KINGBOROUGH COUNCIL

Blackmans Bay Catchment Resilience Project

Report




May 2020

M91000_002-REP-001-3

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1. INTRODUCTION

1.1 Overview

Engeny Water Management (Engeny) was engaged by Kingborough Council (Council) to undertake the Blackmans Bay Catchment Resilience Project (Blackmans Bay CRP). This project builds upon the Kingborough Stormwater System Management Plan (SSMP) previously completed by Engeny. The SSMP identified flooding hotspot areas and potential structural and non-structural flood risk management measures to reduce the existing flood risk. Blackmans Bay was identified to have areas of higher flood risk in comparison to other suburbs within the Kingborough Council local government area.

The Blackmans Bay CRP has utilised the broad scale assessment outcomes from the SSMP and included detailed hydrologic and hydraulic analysis and further investigation of flood risk management measures. Key objectives of the Blackmans Bay CRP were to:

- Provide up-to-date and improved understanding of the local catchment characteristics, drainage systems and overland flow behaviour as well as the likely causes of the severe flooding in the May 2018 event.
- Develop a catchment resilience program, to build resilience in the catchment to future storm events, through the identification of suitable flood mitigation measures inclusive of:
  - Structural measures
  - Non-structural measures (such as education, consultation, risk management etc.).
- Provide greater understanding of flood risks to enhance community awareness and resilience.

The Blackmans Bay study area is approximately 3.2 square kilometres. It is defined by complex stormwater network systems (approximately 2,200 individual pipes) quite commonly located within private property without easement provisions. The stormwater network drains to Blackmans Bay at numerous locations. The Blackmans Bay catchment location is shown in Figure 1.1.

Figure 1.1 Blackmans Bay Catchment Location

1.2 Background

The Blackmans Bay CRP was commissioned in response to flooding experienced in the catchment in 2018. A Community Recovery and Resilience Grant from the state government was received to fund this project. It also builds upon recommendations made in the *Kingborough SSMP* (Engeny, 2020), that further supported the need for a CRP. Key findings relating to Blackmans Bay in the SSMP were:

- Of the 33 identified flooding hotspots in the SSMP, 15 were located within Blackmans Bay.

- Roslyn Avenue and Pearsall Avenue, and Blowhole Road are two Blackmans Bay locations that were identified within the six highest ranked structural mitigation measures in the LGA and therefore further investigation into these measures have been undertaken in the CRP.

As a result of these findings, the following recommendations were made in the SSMP relating to works to be undertaken in the CRP:

- Undertake a CRP that considers and builds upon the outcomes from the Kingborough SSMP, including a more detailed investigation of key hotspots to quantify flood risks and determine suitable mitigation measures.

- Undertake further investigation of mitigation measures identified in the SSMP in a CRP.

1.3 Scope of Works

The scope of works for the project are broken into four (4) key milestones as summarised below.

- Milestone 1
  - Project inception meeting
  - Site investigation
  - Data collection and review

- Milestone 2
  - Development of hydrologic and hydraulic models
  - Simulation of design, sensitivity and climate change events
  - Identification and evaluation of flood mitigation measures
  - Mitigation measure cost estimates
  - Prioritisation of mitigation measures
  - Draft Blackmans Bay Catchment Resilience Project

- Milestone 3
  - Final Blackmans Bay Catchment Resilience Program

- Milestone 4
  - Review, acceptance and endorsement of Final Blackmans Bay Catchment Resilience Project.

2. PROJECT INPUT DATA

2.1 Site Investigation

A site visit was conducted on the 10th October 2019 to provide a detailed understanding of existing drainage assets and flooding patterns. From the site visit an appreciation of the opportunities and constraints for flood mitigation works was developed. Key observations from the site visit include:

- Many inlet pits are less than 500 mm deep.
- Insufficient pit capacity is observed throughout the catchment, with pit lintels less than 1.5 m long with small or absent grate (e.g. side entry only).
- Overland flow paths within properties are not maintained, without easements, and are often built over or obstructed.
- Overland flow paths in the catchment are steep, often in exceedance of 5%.

