

State guideline:

Flood evacuation route improvements

Worked example



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*Diamantina Developmental
Road between Bedourie and
Boulia, 2019*



Introduction

This document supports guidance on the options assessment process outlined in section B of the *State guideline: Flood evacuation route improvements* (the guideline) by applying it to a fictional location. Further support to implement the options assessment process is provided in the *State guideline: Flood evacuation route improvements – Supporting tool*.

The process outlined in the guideline as shown in Figure 1 has been applied to Rivertown. The process for implementation of the preferred option is also discussed in section 5. The Rivertown example works through the following stages:

- understand the evacuation problem
- identify potential options
- options assessment:
 - stage one: option feasibility assessment
 - stage two: multi-criteria assessment (MCA)
 - financial and economic assessments
- review outcomes of the assessment process.

Rivertown has the following characteristics:

- it is a regional town with 300 residents
- a recent significant flood event highlighted evacuation issues
- the entire town is in flood-prone land.

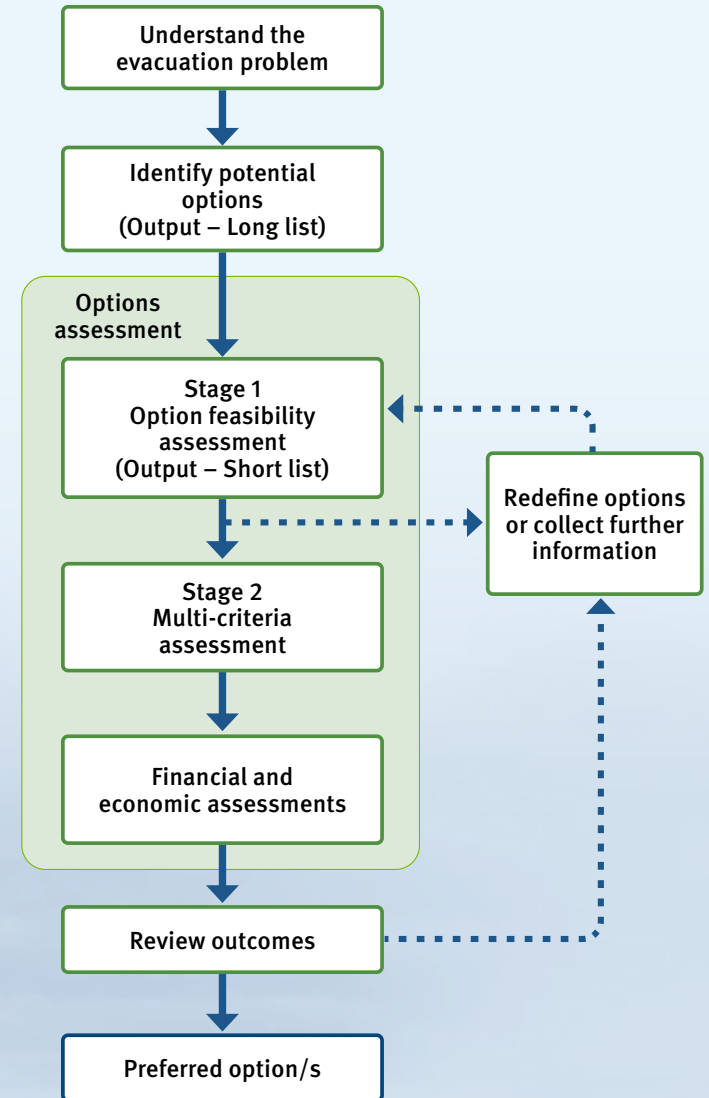


Figure 1 - Assessment process

Worked example

1. Understand the evacuation problem

1.1 Investigating the evacuation problem

Information sourced from an existing flood risk assessment and flood study conducted for Rivertown was used to investigate the problem. An evacuation capability assessment had not been conducted. Constraints to evacuation were derived from the existing studies. Table 1 below shows the results of the investigation.

Table 1 - Investigating the evacuation problem at Rivertown

Question	Response
Why has flood evacuation been identified as a problem for this location, and what is the problem?	<ul style="list-style-type: none">▪ evacuation has been flagged as a problem due to a large historic event where evacuation was challenging▪ a flood risk assessment, using detailed flood modelling, has since been carried out and confirmed that the town is subject to a serious flood risk and there is potential for a more significant flooding event than experienced in the past.
What is acceptable to the community?	<ul style="list-style-type: none">▪ significant reduction in risk to life from flooding▪ the community is comfortable with either evacuating to an evacuation centre or sheltering in place, as long as they feel safe.
What is the flood risk?	<ul style="list-style-type: none">▪ the risk level determined for the town during the detailed flood risk assessment is an intolerable risk (that is, high likelihood of flooding and high consequence and hazard when flooding occurs)▪ inundation starts from the edge of town and gradually increases to inundate the centre of town last▪ the town remains inundated for up to a week due to the size of the catchment▪ there are existing flood warning systems and disaster management planning in place, but they do not provide sufficient time for evacuation for a large flood event▪ the town's whole population is at risk (300 people)▪ some of the population is considered vulnerable due to their age▪ most of the town's residents are familiar with past flood behaviour as the town has few tourists or new residents.

