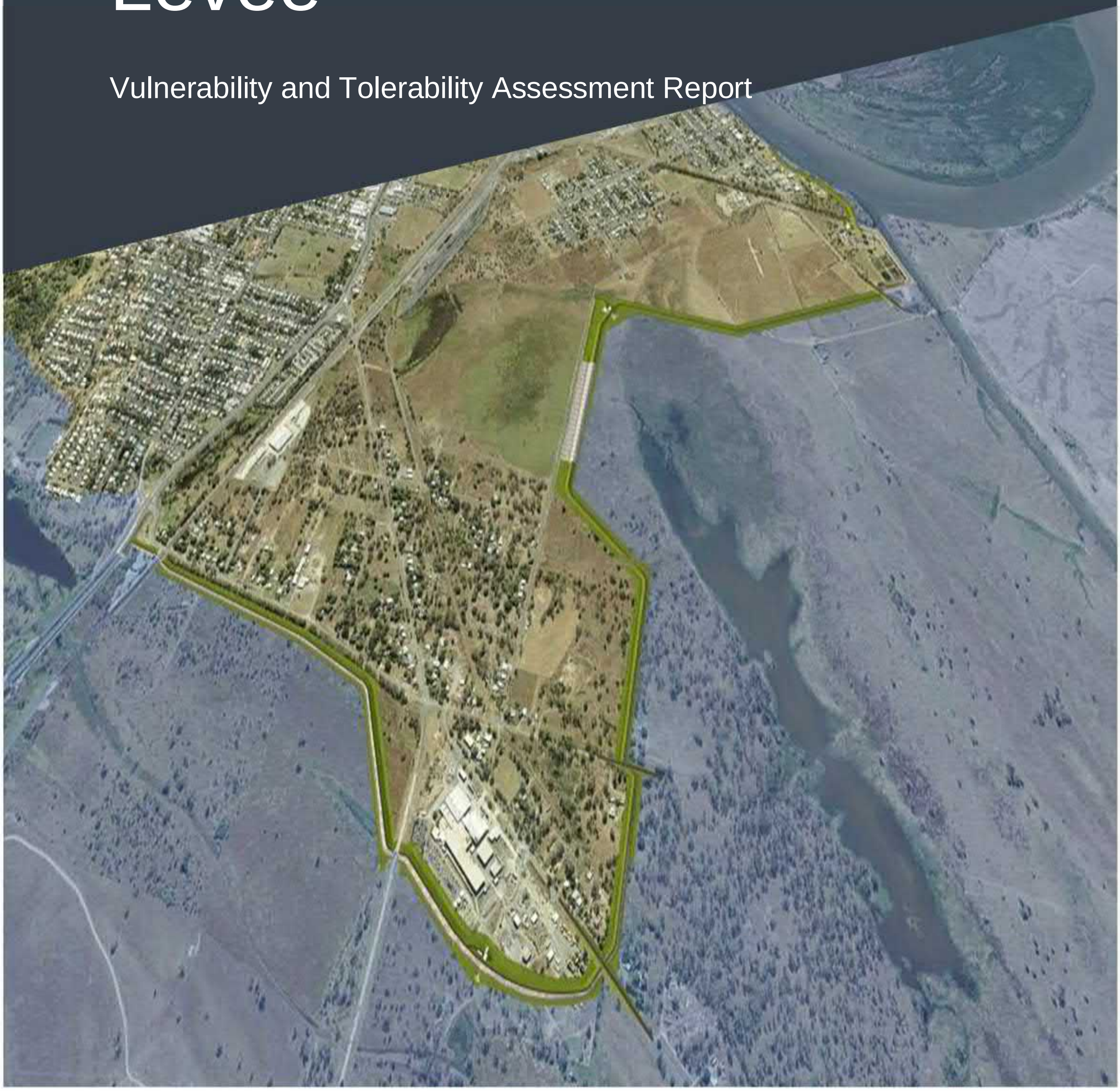
APPENDIX O.

Vulnerability and Tolerability Report

South Rockhampton Flood Levee Project
Rockhampton Regional Council
29-Apr-2019
Doc No. 60589157-REP-023

South Rockhampton Flood Levee

Vulnerability and Tolerability Assessment Report



South Rockhampton Flood Levee

Vulnerability and Tolerability Assessment Report

Client: Rockhampton Regional Council

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Glossary / Abbreviations

AECOM	AECOM Australia Pty Ltd
AEP	Annual Exceedence Probability = $1 - \exp\left(\frac{-1}{ARI}\right)$
AHD	Australian Height Datum
ALARP	As Low as Reasonably Possible
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
CMPS&F	Camp Scott and Furphy
GIS	Geographical Information Systems
QRA	Queensland Reconstruction Authority
RL	Reduced Level
RRC	Rockhampton Regional Council
SRFL	South Rockhampton Flood Levee
TUFLOW	1D / 2D hydraulic modelling software

1.0 Introduction

1.1 Overview

In October 2018, Rockhampton Regional Council (RRC) re-engaged AECOM Australia Pty Ltd (AECOM) to deliver concept, detailed design updates and support the obtainment of Statutory Approvals for the South Rockhampton Flood Levee (SRFL) project.

1.2 Location and Context

Rockhampton is a large regional city located on the Fitzroy River approximately 640 kilometres north of Brisbane. The Rockhampton Regional Council area has a population of some 80,000 people and is a major service centre for the wider Central Queensland region. In addition to serving a range of industries including agriculture and mining, Rockhampton provides a full range of retail, education, health, social, government and professional services to a broad catchment.

The wider Central Queensland region that Rockhampton services and supports is experiencing continuing growth in mining and resources sectors, including Liquid Natural Gas and coal mining in particular. As a consequence, interruptions to logistics and services resulting from flooding in Rockhampton impact to varying degrees on the broader region and its industries.

The Central Queensland region is a world ranked producer and exporter of black coal and a major centre for mineral processing. The region hosts the coal-bearing Bowen and Galilee basins and also produces gold, silver, limestone, coal seam gas, magnesite and gemstones. There are currently 50 coal mines, 25 mineral mines and 30 medium to large (>50 000 tonnes per year) extractive quarries operating in Central Queensland.

1.3 Flooding from Fitzroy River Events

The Fitzroy River, which flows through the city of Rockhampton in the state of Queensland, drains a catchment of approximately 142,000 km^2 and is one of the largest catchments on the east coast of Australia. The catchment extends from the Carnarvon Gorge National Park in the West to Rockhampton on the central Queensland coast and is predominantly dominated by agriculture (grazing, dry land cropping, irrigated cotton and horticulture) and by mining (coal, magnesite, nickel and historically gold and silver).

Due to its immense size and fan-like shape, the Fitzroy River catchment is capable of producing severe flooding following heavy rainfall events in any of its major tributaries. These are the Dawson, Nogoa-Mackenzie and Connors-Isaacs Rivers which rise in the eastern coastal ranges and the Great Dividing Range and join together about 100 kilometres west of Rockhampton. Major floods can result from either the Dawson or the Connors-Mackenzie River catchments. Significant flooding in the Rockhampton area can also occur from heavy rain in the local area below Riverslea.

Rockhampton is the largest urban centre in Central Queensland and is located approximately 60 kilometres from the mouth of the Fitzroy River at Keppel Bay. The Fitzroy River at Rockhampton and adjacent townships has a long and well documented history of flooding with flood records dating back to 1859. The highest recorded flood occurred in January 1918 and reached 10.11 metres (8.65m AHD) on the Rockhampton flood gauge.

It must be noted that extensive social and economic impacts are also experienced in more frequent, flood events. As examples:

- Low lying areas of Port Curtis and Depot Hill are inundated at a gauge height of 7.0m which is equivalent to the Minor Classification given by BOM.
- The Depot Hill community is isolated at a gauge height of 7.5m which is equivalent to the Moderate Classification given by BOM.
- The Bruce Highway at Lower Dawson Road is cut at a gauge height of approximately 8.4m.
- Low lying areas of Allenstown are inundated at a gauge height of 8.5m which is equivalent to the Major Classification given by BOM.

- Depot Hill and Port Curtis have been impacted by 33 historical flood events over 7.0m in gauge height since records commenced in 1859.
- There have been 17 historical flood events over a gauge height of 8.0m in which the Bruce Highway (Lower Dawson Road) has been cut.

1.4 The South Rockhampton Flood Levee

The SRFL project represents one of the most significant regional flood mitigation projects currently proposed in Queensland. The SRFL was identified as a Priority 1 Structural Mitigation Measure in the 1992 Rockhampton Flood Management Study (CMPS&F, 1992). Construction of the levee will significantly reduce flood damage and social impacts for a large portion of the urban area in South Rockhampton.

The SRFL will be approximately 8.74km long, running from the Rockhampton CBD in the north (Fitzroy Street and Quay Street), to Jellicoe Street and Port Curtis Road in the south, and Upper Dawson Road (Yeppen North) in the west (refer to Figure 1). It will consist of sections of earth embankment, crib wall, vertical flood wall and temporary demountable levee structures (component lengths are summarised in Table 1).

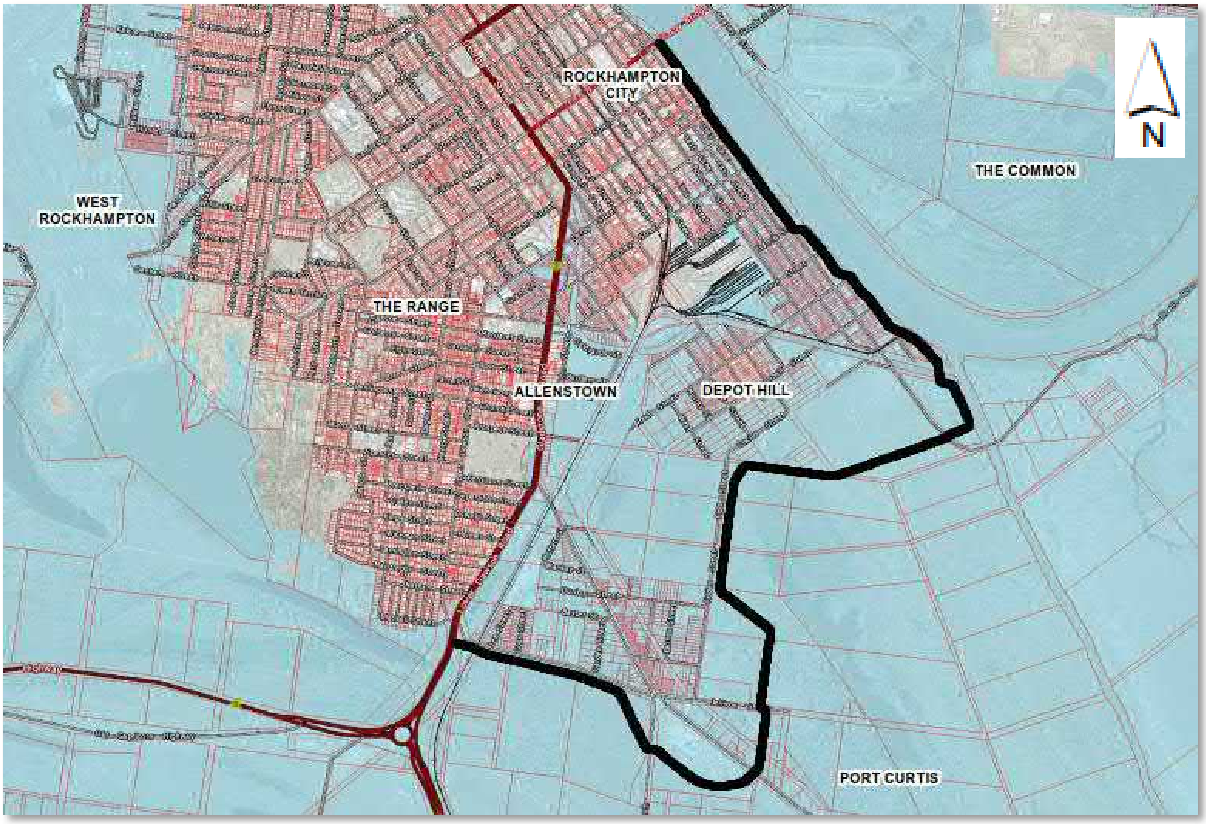


Figure 1 Location of the Proposed SRFL (Baseline Fitzroy River 1% AEP Flood Extents Shown)

The levee will be constructed to 1% Average Exceedance Probability (AEP) or 100 year Average Recurrence Interval (ARI) flood immunity with 600 mm freeboard. This will be equivalent to a 9.89 m gauge level (post SRFL construction).

The levee will incorporate flood gates on the major drainage channels and existing piped drainage networks that discharge outside the levee will be fitted with non-return devices to prevent river back-up. A system of landside drainage channels and three interior pump stations will discharge local catchment runoff should local rainfall events coincide with a regional Fitzroy River flood event.

Table 1 SRFL Component Lengths

Levee Type	Length (m)
Temporary Fully Demountable Wall	732
Composite Demountable / Permanent Levee Wall	967
Levee Emergency Spillway	420
Earth Embankment (incl. road ramps and gates)	5,892
Crib Retaining Wall	729
Total Levee Length	**8,740**

1.5 Project Delivery

The SRFL project is being delivered in two distinct stages, as detailed below.

1.5.1 Stage 1: Early Works (Pre-construction services)

Prior to construction starting on the SRFL project, early works will be completed. The works include land acquisition, stormwater, water and sewage relocations, river bank protection works and drainage works. Early works are anticipated to commence in 2019, and will be undertaken progressively throughout the year.