2.2 Project Data

The following key datasets were made available for use in the study:

- Previous studies – *Kingborough Council Stormwater System Management Plan* (Engeny, 2020)
- Aerial imagery from Land Information Systems Tasmania (LIST) and Google Earth were used for the study
- Mt Wellington and the Derwent 2010 1m LIDAR dataset was utilised for the model topography
- The stormwater pipe and pit network data were supplied by Council. A gap-filling and cleaning process was undertaken, as described in Section 3.3. As constructed or design drawings for the following systems were also supplied by Council:
  - Brightwater Road – new stormwater network
  - Survey of existing stormwater in the north-western side of Blackmans Bay
  - Bluebush Crescent – new stormwater network associated with new development.

3. HYDROLOGIC AND HYDRAULIC MODELLING

3.1 Overview

Combined hydrologic and hydraulic modelling has been undertaken to confirm locations of flooding hotspots identified in the *Kingborough Council Stormwater System Management Plan* (Engeny, 2020), and inform the design of drainage improvement measures.

3.2 Hydrologic Model Development

3.2.1 Introduction

The key objective of hydrological modelling was to produce rainfall excess hydrographs for use in the TUFLOW hydraulic model. The XPRAFTS hydrologic model package was simulated to generate inflow hydrographs for the 1% and 5% AEP storm events using methodologies recommended by AR&R 2019.

The following sections describe the key tasks and assumptions in the development of the XPRAFTS hydrological model.

3.2.2 Catchment and Sub-Catchment Delineation

A total of 84 sub-catchments were delineated across the Blackmans Bay catchment, with consideration given to land-use type and the characteristics of the drainage system. The sub-catchment delineation is shown in Figure 3.1.

Aerial data and the LIST land use GIS layer were utilised to determine the fraction impervious per catchment. The adopted fractions impervious are summarised in Table 3.1.

Table 3.1 Fraction Impervious

LIST Land Use Type	XPRAFTS Adopted Fraction Impervious
Utilities	60%
Open Space	0%
Low Density Residential	60%
General Residential	80%
Environmental Living	10%
Environmental Management	5%
Community Purpose	40%

LIST Land Use Type	XPRAFTS Adopted Fraction Impervious
Recreation	20%
Local Business	90%
Road	90%

C003
C120
Stirling Avenue
C110
C002
C126
C109
Hiern Road
C100
C108
C021
C111
C102
C107
C106
C101
C121
C105
C122
C022
C042
Algona Road
C046
C047
C094
C104
C040
C043
C048
C031
C049
C050
C001
C051
C006
C045
C041
C044
C053
C035
C056
C032
C038
C036
C055
C037
C039
C123
C087
C088
C089
C007
C033
C083
C086
C085
C008
C080
C084
C018
C082
C079
C081
C064
C065
C078
C069
C009
C059
C067
C112
C062
C074
C060
C073
C077
C072
C124
C076
C071
C061
C070
C067
C066
C068
C010
C125

Legend

Catchments

Elevation (m ADH)

0
25
50
75
100

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ENGENY WATER MANAGEMENT

Kingborough

0 100 200 300 400 m

Scale in metres (1:8500 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 56

Blackmans Bay
Catchment Resilience Program

Figure 3.1
Catchment Delineation

Job Number:
M91000_002
Revision: 0
Drawn: JH
Checked: KM
Date: 22/1/2020

3.2.3 XPRAFTS Model Parameters

Table 3.2 provides a summary of the final parameters adopted for the Blackmans Bay hydrologic model. The following sections provide information on the methodology used to determine each parameter.

Table 3.2 XPRAFTS Parameters

Parameter	Value
M	-0.285
Bx	1
Initial Loss (Pervious Areas)	0 mm
Continuing Loss (Pervious Areas)	2.5 mm/hr
Initial Loss (Impervious Areas	0 mm
Continuing Loss (Impervious Areas)	0 mm/hr
Manning's "n" Value (Pervious Areas)	0.04
Manning's "n" Value (Impervious Areas)	0.025

Manning's Roughness Values

Manning's "n" roughness values have been selected for portions of impervious and pervious surfaces based upon aerial inspection of the catchment and comparison against industry standard values, such as Chow (1959).

Intensity-Frequency-Duration (IFD) Data

AR&R 2019 IFD data for the Blackmans Bay catchment was sourced from the Bureau of Meteorology using the online 2019 Rainfall IFD request system. Data was requested for the catchment centroid, represented by the coordinates of -43.002° south and 147.318° east. The individual stormwater network sub-catchments did not exceed 1 sqm, therefore no areal reduction factor was applied.