(continued on next page)

Table 1 - Investigating the evacuation problem at Rivertown (continued)

Question	Response
What is the source of flooding that affects the area?	<ul style="list-style-type: none"> ▪ the source of flooding is slow-onset flooding from a major river.
What is the flood immunity of the area and what is the flood immunity of associated evacuation infrastructure?	<ul style="list-style-type: none"> ▪ lower lying areas are inundated in a 5% Annual Exceedance Probability (AEP) event ▪ most of the township is inundated in a 2% AEP event ▪ the entire town is inundated in a 1% AEP event ▪ access to the next town is via a district road that connects to an arterial road. The district road has a 10% AEP flood immunity and the arterial road is not affected by flooding.
What is the nature of the flood behaviour, including flood hazard and timing?	<ul style="list-style-type: none"> ▪ as flow increases, water levels rise upstream, flooding farmland and eventually properties in the main town ▪ in a 1% AEP event, there is low flood hazard in the highest part of town ▪ flood hazard increases in lower-lying areas with greater flood depth ▪ the district road would be subject to high flood hazard during the peak of a 1% AEP flood event ▪ once the town is inundated, it is anticipated to take up to a week before flood waters recede.
Is there sufficient warning time available for evacuation?	<ul style="list-style-type: none"> ▪ if a flood trigger occurs at the upstream gauge at a 20% AEP level during the Probable Maximum Flood (PMF) event, the warning time before being submerged are: <ul style="list-style-type: none"> – 24 hours for the town – six hours for the district road ▪ six hours is insufficient time to evacuate given the time needed for authorities to decide to evacuate and issue warnings, and for the community to respond and evacuate.
What are the constraints to evacuation?	<ul style="list-style-type: none"> ▪ no evacuation capability assessment has been undertaken but the following can be determined based on the existing flood study and flood risk assessment: <ul style="list-style-type: none"> – low flood immunity of the town and even lower flood immunity of roads – insufficient time to evacuate before roads inundate – the closest place to shelter with adequate essential goods and services is in the next town – access to the next town is constrained during flood events due to the low flood immunity of the district road.



Rockhampton floods, 2011

1.2 Defining the evacuation problem

The nature and scale of the evacuation problem and contributing factors are described below.

The nature of the problem: In a 1% AEP flood event, the entire town is flooded and the population is unable to evacuate. Therefore, the risks to life are due to inundation risks.

The scale of the problem: The scale of the evacuation problem is considered 'significant'. This is based on the risk assessment identifying the risk as being 'intolerable' due to the extent, likelihood and hazard of possible flooding, and constraints to evacuation. There is a significant inability to evacuate which may result in the entire population being exposed to flood hazards.

Contributing factors: Factors contributing to the evacuation problem include:

- river flooding
- low flood immunity of the town, the entire town is in flood-prone land
- inability to evacuate due to low flood immunity of existing linear infrastructure
- insufficient warning time before the evacuation route providing access to shelter in the next town is inundated
- elements of community vulnerability.

1.3 Service need and desired outcome

The preferred option will need to reduce risk to life.

2. Identify potential options

Based on an understanding of the evacuation problem, service need and desired outcome, a long list of potential options was developed as shown in Table 2.

Table 2 - Long list of options

Option	Description of option
1. Raise existing district road	
1a Raise existing district road to achieve a 5% AEP flood immunity	<ul style="list-style-type: none"> will increase the available time to evacuate before roads inundate provides access to the next town by linking to the arterial road which is not flood affected
1b Raise existing district road to achieve a 1% AEP flood immunity	<ul style="list-style-type: none"> the next town is not flood affected and will provide essential goods and a place to shelter the road is affected by a single river crossing. Depending on desired immunity, upgrades may be required for up to 200m
1c Raise existing district road to achieve PMF flood immunity	<ul style="list-style-type: none"> the district road also serves as a freight route.
2. Build new road	
2a Build a new access road to the highest point outside of the town to a 1% AEP flood immunity	<ul style="list-style-type: none"> will increase the available time to evacuate before roads inundate will have a higher immunity than existing evacuation routes
2b Build a new access road to the highest point outside of the town to PMF flood immunity	<ul style="list-style-type: none"> new road will need to be up to 500m long to span the floodplain, depending on desired immunity the area outside of town is flood free.
3. Build new evacuation centre	
3a Build new evacuation centre in the highest point in town with a building floor level above a 1% AEP flood event	<ul style="list-style-type: none"> will provide an evacuation centre in town where access during a flood event is not constrained
3b Build new evacuation centre in the highest point in town with a building floor level above the PMF	<ul style="list-style-type: none"> the location of the evacuation centre is flooded in events larger than and including the 1% AEP but is in a low flood hazard area.
4. Structural flood mitigation options	
4a Build a new levee to achieve a 1% AEP flood immunity for dwellings	<ul style="list-style-type: none"> will protect the town from inundation for the events up to and including specified event.
4b Build new levee to achieve PMF immunity for dwellings	

3. Options assessment

3.1 Stage one: Option feasibility assessment

The options feasibility assessment was conducted in consultation with stakeholders, the community and suitable persons with experience and knowledge of the evacuation problem.

3.1.1 Feasibility indicator assessment

A summary of the feasibility indicator assessment is provided in Table 3.

Generally, all options were likely to reduce risk to life for the affected population by either increasing available time to evacuate or by providing an evacuation centre

within town. However, the new evacuation centre in town with a floor level above the 1% AEP flood event (option 3a) would have significant residual risks during flood events greater than the 1% AEP event. The 'build new road' options (options 2a and 2b) were also deemed to not reduce risk, as the high ground outside of town was undeveloped and did not provide essential goods or a building to shelter. There would be significant isolation risks if residents evacuated to this location.