1.5.2 Stage 2: Main Contract

Council is committed to finalising the consultation, environmental and planning approvals, technical investigations and design of the SRFL project, to facilitate tendering and construction. The SRFL construction works are anticipated to start in late 2019.

The SRFL project has been declared a prescribed project by the Minister for State Development, Manufacturing, Infrastructure and Planning. Approvals for the project are yet to be obtained, and will be facilitated through the Infrastructure Designation process under the *Planning Act 2016*. This will include the preparation and exhibition of an Environment Assessment Report (EAR).

1.6 Scope of Works

This Vulnerability and Tolerability Assessment Report has been undertaken as part of the Concept Design Phase for the SRFL project to support the EAR submission.

The scope of this vulnerability and tolerability assessment is as follows:

- Establish the vulnerability and tolerability of the Lower Fitzroy Catchment community during a riverine flood event under existing conditions. This assessment is based on QRA's Planning for stronger, more resilient floodplains: Part 2 – Measures to support floodplain management in future planning schemes (2012)
- Re-assess the vulnerability and tolerability of the Lower Fitzroy Catchment community under post-SRFL construction conditions.
- Analyse the effects of the levee on the community risk profile.

It is noted that only riverine hydraulic processes are covered in this report. The following is not addressed:

- Assessment of the interior catchment during rainfall event over the urbanised area of South Rockhampton.
- Assessment of breach scenarios and their effect on the risk imposed to the community, which is covered within the Failure Assessment Report (AECOM, 2019).

1.7 Report Structure

The SRFL vulnerability and tolerability assessment has been delivered in a single volume. A3 mapping associated with this assessment have been included as an appendix to this report

This report is structured as follows:

- Section 2.0: Assessment criteria adopted within this report.
- Section 3.0: Details the adopted SRFL design as of the date of this report.
- Section 4.0: Presents results of the vulnerability and tolerability assessment in relation to the proposed infrastructure.
- Section 5.0: Conclusion and Recommendations.
- Section 6.0: References.

2.0 Assessment Criteria

2.1 Definitions

2.1.1 Flood Risk

The level of flood risk exposure is related to the likelihood of flooding and predicted consequence, as shown graphically below.

2.1.2 Likelihood

The likelihood of a specific flood event taking place within a given time period is described in terms of the probability of occurrence of that event, usually described in Annual Exceedance Probability (AEP).

The concept of "encounter probability" which, when linked with the AEP, also provides a useful framework for risk management and decision making. Figure 2 below presents the variation in probability of at least one event occurring (the encounter probability) versus the period of time considered (the design life).

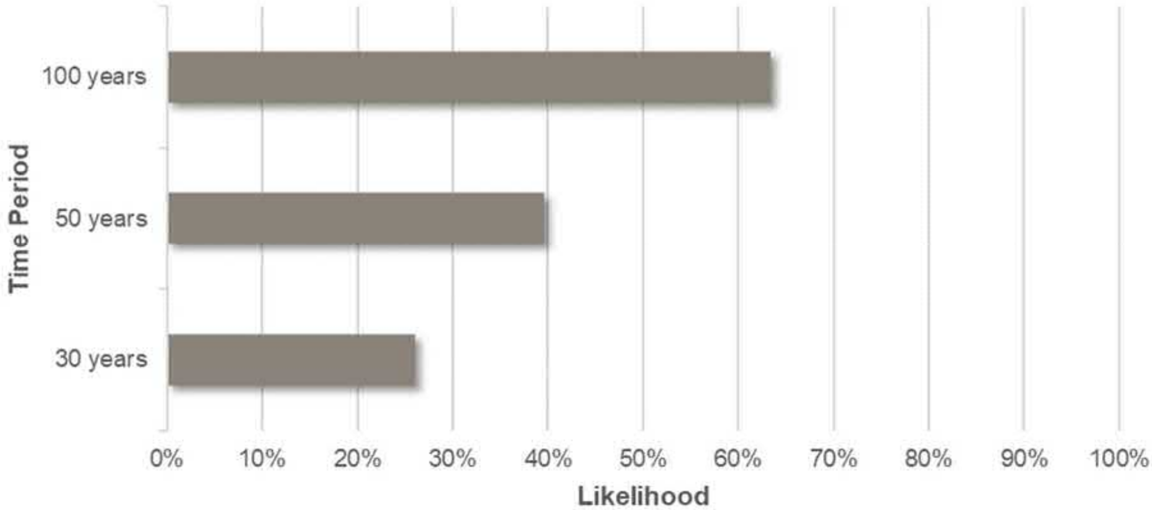
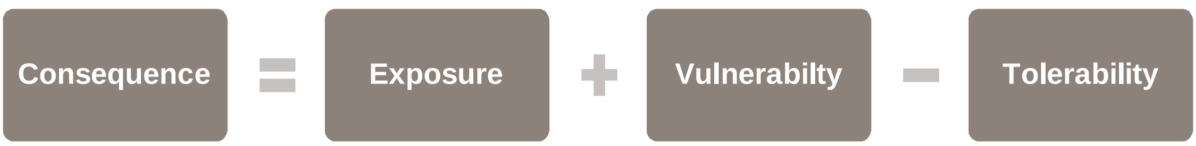


Figure 2 Likelihood of a flood event exceeding the 1% AEP during the specified number of years

2.1.3 Consequences of Flooding

The consequence of flooding is a reflection of who, what and how people, property and infrastructure are impacted by flooding. Consequences are described in terms of exposure to flood hazard and the vulnerability to impacts as a result of that flood event.

As shown graphically below, the consequences of flooding are reduced by the tolerability of people, property and infrastructure to the impacts of flood hazard.



2.1.4 Exposure

Exposure is a measure of the potential for flood hazard to create flood risk. Exposure is measured using a combination of flood hazard severity and land use. Exposure has been measured using a combination of hazard severity (in accordance with Australian Rainfall and Runoff (ARR) 2016, see Figure 3) and land use type as shown in Table 2, from the Planning for stronger, more resilient floodplains: Part 2 (QRA, 2012).

Table 2 Assessment of exposure to hazard (QRA, 2012)

Hazard Severity (at selected likelihood)	Built Form & Associated Safety	Score
H1 – generally safe for people, vehicles and buildings	Landscape	0
H2 – unsafe for small vehicles	Open space and recreation/Rural	1
H3 – unsafe for vehicles, children and the elderly	Industrial	2
H4 – unsafe for people and vehicles	Commercial	3
H5 – unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.	Infrastructure & Utilities/Rural Residential	4
H6 – unsafe for vehicles and people. All building types considered vulnerable to failure.	Residential/Community & Cultural	5

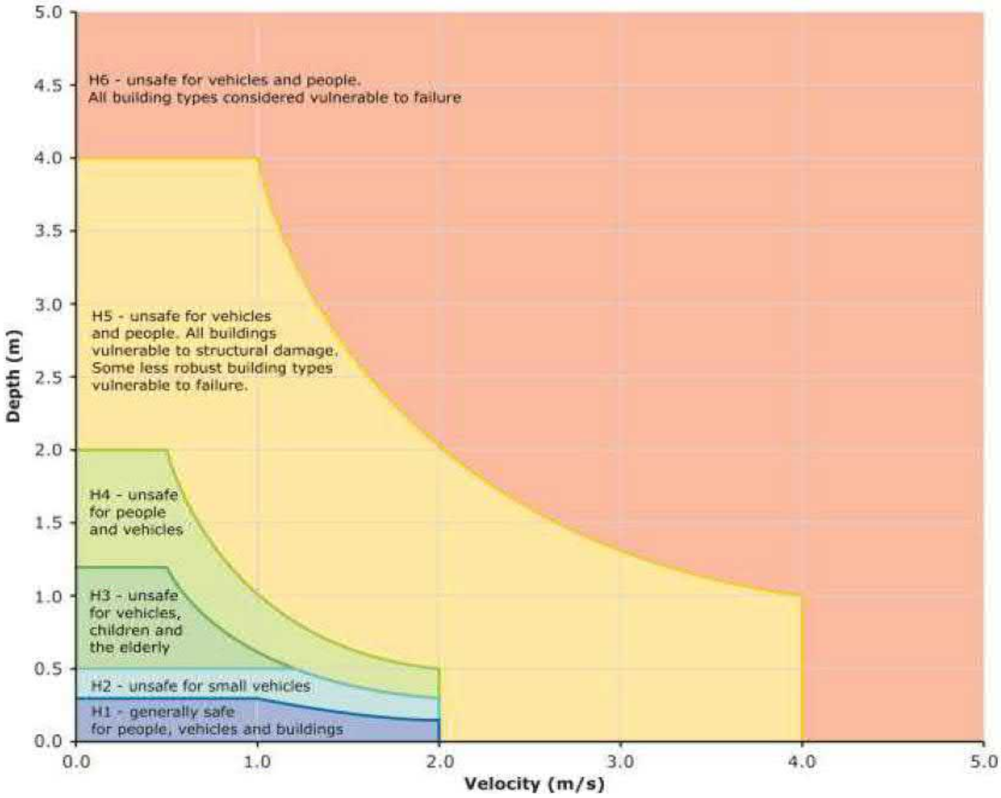


Figure 3 Flood hazard classification (ARR, 2016)

2.1.5 Vulnerability

The Australian Emergency Management Institute (AEMI) define vulnerability as '*the degree of susceptibility and resilience of a community, its social setting, and the natural and built environments to flood hazards*' (AEMI, 2014). Vulnerable communities are impacted by flooding more than non-vulnerable communities due to the inherent characteristics of the community.

Vulnerability is assessed in terms of ability of the community and environment to anticipate, cope and recover from flood events. Flood awareness is an important indicator of vulnerability and is defined as '*an appreciation of the likely effects of flooding, and a knowledge of the relevant flood warning, response and evacuation procedures*' (AEMI, 2014).

In communities with a high degree of flood awareness, the response to flood warnings is prompt and effective. In communities with a low degree of flood awareness, flood warnings are liable to be ignored or misunderstood, and residents are often confused about what they should do, when to evacuate, what to take with them and where it should be taken.

Vulnerability within the context of this assessment is measured using a combination of vulnerable land use types and built form / associated safety as shown in Table 3. These criteria are of particular interest for the subject area as above floor flooding and inundation of critical services are key issues known by the local community.

Table 3 Assessment of vulnerability to hazard severity (QRA, 2012)

Vulnerable Land Use	Built Form & Associated Safety	Score
Existing / proposed built form not affected by hazard (regardless of use), or no existing/proposed vulnerable land use or affected persons (e.g. Landscape, Open Space and Recreation)	Existing built form not affected by hazard	0
Commercial, Industrial, Rural, Rural Residential and Residential without vulnerable persons	At grade – industrial	1
Hazardous Materials / Warehousing	Elevated (elevated above selected flood)	2
Community & Cultural with Vulnerable Property, or Minor infrastructure	At grade – commercial	3
Community & Cultural with Vulnerable Persons, or Residential with Vulnerable Persons	At grade – community	4
Evacuation Centres / Airports / Other Critical Infrastructure or	Not elevated above selected flood – residential	5

2.1.6 Tolerability

Flood tolerability relates to the attitudes and level of resilience within a community, which can reduce the impacts of flood exposure when an event occurs. This can include both qualitative and quantitative metrics, including personal attitudes to and awareness of flood events, levels of insurance, prevalence of use of flood emergency plans, and the extent to which people assist each other in times of flood.

Tolerability within the context of this assessment is measured using the criteria shown in Table 4. These criteria are:

- Level of Protection from Existing / Proposed Structural Works.
- Ability of use to remain operational during / after selected flood event (critical infrastructure only).

The assessment was not able to quantify the following criteria due to limitations of available spatial data:

- Community Awareness / Understanding, Perception of Hazard and Preparedness.
- Emergency Management Procedures / Evacuation.

Table 4 Assessment of tolerability to hazard (QRA, 2012)

Community Awareness / Understanding[1]	Community Perception of Hazard[1]	Community Preparedness[1]	Emergency Management Procedures / Evacuation[1]	Level of Protection from Existing / Proposed Structural Works	Ability of use to remain operational during / after selected flood event (critical infrastructure only)	Score
Unaware	Intolerant and not resilient	No individual preparedness business continuity & social networks	For residential/critical infrastructure - no emergency services access to lot, or For non-residential - no evacuation procedures in place on lot	None	Not able to remain operational	0
Partially Aware	Fearful and generally not resilient	As above, but limited	As above, but limited	< 2% AEP	N/A	1
Moderately Aware	Cautious and moderately resilient	As above, but acceptable	As above, but acceptable	2% - 1% AEP	Reduced but acceptable operations	2
Generally Aware	Generally tolerant and resilient	As above, but strong	As above, but strong	1% AEP	N/A	3
Very Aware	Tolerant and Resilient	As above, but very strong	As above, but very strong	> 1% AEP	Able to remain fully operational	4
No persons or property affected, or emergency services/evacuation procedures and structural controls unnecessary						5

[1] Not included within this assessment due to data limitations.

2.1.7 Risk Level Score

The risk level score has been assessed based on QRA's risk matrix, which multiplies consequence by risk and categorises the result as follows:

- Risk Level < 4 = **Broadly Acceptable**
- Risk Level ≥ 4 *and* < 8 = **Tolerable, subject to ALARP**
- Risk Level > 8 = **Generally Intolerable**

The adopted risk matrix shown in Figure 4 has been used in this assessment to inform the impacts of the SRFL as it takes into account variation in vulnerability and tolerability across a range of likelihoods, enabling quantification and evaluation of the project's effect on risk to the existing community.

