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Emergency management and prioritisation of Tasmanian bridge infrastructure through rapid Multi-Criteria Assessment

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ABSTRACT: As the face of emergency management continues to evolve, we face the humanitarian challenge of large-scale emergencies becoming more prevalent and presenting new threats to infrastructure underpinning our social and economic wellbeing. The need to plan for, prevent and mitigate the consequences of emergencies is greater than ever with increasing population growth, societal expectations, global disruption and uncertainty, and the hyper-connectivity of today's world which allows us to deliver the essential services on which we thrive.

Tasmania experienced a major flood event in June 2016 which had widespread impacts across the state, including loss of life and significant damage to critical infrastructure. The broad impacts and competing requests for urgent bridge infrastructure replacements during the event highlighted the need for the Department of State Growth to better understand the level of emergency bridge stock that would meet Tasmania's needs in a widespread emergency. Underpinning this was the need to establish an approach which allows bridge repairs and replacements to be coordinated and prioritised in an emergency such that road network impacts can be minimised and the safety of road users is ensured.

Jacobs was engaged by the Department of State Growth to undertake a Multi-Criteria Assessment (MCA) to establish a recommendation for emergency bridge stock that should be maintained by the Department into the future. Rapid, large-scale analysis of over 3,000 bridges was conducted using a Geographic Information System (GIS) to prioritise bridges based on their assessed level of importance in the road network and susceptibility to failure based on available bridge asset data. Critical bridges identified in the network were then assessed against various emergency scenarios to estimate the maximum combined length of bridges affected by the scenarios and a recommendation for the amount of emergency bridge stock required.

KEYWORDS: Emergency, Response, Management, Prioritisation, Bridge, MCA, Assessment, GIS

1.0 Introduction

1.1 The impacts of emergency events on infrastructure

Tasmania's social and economic wellbeing is reliant upon the infrastructure which supports and facilitates the delivery of essential services across the state, including roads, rail, energy, communications, ports, water and sewerage. Failure of one or more of these infrastructure elements in an emergency event, natural or man-made, has the potential to significantly disrupt the delivery of essential services and lead to detrimental social, economic and environmental impacts for the community and industry alike.

A poignant example highlighting the significant impacts that a widespread emergency can have on the state was the recent major flood event in June 2016. Many locations, particularly in the northern half of Tasmania, recorded rainfall much greater than the 1% Annual Exceedance Probability (AEP) rainfall intensity over a 48-hour period. This contributed to record high flood levels, exceeding previous flood records in some locations by a substantial margin [1].

Impacts of the flood were devasting and wide-spread, with three lives lost as well as significant damage to houses, farmland and infrastructure. During the flood event, the State Roads division within the Department of State Growth received several requests for emergency bridging from state and local government jurisdictions to restore access and essential services to severed communities in the state's road and bridge network.

1.2 Bridging the gap

The broad impacts and competing requests for urgent infrastructure replacements in the 2016 event highlighted the need for State Growth to better understand the level of emergency bridge stock required to be maintained across the state in a widespread emergency.

The need for understanding is increasingly important in the context of future climate scenarios by the Antarctic Climate and Ecosystems Cooperative Research Centre [2]. These future climate scenarios predict that infrastructure assets across the state will face an increased level of risk through exposure to more extreme weather events, storm surges and longer, more intense fire seasons [3].

In 2017, Jacobs was commissioned by State Growth to develop an approach to assist coordination and prioritisation of bridge repairs and replacement in a widespread emergency event, such as the June 2016 floods. Key objectives of the project were to:

- Review existing emergency bridge stock within Tasmania, including state, local council and industry capabilities.
- Establish a methodology to determine the relative impacts that bridge closures would have on the community and industry following an emergency.
- Provide a recommendation for the amount and type of emergency bridge stock that would meet the State's need in an emergency event, with consideration to the existing available stock in Tasmania.

2.0 Review of Available Tasmanian Emergency Bridge Stock

Emergency bridges are usually comprised of a number of pre-fabricated, modular components that can be easily assembled and deployed in response to an emergency event which has damaged or destroyed existing bridge infrastructure.

The type of emergency bridge that is deployed depends on numerous factors such as the significance of bridge closure in the road network, the likelihood that other bridges may be impacted, available bridge stock, loading considerations and the expected time the bridge will be in-service.

The Department of State Growth currently manages a stock of Bailey bridge components for use as emergency or temporary bridges across Tasmanian state and local government road networks. Bailey bridge components can be assembled by hand or with light plant to form a portable, pre-fabricated truss bridge, historically used in military applications and invented by British engineer, Donald Bailey, in the 1940s.

