling. Given the high blockage (refer section A.1.2.2) and standing water this is unlikely to have a significant impact on modelled flood levels.

Table A.1.2.1-1: Changes to rail culverts in baseline flood modelling

	FRMS&P model	Updated Baseline model
Rail Culvert West	Width – 1.50 m, Height – 1.31 m US invert – 874.02 mAHD, DS invert – 873.89 mAHD Unblocked	1.50 m diameter circular pipe US invert – 874.02 mAHD, DS invert – 873.88 mAHD 50% blocked
Rail Culvert East	1.50 m diameter circular pipe US invert – 875.61 mAHD, DS invert – 875.34 mAHD Unblocked	1.50 m diameter circular pipe US invert – 875.83 mAHD, DS invert – 875.34 mAHD 50% blocked
Underpass	Not constructed at time of modelling.	Width – 3.34 m, Height – 3.00 m US invert – 877.51 mAHD, DS Invert – 877.40 mAHD

A.1.2.2 Blockage assumptions

An ARR2019 blockage assessment suggests that the rail culverts could be 50% blocked in the 1% AEP scenario. This is supported by site inspections at different times which showed significant vegetation and standing water (refer Figure A.1-1). The revised baseline model therefore adopted a 50% blockage as representative of current conditions at the rail culverts.

Figure A.1-1: left: Rail Culvert West Site Photo 15/10/2024 right: Rail Culvert East Site Photo 15/10/2024

A.1.3 Comparison of updated model and FRMS&P model

Council's Flood Planning Area is based on the FRMS&P flood modelling. As this was completed prior to construction of the underpass and associated earthworks, it is prudent to understand any changes in flood behaviour that may impact on the Flood Planning Levels and Flood Planning Area (FPA). The FPA represents the area which will be subject to flood related development controls for mainstream flooding and comprises the area lying within the extent of the 1% AEP flood plus an allowance of 500 mm for freeboard.

A comparison of the predicted 1% AEP flood levels between the FRMS&P model and the updated model is shown in Figure A.1-2 and summarised in Table A.1.2.2-2 for a range of AEPs. As noted above, the FRMS&P model assumes zero blockage of the rail culverts and does not include the underpass. The updated model incorporates the underpass and assumes 50% blockage of rail culverts. A review of the potential flows through the underpass is presented in Table A.1.2.2-3 for the updated modelling.

- The ARR2019 hydrology update results in reduced flows in Rifle Range Creek arriving at the ponding area upstream of the rail embankment from about 14.95 m^3/s for the 1% AEP event in the FRMS&P model to about 11.36 m^3/s for the 1% AEP event in the updated flood model.
- Flows through the culverts is reduced from about 8.7 m^3/s in the western culvert and 5.2 m^3/s in the eastern culvert in the FRMS&P model to about 4.2 m^3/s in the western culvert, 3.4 m^3/s in the eastern culvert and 2.14 m3/s in the underpass in the updated flood model.
- Flood levels increase on the upstream of the rail embankment. This is largely due to the 50% blockage factors applied to the rail culverts compared to the zero blockage in the FRMS&P model.
- Flood levels decrease in the creek downstream as a result of reduced flows through the rail culverts and the general reduction attributed to the revision of the ARR hydrology.
- Minor increases occur in the right bank area as a result of flows through the underpass.

- The updated modelling indicates that flows through the underpass are likely to first occur between the 5% and 2% AEP events. Flood levels immediately downstream of the underpass are increased due to flows through the underpass

Table A.1.2.2-2: Comparison of flood levels on upstream side of underpass location – FRMS&P model and updated flood model

	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMF
Updated flood model	876.59	877.04	*877.4**	*877.8**	878.05	n/a	n/a	879.12	882.23
FRMS&P model	876.06	876.42	876.75	877.25	877.73	878.21	878.80	n/a	882.19

5% AEP and 2% AEP were not assessed as part of the updated flood modelling scope of works. Levels have been estimated from 10% AEP and 1% AEP levels.

Table A.1.2.2-3: Flooding of the underpass – updated flood modelling

	20% AEP	10% AEP	1% AEP	0.05% AEP	PMF
Peak flow (m^3/s)	n/a	n/a	2.14	9.15	45.30
Upstream water level (mAHD)	876.59	877.04	878.05	879.12	882.23
Downstream water level (mAHD)	n/a	n/a	877.82	878.48	879.06

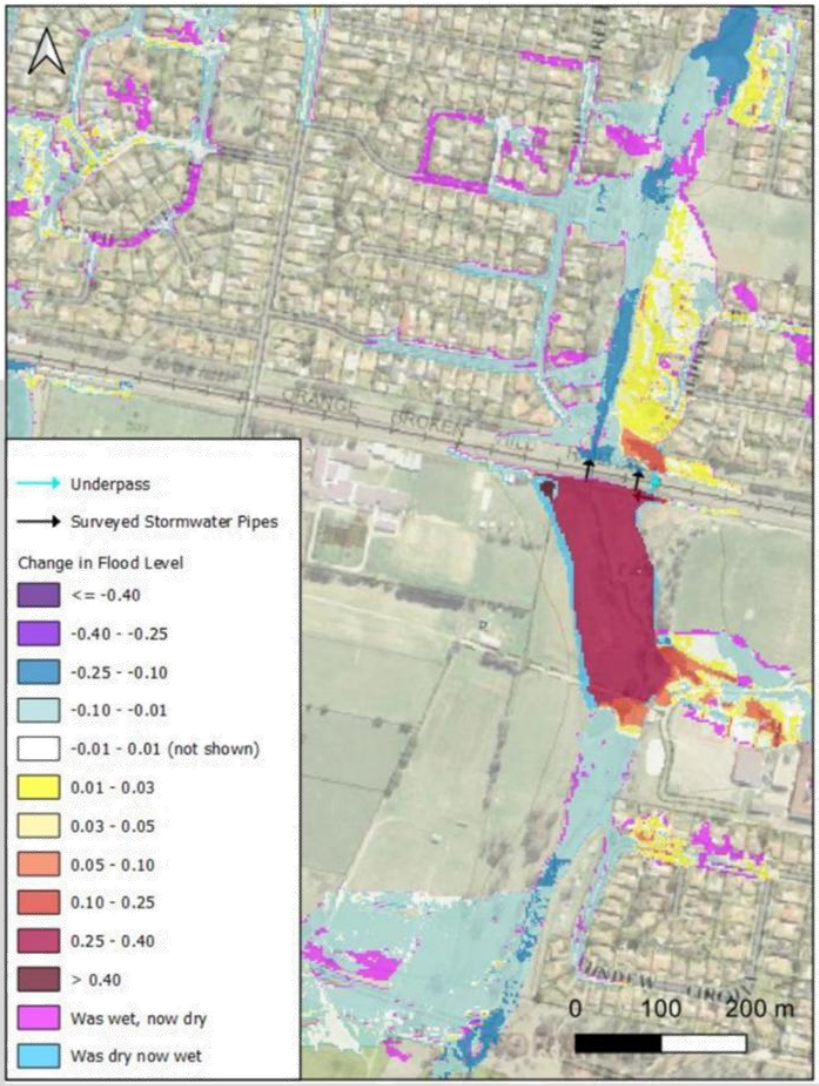


Figure A.1-2: Comparison of FRMS&P flood model 1% AEP flood levels and updated baseline model peak flood levels

A.1.3.1 Consideration for the Flood Planning Area and Flood Planning Levels (in relation to underpass construction)

Although the FRMS&P modelling does not include the underpass, the flood levels determined in the FRMS&P modelling indicate that the underpass would first convey flows between the 2% and 1% AEP events (assuming the FRMS&P hydrology and blockage assumptions) (refer Table A.1.2.2-2). In the updated baseline modelling, the underpass is likely to convey flows between the 5% AEP and 2% AEP events. This increase in predicted frequency of flood of the underpass is largely due to the changed flood assumptions on the rail culvert blockage.

In the 1% AEP event, increases at properties downstream of the underpass are minor (maximum change of 40 mm) and are within the 500 mm freeboard applied to the 1% AEP to determine the FPL. Changes in flood levels are not significant to affect the FPA downstream of the rail embankment.

Upstream of the rail embankment flood levels in the 1% AEP have increased by 370 mm. Although the area affected is mainly open space, the FPLs at the Catholic School would be influenced by this change.

A.1.4 Blockage Sensitivity Assessment

Sensitivity has been undertaken to understand the impact of blockage of the rail culverts on the flood levels. The assumed 50% rail culvert blockage has been compared with a 25% blockage and 75% blockage scenario. The sensitivity was considered for the 10% AEP and 1% AEP events.

A.1.4.1 Blockage impact on culvert flows and upstream peak flood levels

Changes flow conveyance at the culverts and the water levels either side of the rail embankment are presented in Table A.1.4.1-4 and Table A.1.4.1-5. Figure A.1-3 and Figure A.1-4 shows change in peak flood levels as a result of changed blockage assumptions for the 1% AEP event.