	Consequence Score										
Likelihood	0	1	2	3	4	5	6	7	8	9	10
10%	0	10	20	30	40	50	60	70	80	90	100
5%	0	5	10	15	20	25	30	35	40	45	50
2.5%	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
2%	0	2	4	6	8	10	12	14	16	18	20
1%	0	1	2	3	4	5	6	7	8	9	10
0.5%	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
0.2%	0	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2
0.1%	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1

Broadly Acceptable

Tolerable subject to ALARP

Generally Intolerable

Figure 4 Adopted risk matrix (QRA, 2012)

3.0 Design Overview

3.1 Adopted Design

The adopted SRFL horizontal alignment is presented in Figure 6 and the adopted SRFL vertical alignment is presented in Figure 7.

3.2 Levee Types

The levee system utilises six different levee types, ranging from permanent earth embankments and structural walls to temporary demountable walls that are installed at designated trigger levels. Table 5 presents the lengths associated with each type of levee section which are shown spatially in Figure 5.

Table 5 Levee Wall Type Summary

Levee Wall Type	Length (m)
Temporary Fully Demountable Wall	732
Composite Demountable / Permanent Levee Wall	967
Levee Emergency Spillway	420
Earth Embankment (incl. road ramps and gates)	5,892
Crib Retaining Wall	729
Total Levee Length	**8,740**

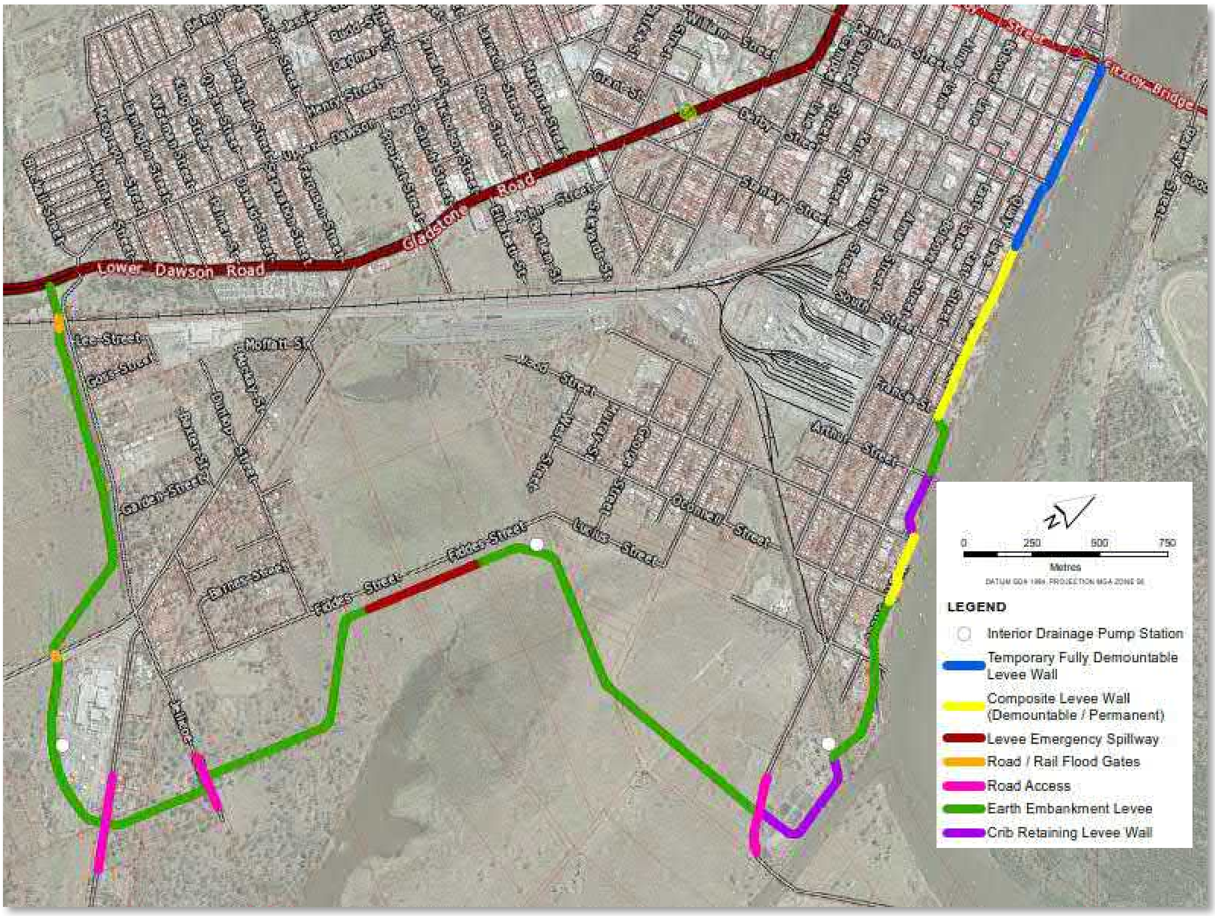
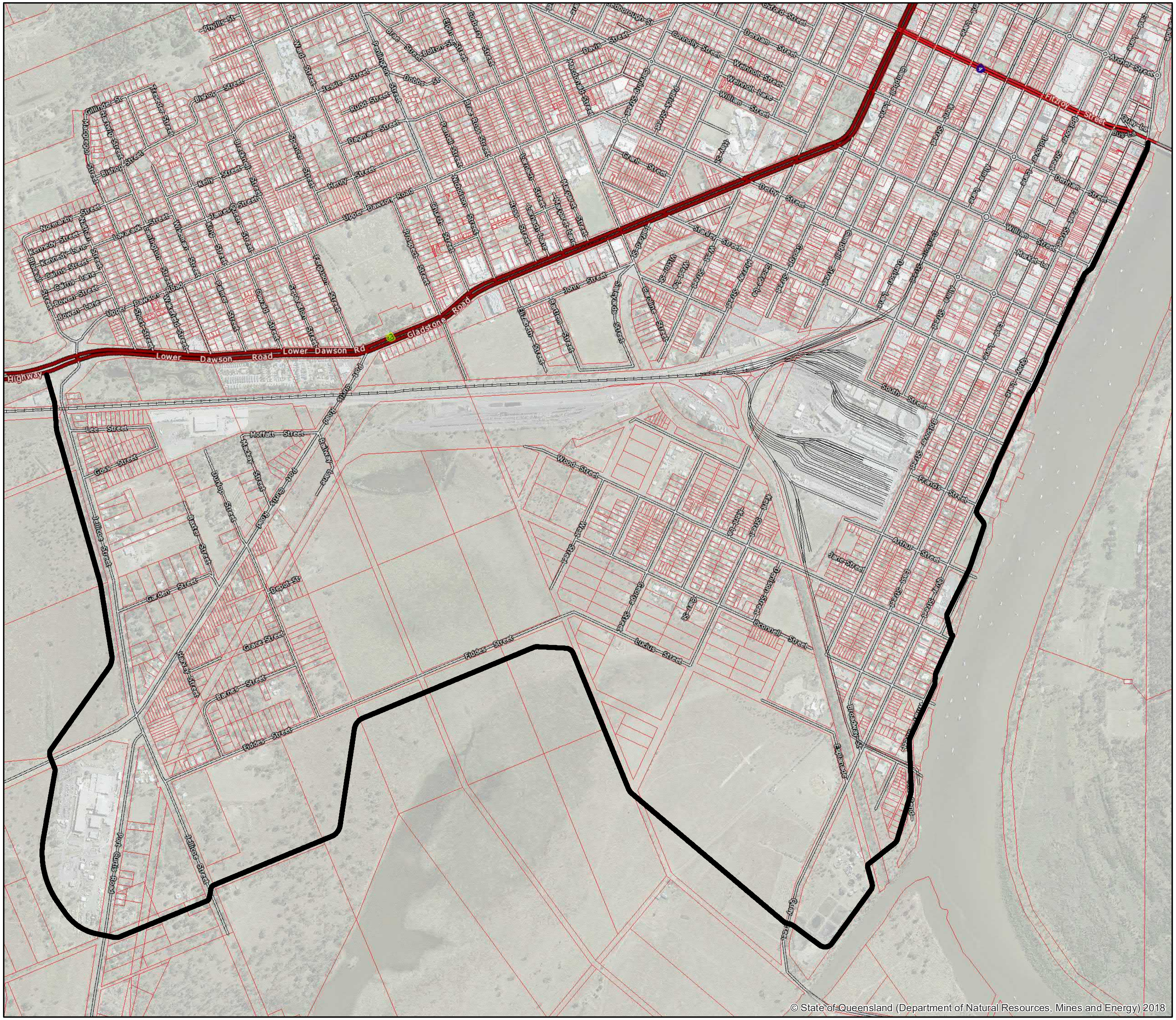


Figure 5 SRFL levee type overview



Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 100 200 300 400 500

Metres

1:12,500
(when printed at A3)

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LEGEND

- Proposed Levee Alignment
- Railway Lines
- Cadastre

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

South Rockhampton Flood Levee

Horizontal Alignment Overview

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	2/04/2019
VERSION:	1

Figure 6

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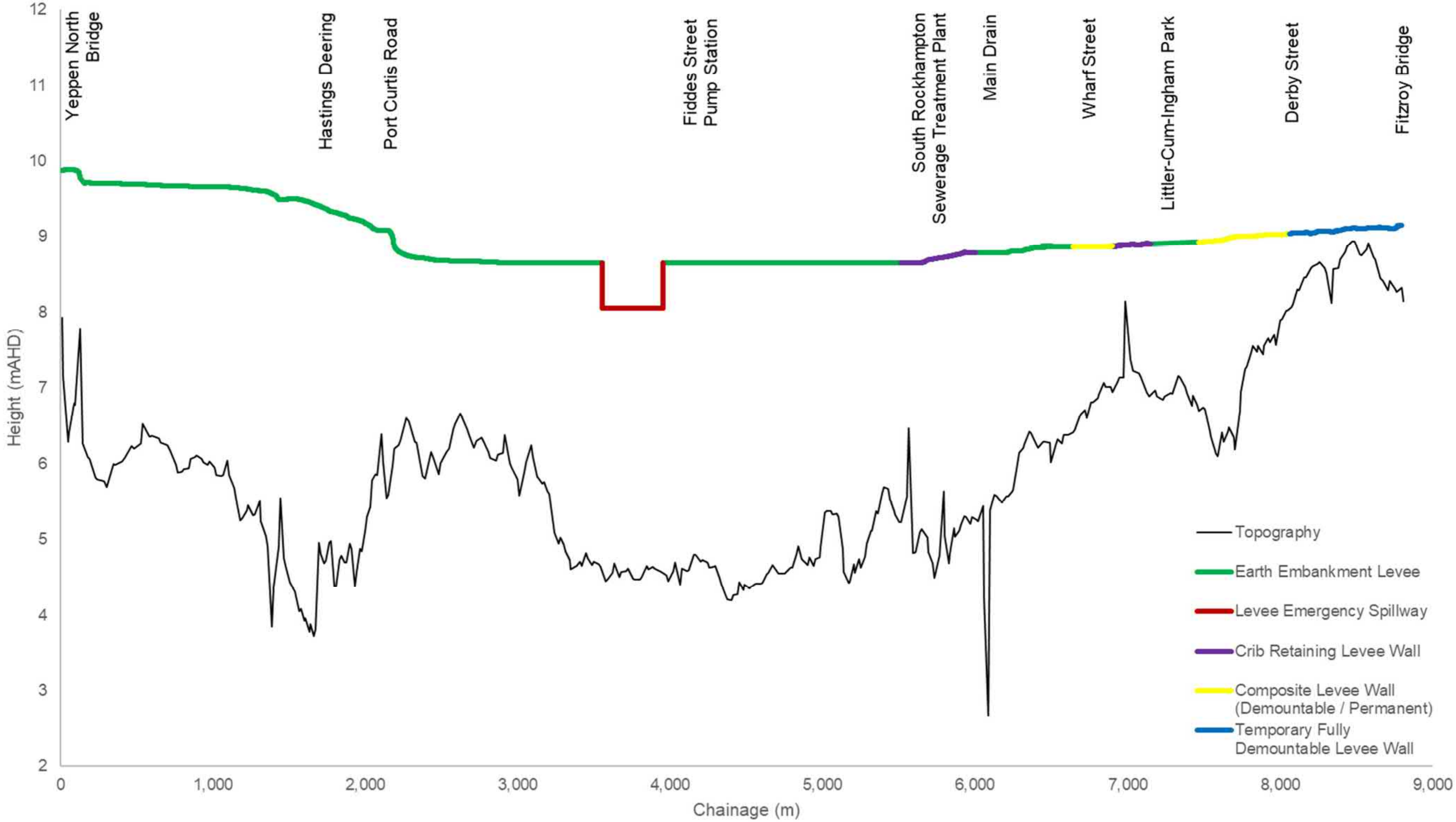


Figure 7 SRFL vertical alignment

4.0 Vulnerability and Tolerability Assessment

4.1 Flood Behaviour

As described in Section 1.3, the Fitzroy River catchment is capable of producing severe flooding following heavy rainfall events in any of its major tributaries. The most notable floods on record have been listed in order of severity below.