2.1 State Growth Stock

State Growth's Bailey bridge stock is currently stored and maintained in northern Tasmania where a minimum stock of Bailey components sufficient for three 15m span bridges (Double-Single truss configuration) and one 45m span bridge (Double-Double truss configuration), 90m in total, is required to be held for deployment. Whilst the components may be able to achieve T44[1] General Access vehicle load ratings, it is unlikely that the current stock would be sufficient to comply with contemporary bridge loading design standards.

Based on recent maintenance reports and Jacobs' inspection of the Bailey components in August 2017 (Figure 1), a number of the components in storage were observed to be ageing and in various stages of deterioration. This makes achieving T44 load rating at longer spans increasingly difficult.

Figure 1: Varying conditions of State Growth Bailey components (Jacobs, 2017)

2.2 Local Council Stock

As part of the review process, each of the Tasmanian Councils were contacted regarding recent requirements for emergency or temporary bridges and their own bridge stock, if

[1] The T44 reference vehicle is the dominant bridge design load used from around 1976 to around 2001 and equates to a 44 tonne truck over 9.1m long.

any. Whilst the majority of Councils who responded had not required emergency bridging in recent times or did not hold any stock, there were some jurisdictions in the north and south of the state with access to their own bailey bridging or other temporary structures, such as shipping container floors, which have been deployed as bypass structures during asset renewal programs. A number of jurisdictions in the north of the state had requested emergency bridging from State Growth to be deployed in the aftermath of the June 2016 floods.

2.3 Local Industry Capabilities

The capacity of local industry to supply and construct emergency bridging was also investigated through discussions with various Tasmanian bridging suppliers. The combined capacity of local industry included:

- Timber logs and stockpiles of timber and concrete decking material to construct short-span timber bridges within a week (Figure 2)
- Three ex-army structures, adequate for highway loading up to 18m spans
- 12m length shipping container bases, adequate for 34-tonne loading
- Multiple concrete planks produced within a week for a short span single lane bridge (12 – 14m long)
- Steel beams and concrete or timber decking sufficient to construct short span temporary bridges

Figure 2: Stockpile of timber logs and decking materials in northern Tasmania (Jacobs, 2017)

3.0 Emergency Bridging Stock Required through Multi-Criteria Assessment

Following the review of emergency bridge stock available from State Growth, Councils and local industry, further analysis was undertaken to establish a recommendation for an appropriate amount of emergency bridge stock that should be maintained in Tasmania. The requirement to supplement the existing available stock could then be determined.

Asset and road network information was compiled for over 3000 bridges across state and council jurisdictions for interrogation and analysis. Rapid, large scale multi-criteria assessment (MCA) of bridge data was facilitated through a Geographic Information System (GIS) which:

- Prioritised bridges based on their assessed level of importance in the road network to better understand the impacts that closures would have on the community and industry in an emergency
- Classified the susceptibility of transport structures to failure based on provided asset information
- Considered the likelihood of multiple bridge failures in various emergency scenarios, such as widespread flooding, fire or dam break.

The protocols and assessment criteria of the MCA were determined in consultation with State Growth. The methodology that was used to develop the GIS database and undertake the multi-criteria assessment is outlined in the sections below.

3.1 GIS Database

The GIS database created for this project made use of information compiled in the Tasmanian Class 1 Heavy Vehicle Assessment project, completed for State Growth in 2015, as well as additional data from State Growth and the Department of Primary Industries, Parks, Water and Environment (DPIPWE). The data gathered consisted of four main categories as summarised in Table 1, namely: bridge asset data, bridge location data, road network data, and emergency situation data. A snapshot of the compiled database is shown in Figure 3.

Table 1: Key information in the GIS database

Category	Data	Details
Bridge Location Data	Location	Eastings and northings
	Length	Overall bridge lengths and details on number of spans
Bridge Asset Data	Material	Superstructure construction material (e.g. concrete, steel, timber, etc.)
	Condition	Condition ratings from 1 (new bridge) to 5 (replacement due)
Road Network Information	Road category	Categories include highways, arterial roads, collector roads, local roads
	Strategic and extended routes	State Growth and Council defined heavy vehicle roads
	Alternate route assessment	Minimum distance to detour a single bridge asset failure
	Annual Average Daily Traffic	AADT and heavy vehicle numbers for State Roads
Emergency Situation Information	Flood	1% AEP inundation mapping and highest water levels in June 2016 floods
	Fire	Bushfire likelihood mapping
	Dam break	Dam break inundation mapping