There were unlikely to be significant environmental or cultural heritage impacts for all options.

Most options were supported by Rivertown's residents except for the 'building a new road' options (options 2a and 2b) given there was nowhere for the population to shelter.

There are likely to be impacts from changes in flood behaviour associated with raising the existing district road or building a new road (options 1 and 2). These impacts could be mitigated with significant new or upgraded cross drainage. Raising the existing district road to a 5% AEP flood immunity level (option 1a) would result in impacts from minor flood behaviour changes on undeveloped areas upstream of town. There is likely to be significant flood impacts to nearby properties for the 1% AEP levee (option 4a). Further investigation was required to determine if this could be mitigated. The PMF levee (option 4b) would likely have unacceptable flood impacts to private land.

There would be insufficient space to achieve the required embankment for raising the existing district



road to PMF immunity (option 1c), the new road with PMF immunity (option 2b) and new levees (options 4). Subsequently, these options were not deemed to be physically and technically feasible. The new levees (options 4) were also not deemed physically or technically feasible due to impacts on visual amenity.

The new evacuation centre in town with a 1% AEP flood immunity (option 3a), was not deemed physically or technically feasible. The building floor level above a 1% AEP did not meet the minimum floor level requirements in Rivertown's planning scheme.

3.1.2 High level cost estimate

A high-level cost estimate was undertaken for the long list of options. All options were within Rivertown's budget and commensurate with the scale of the evacuation problem given the significant risk posed to Rivertown as shown in Table 3.

3.1.3 Determining outcomes of the option feasibility assessment

A summary of the outcomes of the options feasibility assessment is shown in Table 3.

The feasibility assessment was reviewed to determine the outcome of each option and develop a short-list of options to progress to stage two: MCA. Options were either eliminated, redefined or progressed to the stage two: MCA.

The new 1% AEP access road to the highest point outside of town (Option 2a) was redefined to resolve the community concerns and risks due to the absence of adequate shelter. The option was redefined to include a new evacuation centre. This option was reassessed in the option feasibility assessment and was determined to be feasible.



Yeppen Floodplain Crossing, Bruce Highway following Ex-Tropical Cyclone Debbie

Further information was required to assess flood impacts from changed flood behaviour for the new 1% AEP levee (Option 4a). Additional information would not impact on its outcome. It would ultimately be unfeasible due to insufficient space for high embankments and impacts on visual amenity. As a result, the option was eliminated.

The new evacuation centre in town with a building floor level above a 1% AEP flood event (option 3a) was eliminated as the residual risk was considered significant and the building floor level did not meet the requirements of Rivertown’s planning scheme.

Options were eliminated that were not physically or technically feasible. Redefinition or mitigation was considered but would not result in the indicator being met due to the significance of the constraint. The following options met all the feasibility indicators and were progressed to the MCA:

- Option 1a - Raise existing district road to achieve a 5% AEP flood immunity
- Option 1b - Raise existing district road to achieve a 1% AEP flood immunity

- Option 2a – Build new access road to the highest point outside of the town to a 1% AEP flood immunity combined with a new evacuation centre (redefined).
- Option 3b - Build a new evacuation centre in the highest point in town with a building floor level above the PMF.

Table 3 - Options feasibility assessment results

Option	Feasibility indicator (✓ = Met, × = Not met)					The cost is practical and suitable for the scale of the evacuation problem	Outcome of option feasibility assessment
	The option is likely to reduce risk to life for the affected population	The option is unlikely to cause significant environmental or cultural heritage impacts that are unable to be mitigated	The community supports the option and is likely to respond	The option is unlikely to cause significant adverse flood impacts that cannot be mitigated	The option is physically and technically feasible when considering engineering, constructability, or legal constraints		
Raise existing road							
1a	Raise existing district road to achieve a 5% AEP flood immunity	✓	✓	✓	✓	✓	Progress to stage two: MCA
1b	Raise existing district road to achieve a 1% AEP flood immunity	✓	✓	✓	✓	✓	Progress to stage two: MCA
1c	Raise existing district road to achieve PMF flood immunity	✓	✓	✓	×	✓	Eliminated

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Table 3 - Options feasibility assessment results (continued)

Option	Feasibility indicator (✓ = Met, × = Not met)					The cost is practical and suitable for the scale of the evacuation problem	Outcome of option feasibility assessment
	The option is likely to reduce risk to life for the affected population	The option is unlikely to cause significant environmental or cultural heritage impacts that are unable to be mitigated	The community supports the option and is likely to respond	The option is unlikely to cause significant adverse flood impacts that cannot be mitigated	The option is physically and technically feasible when considering engineering, constructability, or legal constraints		
Build new road							
2a	Build new access road to the highest point outside of the town to a 1% AEP flood immunity	×	✓	×	✓	✓	Redefined to include new evacuation centre, progressed to stage two: MCA (reassessment indicated it was feasible)
2b	Build new access road to the highest point outside of the town to PMF immunity	×	✓	×	✓	×	Eliminated
Build new evacuation centre							
3a	Build a new evacuation centre at the highest point in town with a building floor level above a 1% AEP	×	✓	✓	✓	×	Eliminated
3b	Build a new evacuation centre in the highest point in town with building floor level above the PMF	✓	✓	✓	✓	✓	Progress to stage two: MCA
Structural flood mitigation options							
4a	Build a new levee to achieve a 1% AEP flood immunity for dwellings	✓	✓	✓	More information required	×	Eliminated
4b	Build new levee to achieve PMF immunity for dwellings	✓	✓	✓	×	×	Eliminated

3.2 Stage two: multi-criteria assessment

Shortlisted options were assessed in the stage two: MCA.