1. January 1918 – 10.11mRGD (8.65mAHD)
2. February 1954 – 9.40mRGD (7.95mAHD)
3. January 1991 – 9.30mRGD (7.85mAHD)
4. January 2011 – 9.20mRGD (7.75mAHD)
5. April 2017 – 8.90mRGD (7.45mAHD).

To the northwest of Rockhampton, at the Pink Lily meander, significant overbank flow occurs in major flood events where the discharge exceeds 6,200 m^3/s (approximately 1 in 6-year Average Recurrence Interval). This results in flood flows spreading over a broad floodplain to the west and south of Rockhampton. This floodwater re-joins the Fitzroy River south of the city at Gavial Creek.

The inundation of the floodplain can result in the closure of Rockhampton Airport, the Bruce and Capricorn Highways and the North Coast Rail Line. The Bruce Highway and North Coast Rail Line can also be cut by floodwaters at the Alligator Creek Crossing near Yaamba (30 kilometres north of Rockhampton). As major floods can last for several weeks there is often an extensive disruption to road, rail and air traffic that results in extensive indirect losses. Extensive property damage can also occur within Rockhampton during flood events which can result in significant direct losses and pose a safety risk to the population.

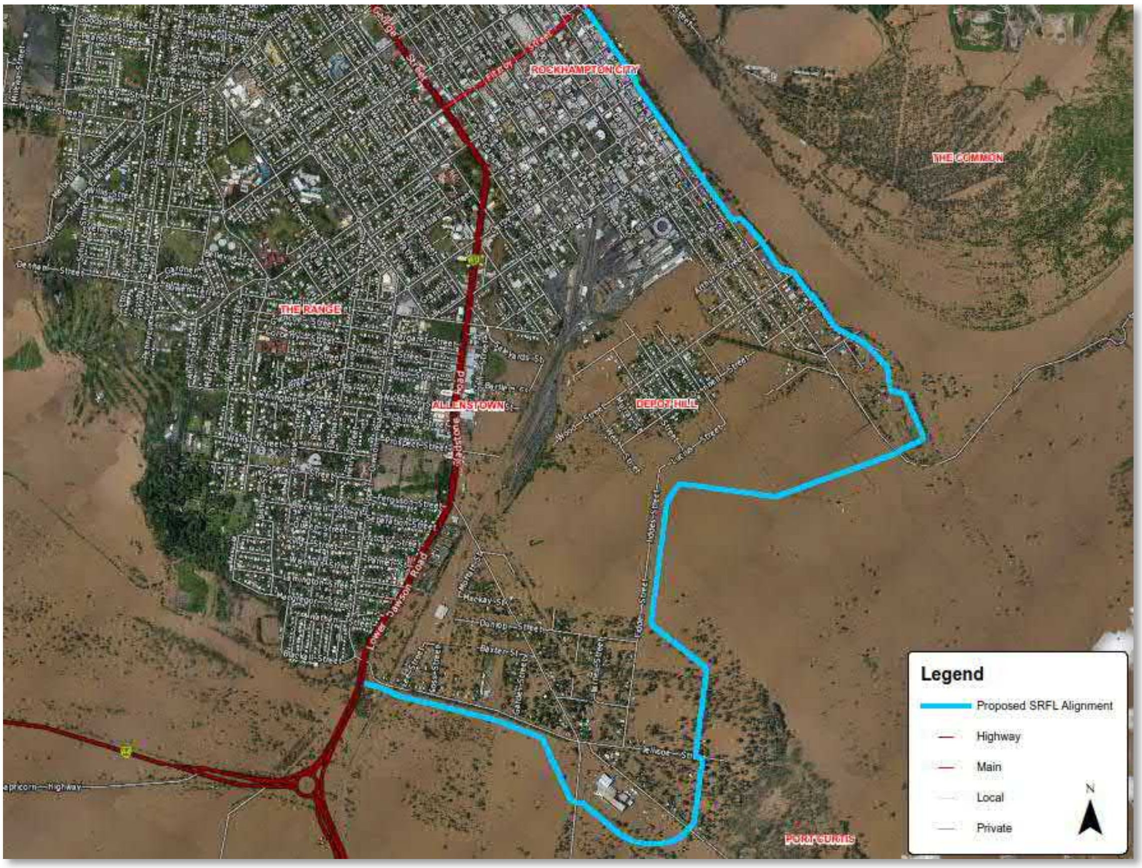


Figure 8 2011 Fitzroy River Flood Extent overlaid with SRFL Alignment

4.2 Building Database

The building database adopted for the assessment was sourced from the work completed in the SRFL Hydraulic Assessment Report – Volume 1 (AECOM, 2019). This database featured 9,767 buildings which represents the majority of structures within the Fitzroy River Probable Maximum Flood (PMF) extent. Of this number, 4,687 had a surveyed floor height with the remaining being generated using desktop GIS estimation methods.

4.3 Selected Likelihoods

The likelihoods (flood magnitudes) selected for inclusion within this assessment includes the 5%, 2%, 1%, 0.5% and 0.2% AEP flood events. Events rarer than the 0.2% AEP event were not included as all combinations of consequence are considered broadly acceptable (due to diminishing likelihood) – refer to Figure 9, reproduced from Planning for stronger, more resilient floodplains: Part 2.

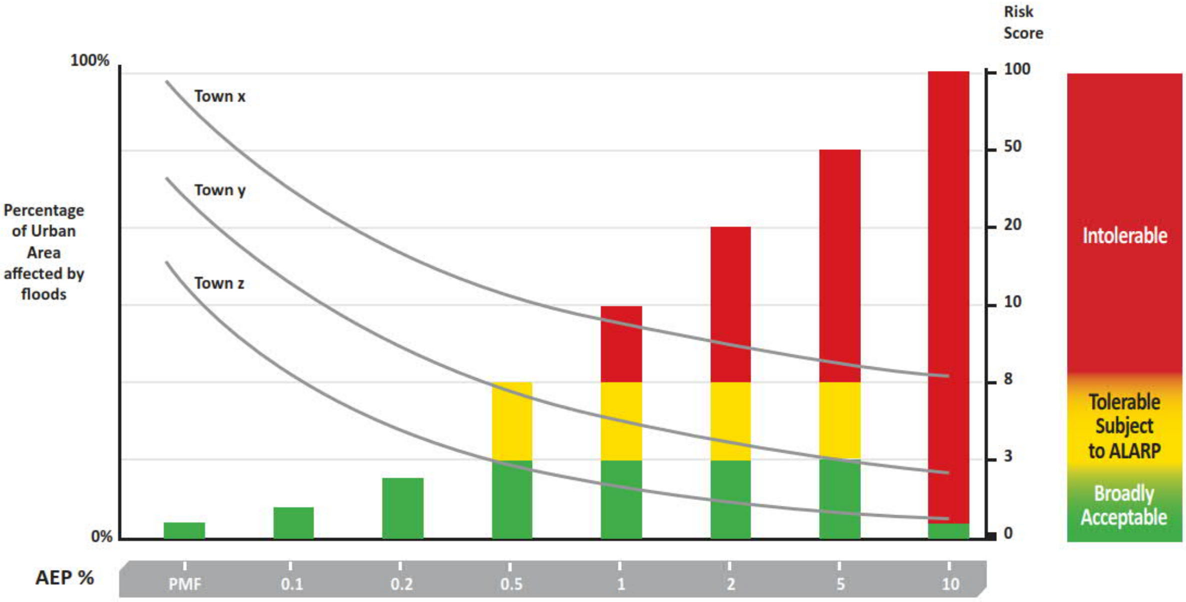


Figure 9 The risk scores possible at each level of AEP (QRA, 2012)

4.4 Limitations and Constraints

This assessment is constrained by availability of the following:

- Spatial data of Community Awareness / Understanding, Perception of Hazard and Preparedness.
- Spatial data of Emergency Management Procedures / Evacuation.

Should these datasets become available at a suitable level of detail, this assessment should be updated to consider their effect on tolerability score. Refer to Section 4.10 for a high-level sensitivity analysis of potential effects on the assessment outcomes.

4.5 Exposure

Exposure was scored at a building-by-building basis according to the worst case between:

- flood hazard, which varies with likelihood and scenario (existing or Post-SRFL Construction); and
- land use.

The peak flood hazard for each building across all likelihoods and scenarios was sourced from the recently updated Fitzroy River TUFLOW model. The land use was sourced from Council's latest available zoning (2015). The adopted exposure score was the greater of each - i.e. if an industrial building experienced a flood hazard of H1 during a 5% AEP event, the exposure score would be 2. If this same structure experienced a flood hazard of H4 during a 1% AEP event, the exposure score would be 3. This is aligned to guidance provided in Planning for stronger, more resilient floodplains: Part 2.

The exposure scores across all assessed buildings are summarised in Table 6 and Table 7 with the change quantified in Table 8.

Table 6 Exposure Assessment Results – Existing Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	2	2	2	2	2
1	93	75	63	52	39
2	736	718	692	666	610
3	702	725	750	756	788
4	526	539	552	583	615
5	7,708	7,708	7,708	7,708	7,713

Table 7 Exposure Assessment Results – Post-SRFL Construction Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	2	2	2	2	2
1	94	76	66	52	39
2	736	744	740	678	634
3	700	699	706	758	776
4	527	538	545	569	603
5	7,708	7,708	7,708	7,708	7,713

Table 8 Difference in Exposure as a result of the SRFL Project

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0					
1	+1 ▲	+1 ▲	+3 ▲		
2		+26 ▲	+48 ▲	+12 ▲	+24 ▲
3	- 2 ▼	- 26 ▼	- 44 ▼	+2 ▲	- 12 ▼
4	+1 ▲	- 1 ▼	- 7 ▼	- 14 ▼	- 12 ▼
5					

4.6 Vulnerability

Vulnerability was scored at a building-by-building basis according to the worst case between:

- vulnerable land use; and
- built form & associated safety, which is related to the proximity of the building's floor level to the flood level, which varies with likelihood and scenario (existing or Post-SRFL Construction).

The peak flood level for each building across all likelihoods and scenarios was sourced from the recently updated Fitzroy River TUFLOW model. The vulnerable land use was sourced from Council's latest available zoning (2015). The adopted vulnerability score was the greater of each. This is aligned to guidance provided in Planning for stronger, more resilient floodplains: Part 2.

The vulnerability scores across all assessed buildings are summarised in Table 9 and Table 10 with the change quantified in Table 11.

Table 9 Vulnerability Assessment Results – Existing Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	76	61	52	39	33
1	8,676	8,065	7,400	6,332	5,546
2	8	11	9	9	7
3	71	123	141	171	163
4	697	1,000	1,259	1,680	1,649
5	239	507	906	1,536	2,369

Table 10 Vulnerability Assessment Results – Post-SRFL Construction Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	79	64	55	39	33
1	9,260	8,845	8,399	6,402	5,589
2	5	9	8	9	7
3	2	8	7	168	170
4	256	493	695	1,726	1,685
5	165	348	603	1,423	2,283

Table 11 Difference in Vulnerability as a result of the SRFL Project

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	+3 ▲	+3 ▲	+3 ▲		
1	+584 ▲	+780 ▲	+999 ▲	+70 ▲	+43 ▲
2	- 3 ▼	- 2 ▼	- 1 ▼		
3	- 69 ▼	- 115 ▼	- 134 ▼	- 3 ▼	+7 ▲
4	- 441 ▼	- 507 ▼	- 564 ▼	+46 ▲	+36 ▲
5	- 74 ▼	- 159 ▼	- 303 ▼	- 113 ▼	- 86 ▼

4.7 Tolerability

Tolerability was scored at a building-by-building basis according to the worst case between:

- Level of Protection from Existing / Proposed Structural Works.
- Ability of use to remain operational during / after selected flood event (critical infrastructure only).

The level of protection for each building across all likelihoods and scenarios was determined based on existing flood mitigation works and the flood magnitude to which the structure is anticipated to be protected. A building which is not affected by natural hazard during the assessed likelihood would return a tolerability score of 5. A building protected by the SRFL during the 1% AEP event or less would return a score of 3 and a building not protected by structural works (existing or proposed) would return a score of 0.

Demographics were not taken into consideration as the detail of spatial information required was not available at the time of this assessment. A sensitivity analysis of the potential effects of incorporating demographic information has been included in Section 4.10.

The tolerability scores across all assessed buildings are summarised in Table 12 and Table 13 with the change quantified in Table 14.

Table 12 Tolerability Assessment Results – Existing Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	1,015	1,641	2,315	3,396	4,188
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	8,752	8,126	7,452	6,371	5,579

Table 13 Tolerability Assessment Results – Post-SRFL Construction Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	428	858	1,313	3,234	4,054
1	0	0	0	0	0
2	0	0	0	0	0
3	75	166	313	139	119
4	0	0	0	0	0
5	9,264	8,743	8,141	6,394	5,594

Table 14 Difference in Tolerability between Assessed Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	- 587 ▼	- 783 ▼	- 1,002 ▼	- 162 ▼	- 134 ▼
1					
2					
3	+75 ▲	+166 ▲	+313 ▲	+139 ▲	+119 ▲
4					
5	+512 ▲	+617 ▲	+689 ▲	+23 ▲	+15 ▲

4.8 Consequence

Consequence was calculated for each building using the equation presented in Section 2.1.3.

The tolerability scores across all assessed buildings are summarised in Table 12 and Table 13 with the change quantified in Table 14.