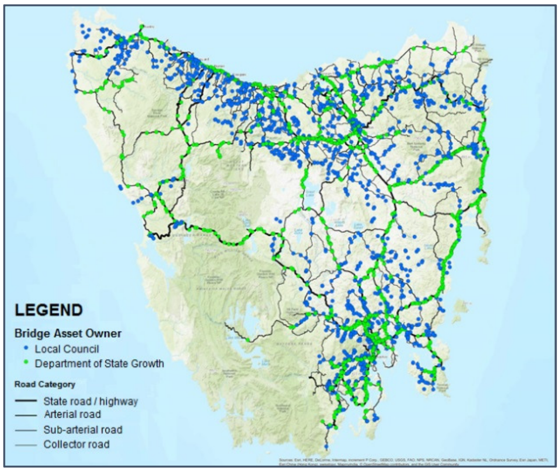

Figure 3: GIS database of Tasmanian bridges

3.2 Multi-Criteria Assessment

Drawing on the information in the GIS database, a multi-criteria assessment (MCA) was undertaken to predict an appropriate amount of emergency bridge stock required in Tasmania by assessing a bridge's network importance, susceptibility to failure and likelihood of failure, as indicated by the flowchart in Figure 4.

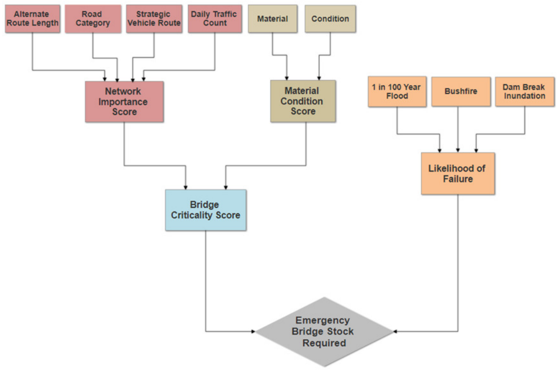

Figure 4: Flowchart for assessing emergency bridge stock required

Sub-criteria in the Road Network Information category were scored individually and assigned a weighting which was then combined to give an overall *Network Importance Score*, indicative of a bridge's relative importance in the road network.

A bridge's susceptibility to failure was measured by the *Material Condition Score* which combined and weighted Bridge Asset Data sub-criteria, including the asset construction material and current condition.

Adopted weightings for sub-criteria within the MCA were devised and calibrated based on discussions with State Growth, previous knowledge of MCA processes and careful consideration of the particular areas of importance for this project and its objectives.

The overall scores allowed each bridge site to be compared to determine a prioritised list of bridge sites.

3.2.1 Network Importance Score

The Network Importance Score was determined in the MCA by assigning scores and weightings to Road Network information, namely:

- The presence and length of alternate routes around a bridge site; the longer the detour, the greater the impact to road users.
- The category of road in which a bridge is located; the higher the road category, the greater the impact to road users.
- If a bridge was located on a strategic heavy vehicle route to account for impacts to private sector and industry. There is a

greater impact to industry if a bridge fails on a strategic heavy vehicle route

- Daily traffic counts at bridge locations; the greater the traffic numbers, the greater the impact to road users

The MCA scores and weightings used for the Network Importance Score are shown in Table 2 below. Score ranges were kept equal for each sub-criterion in order to reduce bias in the analysis. An even distribution of weightings across each of the sub-criteria resulted in an unfair bias towards rural bridges. As such, heavier weightings were applied to the alternate route length, AADT and road category criteria to magnify the importance of bridges which would affect a greater numbers of road users.

Table 2: Road network scores and weightings

Road Network Information	Score Range	Weighting (%)	Weighted Score Range
Alternate route length	1-7	25	25 – 175
Road category	1-7	30	30– 210
Strategic & extended routes	1-7	15	15 – 105
AADT	1-7	30	30 – 210
TOTAL		**100**	**100 - 700**

3.2.2 Material Condition Score

The Material Condition Score was determined in the MCA by assigning scores and weightings to key Bridge Asset information, namely:

- Material - timber bridges are more susceptible to failure than concrete bridges due to flammability, reduced loading capacity and design life.

- Condition - bridges recently inspected and identified as being in poor condition are more susceptible to failure than bridges in good condition. This is generally correlated with the age of a structure and its environment.