3.2.1 MCA weighting

Prior to assessing options, a pairwise assessment was used to weight the criteria. Weighting was determined in a workshop with a small group of Rivertown’s key internal and external stakeholders. A summary of the results of the pairwise assessment is provided below.

Criteria		Safety	Economic	Environmental and cultural heritage impact	Social	Flood behaviour / impacts	Additional constraints	Occurrence +1	Weighting
		A	B	C	D	E	F		
Safety	A		A	A	A	A	A	6	28.57%
Economic	B			B	D	B	B	4	19.05%
Environmental and cultural heritage impact	C				D	C	C	3	14.29%
Social	D					E	D	4	19.05%
Flood behaviour / impact	E						E	3	14.29%
Additional Constraints	F							1	4.76%
Total								21	100%



*Bridge damage,
Flinders Highway*

Targeted indicators within criteria were weighted equally. Weights are summarised in Table 4.

Table 4 - Criteria weighting

Criteria	Criteria weighting (%)	Targeted indicator	Targeted indicator weighting (%)
Safety	28.57%	Ability to evacuate to safer locations or evacuation centres	9.52%
		Population at risk	9.52%
		Isolation duration and risk	9.52%
Economic	19.05%	Economic growth and investment	9.53%
		Damages and costs (property, assets and operations)	9.53%
Environmental and cultural heritage impact	14.29%	Overall impact on fauna connectivity (fish passage / fauna movement)	4.76%
		Overall impacts to vegetation and habitat	4.76%
		Impact on cultural heritage	4.76%
Social	19.05%	Disruption to daily life	9.53%
		Additional community benefits	9.53%
Flood behaviour / impacts	14.29%	Flood impacts	14.29%
Additional constraints	4.76%	Engineering/construction constraints	4.76%
Total	100%		100%

3.2.2 MCA targeted indicators

A detailed assessment of each of the targeted indicators was conducted. This was informed by available data and additional studies such as a flood impact assessment. Details including scores and justifications for the targeted indicators are provided in Tables 7 to 10 in Appendix A. A summary of the assessment is provided in the following sections.

3.2.2.1 Safety

If the district road was raised to a 1% AEP flood immunity (options 1b), there would be substantial time for the population to evacuate. In events larger than a 1% AEP, the road would eventually inundate, however, there would still be substantial time for residents to evacuate before this occurs. There would also be no isolation risks as Rivertown's population would be evacuated to the next town which is not in flood-prone land.

The new road and evacuation centre outside of town (option 2a) would provide substantial time for residents

to evacuate during flood events. However, there are some isolation risks as the area outside of town is undeveloped with no road access to other areas. If isolated for a week, vulnerable sectors of the community (for example, those requiring urgent medical attention) may be at risk. Given the location of the proposed evacuation centre is not subject to flooding and is undeveloped, emergency services via helicopter can provide supplies or further evacuate high risk members of the community if required.

In events greater than its design flood immunity, raising the district road to a 5% AEP flood immunity (option 1a) would not provide enough time to evacuate residents who did not respond quickly to warnings, including vulnerable sectors of the community. In flood events where Rivertown was not completely inundated there would also be isolation risks for residents who were unable to evacuate. The new evacuation centre in town (option 3b) would have high isolation risks as residents could be isolated for up to a week while being surrounded by flood waters.

3.2.2.2 Economic

There would be economic benefits if the district road was raised (options 1a and 1b). Raising the district road would reduce road damages as a result of less frequent overtopping. Given the district road is a freight route, business costs would also be reduced as the road would experience fewer closures.

Other options did not have economic benefits.

3.2.2.3 Social

There would be social benefits if the district road was raised (options 1a and 1b). In flood events smaller than the design flood immunity for those options, the road would experience fewer closures, resulting in fewer disruptions for residents wanting to access the next town. The new evacuation centre in town (option 3b) would also have social benefits as it could be used for recreational purposes, providing an additional community benefit.

There would be minor additional community benefits if the new road to a 1% AEP flood immunity and evacuation centre (option 2a) was delivered. The new evacuation centre may be used for recreational or community purposes. There are only minor benefits, given its location outside of town.

3.2.2.4 Environmental and cultural heritage impacts

Due to clearing required to accommodate the new road corridor and site, the new road with a 1% AEP flood immunity combined with an evacuation centre (option 2a) would have moderate impacts to vegetation and habitat.

Other options would have negligible environmental impacts and all options had no cultural heritage impacts.



Traffic Control, Rockhampton, Tropical Cyclone Oswald, 2013

3.2.2.5 Flood behaviour/impact

All options were shown to cause either minor or negligible flood impacts and either minor or negligible changes in flood behaviour.

3.2.2.6 Additional constraints

There would be some minor engineering issues with the new road and evacuation centre (option 2a) and raising the district road (options 1). The new evacuation centre in town (option 3b) may have some issues with site availability, as most sites in the location are privately owned and developed.