Table 15 Consequence Assessment Results – Existing Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	1,684	1,470	1,291	1,090	952
1	7,068	6,656	6,161	5,281	4,627
2	0	0	0	0	0
3	5	7	4	4	3
4	0	1	3	3	1
5	52	77	84	82	69
6	36	57	66	96	90
7	37	85	127	143	134
8	178	225	279	328	383
9	611	959	1,291	1,851	1,983
10	96	230	461	889	1,525

Table 16 Consequence Assessment Results – Post-SRFL Construction Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	1,857	1,723	1,603	1,126	972
1	7,441	7,106	6,704	5,303	4,640
2	20	27	37	11	5
3	23	58	115	23	30
4	0	1	1	5	1
5	3	9	4	98	95
6	17	11	13	133	119
7	16	32	47	127	140
8	84	116	124	296	349
9	231	500	759	1,789	1,915
10	75	184	360	856	1,501

Table 17 Difference in Consequence between Assessed Conditions

Score	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
0	+173 ▲	+253 ▲	+312 ▲	+36 ▲	+20 ▲
1	+373 ▲	+450 ▲	+543 ▲	+22 ▲	+13 ▲
2	+20 ▲	+27 ▲	+37 ▲	+11 ▲	+5 ▲
3	+18 ▲	+51 ▲	+111 ▲	+19 ▲	+27 ▲
4			- 2 ▼	+2 ▲	
5	- 49 ▼	- 68 ▼	- 80 ▼	+16 ▲	+26 ▲
6	- 19 ▼	- 46 ▼	- 53 ▼	+37 ▲	+29 ▲
7	- 21 ▼	- 53 ▼	- 80 ▼	- 16 ▼	+6 ▲
8	- 94 ▼	- 109 ▼	- 155 ▼	- 32 ▼	- 34 ▼
9	- 380 ▼	- 459 ▼	- 532 ▼	- 62 ▼	- 68 ▼
10	- 21 ▼	- 46 ▼	- 101 ▼	- 33 ▼	- 24 ▼

4.9 Results

The consequence calculated at each building was multiplied by the likelihood of the assessed event in order to output the risk level. The calculated risk was then categorised using the following criteria (see Figure 4):

- Risk Level < 4 = **Broadly Acceptable**
- Risk Level ≥ 4 *and* < 8 = **Tolerable, subject to ALARP**
- Risk Level > 8 = **Generally Intolerable**

Finally, the count of buildings and sum of risk level for each category across the range of assessed likelihoods and conditions was determined in order to quantify the effect of the SRFL on the community.

4.9.1 Buildings

The count of buildings for each risk category are summarised in Table 18 and Table 19 with the change quantified in Table 20. Refer to Appendix A of this report for spatial mapping of each building's categorised risk level.

Table 18 Count of Buildings – Existing Conditions

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Broadly Acceptable	8,752	8,126	7,456	6,699	9,767
Tolerable, subject to ALARP	5	7	280	3,068	0
Generally Intolerable	1,010	1,634	2,031	0	0

Table 19 Count of Buildings – Post-SRFL Construction Conditions

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Broadly Acceptable	9,298	8,829	8,459	6,826	9,767
Tolerable, subject to ALARP	43	85	65	2,941	0
Generally Intolerable	426	853	1,243	0	0

Table 20 Difference in Count of Buildings between Assessed Conditions

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Broadly Acceptable	+546 ▲	+703 ▲	+1,003 ▲	+127 ▲	-
Tolerable, subject to ALARP	+ 38 ▲	+ 78 ▲	- 215 ▼	-127 ▼	-
Generally Intolerable	-584 ▼	-781 ▼	-788 ▼	-	-

The existing and post-SRFL construction conditions have been graphed for each flood likelihood in Figure 10 to Figure 14.

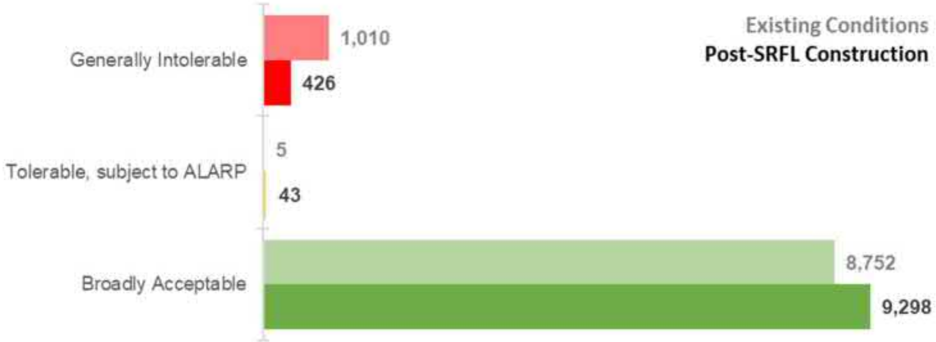


Figure 10 Count of Buildings pre- and post-SRFL construction conditions – 5% AEP

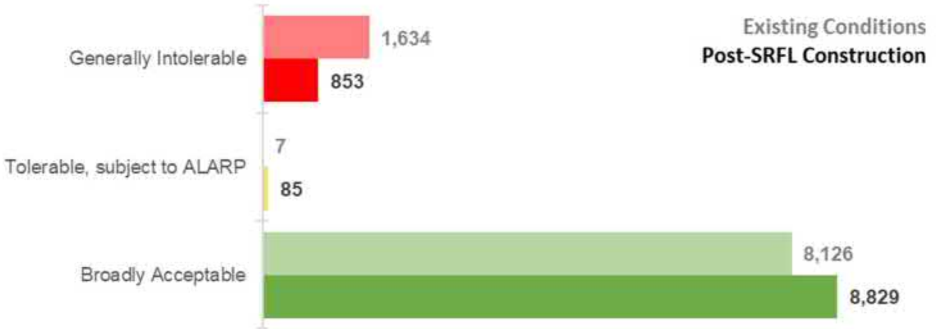


Figure 11 Count of Buildings pre- and post-SRFL construction conditions – 2% AEP

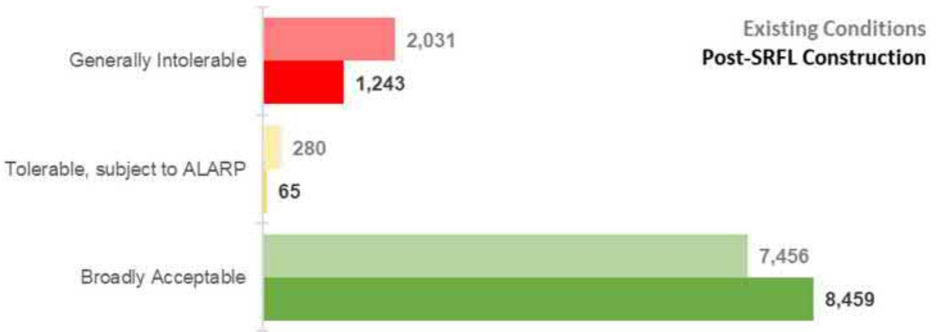


Figure 12 Count of Buildings pre- and post-SRFL construction conditions – 1% AEP

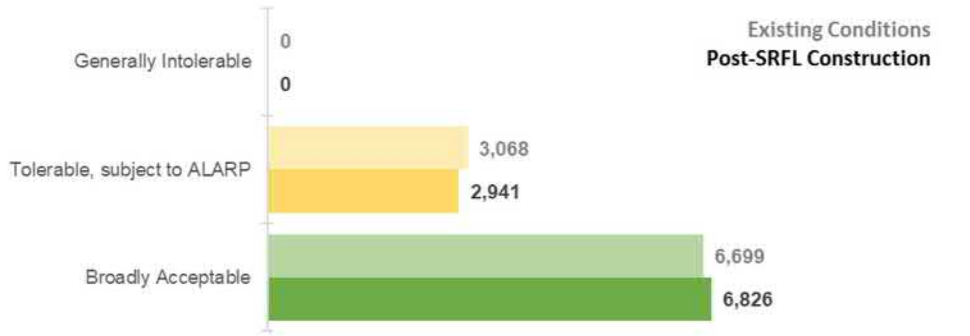


Figure 13 Count of Buildings pre- and post-SRFL construction conditions – 0.5% AEP

Figure 14 Count of Buildings pre- and post-SRFL construction conditions – 0.2% AEP

The change in building risk level presented in Table 20 has been further categorised to clearly present the number of buildings benefited (risk level reduced) and impacted (risk level increased) due to construction of the SRFL. Buildings identified as being impacted have been further delineated to separate those increased to a 'Tolerable, subject to ALARP' level and those increased to 'Generally Intolerable'. These results are presented in Table 21 and show:

- Benefits heavily outweigh impacts across all events.
- The 1% AEP event realises the most benefited buildings.
- A total of 38 building's risk level are anticipated to increase to 'Tolerable, subject to ALARP'.
- A total of 29 building's risk level are anticipated to increase to 'Generally Intolerable'.

Table 21 Categorised Impacts and Benefits to Building Risk Levels

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Risk Level Reduced	**592**	**799**	**1,011**	**164**	**0**
Risk Level Unchanged	**9,169**	**8,952**	**8,748**	**9,566**	**9,767**
Risk Level Increased to Tolerable, subject to ALARP[1]	**0**	**1**	**0**	**37**	**0**
Risk Level Increased to Generally Intolerable[1]	**6**	**15**	**8**	**0**	**0**

[1] *Results have been cross-checked between assessed likelihoods to remove double-counting.*

No benefits or impacts to risk level are anticipated during the 0.2% AEP event (or rarer) due to the low likelihood (see Figure 4).

These results have also been visualised in Figure 15. Refer to Volume 2 of this report for spatial locations of each impacted and benefited structure.

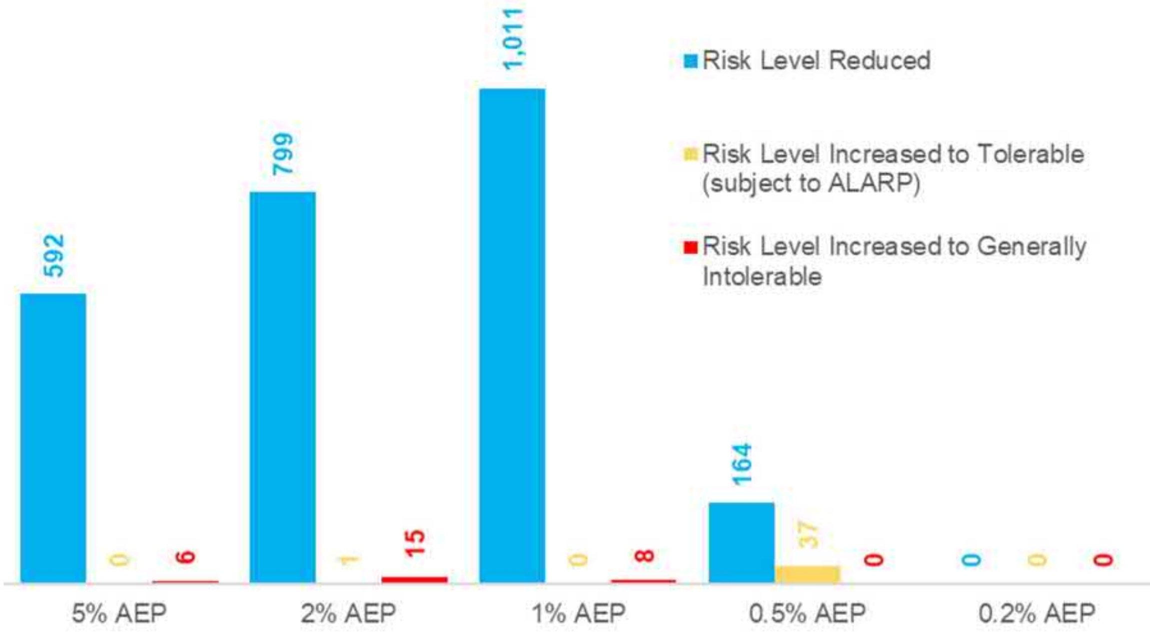


Figure 15 Categorised Impacts and Benefits to Building Risk Levels

4.9.2 Cumulative Risk Level

The sum of the risk level accumulated at each building are summarised in Table 22 and Table 23 with the change quantified in Table 24.

Table 22 Cumulative Risk – Existing Conditions

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	Total
Broadly Acceptable	14,136	13,312	6,173	3,646	8,525	*45,792*
Tolerable, subject to ALARP	30	42	1,717	14,087	0	*15,876*
Generally Intolerable	17,236	28,114	18,461	0	0	*63,811*
Total	*29,372*	*38,186*	*24,036*	*16,035*	*7,687*	***125,478***

Table 23 Cumulative Risk – Post-SRFL Construction Conditions

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	Total
Broadly Acceptable	14,882	14,212	7,123	3,796	8,390	*48,402*
Tolerable, subject to ALARP	218	456	431	13,515	0	*14,620*
Generally Intolerable	7,460	15,214	11,423	0	0	*34,097*
Total	*21,704*	*28,166*	*17,664*	*15,693*	*7,579*	***97,119***

Table 24 Difference in Cumulative Risk Level between Assessed Conditions

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	Total (%)
Broadly Acceptable	**+746 ▲**	**+900 ▲**	**+950 ▲**	**+150 ▲**	**-135 ▼**	***+2,611 ▲ (+6%)***
Tolerable, subject to ALARP	**+188 ▲**	**+414 ▲**	**- 1,286 ▼**	**- 572 ▼**	**-**	***-1,256 ▼ (-8%)***
Generally Intolerable	**-9,776 ▼**	**-12,900 ▼**	**-7,038 ▼**	**-**	**-**	***-29,714 ▼ (-47%)***
Total	*-8,842 ▼*	*-11,586 ▼*	*-7,374 ▼*	*-423 ▼*	*-135 ▼*	***-28,359▼ (-23%)***

The results presented in Table 22 and Table 23 have been plotted in Figure 16 to visualise the change shown in Table 24. In summary:

- Construction of the SRFL is responsible for a 47% reduction in 'Generally Intolerable' risk and a 23% reduction of overall risk.
- The largest benefits are realised in the more frequent events, i.e. the 5%, 2% and 1% AEP.
- More than half (54%) of the risk remaining post-SRFL construction is within the 5% and 2% AEP events.