The MCA scores and weightings used for the Bridge Asset information are shown in Table 3 below. The condition of a bridge was identified as being the most critical sub-criterion in regards to its susceptibility to failure, and was weighted accordingly. By introducing a more even weighting between the material and condition categories, it was found that there was a strong bias towards timber bridges. A 90% weighting towards bridge condition was found to be appropriate.

Table 3: Material and condition scores and weightings

Bridge Asset Information	Score Range	Weighting (%)	Weighted Score Range
Material	1-5	10	10 – 50
Condition	1-5	90	90 – 450
TOTAL		**100**	**100 – 500**

3.2.3 Critical Bridge Rankings

The Network Importance and Material Condition Scores were combined to provide an indication of a bridge's relative criticality based on its level of importance in the road network and susceptibility to failure, as indicated in Figure 5.

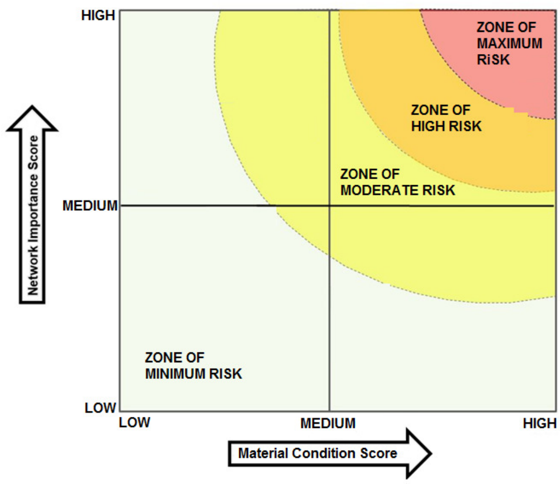

Figure 5: Criticality bandings using Network Importance and Material Condition Scores

Bridge criticality bands of relatively uniform width were obtained using circular functions radiating out from a theoretical bridge with the highest Network Importance Score (700) and Material Condition Score (500). This placed an intentional bias towards the network importance of a bridge in comparison to its susceptibility to failure, since a bridge in poor condition with low network importance would have less of an impact on road users if it was not replaced.

3.2.4 Likelihood of Failure

Estimating the likelihood of multiple bridge failures in an emergency event focused on critical bridges that had a high Network Importance Score and Material Condition Score. This approach was applied to better understand the structures with a higher susceptibility to failure and were also more important to the road network, so that the length of emergency bridge stock considered both effect on road users and the likelihood of failure.

Critical bridges identified though the MCA were then assessed against different emergency situations in the GIS database. The purpose of this exercise was to help predict the number of critical bridges that may be affected by one of the following emergency events:

- 1% AEP flood
- Inundation due to dam break
- Bushfire

To simplify the analysis, each of the emergency scenarios assessed were treated as mutually exclusive, independent events, such that events would not occur simultaneously, and the occurrence of a particular event would not influence the probability of subsequent events occurring. For example, a 1% AEP flood would not occur at the same time as a dam break, nor would a 1% AEP flood increase the probability of a subsequent dam break event.

(a) Flood

The number of critical bridges affected in a 1% AEP flood scenario was determined using available 1 in 100-year Average Recurrence Interval (ARI) flood mapping sourced from DPIPWE [5], which was developed for the state's key river systems.

A critical bridge was deemed susceptible to failure if it fell within the 1 in 100-year ARI flood zone. It is acknowledged that the majority of contemporary bridges, depending on their application, are designed to withstand much higher hydraulic loads. As such, the assumption that any bridge within a 1 in 100-year ARI flood zone will be affected is conservative. The combined length of critical bridges within the 1 in 100-year ARI flood was then calculated.

As a verification exercise, the analysis considered the impacts of widespread flooding, as per the recent floods in June 2016. Hydrologic analysis of this 2016 event highlighted that five catchments in the north of the state experienced rainfall events greater than a 1% AEP flood scenario. Maps of the highest water mark levels for major water courses in the June 2016 floods, provided by DPIPWE [5], were assessed to determine the combined length of critical bridges affected.

(b) Dam break

Dam break inundation scenarios were based on either a "sunny day" spillway failure, dam crest failure, or extreme rainfall event failure scenario (i.e. 1 in 1000 years or greater). Dam inundation zone mapping was provided by DPIPWE [5]. In the analysis, it was assumed that only a single dam would fail at any instant in time. The dam inundation zone which gave rise to the longest length of critical bridges impacted provided an estimate of the bridge stock required.