3.2.2.7 Results

The final scores for each option are:

- Option 1a - Raise district road to a 5% AEP flood immunity – 2.81
- Option 1b - Raise district road to a 1% AEP flood immunity – 3.48
- Option 2a - New road at a 1% AEP flood immunity to high point outside of town combined with a new evacuation centre – 2.76
- Option 3b - New evacuation centre in town with a building floor level above the PMF – 2.81.

3.2.3 Sensitivity testing of criteria weighting

A sensitivity test was carried out which tested a 50% and 25% reduction in weight and a 50% and 25% increase in weight for each criterion while keeping the weighting of each of the other criteria proportionally unchanged. The highest scoring option for each test is shown in Table 5. Raising the existing district road to a 1% AEP flood immunity (option 1b) remains the highest scoring option in all scenarios.

Table 5 – Outcomes of sensitivity test

Weight	Safety	Economic	Environmental and cultural heritage impact	Social	Flood impacts	Other constraints
-50%	Option 1b	Option 1b	Option 1b	Option 1b	Option 1b	Option 1b
-25%	Option 1b	Option 1b	Option 1b	Option 1b	Option 1b	Option 1b
50%	Option 1b	Option 1b	Option 1b	Option 1b	Option 1b	Option 1b
25%	Option 1b	Option 1b	Option 1b	Option 1b	Option 1b	Option 1b

3.3 Financial and economic assessments

3.3.1 Cost estimation

Detailed costing was undertaken for the four options, incorporating costs to mitigate any potential impacts. The new road at a 1% AEP flood immunity combined with the new evacuation centre (option 2a) was identified as the most expensive and may exceed Rivertown’s budget. All other options were determined to be affordable and commensurate with the scale of the evacuation problem.

3.3.2 Cost-benefit analysis

A cost benefit analysis was conducted to provide an additional means of comparison. The Benefit Cost Ratios (BCRs) of the options are shown in Table 6. No options achieved a BCR greater than one. This was due the difficulty monetising the social and risk to life benefits of the options.

Table 6 - BCR results

Option	BCR
Option 1a: Raise district road to a 5% AEP flood immunity	0.5
Option 1b: Raise district road to a 1% AEP flood immunity	0.5
Option 2a: New road to a 1% AEP flood immunity and evacuation centre	0.3
Option 3b: New evacuation centre in town with a building floor level above the PMF	0.8

4. Reviewing outcomes of the assessment process

The outcomes of the assessment were reviewed to determine which evacuation route improvement was most 'fair and reasonable'. The following was considered when reviewing the outcomes of the assessment process.

Do the options sufficiently address the evacuation problem, service need and desired outcomes?

Raising the district road to a 1% AEP (option 1b) would address the evacuation problem by allowing the population to evacuate in major flood events. Evacuation to the next town provides access to essential goods and services and does not have any isolation risks. This option will also meet the service need and desired outcome (reduces risk to life).

The new road combined with the new evacuation centre (option 2a) would resolve the evacuation problem and meet the service need and desired outcome. There are some residual isolation risks for vulnerable sectors of the community requiring urgent medical attention, however, given the location, emergency services are likely to be able to provide additional assistance via rescue helicopter if necessary.

The evacuation centre in town with a building floor level above the PMF (option 3b) and raising the district road to a 5% AEP flood immunity (option 1a) would not address the evacuation problem. The evacuation centre creates a potential isolation risk given the duration of time isolated, presence of flood waters and the vulnerability of the community. Raising the district road to a 5% AEP flood immunity does not provide sufficient time to allow for evacuation in flood events greater than its design flood immunity and there are isolation risks for residents unable to evacuate in flood events where the town is not completely inundated.

Was it possible to appropriately capture all benefits, impacts, costs and constraints in the assessment process?

All known benefits, impacts, costs and constraints have been considered.

Should scores for a targeted indicator eliminate an option, irrespective of the overall MCA score?

Targeted indicators in the safety criterion immediately eliminated the evacuation centre in town (option 3b) and raising the district road to achieve a 5% AEP flood immunity (options 1a). Both options would result in an intolerable risk to life.

How do the MCA results compare with the economic and financial assessments?

The evacuation centre in town built to PMF immunity (option 3b) had both the lowest cost and highest BCR. The option does not resolve the evacuation problem. The results of the economic and financial assessments do not justify the option.

Raising the district road to a 1% AEP flood immunity (option 1b) achieved the highest MCA score. The economic and financial assessments further supported this option. It had a lower cost and higher BCR than the new road to a 1% AEP flood immunity and new evacuation centre (option 2a), which was the only other option considered to resolve the evacuation problem.

Is the cost of each option affordable and commensurate with the scale of the evacuation problem?

The new road to a 1% AEP flood immunity and new evacuation centre (Option 2a) may have difficulty obtaining funding due to its high cost.

The cost of all the options are commensurate with the scale of the evacuation problem, given the significant flood risk posed to Rivertown.

Based on the assessment results and review of the outcomes, it was determined that the option to raise the existing district road to a 1% AEP flood immunity (Option 1b) was the preferred 'fair and reasonable' evacuation route improvement.

5. Implementation

Further approvals and agreements are required before implementing the option to raise the existing district road to a 1% AEP flood immunity (Option 1b). Relevant stakeholders, including the owner(s) of relevant infrastructure and assets, and decision makers responsible for funding and implementation, will need to be engaged and relevant agreements obtained (these stakeholders have been involved throughout the assessment process). Once the preferred option is ready to be considered for investment, a business case will need to be prepared to seek funding for the preferred option.