In the 1% AEP event, the analysis shows that as blockage increases from 50% to 75%, peak flow capacity decreases by almost half in each culvert. With a reduced blockage of 25%, flows in the rail culverts increase by 25% to 40%.

Upstream water levels rise due to reduced flow conveyance. Flood level changes due to blockage are most significant upstream of the rail embankment where levels increase by about 500 mm in the 1% AEP event when assuming a 75% blockage and compared to the adopted 50% blockage baseline. A reduced blockage of 25% causes a reduction in upstream water level of about 350 mm.

James Sheahan Catholic High School located approximately 275 m upstream of the rail culvert, is affected by a flood level increase of about 500 mm in the 75% blockage scenario compared to the 50% blocked baseline scenario and flood extents encroach further into the school property. A school storage building near the oval is impacted however the main learning building remain above the flood levels.

The impact of blockage on flood levels is more significant in the 10% AEP event where an increase in blockage from 50% to 75% results in about 780 mm increase in flood levels upstream of the rail embankment.

Table A.1.4.1-4: Blockage sensitivity peak flows and water levels – 10% AEP event

	Rail Culvert West			Rail Culvert East			Underpass		
Blockage scenario:	25%	50%	75%	25%	50%	75%	25%	50%	75%
Peak flow (m^3/s)	4.51	3.39	1.93	1.10	1.34	1.63	N/A	N/A	0.75
Upstream water level (mAHD)	876.65	877.04	878.05	876.65	877.02	878.05	N/A	N/A	878.05
Downstream water level (mAHD)	875.45	875.40	875.31	875.83	875.57	876.06	N/A	N/A	877.60

Table A.1.4.1-5: Blockage sensitivity peak flows and water levels – 1% AEP event

	Rail Culvert West			Rail Culvert East			Underpass		
Blockage scenario:	25%	50%	75%	25%	50%	75%	25%	50%	75%
Peak flow (m^3/s)	5.93	4.21	2.15	4.23	3.36	1.83	0.39	1.85	4.39
Upstream water level (mAHD)	877.69	878.05	878.57	877.69	878.05	878.58	877.69	878.02	878.58
Downstream water level (mAHD)	875.59	875.54	875.37	876.50	876.43	876.26	877.52	877.80	878.14

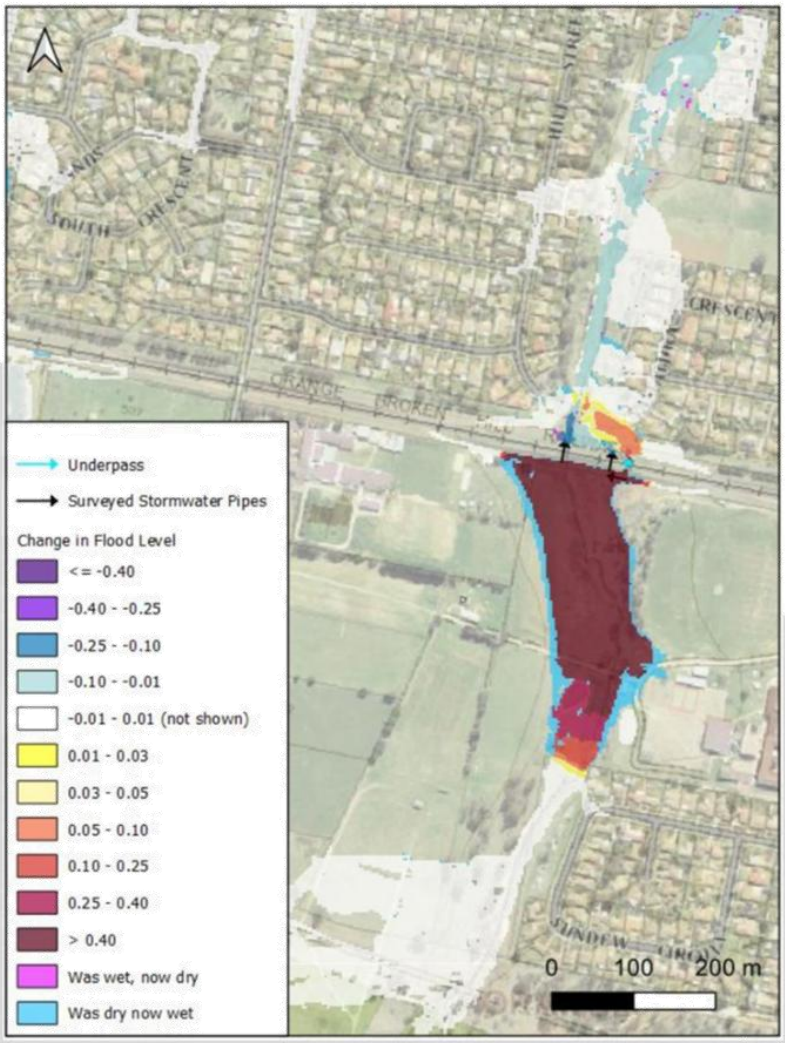


Figure A.1-3: Change in 1% AEP peak flood level as a result of a 75% blockage assumption compared to 50% blockage

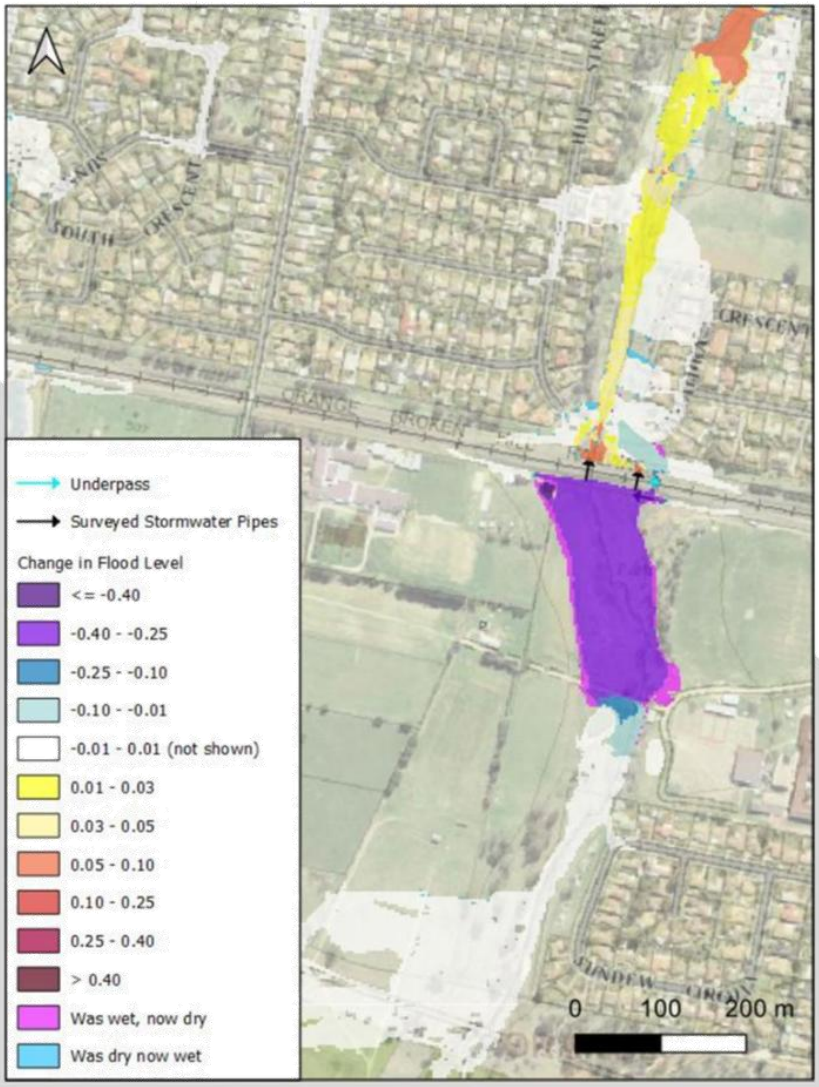


Figure A.1-4: Change in 1% AEP peak flood level as a result of a 25% blockage assumption compared to 50% blockage

A.1.4.2 Blockage impact on downstream flood behaviour

Figure A.1-3 and Figure A.1-4 shows change in peak flood levels as a result of changed blockage assumptions. Changes in flood levels downstream of the rail embankment are less sensitive to culvert blockage.

There are six properties along Namatjira Crescent and three properties on Hill Street that are affected by increasing blockage from 50% to 75%, the observed increases remained below 25 mm. Increasing blockage from 25% to 50% did not result in any increase of flood levels on nearby properties.

A.1.4.3 Underpass and rail culvert blockage assumptions

Inundation of the pedestrian underpass is sensitive to the blockage assumptions of the rail culverts. A comparison of the peak flows through the underpass for each of the blockage in scenarios in presented in Table A.1.4.3-6.