(c) Bushfire

To determine the length of critical bridges impacted by bushfire, only timber bridges were analysed (including timber composite bridges) since these were deemed to be most susceptible. The analysis considered the scenario in which timber bridges with a high Network Importance Score (≥400) were located in an area of high fire likelihood based on fire likelihood classifications provided by DPIPWE [6]. To assess the implications of multiple timber bridge failures due to bushfire, clusters of important bridges in high fire likelihood areas were identified within 10km x 10km zones. The zone which impacted the longest length of important timber bridges was identified. A second scenario considered all timber bridges across local and state jurisdictions, regardless of fire risk, to identify the 10km x 10km zone which contained the longest length of combustible bridges.

Based on the criteria above, the emergency scenario which affected the largest length of critical bridges provided the overarching prediction of the emergency bridge stock required within Tasmania.

3.3 Results

Bridge criticality bands created using the methodology in Section 3.2.3 are shown in Figure 6 and indicated geospatially in Figure 7. The most important and susceptible bridges are deemed to be those located in the top right corner (band AA).

For the purposes of analysis, the amount of emergency bridge stock required was assessed for bridges deemed to be of the highest criticality (i.e. those in Band AA), which contained approximately 1% of all Tasmanian bridges. These bridges were assessed against each of the individual emergency scenarios described in Section 3.2.4. The combined length of critical bridges was determined for a 1% AEP flood event, the June 2016 flood event, dam break inundation and bushfire, as shown in Table 4.

Table 4: Critical bridges affected in various emergency scenarios

Parameter	1% AEP flood	June 2016 flood	Dam break	Fire
Number of critical bridges affected – AA Criticality Band	2	5	1	3*
Combined length of critical bridges affected (m) – AA Criticality Band	93	115	62	77

** Critical bridges affected in the fire scenario were assessed differently to the other three events by identifying all combustible (timber) bridges with a Network Importance Score ≥400, within a 10km x 10km area with high fire likelihood.*