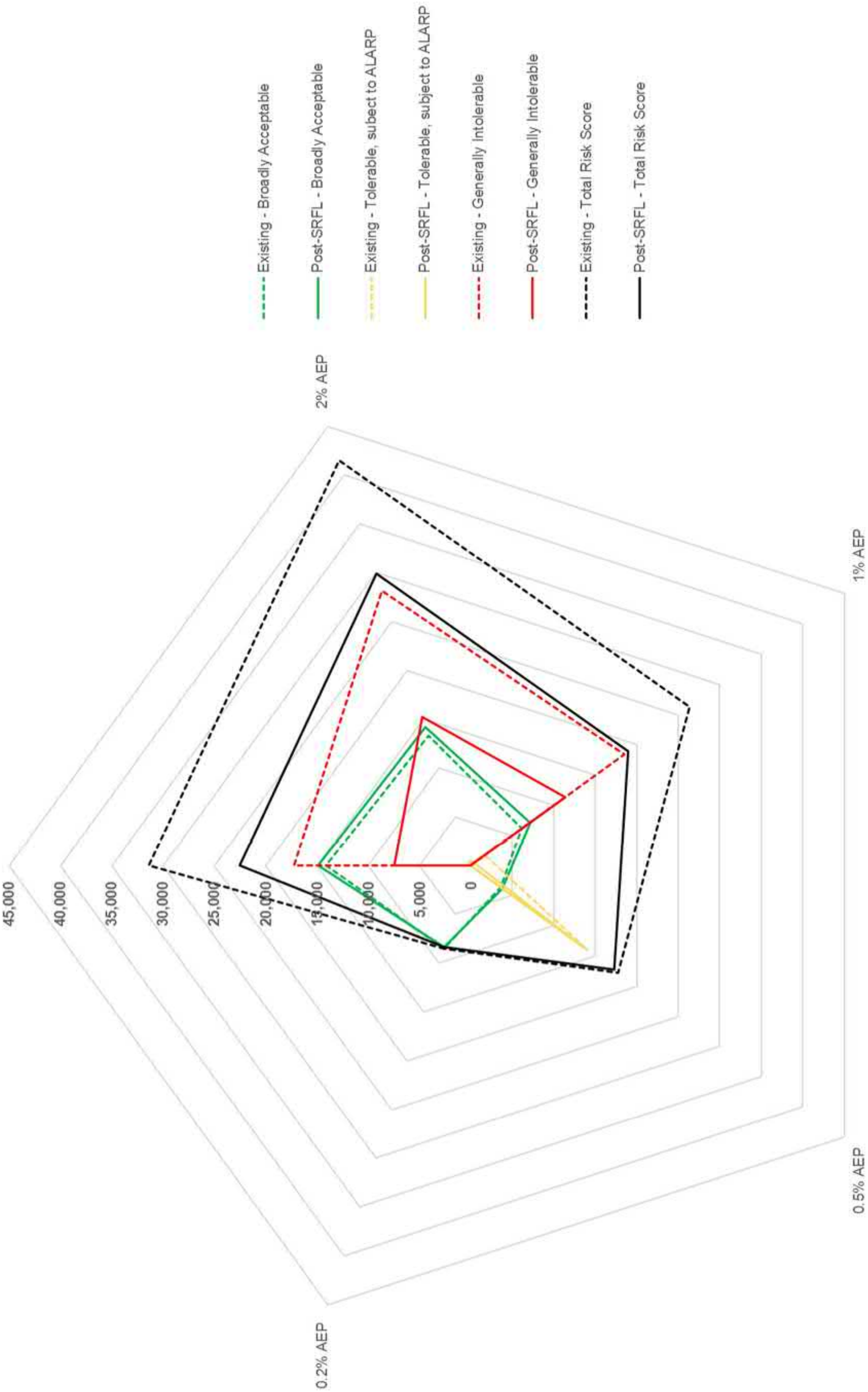


Figure 16 Cumulative risk for pre- and post-SRFL construction conditions

4.10 Sensitivity Analysis

A range of sensitivity analyses have been undertaken for the tolerability scoring in order to understand the potential effects of incorporating spatially delineated data for:

- Community Awareness / Understanding, Perception of Hazard and Preparedness.
- Emergency Management Procedures / Evacuation.

Currently, the assessment detailed in previous sections of this report has assigned a tolerability score of 0 for buildings which are within the flood hazard and are not protected by some form of mitigation.

The sensitivities are as follows:

Sensitivity 1 → Community are partially aware, resilient and have limited preparedness & evacuation procedures in place. Minimum tolerability score of 1.

Sensitivity 2 → Community are moderately aware, resilient and have acceptable preparedness and evacuation procedures in place. Minimum tolerability score of 2.

Sensitivity 3 → Community are generally aware, resilient and have strong preparedness and evacuation procedures in place. Minimum tolerability score of 3.

The results for each sensitivity have been summarised in Table 25 to Table 27. The results demonstrate the effect of each case on the categorised benefits and impacts of the SRFL. In summary:

- Cumulative benefits reduce by up to 12% with increasing tolerability.
- Up to 3 additional buildings see their risk level increased to 'Generally Intolerable' in Sensitivity 1. Aside from this case, impacts reduce with increasing tolerability.
- Impacts to building risk levels are completely absent during the 0.5% AEP event and significantly reduced during the 1% AEP event in Sensitivity 3.

Table 25 Sensitivity 1 – Categorised Impacts and Benefits to Building Risk Levels

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Risk Level Reduced	592	799	1,009	132	0
Risk Level Unchanged	9,169	8,952	8,747	9,598	9,767
Risk Level Increased to Tolerable, subject to ALARP[1]	0	1	0	37	0
Risk Level Increased to Generally Intolerable[1]	6	15	11	0	0

[1] Results have been cross-checked between assessed likelihoods to remove double-counting.

Table 26 Sensitivity 2 – Categorised Impacts and Benefits to Building Risk Levels

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Risk Level Reduced	590	796	929	56	0
Risk Level Unchanged	9,171	8,956	8,822	9,688	9,767
Risk Level Increased to Tolerable, subject to ALARP[1]	0	0	8	23	0
Risk Level Increased to Generally Intolerable[1]	6	15	8	0	0

[1] Results have been cross-checked between assessed likelihoods to remove double-counting.

Table 27 Sensitivity 3 – Categorised Impacts and Benefits to Building Risk Levels

Category	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Risk Level Reduced	590	796	877	0	0
Risk Level Unchanged	9,171	8,956	8,881	9,767	9,767
Risk Level Increased to Tolerable, subject to ALARP[1]	1	0	9	0	0
Risk Level Increased to Generally Intolerable[1]	5	15	0	0	0

[1] *Results have been cross-checked between assessed likelihoods to remove double-counting.*

5.0 Conclusion

A vulnerability and tolerability assessment was undertaken using the planning evaluation process detailed in Schedule 5 of QRA's Planning for stronger, more resilient floodplains: Part 2 – Measure to support floodplain management in future planning schemes (2012). This methodology includes assessment of the community's vulnerability and tolerability at a building-by-building basis and utilises exposure and likelihood to determine the risk level.

The assessment was undertaken for the pre- (existing) and post-SRFL construction conditions for the 5%, 2%, 1%, 0.5% and 0.2% AEP likelihoods in order to quantify the benefits and impacts of the SRFL to the community across a range of flood events.

The assessment showed that (in terms of **number of buildings**):

- Benefits heavily outweigh impacts across all events.
- The 1% AEP event realises the most benefited buildings.
- A total of 38 building's risk level are anticipated to increase to 'Tolerable, subject to ALARP'.
- A total of 29 building's risk level are anticipated to increase to 'Generally Intolerable'.

Furthermore, the assessment identified that (in terms of **cumulative risk level**):

- Construction of the SRFL is responsible for a 47% reduction in 'Generally Intolerable' risk and a 23% reduction of overall risk.
- The largest benefits are realised in the more frequent events, i.e. the 5%, 2% and 1% AEP.

Limitations and constraints within this assessment surrounded the availability of:

- Spatial data of Community Awareness / Understanding, Perception of Hazard and Preparedness.
- Spatial data of Emergency Management Procedures / Evacuation.

Should these datasets become available at a suitable level of detail, this assessment should be updated to consider their effect on tolerability score. In the interim, a high-level investigation of potential effects on the assessment outcomes was undertaken in the form of sensitivities which showed that:

- cumulative benefits may reduce by up to 12% with increasing tolerability; and
- up to 3 additional buildings may see their risk level increased to 'Generally Intolerable', although generally impacts reduce with increasing tolerability.

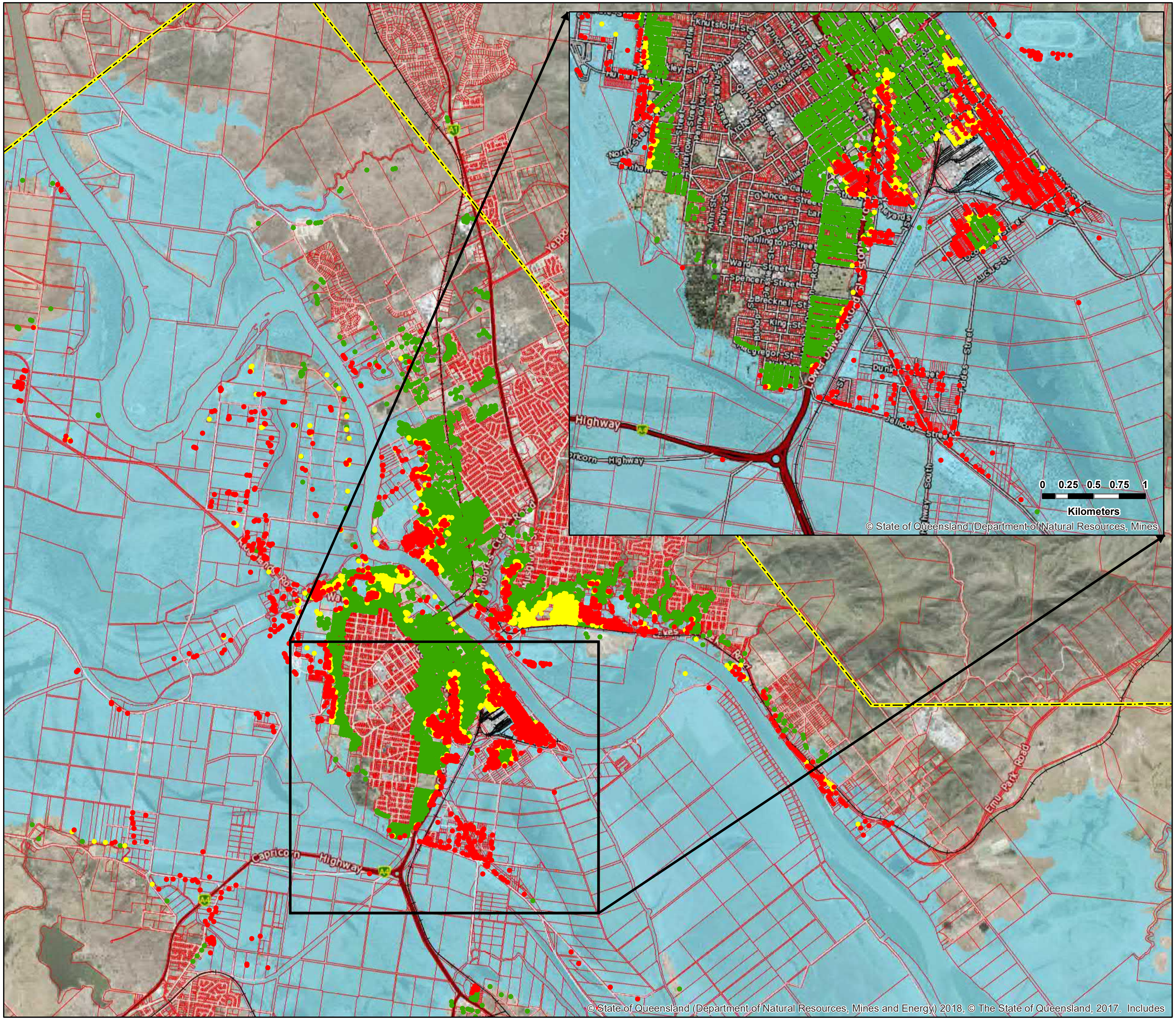
6.0 References

Australian Emergency Management Institute (2013), *Managing the floodplain: a guide to best practice in flood risk management in Australia – Handbook 7*.

Queensland Reconstruction Authority (2012), *Planning for stronger, more resilient floodplains: Part 2 – Measure to support floodplain management in future planning schemes*.