Increased blockage of the rail culverts is likely to lead to more frequent inundation through the underpass. The sensitivity assessment indicates that increasing blockage from 50% to 75% would mean that the underpass becomes inundated in as frequent as the 10% AEP event.

It is recommended that consideration is given to maintenance of the rail culverts to minimise risk of full blockage and increased risk of flooding of the underpass.

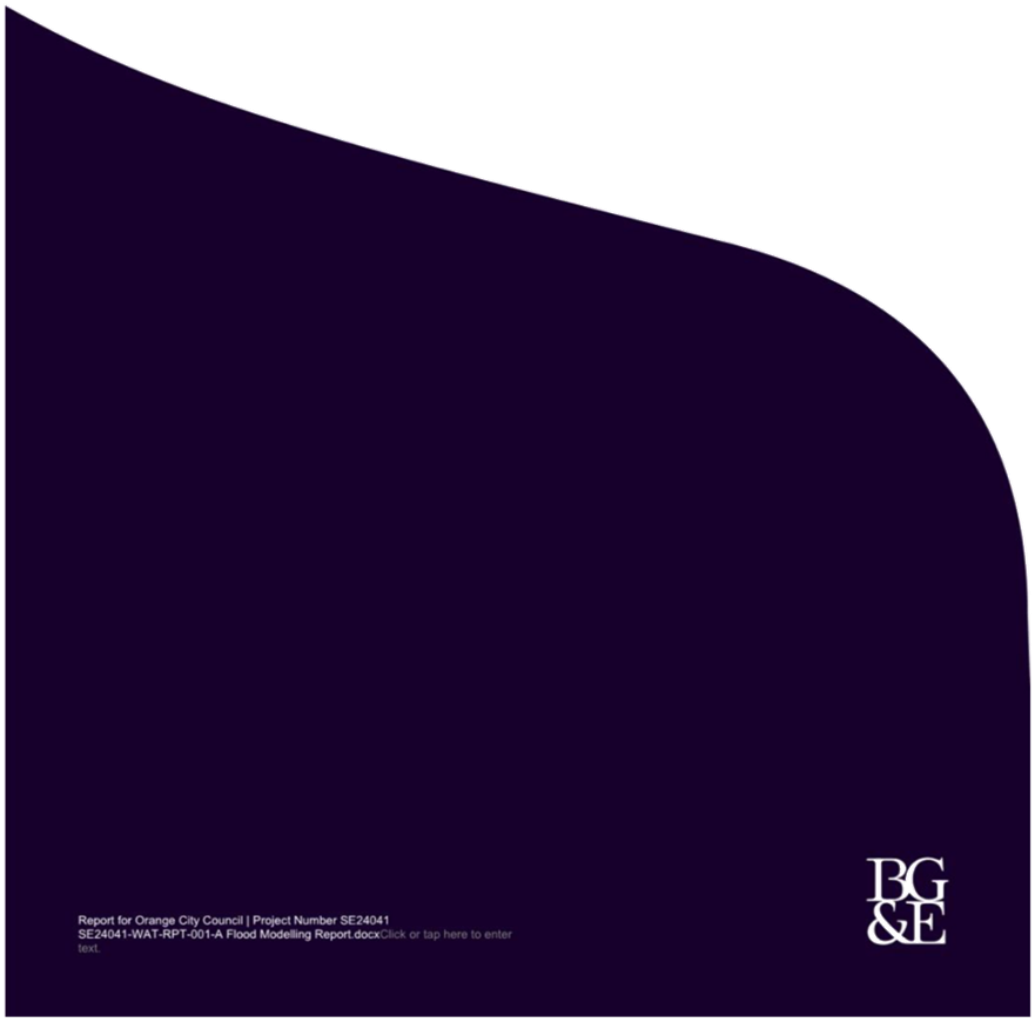
Table A.1.4.3-6: Summary of underpass inundation due to changes in blockage assumptions for the rail culverts

	10% AEP event			1% AEP event		
Blockage scenario:	25%	50%	75%	25%	50%	75%
Peak water level upstream rail embankment (mAHD)	877.25	877.25	878.05	877.69	878.05	878.58
Flow through underpass (m^3/s)	0	0	0.75	0.39	1.85	4.39
Depths of inundation in the underpass (m)	0	0	0.29	0.18	0.50	0.92

A.1.5 Summary

- Blockage on culverts was assumed at 50% for the updated baseline modelling based on site observations. This blockage assumption, plus the other modelling updates results in higher upstream flood levels compared to the FRMS&P model however the Flood Planning Area upstream at residential properties is not significantly impacted.
- Downstream of the rail embankment there are minor changes in flood level caused by redirected flows through the underpass. In the 1% AEP changes in flood level are typically not more than +/- 40 mm and therefore within the 500 mm freeboard applied to the 1% AEP to define the Flood Planning Area. It is not recommended to revise the Flood Planning Area.
- The updated flood modelling indicates that the pedestrian underpass is likely to first convey flows somewhere between the 5% AEP and the 2% AEP event.
- Sensitivity testing of blockage scenarios shows significant increases in upstream water levels with increased blockage. As culvert blockage increases and level rise upstream of the rail embankment and more flow is redirected through the underpass. The impact on upstream water levels as result of blockage is greater than the impact on downstream flood behaviour.
- It is recommended that Council consider agreement with the rail authority for culvert maintenance to minimise risk of increased frequency of inundation through the underpass given the sensitivity to blockage.

Appendix B - Flood Mapping – Model Updates and Baseline Conditions



B.1 Flood Mapping – Model Updates and Baseline Conditions

Figure B 1 – Comparison of FRMS&P and updated flood modelling – change in peak flood levels – 10% AEP event
Figure B 2 – Comparison of FRMS&P and updated flood modelling – change in peak flood levels – 1% AEP event
Figure B 3 – Critical duration distribution – 10% AEP event
Figure B 4 – Critical duration distribution – 1% AEP event
Figure B 5 – Critical duration distribution – PMF event
Figure B 6 – Existing Conditions - Maximum flood depth – 20% AEP
Figure B 7 - Existing Conditions - Maximum flood depth – 10% AEP
Figure B 8 - Existing Conditions - Maximum flood depth – 1% AEP
Figure B 9 - Existing Conditions - Maximum flood depth – 0.05% AEP
Figure B 10 - Existing Conditions - Maximum flood depth – PMF
Figure B 11 – Existing Conditions - Peak flood levels – 20% AEP
Figure B 12 - Existing Conditions - Peak flood levels – 10% AEP
Figure B 13 - Existing Conditions - Peak flood levels – 1% AEP
Figure B 14 - Existing Conditions - Peak flood levels – 0.05% AEP
Figure B 15 - Existing Conditions - Peak flood levels – PMF
Figure B 16 - Existing Conditions - Maximum flood velocity – 10% AEP event
Figure B 17 - Existing Conditions - Maximum flood velocity – 1% AEP event
Figure B 18 - Existing Conditions - Flood hazard – 10% AEP event
Figure B 19 - Existing Conditions - Flood hazard – 1% AEP event
Figure B 20 – Climate change sensitivity – 1% AEP event – 10% increase in flows
Figure B 21 – Climate change sensitivity – 1% AEP event – 30% increase in flows