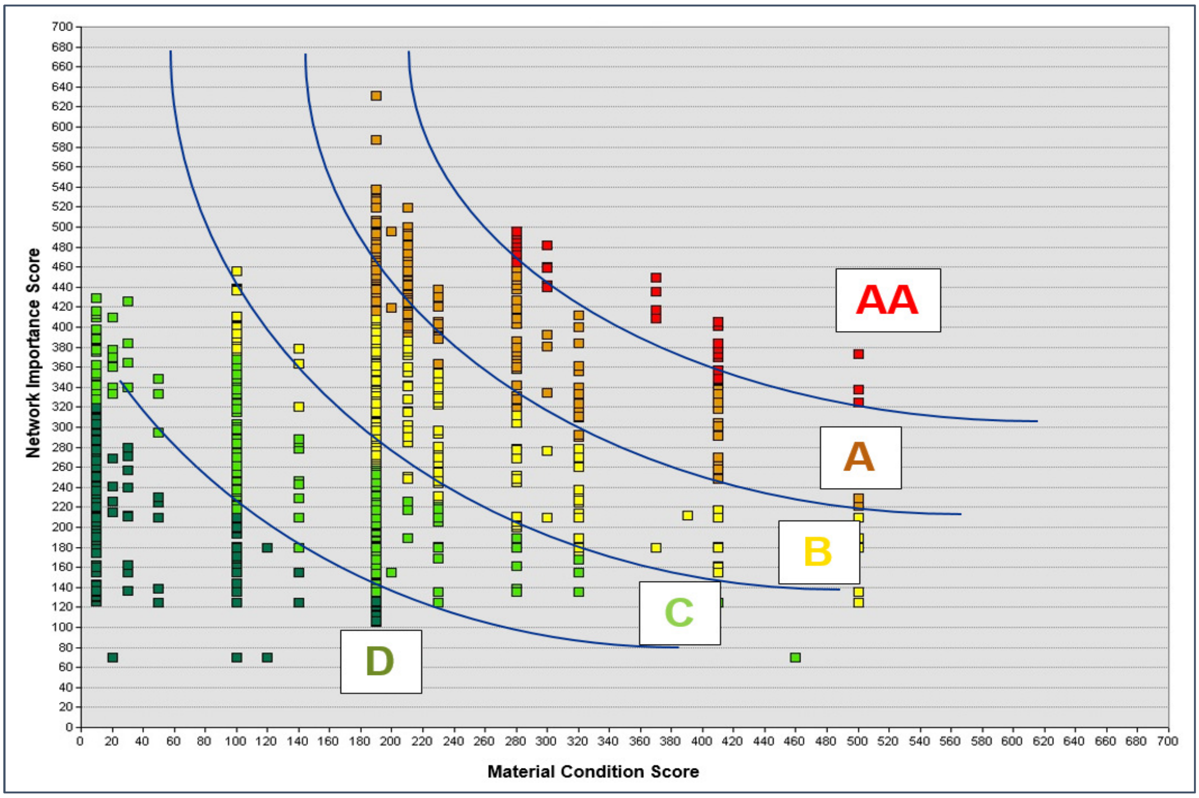

Figure 6: Criticality band categories for Tasmanian bridges

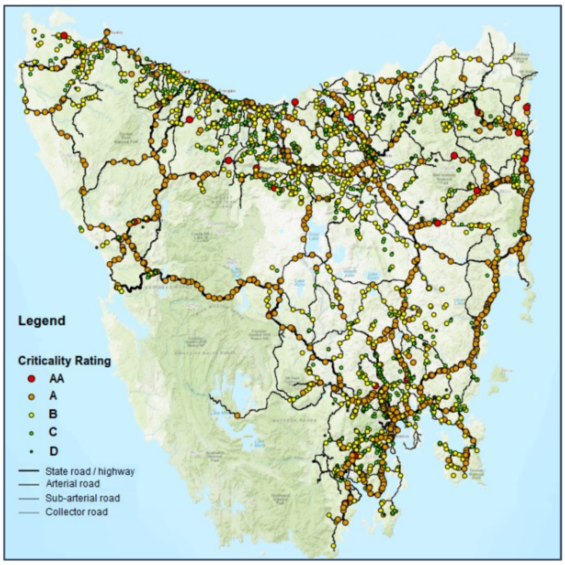

Figure 7: Geospatial variation in bridge criticality bandings for Tasmanian bridges

3.3.1 Sensitivity Analysis

If the cut-off scores for the AA criticality band are lowered, a greater length of bridges would be affected in the assessed emergency scenarios. In order to rationalise the positioning of this band for assessment of multiple failure scenarios, learnings from previous MCA processes and careful consideration of the project objectives were applied.

Sensitivity of the analysis was considered by adjusting the location of the AA band and using the June 2016 flood event as the governing scenario to determine differences obtained in critical bridge length. Adjusting the AA band to contain 5% of the state's most critical bridges resulted in a combined bridge length of 1015m contained within the June 2016 flood level mapping. Whilst there are limitations with this analysis, as discussed further in Section 3.5, procuring 1015m of emergency bridge stock is not a reasonable recommendation.

A case study addressing bridge failure rates based on a sample population of bridges was undertaken by the American society of Civil Engineers in 2015 [4]. The study predicted the average number of bridge failures annually was 0.00021 bridges per year, with a 95% confidence interval of 0.00014 to 0.00037 failures per year. Adopting the same average failure rate in the Tasmanian context predicts that 2.1% of all Tasmanian bridges would fail - i.e. 64 bridges - over a 100-year period (which was the assumed average bridge design life).

Adjusting the AA criticality band to match this failure rate and contain 2.1% of all Tasmanian bridges resulted in a combined bridge length of 184m within the 2016 June flood level mapping. The combined bridge length affected in the 1% AEP flood and dam break emergency mapped scenarios remained unchanged at 93m and 62m, respectively. Given these results, as well as knowledge of the amount of emergency bridge stock kept in other interstate jurisdictions, the assessment of criticality bands based on 2.1% of bridges within Tasmania was deemed too conservative, and therefore the lengths shown Table 4 were considered appropriate estimations.

3.3.2 Other Failure Scenarios

The assessment of multiple bridge failures in an emergency situation focused on bridges with high criticality (i.e. high Network Importance and Material Condition Scores). However, it is acknowledged that bridges deemed to be important to the network with a lower failure likelihood may still be affected in an emergency.

As such, the implications of multiple failures, or a single, isolated failure were considered for bridges with lower criticality. In order to do this, Network Importance Scores were mapped against individual bridge lengths to determine the proportion of bridges less than or equal to a certain length, as shown in Figure 8. This helps to provide an understanding of the amount of bridge lengths that are catered for by different levels of emergency bridge stock. For example, Figure 8 highlights that the minimum bridging stock of 90m (total length) currently maintained for State Growth can theoretically cater for 98.1% of bridge lengths across state and council jurisdictions, if a single bridge failed at any one time.