Appendix A

A3 Mapping



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 1 2 3

Kilometers

1:67,500
(when printed at A3)

AECOM
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LEGEND

Risk Level

- Generally Acceptable
- Tolerable, subject to ALARP
- Generally Intolerable
- Hydraulic Model Boundary
- Cadastre
- 1% AEP Flood Extent

Data Sources:

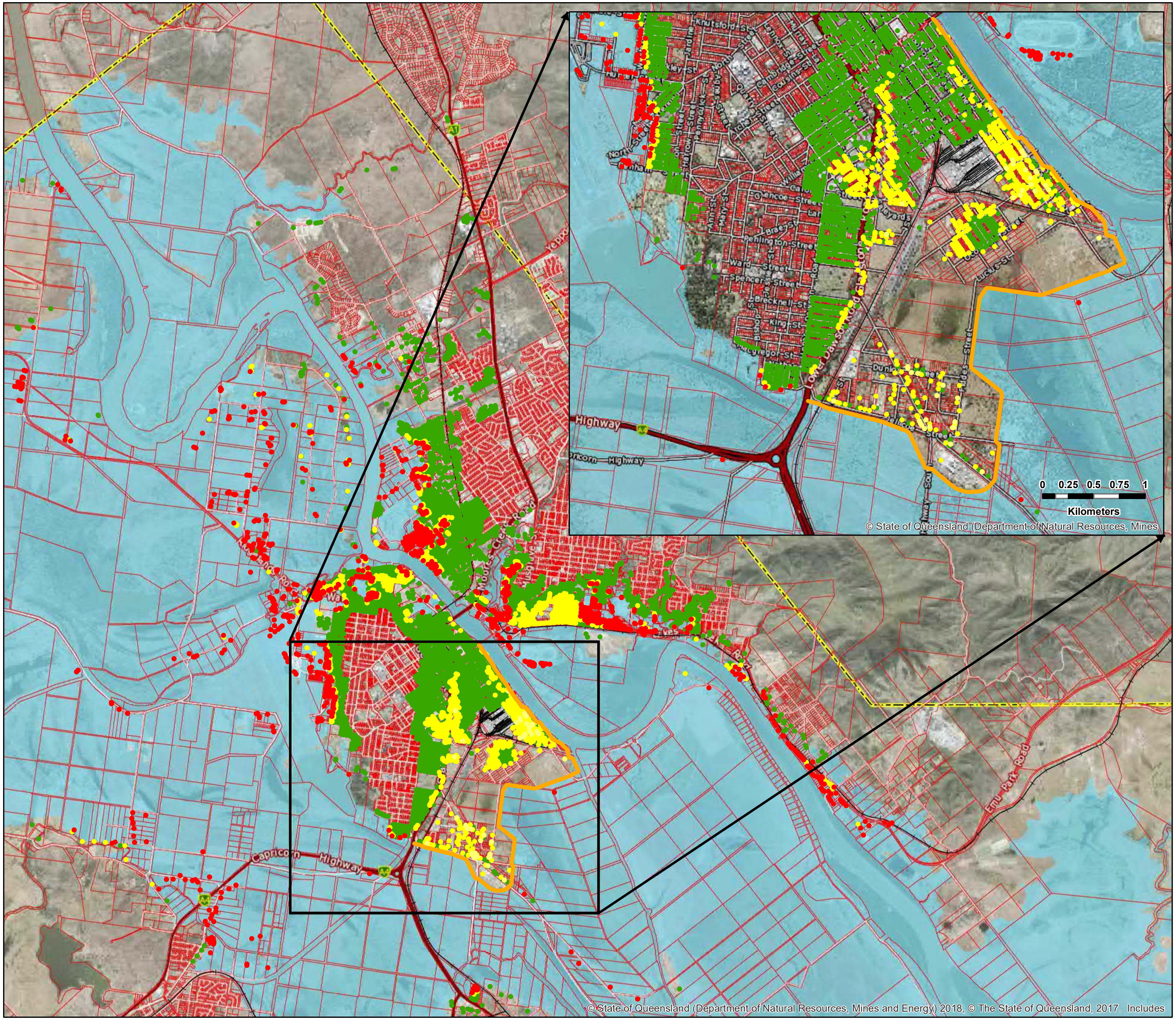
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

SOUTH ROCKHAMPTON FLOOD LEVEE

Risk Level Overview Existing Conditions (Pre-SRFL Construction)

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	17/04/2019
VERSION:	1

Figure A1



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Rockhampton Regional Council

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Kilometers

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AECOM
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LEGEND

Risk Level

- Generally Acceptable
- Tolerable, subject to ALARP
- Generally Intolerable
- Proposed Levee Alignment
- Cadastre
- Hydraulic Model Boundary
- 1% AEP Flood Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

SOUTH ROCKHAMPTON FLOOD LEVEE

Risk Level Overview
Developed Conditions
(Post-SRFL Construction)

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	17/04/2019
VERSION:	1

Figure A2

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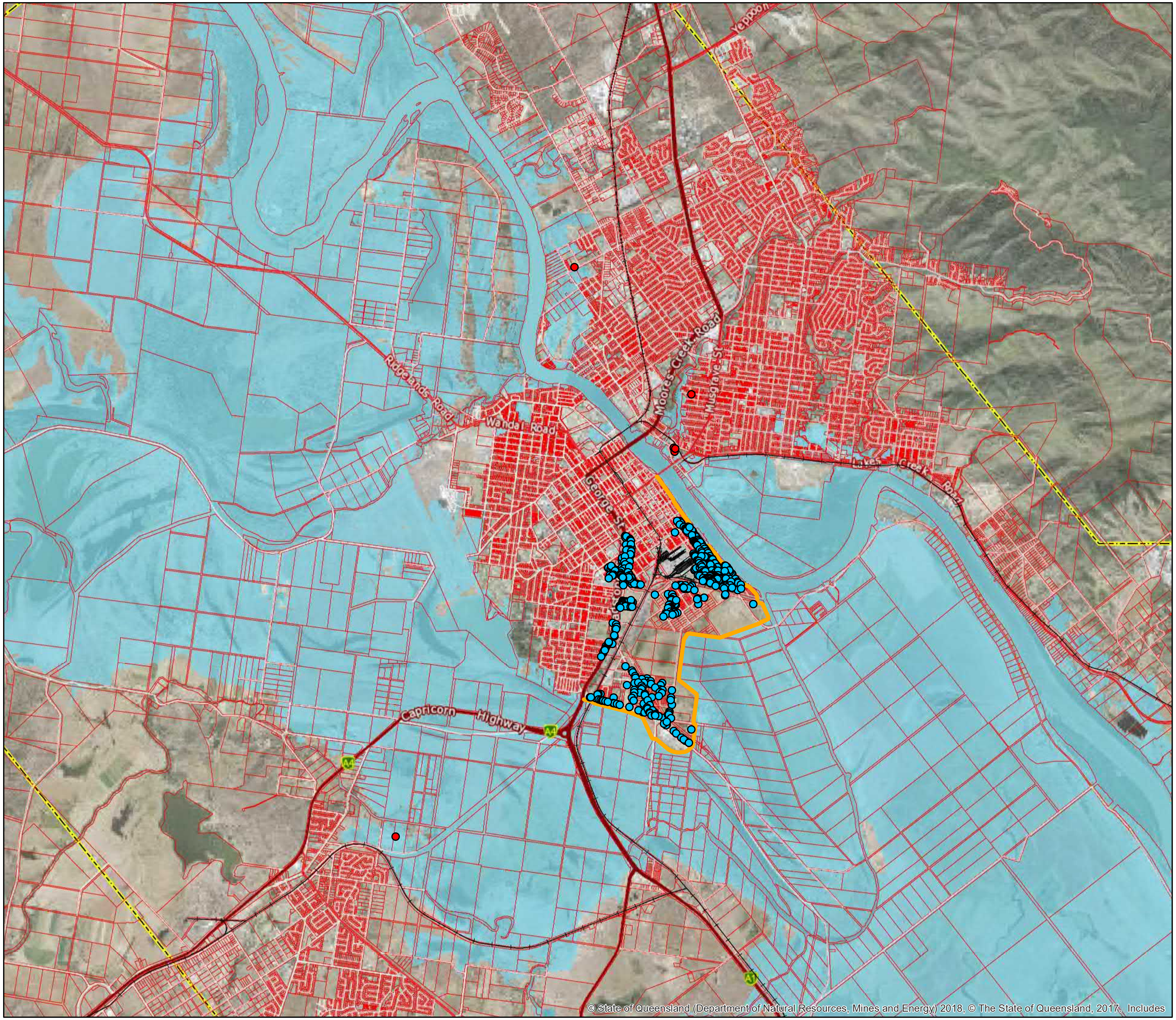

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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 1 2 3

Kilometers

1:60,000
(when printed at A3)

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LEGEND

Impact to Risk Level

- Unchanged (Not Shown)
- Reduced
- Increased to Tolerable, subject to ALARP
- Increased to Generally Intolerable
- Proposed Levee Alignment
- Cadastre
- Hydraulic Model Boundary
- 5% AEP Flood Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

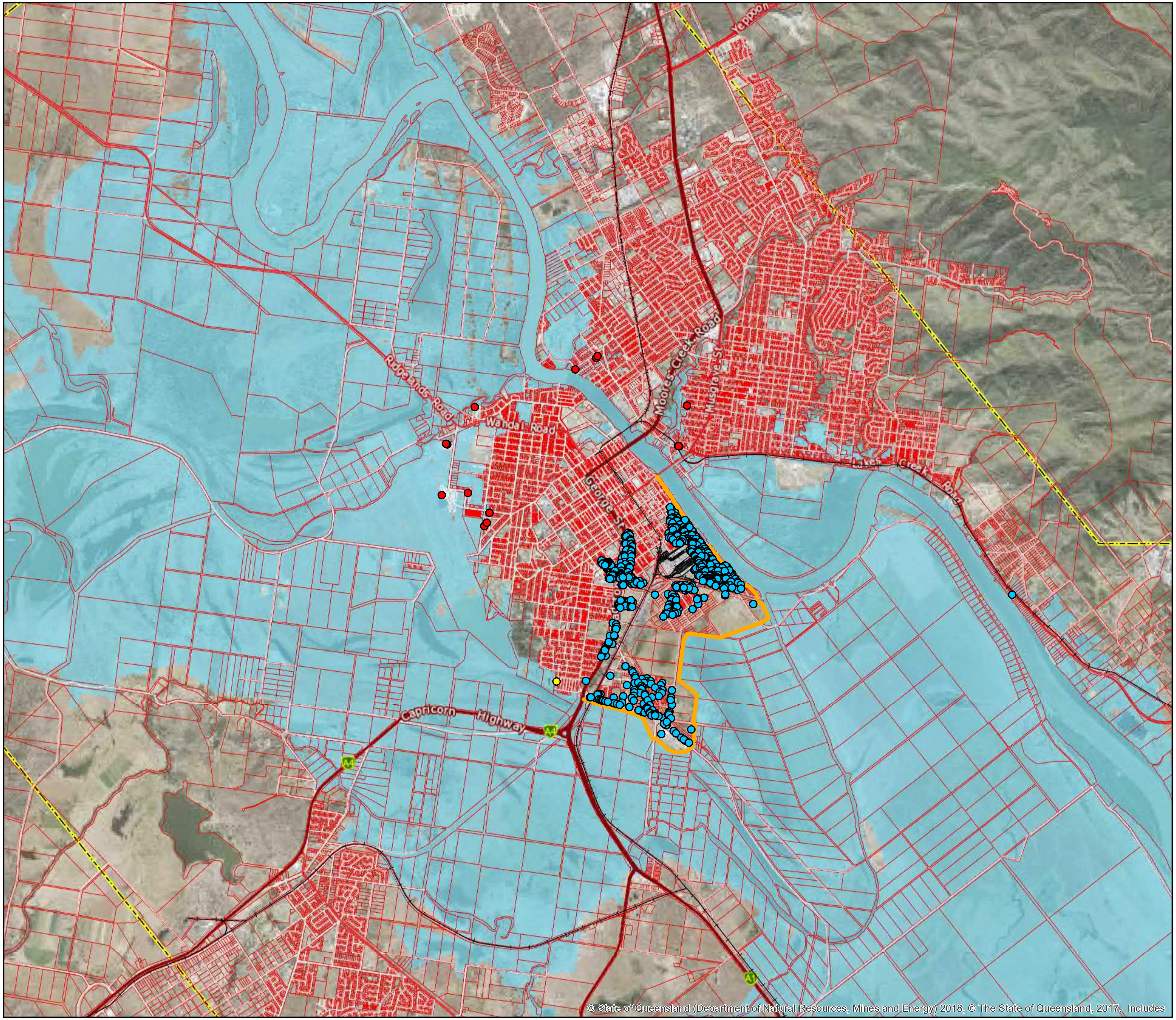
SOUTH ROCKHAMPTON FLOOD LEVEE

Risk Level Impact due to Construction of the SRFL
5% AEP Flood Event

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	17/04/2019
VERSION:	1

Figure A3

Filename: P:\605x\60589157\900_CAD_GIS\920_GIS\MXD's\Vulnerability and Tolerability Report\Figure A3.mxd



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 1 2 3
Kilometers

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(when printed at A3)

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LEGEND

Impact to Risk Level

- Unchanged (Not Shown)
- Reduced
- Increased to Tolerable, subject to ALARP
- Increased to Generally Intolerable
- Proposed Levee Alignment
- Cadastre
- Hydraulic Model Boundary
- 2% AEP Flood Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