Appendix C - Flood Mapping – Flood Modification Measure Concept Design

C.1 Flood Mapping – FMM Concept Design

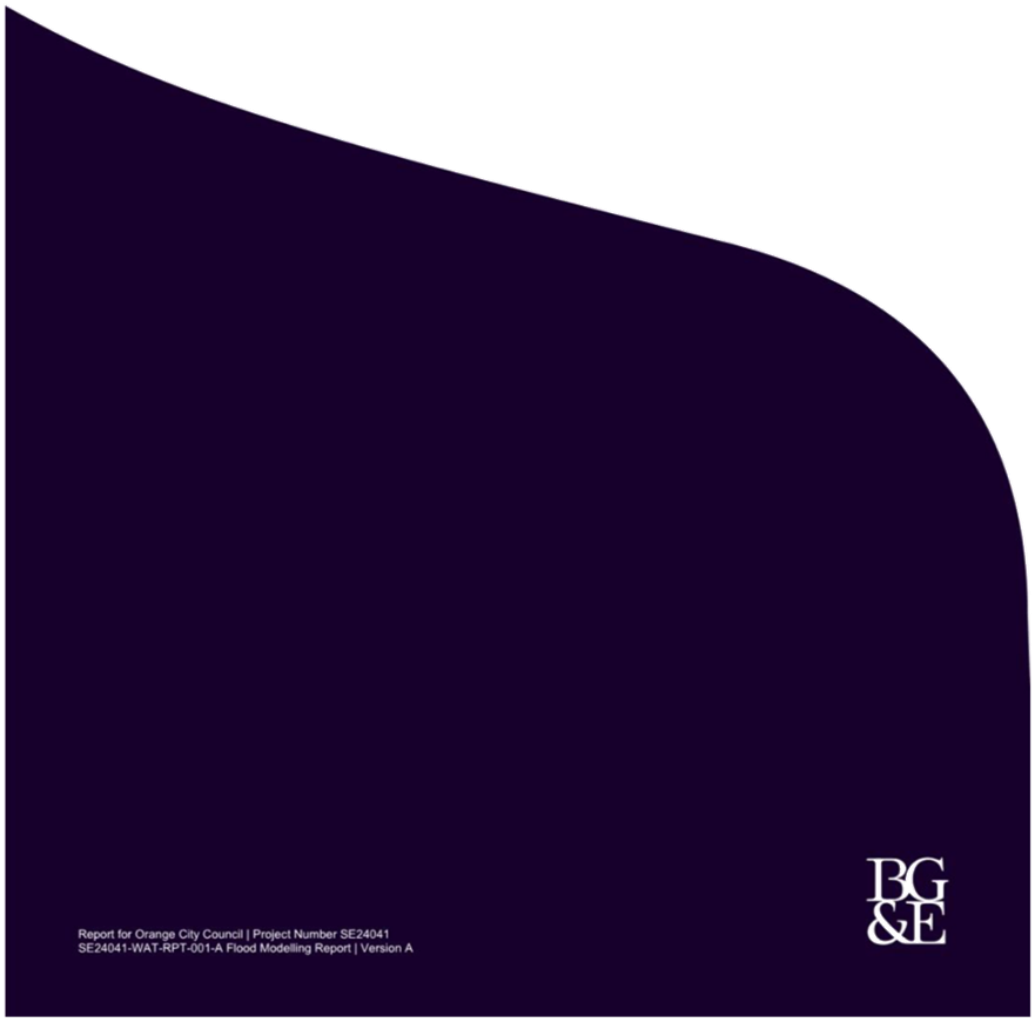
Figure C 1: FMM1 – Change in peak flood levels - 10% AEP event
Figure C 2: FMM1 – Change in peak flood levels 1% AEP event
Figure C 3: FMM1 – Flood hazard - 10% AEP event
Figure C 4: FMM1 – Flood hazard - 1% AEP event
Figure C 5: FMM2 – Change in peak flood levels - 10% AEP event
Figure C 6: FMM2 – Change in peak flood levels 1% AEP event
Figure C 7: FMM2 – Flood hazard - 10% AEP event
Figure C 8: FMM2 – Flood hazard - 1% AEP event
Figure C 9: FMM5 – Change in peak flood levels - 10% AEP event
Figure C 10: FMM5 – Change in peak flood levels 1% AEP event
Figure C 11: FMM5 – Flood hazard - 10% AEP event
Figure C 12: FMM5 – Flood hazard - 1% AEP event
Figure C 13: FMM6 – Change in peak flood levels - 10% AEP event
Figure C 14: FMM6 – Change in peak flood levels 1% AEP event
Figure C 15: FMM6 – Flood hazard - 10% AEP event
Figure C 16: FMM6 – Flood hazard - 1% AEP event
Figure C 17: FMM7 – Change in peak flood levels - 10% AEP event
Figure C 18: FMM7 – Change in peak flood levels 1% AEP event
Figure C 19: FMM7 – Flood hazard - 10% AEP event
Figure C 20: FMM7 – Flood hazard - 1% AEP event
Figure C 21: FMM8a – Change in peak flood levels - 10% AEP event
Figure C 22: FMM8a – Change in peak flood levels 1% AEP event
Figure C 23: FMM8a – Flood hazard - 10% AEP event
Figure C 24: FMM8a – Flood hazard - 1% AEP event
Figure C 25: FMM9a – Change in peak flood levels - 10% AEP event
Figure C 26: FMM9a – Change in peak flood levels 1% AEP event
Figure C 27: FMM9a – Flood hazard - 10% AEP event
Figure C 28: FMM9a – Flood hazard - 1% AEP event
Figure C 29: FMM9c – Change in peak flood levels - 10% AEP event
Figure C 30: FMM9c – Change in peak flood levels 1% AEP event
Figure C 31: FMM9c – Flood hazard - 10% AEP event
Figure C 32: FMM9c – Flood hazard - 1% AEP event

Appendix D - Flood Mapping – Flood Modification Schemes and Ultimate Modification Scheme

D.1 Flood Mapping - FMS and Ultimate Modification Scheme

Figure D 1 FMS1 – Change in peak flood levels - 10% AEP event
Figure D 2 FMS1 – Change in peak flood levels - 1% AEP event
Figure D 3 FMS1 – Flood Hazard - 10% AEP event
Figure D 4 FMS1 – Flood Hazard - 1% AEP event
Figure D 5 FMS2 – Change in peak flood levels - 10% AEP event
Figure D 6 FMS2 – Change in peak flood levels - 1% AEP event
Figure D 7 FMS2 – Flood Hazard - 10% AEP event
Figure D 8 FMS2 – Flood Hazard - 1% AEP event
Figure D 9 FMS3 – Change in peak flood levels - 10% AEP event
Figure D 10 FMS3 – Change in peak flood levels - 1% AEP event
Figure D 11 FMS3 – Flood Hazard - 10% AEP event
Figure D 12 FMS3 – Flood Hazard - 1% AEP event
Figure D 13 Ultimate Scheme – Change in peak flood levels - 10% AEP event
Figure D 14 Ultimate Scheme – Change in peak flood levels - 1% AEP event
Figure D 15 Ultimate Scheme – Flood Hazard - 10% AEP event
Figure D 16 Ultimate – Flood Hazard - 1% AEP event
Figure D 17 Ultimate Scheme – Climate change sensitivity – 1% AEP event – 10% increase in flows
Figure D 18 Ultimate Scheme – Climate change sensitivity – 1% AEP event – 30% increase in flows

Appendix E - Flood Mapping – Dam Break

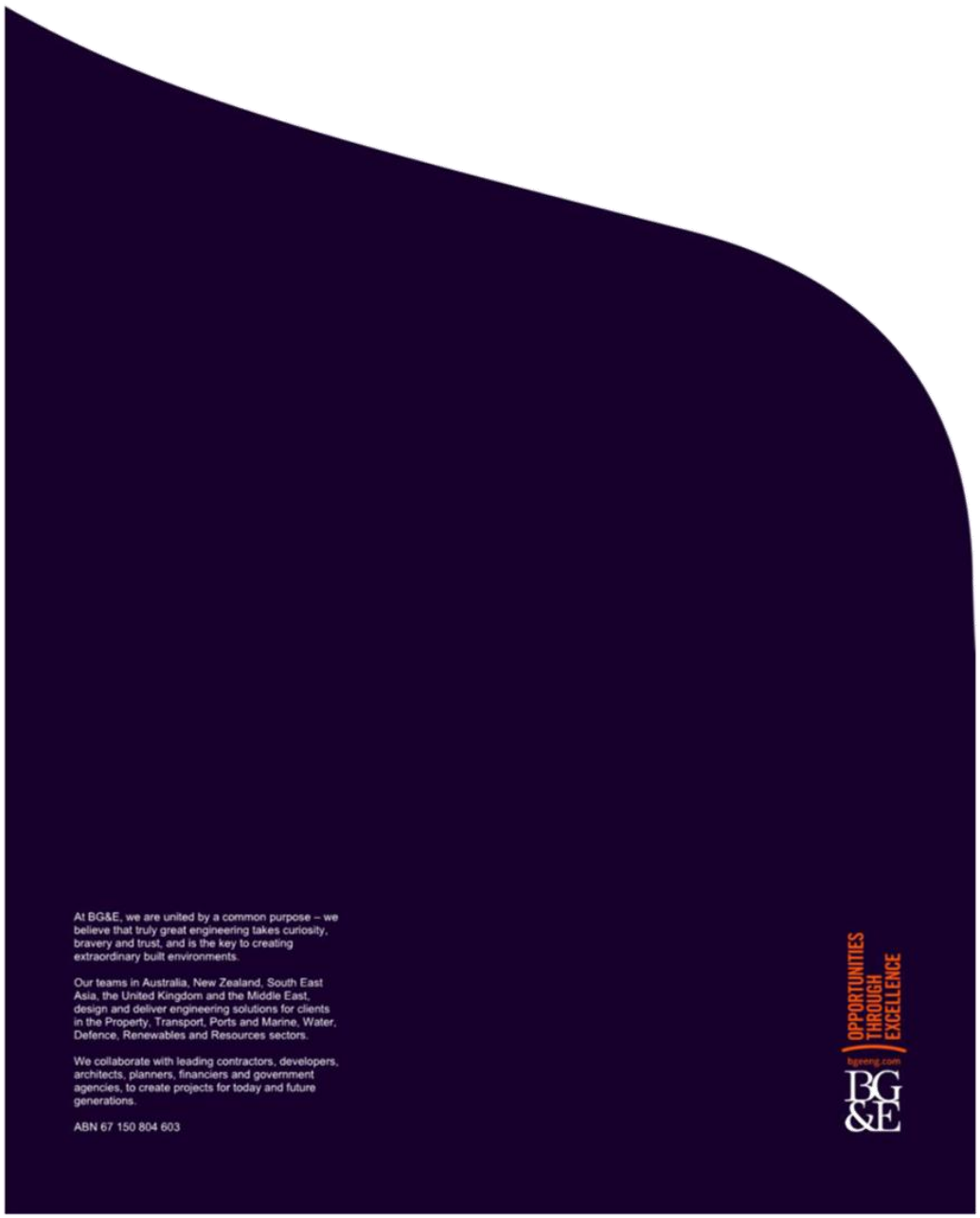


E.1 Flood Mapping – Dam Break

Figure E 1 FMM1 - Dam break flood level change – 1% AEP event
Figure E 2 FMM6 - Dam break flood level change – 1% AEP event (TO BE COMPLETED)
Figure E 3 Rifle Range Creek railway crossing - Dam break flood level change – 1% AEP event
Figure E 4 FMM7 - Dam break flood level change – 1% AEP event
Figure E 5 FMM8A - Dam break flood level change – 1% AEP event