Glossary

Term	Definition
Annual Exceedance Probability	The chance that a flood will reach or exceed a particular level in any given year. For example, a 1% (1 in 100) AEP (Queensland Reconstruction Authority (QRA), 2019).
Benefit Cost Ratio	Ratio of the present value of benefit over the present value of costs (QRA, 2021).
Cost benefit analysis	An economic assessment methodology to support decision making which assesses the long-term benefits and costs in monetary terms (QRA, 2021).
Evacuation	The planned movement of persons from an unsafe or potentially unsafe location to a safer location and their eventual return (Queensland Fire and Emergency Services (QFES), 2018).
Evacuation centre	A building located beyond a hazard to provide temporary accommodation, food and water until it is safe for evacuees to return to their homes or alternative temporary emergency accommodation (QFES, 2018).
Essential goods	Essential goods are considered to include: <ul style="list-style-type: none"> ▪ basic foodstuffs, basic cleaners ▪ disinfectants, etc. to enable communities to maintain adequate hygiene practices ▪ baby foods, formula feeds for babies and nappies ▪ foodstuffs to meet special dietary requirements ▪ medicines and medical supplies, water purification tablets/treatments ▪ dried pet foods ▪ fuels for essential activities ▪ batteries ▪ other goods deemed necessary to maintain the physical and/or psychological welfare of the inhabitants of isolated communities (see QFES, 2018 for detailed definition).
Floodplain	An area of land that is subject to inundation by floods up to and including the probable maximum flood event – that is, flood-prone land (Australian Institute for Disaster Resilience (AIDR), 2017).

Term	Definition
Flood-prone land	Land susceptible to flooding by the Probable Maximum Flood event. Flood-prone land is synonymous with the floodplain (AIDR, 2017).
Immunity / Flood Immunity	The probability of the storm event for which flood extents do not exceed above or encroach beyond defined limits. Expressed as either an Annual Exceedance Probability (AEP) or a number of Exceedances per Year (EY) (Department of Transport and Main Road, 2019).
Intolerable risk	Is a risk that, following an understanding of the likelihood and consequence, is so high that it requires actions to avoid or reduce the risk. Individuals and society will not accept this risk and measures are put in place to reduce the risk to at least a tolerable level (QRA, 2019).
Likelihood	The chance of something happening whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively and described using general terms or mathematically. (Standards Australia/ Standards New Zealand Standard Committee, 2009)
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation and, where applicable, snow melt, coupled with the worst flood-producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood-prone land – that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event, should be addressed in a floodplain risk management study (AIDR, 2017).

Acronym Definition

Acronym	Definition
AEP	Annual exceedance probability
AIDR	The Australian Institute of Disaster Resilience
BCR	Benefit cost ratio
MCA	Multi-criteria assessment
PMF	Probable maximum flood
QFES	Queensland Fire and Emergency Services
QRA	Queensland Reconstruction Authority

References

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Road train, Boulia

Appendix A

Option
1a

Table 7 - MCA for Option 1a: Raise district road to a 5% AEP flood immunity level

Raise district road to a 5% AEP flood immunity level							
Criteria	Criteria weighting (%)	Target indicator	Targeted indicator weighting (%)	Score	Criteria score (average score within criteria)	Weighted score (overall)	Comment
Safety	28.57%	Ability to evacuate to safer locations or evacuation centres	9.52%	2	2.33	0.19	This option would enable the population to evacuate in events up to and including the road's design flood immunity. However, for larger events such as a 1% AEP event, there would not be enough time to evacuate all of the residents. For example, where residents do not respond quickly to warnings, or where there are vulnerable sectors of the community who require assistance to evacuate, there may not be sufficient time to evacuate before roads inundate.
		Population at risk	9.52%	2		0.19	There would still be a high risk to life as not all residents are able to evacuate. Given the entire town is flooded in the 1% AEP event this may result in residents being exposed to flood hazards.
		Isolation duration and risk	9.52%	3		0.29	For residents able to evacuate, evacuating and sheltering in place in the next town would provide access to essential goods and services and would not pose a risk to life due to isolation. For events where the town is not completely inundated, there would be some isolation risks for residents who were unable to evacuate.

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Option
1a

Table 7 - MCA for Option 1a: Raise district road to a 5% AEP flood immunity level (continued)

Raise district road to a 5% AEP flood immunity level							
Criteria	Criteria weighting (%)	Target indicator	Targeted indicator weighting (%)	Score	Criteria score (average score within criteria)	Weighted score (overall)	Comment
Economic	19.05%	Economic growth and investment	9.53%	1	2.00	0.10	Risk to life would still be a concern despite the option allowing for some ability to evacuate. Therefore, there would be no increase in confidence in flood resilience and no potential economic growth or investment.
		Damages and costs (property, assets and operations)	9.53%	3		0.29	There would be minor reduction in damages and costs due to improved road immunity resulting in less frequent overtopping (resulting in road damage). The district road functions as a freight route. The road currently closes in a 10% AEP event, affecting business operations. However, if raised, the road would remain open up until a 5% AEP flood event, reducing impacts and costs on business operations.
Environmental & cultural heritage impact	14.29%	Overall impact on fauna connectivity (fish passage / fauna movement)	4.76%	4	4.33	0.19	The road is existing and therefore would result in negligible impacts to fauna connectivity.
		Overall impacts to vegetation and habitat	4.76%	4		0.19	The road is existing and therefore would result in negligible impacts to vegetation and habitat.
		Impact on cultural heritage sites	4.76%	5		0.24	There are no cultural heritage sites impacted by the option.