SOUTH ROCKHAMPTON FLOOD LEVEE

Risk Level Impact due to Construction of the SRFL
2% AEP Flood Event

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	17/04/2019
VERSION:	1

Figure A4

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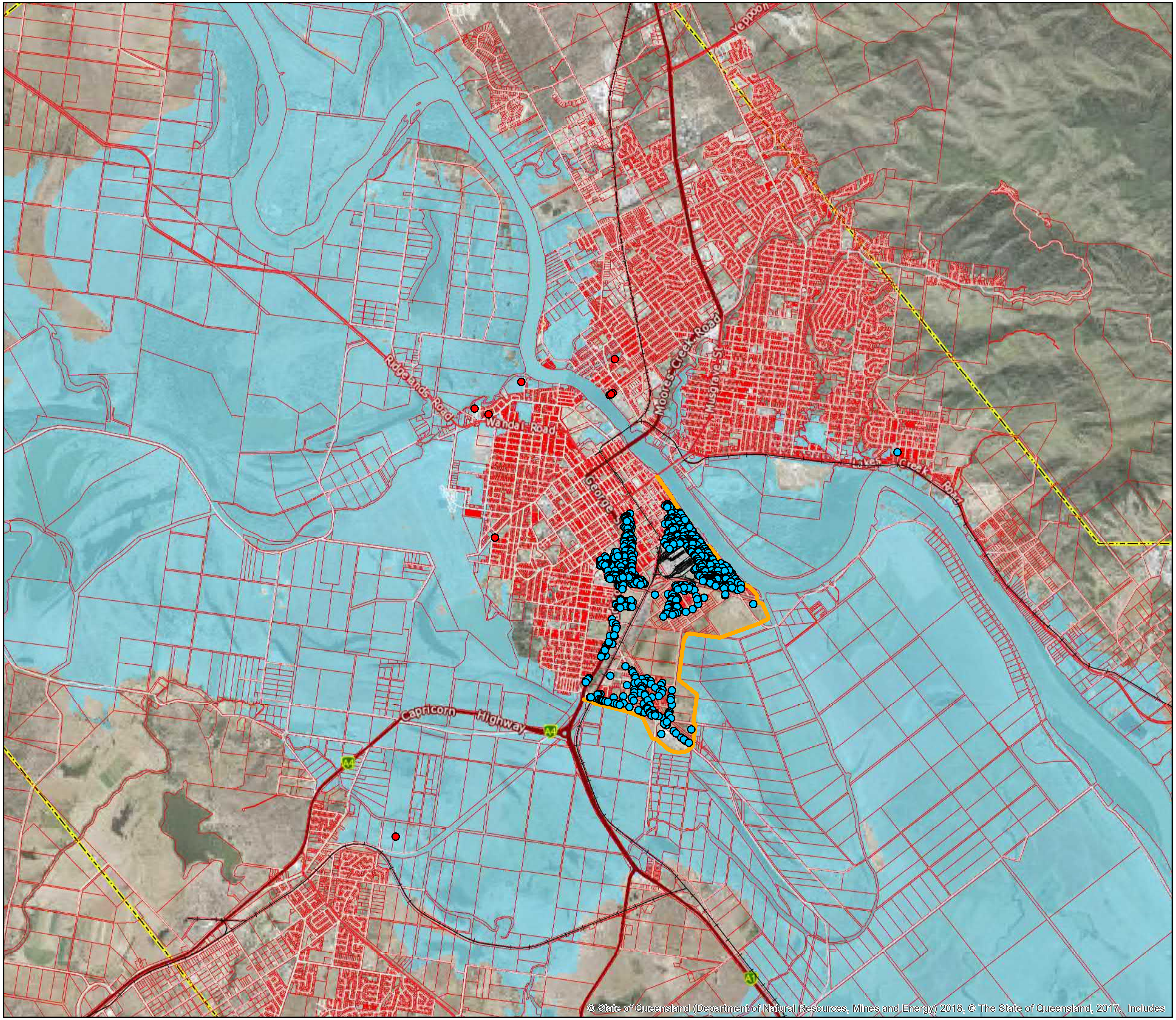

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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

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Kilometers

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(when printed at A3)

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LEGEND

Impact to Risk Level

- Unchanged (Not Shown)
- Reduced
- Increased to Tolerable, subject to ALARP
- Increased to Generally Intolerable
- Proposed Levee Alignment
- Cadastre
- Hydraulic Model Boundary
- 1% AEP Flood Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

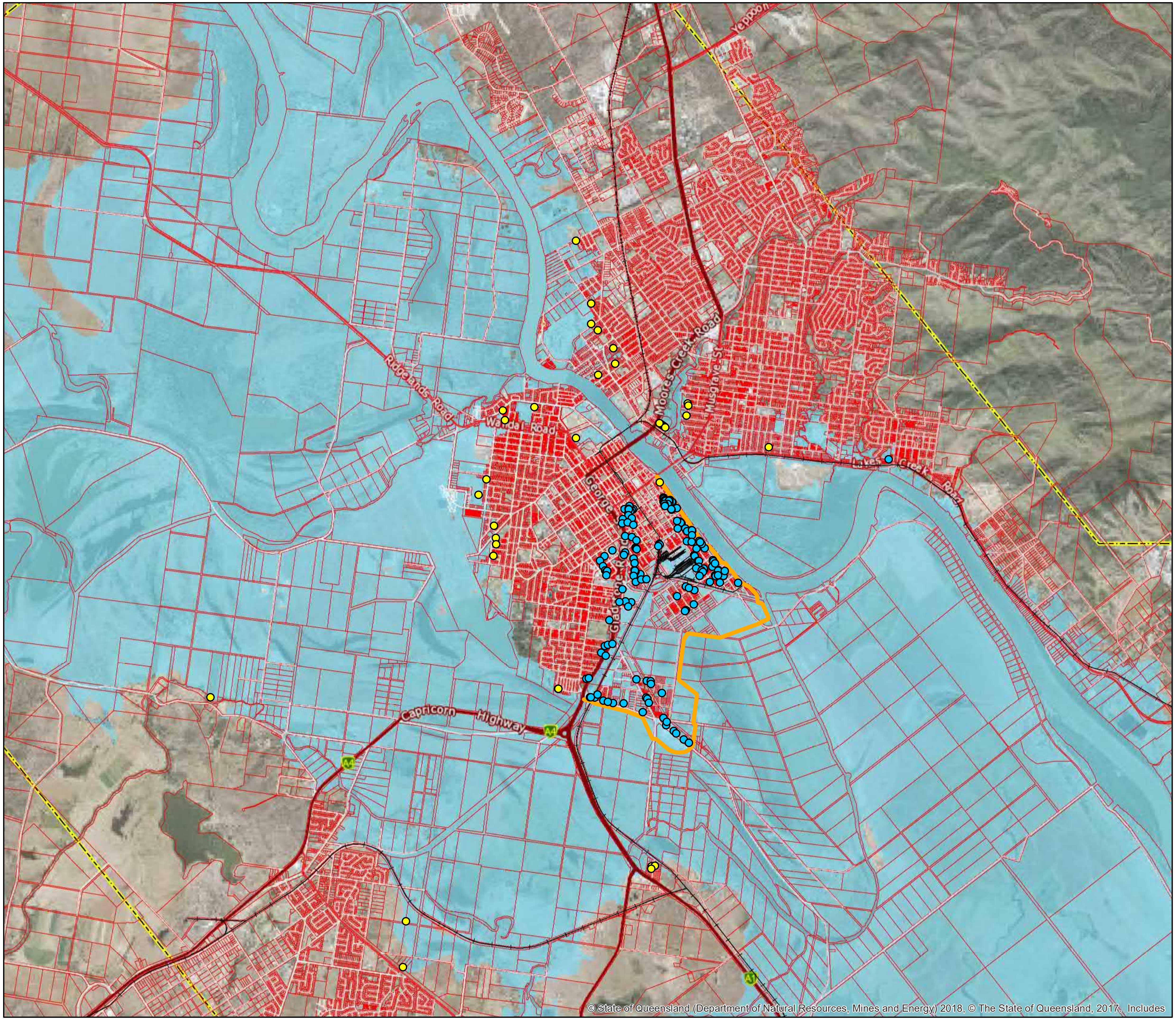
SOUTH ROCKHAMPTON FLOOD LEVEE

Risk Level Impact due to Construction of the SRFL
1% AEP Flood Event

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	17/04/2019
VERSION:	1

Figure A5

Filename: P:\605x\60589157\900_CAD_GIS\920_GIS\MXD's\Vulnerability and Tolerability Report\Figure A5.mxd



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 1 2 3
Kilometers

1:60,000
(when printed at A3)

AECOM
www.aecom.com

LEGEND

Impact to Risk Level

- Unchanged (Not Shown)
- Reduced
- Increased to Tolerable, subject to ALARP
- Increased to Generally Intolerable
- Proposed Levee Alignment
- Cadastre
- Hydraulic Model Boundary
- 0.5% AEP Flood Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

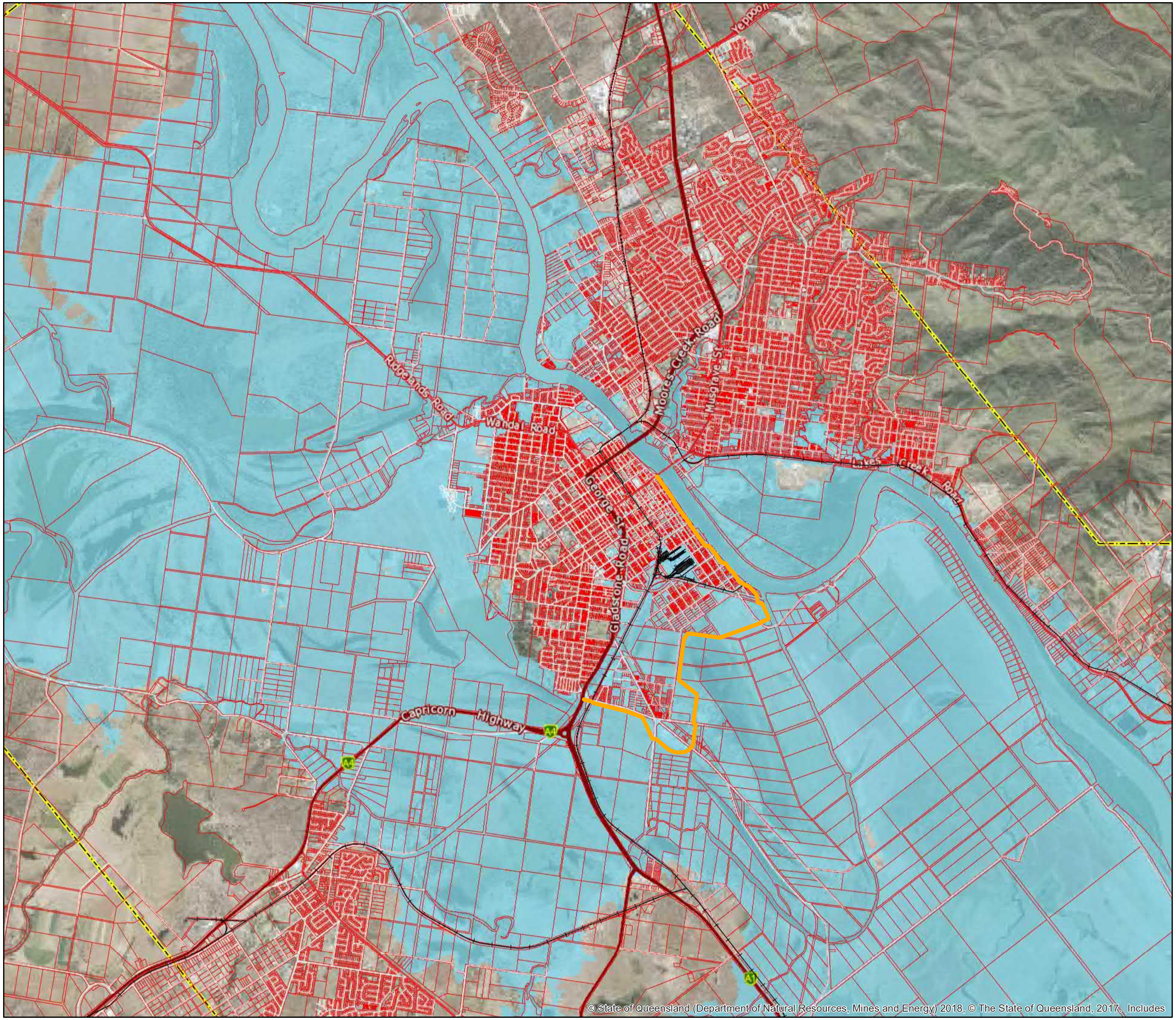
SOUTH ROCKHAMPTON FLOOD LEVEE

Risk Level Impact due to Construction of the SRFL
0.5% AEP Flood Event

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	17/04/2019
VERSION:	1

Figure A6

Filename: P:\605x\60589157\900_CAD_GIS\920_GIS\MXD's\Vulnerability and Tolerability Report\Figure A6.mxd



Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 1 2 3

Kilometers

1:60,000
(when printed at A3)

AECOM
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LEGEND

Impact to Risk Level

- Unchanged (Not Shown)
- Reduced
- Increased to Tolerable, subject to ALARP
- Increased to Generally Intolerable
- Proposed Levee Alignment
- Cadastre
- Hydraulic Model Boundary
- 0.2% AEP Flood Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

SOUTH ROCKHAMPTON FLOOD LEVEE

Risk Level Impact due to Construction of the SRFL
0.2% AEP Flood Event

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	17/04/2019
VERSION:	1

Figure A7

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