Report for Orange City Council | Project Number SE24041
SE24041-WAT-RPT-001-A Flood Modelling Report | Version A

BG&E


At BG&E, we are united by a common purpose – we believe that truly great engineering takes curiosity, bravery and trust, and is the key to creating extraordinary built environments.
Our teams in Australia, New Zealand, South East Asia, the United Kingdom and the Middle East, design and deliver engineering solutions for clients in the Property, Transport, Ports and Marine, Water, Defence, Renewables and Resources sectors.
We collaborate with leading contractors, developers, architects, planners, financiers and government agencies, to create projects for today and future generations.
ABN 67 150 804 603
OPPORTUNITIES THROUGH EXCELLENCE
bgeeng.com
BG&E

3 GENERAL REPORTS

3.1 Current Works

RECORD NUMBER: 2026/46
AUTHOR: Jason Theakstone, Acting Director Technical Services

EXECUTIVE SUMMARY

The purpose of this report is to update Council on construction and maintenance works which have been carried out since the last current works report to Council.

LINK TO DELIVERY/OPERATIONAL PLAN

The recommendation in this report relates to the Delivery/Operational Plan strategy "9.2 Design and deliver the road infrastructure for a growing city".

FINANCIAL IMPLICATIONS

Nil

POLICY AND GOVERNANCE IMPLICATIONS

Nil

RECOMMENDATION

That the information provided in the report on Current Works report be acknowledged.

FURTHER CONSIDERATIONS

The recommendation of this report has been assessed against Council's key risk categories and the following comments are provided:

Service/ Project Delivery	Nil
Financial	No change to the financial risk profile with this report for information.
Reputation/Political	The temporary closure of the Ash Street crossing for works on Huntley Road is in place with no further issues identified.
Environment	Nil
Compliance	Nil issues.
People & WHS	Nil
Information Technology/ Cyber Security	No identified IT/Cyber Security Risks with this report for information.

SUPPORTING INFORMATION

Road Maintenance

Resources have been continuously applied to pothole repairs on sealed roads across the city. Patching of watermain upgrades was undertaken on Hill Street and Dalton Street and heavy patching works were undertaken on Wolsley Street ahead of a full reseal in early February.

Rail Level Crossings

An audit of Council's level crossing management was conducted by the Office of the National Rail Safety Regulator (ONRSR) to assess Council's compliance with its obligations as a road manager under sections 105 to 109 of the Rail Safety National Law.

3.1 Current Works

During the audit, Council was able to demonstrate a thorough understanding of its obligations to managing the risks posed by level crossings in general and that Council has implemented inspection and maintenance works to our level crossings as a separate activity alongside its road maintenance and inspection program.

"ONRSR identified no non-conformances with the law during this audit of Orange City Council's level crossing management, and therefore Orange City Council is not required to take any action."

It should be noted that the scope of this audit did not include the identification or implementation of new rail safety initiatives by TfNSW such as boom gates at Woodward Street.

Road Upgrading

Huntley Road

Asphalt surfacing was applied to the completed roadworks and line marked with the priority through the intersection favouring Huntley Road. Ash Street level crossing was reopened to traffic.

Photo: Completed intersection works at Huntley Road and Ash Street

Whiley Road

Council staff continued works on site with:

- Culvert widening;
- Table drain clearing;
- Drainage construction;
- Road widening;
- Pavement construction.

3.1 Current Works

Photo : Pavement rehabilitation on Hill Street

Road Rehabilitation

Works were completed on the pavement strengthening and asphalt sealing of:

- Leeds Parade – Phillip Street to Honeyman Drive;
- Hill Street – Byng Street to March Street;
- Dalton Street – Spring Street to Park Street;
- Anson Street – Gardiner Road to Rail Bridge;
- Hawthorn Place – Leewood Drive to end.

Concrete and Drainage

Footpaths

Work has commenced or continued on new footpaths and footpath reconstructions at:

- Spring Street – March Street to Byng Street;
- Seaton Street – Post Office / Shop to Grove Street (Spring Hill);
- Downey Street – Dimboola Way to Glasson Drive.

Work was completed on new footpaths and footpath reconstructions at:

- Allenby Road – Icely to school entry;
- Seville Parade – Cecil Road to Hill Street;
- Dimboola Way – Glasson Drive to Downey Crescent.

3.1 Current Works

Photo: New footpath in Seville Parade

Upcoming major works

Major road upgrading works, status and timing (as weather permits) as follows:

Work	Location	Status
Woodward Street rehabilitation	Wentworth Avenue to Gardiner Road	Contract awarded. Expect works to commence in March 2026.
Dalton Street asphalt pavement seal renewal	At the rail level crossing	All rail approvals in place. Works planned for February.
Peisley Street rehabilitation	Franklin Road to Warrendine Street	Procurement complete, contract awarded. Expected works to commence early February.
Peisley Street rehabilitation	Moulder Street to Warrendine Street (stg2)	Procurement phase. Expect works to commence late March.

WATER SUPPLY SERVICES

The type and number of water supply service responses by maintenance staff are shown in the table below.

Category	July 2024 – June 2025	November 2025	December 2025
Water - Leak (Meter)	369	35	24
Water Request - Meters Faulty (incorrect readings)	115	3	4
Water - No Water Supply	69	5	4
Water – Pressure	25	4	1
Water Request - Replace Meter box/lid	24	0	1

3.1 Current Works

Category	July 2024 – June 2025	November 2025	December 2025
Water quality – Dirty	35	2	2
Water - Burst Main	114	5	11
Water - leak (Main, Valve, Hydrant)	579	44	45
Total Water Requests	**1,330**	**98**	**92**

Construction Works

- Work have been completed on the renewal of Maxwell Avenue water main. This has seen a service improvement for Maxwell Avenue residents and the Glenroi Heights Public School.
- Works are nearing completion on the Hill Street water main renewal. The remaining works are the connection around the Gladstone Hotel which is planned for February 2026.
- Works have commenced on the renewal of the water main in March Street between William Street and McLachlan Street. These works see the upgrade of the existing 100mm main to a new 150mm main located on the shoulder of the road. Works are expected to be completed in February 2026.
- Planning works are underway for the renewal of the 100mm water main in Kileys Run. These works are expected to commence in April.

New Water Connections

- New service to 20 Melaleuca Way;
- New service to 27 Jindalee Avenue.

Renewals

- Council has been undertaking the renewal of water services on Northstoke Way these include properties 16, 18, 20, 22, 24, 26, 28, 30 Northstoke Way.
- 34 Glenroi Avenue water service renewal.

SEWER SERVICES

The type and number of sewer service responses by maintenance staff are shown in the table below.

Category	July 2024 – June 2025	October 2025	December 2025
Sewer Choke - Blockages	260	19	19
Sewer Complaint - Odour	5	1	1
Sewer Complaint - Overflow	217	26	15
Total Sewer Requests	**482**	**46**	**35**

Construction Works

- Works have commenced on the sewer main rehabilitation program with all mains currently cleaned and relining commenced. Relining works are expected to be completed by March 2026 with sewer junction sealing to continue into April 2026.