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Option
1a

Table 7 - MCA for Option 1a: Raise district road to a 5% AEP flood immunity level (continued)

Raise district road to a 5% AEP flood immunity level							
Criteria	Criteria weighting (%)	Target indicator	Targeted indicator weighting (%)	Score	Criteria score (average score within criteria)	Weighted score (overall)	Comment
Social	19.05%	Disruption to daily life	9.53%	3	2.00	0.29	In smaller flood events than the design flood immunity, the road would remain open allowing an improvement in access to the next town and areas within Rivertown. However, in major flood events the population would be required to evacuate to the nearest town which will disrupt their lives.
		Additional community benefits	9.53%	1		0.10	The road is existing; therefore, the option would not provide any additional community benefits such as improved road network efficiency. There is also unlikely to be network efficiency issues given the small population of Rivertown.
Flood behaviour / impacts	14.29%	Flood impacts	14.29%	4	4.00	0.57	Flood impacts would be able to be mitigated by improved cross drainage structures, resulting in minor flood impacts.
Additional constraints	4.76%	Engineering/construction constraints	4.76%	4	4.00	0.19	There would be minor engineering issues with raising the road.
Total	100%					2.81	

Option
1b

Table 8 - MCA for Option 1b: Raise district road to a 1% AEP flood immunity level

Raise district road to a 1% AEP flood immunity level							
Criteria	Criteria weighting (%)	Target indicator	Targeted indicator weighting (%)	Score	Criteria score (average score within criteria)	Weighted score (overall)	Comment
Safety	28.57%	Ability to evacuate to safer locations or evacuation centres	9.52%	4	4.33	0.38	This option would enable the population to evacuate in events up and to and including the road's design flood immunity. In events larger than a 1% AEP, the road would eventually inundate, however, there would still be substantial time for residents to evacuate before this occurs and the residual risk is therefore considered acceptable.
		Population at risk	9.52%	4		0.38	A low level of risk would be achieved by this option by facilitating evacuation to the next town to shelter during flood events.
		Isolation duration and risk	9.52%	5		0.48	Evacuating and sheltering in place in the next town would provide essential goods and services and would not pose a risk to life due to isolation.
Economic	19.05%	Economic growth and investment	9.53%	2	2.50	0.19	This option would resolve known evacuation issues for Rivertown. However, there would only be a minor potential for economic growth and investment as risks to property damage are not mitigated.
		Damages and costs (property, assets and operations)	9.53%	3		0.29	There would be a minor reduction in damages and costs due to improved road immunity resulting in less frequent overtopping (resulting in road damage). The district road also functions as a freight route. The road currently closes in a 10% AEP event. The road would now remain open up to a 1% AEP event, reducing costs to impacted business operations. However, the reduced cost only applies in events where the population is not required to evacuate.

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Table 8 - MCA for Option 1b: Raise district road to a 1% AEP flood immunity level (continued)

Raise district road to a 1% AEP flood immunity level							
Criteria	Criteria weighting (%)	Target indicator	Targeted indicator weighting (%)	Score	Criteria score (average score within criteria)	Weighted score (overall)	Comment
Environmental & cultural heritage impact	14.29%	Overall impact on fauna connectivity (fish passage/ fauna movement)	4.76%	4	4.33	0.19	The road is existing and therefore would result in negligible impacts to fauna connectivity.
		Overall impacts to vegetation and habitat	4.76%	4		0.19	The road is existing and therefore would result in negligible impacts to vegetation and habitat.
		Impact on cultural heritage sites	4.76%	5		0.24	There are no cultural heritage sites impacted by the option.
Social	19.05%	Disruption to daily life	9.53%	3	2.00	0.29	The road would only close in very rare events larger than the design flood immunity, improving access to the next town and areas within Rivertown. However, in major flood events the population would be required to evacuate to the nearest town which will disrupt their lives.
		Additional community benefits	9.53%	1		0.10	The road is existing and would not provide any additional community benefits such as improved road network efficiency. There is also unlikely to be network efficiency issues given the small population of Rivertown.
Flood behaviour / impacts	14.29%	Flood impacts	14.29%	4	4.00	0.57	Flood impacts would be able to be mitigated by improved cross drainage structures, resulting in minor flood impacts.
Additional constraints	4.76%	Engineering/construction constraints	4.76%	4	4.00	0.19	There would be minor engineering issues with raising the road.
Total	100%					3.48	

Option
2a

Table 9 - MCA for Option 2a: New road with a 1% AEP immunity, combined with new evacuation centre