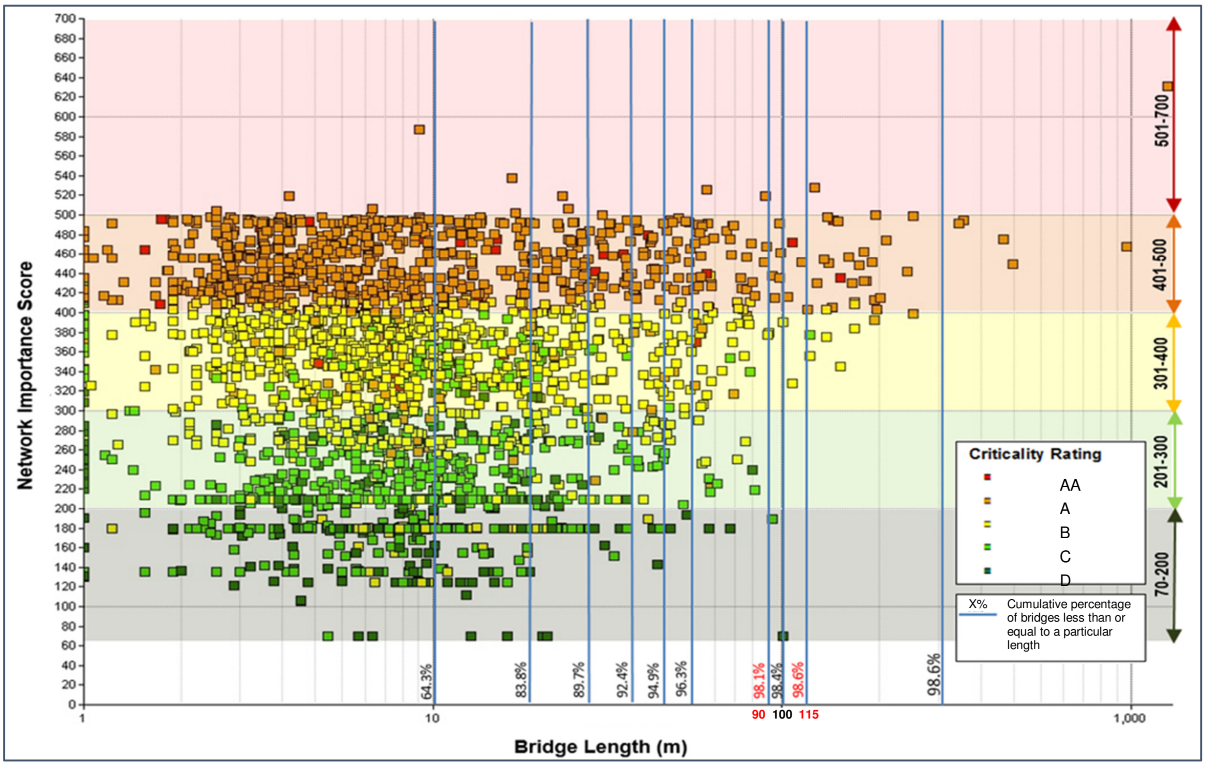

Figure 8: Capacity of emergency bridge stock to cope with other failure scenarios

3.4 Calibration

Various adjustments and calibration exercises were undertaken during the initial stages of the assessment to improve the logic and accuracy of the criticality bands. This included manual checks of bridges identified as being critical, and where these were located in the network. Based on local knowledge and judgment, some of these checks resulted in iterations to the scores and weightings applied in the analysis.

Initial results heavily prioritised the Network Importance Score for State Growth bridges since the majority of these bridges are located on State roads or highways, with high AADTs. Since AADT information was not available for most Council bridges, the AADT score defaulted to the lowest score of 1, causing a skew in the results and not accounting for the large populations which use some of these structures in urban municipalities. In the absence of AADT information, relative population densities were incorporated in the Network Importance Score to reduce the skew in results. This magnified the importance of some Council bridges and created greater diversity in the list of prioritised bridges.

3.4.1 Stakeholder Consultation

Network Importance Scores were further calibrated by incorporating feedback from key State Growth and local council stakeholders. An adjustment factor was applied to bridges deemed to be of higher importance to ensure that the list of priority bridges agreed with stakeholder feedback.

The majority of local council representatives responded to queries and provided information useful to the analysis such as up-to-date bridge asset inventories, flood maps and emergency response plans. Follow up messages were sent out to councils where feedback had not yet been received.