3.1 Current Works

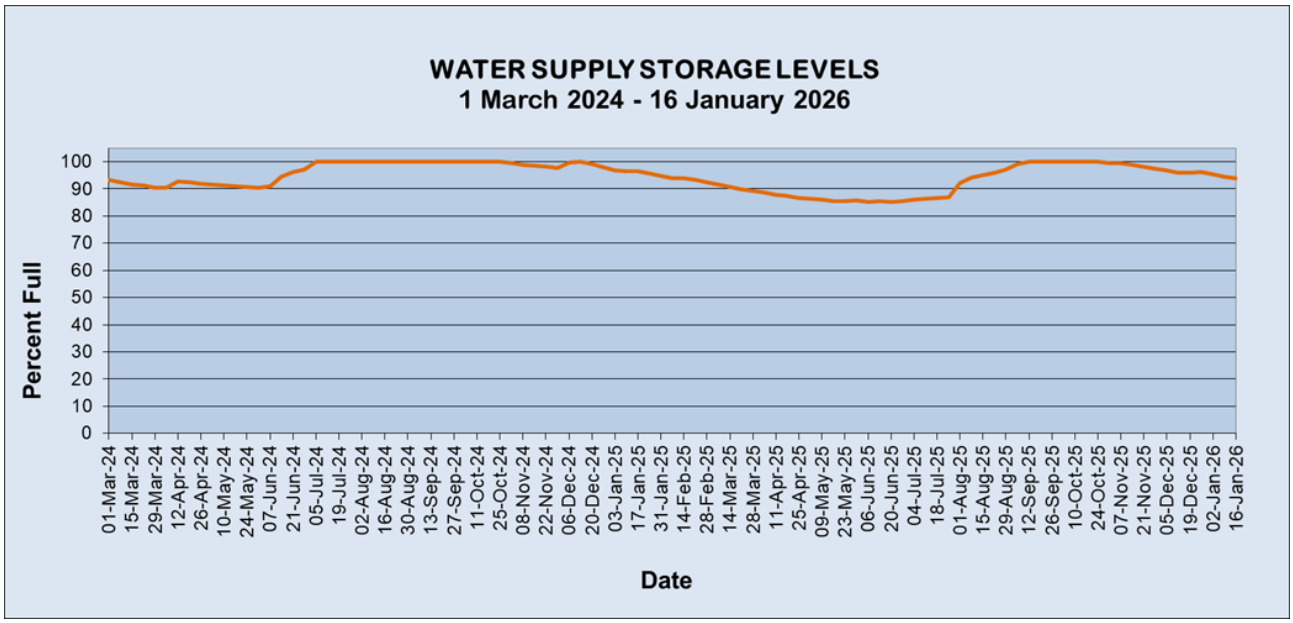
Sewer Reconstruction

- 20 Jubilee Avenue- sewer junction reconstruction;
- 18 Braemar Circuit - sewer junction reconstruction;
- 16 Turner Crescent - sewer junction reconstruction;
- 45 Bletchington Street - sewer junction reconstruction;
- 159 Little Warrendine Street - sewer junction reconstruction.

WATER SUPPLY SECURITY

Water Storage Levels

The water storage trend for the combined storages from 1 March 2024 to 16 January 2026 is shown in the graph below.



Below levels current at 16 January 2026:

Location	Level Below Spillway (mm)	% of Capacity
Suma Park Dam	811	92.85%
Spring Creek Dam	71	98.35%
Lake Canobolas	10	99.70%
Gosling Creek Dam	102	97.03%

3.1 Current Works

Supplementary Raw Water Sources

Extractions from the supplementary raw water supplies in recent months are provided in the table below. The 'Total' column is the tally for all months in the water year (starting July).

Raw Water Source	October 2025 (ML)	November 2025 (ML)	December 2025 (ML)	Total 2025/2026 (ML)
Bores*	4.48	5.29	8.22	30.99
Stormwater	0.00	0.00	0.00	0.00
Macquarie River	0.00	0.00	0.00	0.00
Total	**4.48**	**5.29**	**8.22**	**30.99**

** Bores include two at Clifton Grove and two at the Showground/Margaret Street*

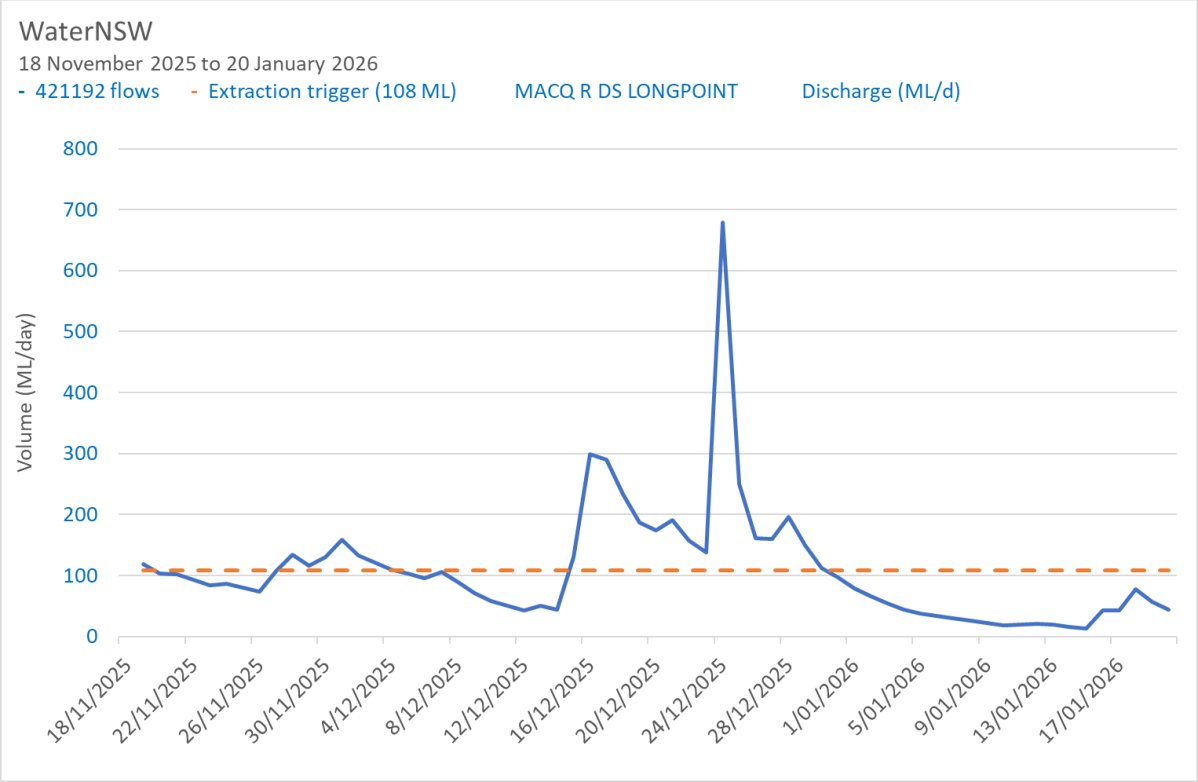
A more detailed monthly summary of raw water transfers can be found on Council's website at https://www.orange.nsw.gov.au/water/oranges-water-supply/.

The first quarter Decision Support Tool (DST) was conducted 12 January 2026 predicting neutral conditions for the year ahead from the Bureau of Meteorology's POAMA forecast. No supplementary supplies are predicted to be required in the third quarter.

Macquarie River Flows

The mean daily flows in the Macquarie River monitored downstream of Long Point (Station 421192) for 18 November 2025 to 20 January 2026 are presented below. The data was sourced from the WaterNSW website with flows presented in megalitres per day (ML/d).

There was a maximum flow rate of 679 ML/d on 23 December 2025 before reducing to a minimum of 13 ML/d on 14 January 2026. The flow rates have remained below the extraction trigger value of 108 ML/d from 30 December to the end of the period.