New road with a 1% AEP flood immunity, combined with new evacuation centre							
Criteria	Criteria weighting (%)	Target indicator	Targeted indicator weighting (%)	Score	Criteria score (average score within criteria)	Weighted score (overall)	Comment
Safety	28.57%	Ability to evacuate to safer locations or evacuation centres	9.52%	4	3.33	0.38	The new road would enable the population to evacuate in events up to and including the road's design flood immunity. In events larger than the road's design flood immunity, there would still be substantial time to evacuate to the evacuation centre before the road will inundate.
		Population at risk	9.52%	3		0.29	A medium level of risk would be achieved by this option. Risk is mitigated by improving the community's ability to evacuate and providing an evacuation centre located in a flood free area. However, there are some isolation risks as discussed in the 'Isolation duration and risk targeted indicator' below.
		Isolation duration and risk	9.52%	3		0.29	The proposed evacuation centre would be located in a flood free, undeveloped area with no road access to other areas, resulting in isolation for up to a week until flood waters recede. Essential goods can be provided at the evacuation centre but there is no access to services. Vulnerable sectors of the community requiring urgent medical attention may be at risk, however, emergency services via helicopter may be able to provide supplies or further evacuate high risk members of the community if necessary.
Economic	19.05%	Economic growth and investment	9.53%	1	1.00	0.10	There would be no potential for economic growth and investment. Potentially being isolated away from people's homes for up to a week would not result in increased confidence in flood resilience.
		Damages and costs (property, assets and operations)	9.53%	1		0.10	There would be no reduction in damages and costs, given the new road does not link to any development other than the new evacuation centre.

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Table 9 - MCA for Option 2a: New road with a 1% AEP immunity, combined with new evacuation centre (continued)

New road with a 1% AEP flood immunity, combined with new evacuation centre							
Criteria	Criteria weighting (%)	Target indicator	Targeted indicator weighting (%)	Score	Criteria score (average score within criteria)	Weighted score (overall)	Comment
Environmental & cultural heritage impact	14.29%	Overall impact on fauna connectivity (fish passage / fauna movement)	4.76%	4	4.00	0.19	There would be negligible impacts to fauna connectivity.
		Overall impacts to vegetation and habitat	4.76%	3		0.14	Some vegetation clearing would be required to accommodate the road corridor and evacuation centre site. However, the vegetation does not have any major environmental significance.
		Impact on cultural heritage sites	4.76%	5		0.24	There would be no cultural heritage impacts.
Social	19.05%	Disruption to daily life	9.53%	1	1.50	0.10	There would be no reduction in disruption to daily life given the new road does not link to any services other than the new evacuation centre.
		Additional community benefits	9.53%	2		0.19	The evacuation centre may be used for recreational purposes. However, given it is located away from town, it may rarely be used for this purpose.
Flood behaviour / impacts	14.29%	Flood impacts	14.29%	4	4.00	0.57	There would be changes in flood behaviour for the new road which can be mitigated with cross drainage structures. However, there will be some minor impacts to undeveloped rural land.
Additional constraints	4.76%	Engineering/construction constraints	4.76%	4	4.00	0.19	There would be minor engineering issues building the new road.
Total	100%					2.76	

Table 10 - MCA for Option 3b: Evacuation centre in town with a building floor level above the PMF

Evacuation centre in town with a building floor level above the PMF							
Criteria	Criteria weighting (%)	Target indicator	Targeted indicator weighting (%)	Score	Criteria score (average score within criteria)	Weighted score (overall)	Comment
Safety	28.57%	Ability to evacuate to safer locations or evacuation centres	9.52%	4	2.67	0.38	There would be a substantial ability to evacuate given evacuees do not need to travel far to access the evacuation centre in town. There would be substantial time to evacuate before local roads to the evacuation centre will inundate.
		Population at risk	9.52%	2		0.19	Although the community is able to evacuate, there would be a high risk to life as a result of being isolated in the evacuation centre.
		Isolation duration and risk	9.52%	2		0.19	There would be a high risk to life from isolation. If evacuated to the evacuation centre, evacuees could be isolated for up to a week while being surrounded by flood waters. Although there would be essential goods in the evacuation centre, vulnerable sectors of the community may be at risk if requiring medical attention. Emergency services via helicopter may not be able to assist in these situations, given access is impeded by surrounding development such as overhead powerlines. There are also mental health impacts and the potential for evacuees to venture into flood waters.
Economic	19.05%	Economic growth and investment	9.53%	1	1.00	0.10	There would be no potential for economic growth and investment. Significant risks to the population are still present, affecting confidence for development and investment.
		Damages and costs (property, assets and operations)	9.53%	1		0.10	There would be no reduction in damages and costs.

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Option
3b

Table 10 - MCA for Option 3b: Evacuation centre in town with a building floor level above the PMF (continued)

Evacuation centre in town with a building floor level above the PMF							
Criteria	Criteria weighting (%)	Target indicator	Targeted indicator weighting (%)	Score	Criteria score (average score within criteria)	Weighted score (overall)	Comment
Environmental & cultural heritage impact	14.29%	Overall impact on fauna connectivity (fish passage / fauna movement)	4.76%	4	4.33	0.19	There would be negligible impacts on fauna connectivity, given the area where the building would be located is already developed.
		Overall impacts to vegetation and habitat	4.76%	4		0.19	There would be negligible impacts on vegetation and habitat, given the area where the building would be located is developed.
		Impact on cultural heritage sites	4.76%	5		0.24	There would be no cultural heritage impacts.
Social	19.05%	Disruption to daily life	9.53%	1	2.00	0.10	There would be no reduction in disruption to daily life as residents are isolated in the evacuation centre and there are no improvements in access.
		Additional community benefits	9.53%	3		0.29	The new evacuation centre may benefit the community by being utilised for community or recreational purposes.
Flood behaviour/ impacts	14.29%	Flood impacts	14.29%	5	5.00	0.71	There would be negligible flood impacts caused by the new evacuation centre.
Additional constraints	4.76%	Engineering/construction constraints	4.76%	3	3.00	0.14	There would be moderate constraints given a suitable site will need to be acquired to accommodate the development.
Total	100%					2.81	