The same council representatives were contacted following establishment of Network Importance Scores and given time to provide feedback to enable calibration of the analysis using their local knowledge of the bridge network and impacts to industry. Follow up discussions were had to ensure a sufficient amount of feedback was obtained.

3.5 Limitations of the Assessment

The data gathered during this assessment represents a snapshot in time based on what information could be readily compiled and rapidly analysed within the MCA to develop a priority list of bridges within the state. There may be minor errors in data provided for bridge lengths, material types or alternate route lengths, and bridges may be replaced over time changing some of their key aspects (such as span length, condition and material type).

One of the key limitations when assessing the likelihood of multiple bridge failures in an emergency event is the difficulty in determining whether or not a structure will be impacted. For example, a fire may only inflict inconsequential damage to a timber bridge and a bridge identified within a 1% AEP flood zone may be designed to withstand such an event. The ability to calibrate bridge failures against known emergency scenarios is difficult due to the variable nature inherent to isolated emergency events. As such, critical bridges identified within 1% AEP flood levels, 2016 flood levels, dam break and high fire risk areas may not necessarily be affected in those events.

3.5.1 Additional Data

The assumption to provide enough bridge stock to cater for the combined length of critical bridges affected in emergency scenarios is somewhat conservative in nature, but believed to be appropriate given the data, past case studies and material available for interpretation.

Additional information such as bridge soffit levels, substructure details, bridge design criteria, further emergency scenarios, or updates to the existing data could be included within the existing database. Furthermore, additional feedback from industry and emergency service authorities would enable the analysis to be further refined in the future to incorporate greater levels of detail and local knowledge such as known impacts to industry, prioritisation of routes for emergency services, just to name a few. Any of this additional information would only serve to strengthen what are considered to be already sound results.

4.0 Conclusion

This paper has presented an approach which enables the prioritisation of bridge repairs and replacements in a widespread emergency event. Rapid, large-scale analysis of over 3,000 state and council bridges was conducted using a Geographic Information System (GIS) to prioritise bridges based on their assessed level of road network importance and susceptibility to failure based on bridge material and condition data. Bridges with the highest criticality (AA banding) were then assessed against different emergency situations; flood, fire and dam break in order to identify the governing combined length of critical bridges that may be affected by any one emergency event.

4.1 Emergency Bridge Stock

The maximum combined length of critical bridges affected by one of the four mapped emergency scenarios was 115m based on June 2016 flood levels. The proportion of bridge lengths within Tasmania that can be catered for in an isolated, random failure was also determined.

The current minimum bridging stock of 90m (total length) maintained for State Growth theoretically has capacity to cater for 98.1% of bridges around Tasmania, if a single bridge failed at any one time. However, this does not consider the capability of State Growth's ageing Bailey Stock to withstand contemporary design loading at greater spans. Increasing the stock of emergency bridging to 115m (total length) only slightly increases the proportion of bridge lengths catered for (i.e. 98.6%).

The ability of State Growth's existing Bailey bridge stock to handle contemporary loads at longer spans is uncertain, with a number of components showing signs of ageing and deterioration. An additional 25m length of contemporary panel bridging is unlikely to be compatible with State Growth's existing components. In order to ensure the capacity of Tasmanian emergency bridge stock to cater for the majority of bridge lengths as well as contemporary design loads, it would be reasonable to consider an entire replacement of existing Bailey components with 115m of contemporary panel bridging.

4.2 Other Considerations

Additional Bailey components could be borrowed from interstate jurisdictions or local councils if shortages of emergency or temporary bridging systems occurred. Local bridging suppliers and other industries may also have capacity to fulfil emergency bridging requirements, as discussed in Section 2.3.

4.3 Closing Statements

This project has highlighted the powerful role that GIS technologies are having in emergency management. Using the computational power of location-based analytics, data from a myriad of sources can be turned into information which allows us to interpret asset information, identify vulnerabilities, set priorities and develop actions which can be taken to mitigate and respond to emergency events.

As we are faced with new threats and more frequent and intense emergency scenarios, these systems and technologies will continue to evolve and adapt, and with appropriate application, can be used to significantly bolster the resilience of our state's infrastructure.

5.0 Acknowledgements

The authors would like to thank and acknowledge the assistance and cooperation of parties involved in the development of this project including; Department of State Growth, Department of Primary Industries, Parks, Water and Environment, local Tasmanian bridging suppliers and local Councils who responded to our queries and provided feedback.

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