3.1 Current Works

Demand Management

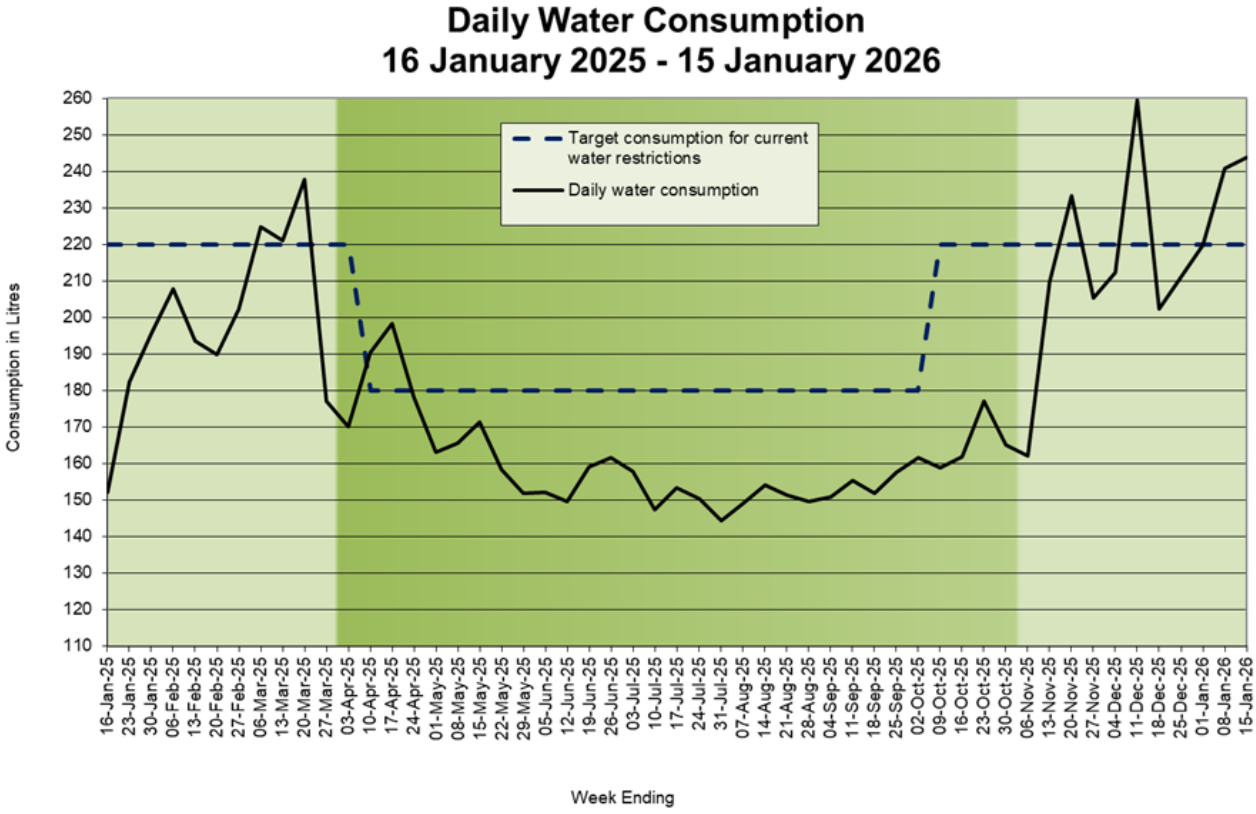
Residential water use

Permanent Water Saving Standards came into effect on Friday 25 June 2021.

Average daily residential water consumption for the period 14 November 2025 to 18 December 2025 was 223 litres per person per day.

Average daily residential water consumption for the period 19 December 2025 to 15 January 2026 was 226 litres per person per day.

The graph below shows the average daily residential water consumption trend from 16 January 2025 to 15 January 2026.



Total water use

The average daily city-wide water consumption for the period 14 November 2025 to 18 December 2025 was 14.36 ML/day.

The average daily city-wide water consumption for the period 19 December 2025 to 15 January 2026 was 14.59 ML/day.

DRINKING WATER QUALITY

Water samples are collected as a component of Orange City Council's Drinking Water Quality Monitoring Program in accordance with NSW Health requirements. Samples are collected regularly and sent to the NSW Government National Association of Testing Authorities (NATA) accredited laboratory for analysis.

The Icely Road supply system achieved 100% compliance for physical, chemical and microbiological samples in November and December 2025. A drinking water quality report for 2025 is provided on Council's website at https://www.orange.nsw.gov.au/water/water-treatment-plant/.

3.1 Current Works

PROJECT MANAGEMENT OFFICE

East Orange Harvesting Wetlands
(Blackman's Swamp Creek Stormwater Harvesting Stage 2)

The East Orange Harvesting Wetlands project will deliver new offline water storage on Blackman's Swamp Creek to increase the city's secure water supply through stormwater harvesting. As the second stage of Council's broader stormwater harvesting program, the project is an important part of improving Orange's long-term water resilience. When completed, the wetlands will allow additional stormwater to be captured, treated and stored for future use, helping to strengthen the city's water security during dry periods.

Approval for the project was issued by DCCEEW in October 2024 under the Water Management Act 2000. A joint appeal against this approval was lodged in November 2024, which required extended engagement between the parties throughout 2025. Council and its legal representatives participated in a series of discussions and meetings aimed at addressing the concerns raised. These discussions continued over the year and ultimately led to the matter being resolved prior to Christmas in December 2025. With the appeal process now finalised, there are no remaining impediments from this process.

Council's project team is now progressing the next steps in the project. Work will continue to focus on planning, preparation and coordination activities necessary to advance the delivery of the wetlands. The project remains an important component of Council's long-term water management strategy, and the resolution of the appeal enables the team to move forward with greater certainty and focus.

Sewage Treatment Plant Inlet Works

Progress on the Inlet Works component of the Sewage Treatment Plant has been slower than planned, largely due to the contractor's challenges in progressing the required works. All defective epoxy coating has now been fully removed, which allows the project to move toward the next critical stages. Several high-risk activities remain outstanding, including the reapplication of the epoxy coating and the installation of the bypass chamber, both of which are essential to the functioning of the upgraded inlet works.

A third-party specialist inspector and the specialist applicator is scheduled to be onsite toward the end of January to commence the epoxy reapplication. The contractor continues to require ongoing support with this project and these high risk items.

Orange Conservatorium and Planetarium

The Orange Conservatorium and Planetarium project continues to make steady progress, with significant work advancing across both buildings. Major structural elements are now largely complete, including the suspended Level 2 slab, precast panels and a majority of the structural steel. Roofing works are well progressed, and internal services and linings continue to advance across both levels. Externally, cladding and glazing installation is ongoing, contributing to the building becoming increasingly enclosed and weather-tight. Recent works have also focused on the Recital Hall, where structural steel, stairs and internal fit-out items continue to take shape.

As construction has progressed, a number of design-related clarifications have continued to come through, including coordination issues between architectural, structural and building services drawings. These require detailed input from the design consultants and are generating a steady flow of RFIs on site. The project team is working collaboratively to resolve these items efficiently so that they do not adversely impact progress.

3.1 Current Works

There are still several high-risk activities remaining, particularly the installation of the Planetarium structure and dome. These are highly specialised and complex elements that require precise sequencing, coordination and quality control. Their installation poses some risk to the program given the detailed structural interfaces involved, but planning is well underway to manage these challenges and minimise disruption.

Based on progress to date and the remaining scope of internal fit-out, services integration and specialist installations, the project team expects that completion is likely to fall sometime around mid-2026, subject to progress on the remaining works.

Photo – Construction of Orange Conservatorium and Planetarium – Main Entrance – March Street steel is underway including the external façade.

Orange Sports Precinct

The Orange Sports Precinct continues to make steady progress across multiple components of the project. Turf installation for Fields 1–8 was completed in April 2025, and the fields have since undergone standard establishment and maintenance activities. Council and the contractor have continued working through some issues identified during the establishment phase, with the contractor undertaking additional testing prior to Christmas to confirm material suitability. Refinement works are now being carried out to ensure the playing surfaces meet the required performance standards.

Topsoil placement around the main eight fields has also been finalised, and further concrete drainage works have been completed to support long-term field performance and improve water management across the precinct. Final documentation and maintenance plans are being prepared to enable a smooth transition to operational use.

The John Davis OAM Stadium has reached an important milestone, with the contractor now mobilising to site and commencing early works. The stadium is a highly significant element of the overall precinct, and activity is progressing following the receipt of the required Heritage

3.1 Current Works

Construction and Section 60 approvals. Council also continues to work through several value-management items as part of the contract formalisation process.

Electrical infrastructure works are advancing, with the tender awarded and onsite installation scheduled to begin shortly. Across the precinct, earthworks and supporting works are continuing, including concrete footpath installation and preparation of landscaped areas.

Progress along Huntley Road remains strong despite intermittent wet weather. Recent work has included realignment of the Ash Street intersection, completion of the water main relocation, pavement widening and asphalt works in selected areas. A temporary carpark has also been established to support users during verge construction.

Several additional tenders and design packages are currently out to market, including those for carparks and the Forest Road intersection. Council is also progressing Construction Certificates and other required approvals to ensure upcoming work packages can begin without delay and support the long-term operation and accessibility of the precinct

Photo – Sports Precinct – Spreading of Topsoil to Northern End of fields 1-8

Lone Pine Culvert Upgrade

Works on the Lone Pine project have now commenced, with all required approvals in place. The presence of natural occurring asbestos (NOA) was managed in full accordance with legislative requirements before construction began, ensuring the site could progress safely and compliantly. Early works have included the installation of the base slab for the new culverts, representing a key milestone in the delivery of the upgraded access and drainage structures.

To complete these works safely, the road has been fully closed during the initial phase of construction. This approach allows crews to work efficiently while managing environmental risks such as washout during excavation and concrete placement. The project is progressing well, and construction is expected to be completed over the coming months

3.1 Current Works

March Street Bridge

The March Street Bridge project is progressing, with detailed design work currently underway to finalise the structure and delivery approach. Recent enabling activities have included the relocation of electrical poles, and preparations for the water line relocation are also advancing.

Onsite construction works are expected to commence in March or April, subject to the completion of design. The project will replace the existing culvert with a new small bridge to improve drainage capacity and strengthen the long-term structural performance of the corridor. This upgrade remains an important part of Council's broader infrastructure renewal program and will support improved safety and resilience for the community.

C2 Basin

The C2 Basin project is progressing well, with onsite activities now underway following completion of key planning, coordination, and mobilisation tasks. The project involves constructing a new stormwater basin near Shiralee Road to improve stormwater management and support future development in the area.

Initial onsite works have commenced, including site establishment, survey set out, and early earthworks. These activities mark an important step toward full construction, with the project team closely managing operations to ensure a smooth rollout and minimise disruption to the surrounding area.

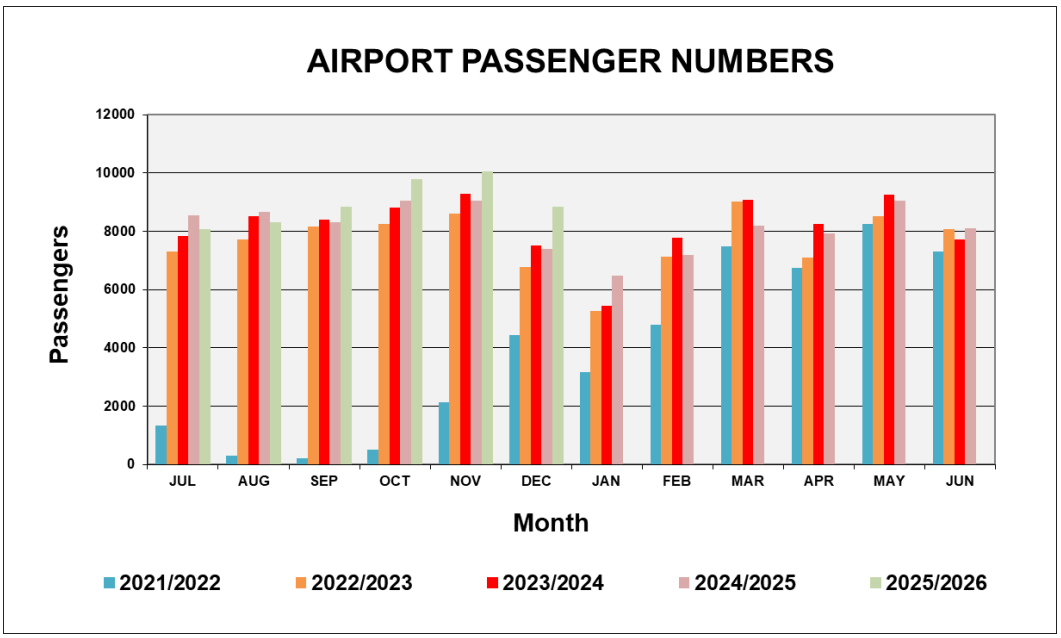
Further construction activities will continue over the coming weeks as the contractor advances through the planned program of works. Regular updates will be provided as the project progresses.

AIRPORT PASSENGER NUMBERS

Passenger numbers during November 2025 were 10,050 compared to 9,038 for the same month in 2024.

Passenger numbers during December 2025 were 8,853 compared to 7,385 for the same month in 2024.

These figures include passenger numbers from Regional Express, Link Airways (formerly Fly Corporate) and QantasLink.

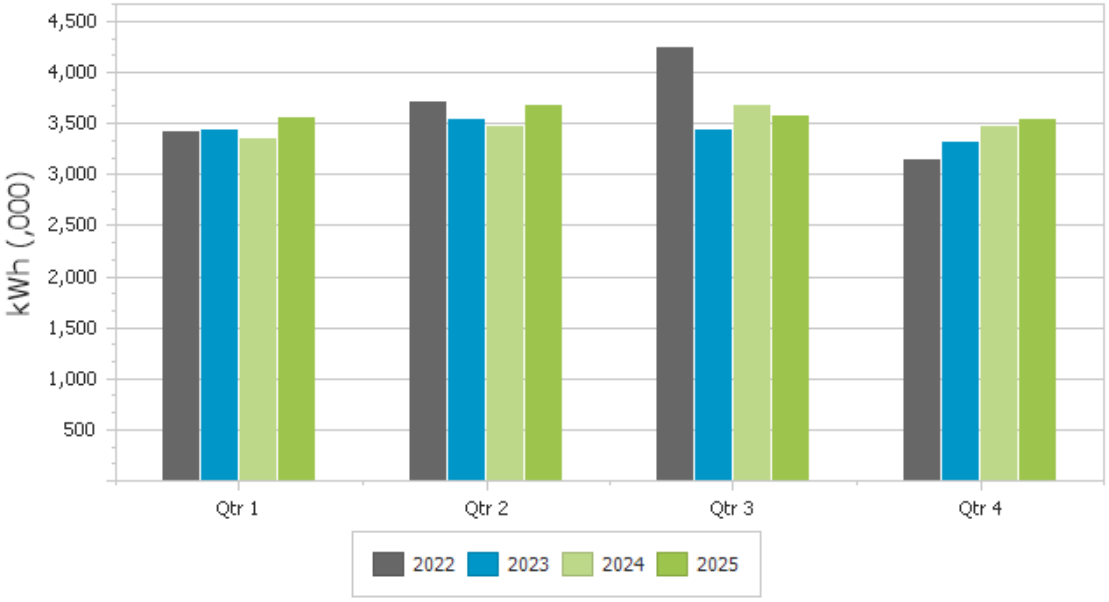


3.1 Current Works

ENERGY USE

The following information is sourced from E21, Council's energy software.

Consumption History - up to 4 Years — **Thursday, 22 January 2026 8:33 AM**



History - Last 12 Months

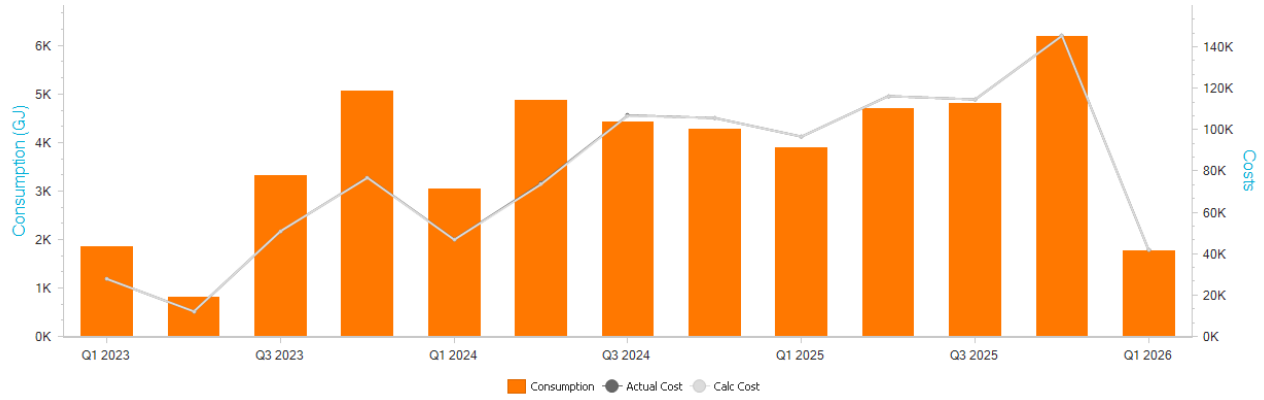
GROUP	CONSUMPTION (kWh)	BILL (ex GST)
Parks & Gardens	0	$0
Water	4,789,802	$1,290,609
Public Buildings & Facilities	3,022,928	$912,651
Lighting	1,435,243	$455,414
Other	0	$0
Sewer	3,383,006	$922,424
Macquarie Pipeline	17,185	$17,245
Ungrouped	149,742	$50,413
Total	12,797,906	$3,648,757

3.1 Current Works

Gas Consumption

Please note discrepancies in historic gas consumption are due to gaps in data captured. This issue was rectified in Q3 2023.

Quarterly Data Charts



Period	Consumption (GJ)	Actual	Calculated	$/GJ	Emissions
Mar-2023	1,855.8	$27,836.11	$27,824.77	15.00	119.7
Jun-2023	822.3	$12,148.66	$12,146.93	14.77	53.0
Sep-2023	3,317.7	$50,958.97	$50,993.39	15.36	214.0
Dec-2023	5,079.3	$76,928.44	$76,768.41	15.15	327.6
Mar-2024	3,043.2	$46,976.20	$46,832.11	15.44	196.3
Jun-2024	4,876.4	$74,025.48	$73,627.91	15.18	314.5
Sep-2024	4,434.5	$106,921.79	$106,779.35	24.11	286.0
Dec-2024	4,273.6	$105,654.16	$105,642.01	24.72	275.6
Mar-2025	3,906.3	$96,670.27	$96,661.61	24.75	252.0
Jun-2025	4,702.6	$116,248.52	$116,239.28	24.72	303.3
Sep-2025	4,816.5	$114,625.40	$114,618.27	23.80	310.7
Dec-2025	6,204.8	$145,409.81	$145,397.17	23.44	400.2
Mar-2026	1,779.6	$41,609.66	$41,608.78	23.38	114.8
	49,112.6	**$1,016,013.5**	**$1,015,140.0**		**t 3,167.8**