Temporal Rainfall Patterns

AR&R 2019 temporal patterns, downloaded from the AR&R Data Hub, were adopted for the XPRAFTS model. AR&R 2019 states that point temporal patterns should be used for catchments less than 75 km^2. As previously stated, the study catchment size for Blackmans Bay is 3.2 km^2 therefore, point temporal patterns were adopted.

Initial and Continuing Loss Model

The initial and continuing loss model was adopted for the study. The AR&R Data Hub provides estimates for initial and continuing losses. However, it was found that the adoption of the specified losses produced unreasonable results such as no runoff in the 5% AEP event for short duration storms. This is a similar finding to other studies conducted in Tasmania and more broadly across Australia.

Initial and continuing losses of 0 mm and 2.5 mm/h were adopted for pervious areas and no losses were adopted for impervious areas. These losses were selected based on the following:

- Consistency with recommendations by Cordery and Pilgrim (1983) for Tasmanian catchments (recommendation for continuing loss of 2.5 mm/h, with no available data for initial losses).
- Consistency with the Bellerive and Howrah SSMP where catchment characteristics (such as soils, land use and climate) are similar.

Rainfall Pre-Burst

The initial losses provided on the AR&R Data Hub are for complete storms (abbreviated as IL_s), however the IFD data provided by the BoM is for rainfall bursts only. To account for this difference, XPRAFTS hydrologic model applies the pre-burst depths to the model as recommended by AR&R 2019, and summarised in Table 3.3.

Table 3.3 Pre-Burst Rainfall Depths

Event Duration	5% AEP	1% AEP
< 60 minute	7.2 mm	4.6 mm
90 minute	4.6 mm	6.1 mm
120 minute	7.1 mm	4.9 mm
180 minute	7.7 mm	18.2 mm

3.3 Hydraulic Model Development

This section documents the methodology and investigations used by Engeny to develop a TUFLOW hydraulic model for the Blackmans Bay catchment. The key objective of hydraulic modelling was to develop a model capable of accurately depicting existing flooding conditions and to assess the effectiveness of potential flood mitigation works.

Model Extent and Topography

The entirety of the Blackmans Bay catchment has been modelled in TUFLOW. The 2010 1m LiDAR data has been used as the base topography and a cell-size of 3 m has been selected.

1-D Network Data Gap Filling

A review of Council's pit and pipe data was undertaken. Although the data was found to be incomplete, it was deemed sufficient for the purposes of this study. However, a gap filling process was required prior to the drainage assessment. A description of the data issues and adopted gap filling assumptions are summarised in Table 3.4.

Table 3.4 Pit and Pipe Data Gap Filling

Data Issue	Gap Filling Assumption
Approximately 1% of pipe diameters/dimensions missing	The missing pipe diameters/dimensions were filled based on the following hierarchy of information: 1. Key missing dimensions (major structures) were supplied by Council upon further data request. 2. Where upstream or downstream pipe sizes were known, the same size pipe as the downstream pipe was assumed. 3. Where there are no upstream or downstream pipe sizes, a pipe size based on a similar drainage catchment was assumed.
Approximately 60% of pipe invert levels missing	Pipe slopes were calculated based on the topographic slope where invert levels were unavailable or unrealistic.
Pit inlet and manhole invert levels not available	Pit inlet and manhole invert levels assumed to be the lowest invert level of the connecting pipes.
Pit inlet and manhole dimensions not available	Typical pit inlet dimensions were assumed based on site observations, discussions with Council and measurement of detailed aerial photography.
Unrealistic invert levels (e.g. pit and pipe invert levels 100 m above the surface)	Unrealistic invert levels were manually rectified based as follows: 1. Where the invert levels were approximately 10 or 100 times higher or lower than surrounding levels, it was assumed that this is a data entry error (e.g. 178 m AHD intended to be 17.8 m AHD) 2. Otherwise, invert levels were calculated based on 600 mm cover above the top of the largest connecting pipe.

Pits

Inlet pits have generally been modelled using the "Q" type pits, with a relationship between depth of ponding and inlet capacity calculated using a pit inlet capacity spreadsheet. The pit inlet capacity was modelled to be consistent with the Tasmanian IPWEA standard drawings for pits present in the catchment. Inflows at junction pits were allowed to reflect direct property connections to the drainage network.

Pit and Pipe Losses

A manhole layer within TUFLOW can be either automatically or manually created and used to apply the losses to the nodes created in the 1-dimensional network layers in a variety of different ways. Engeny used the automatically generated manhole layer, applying losses using the Engelund method. This method recalculates losses at each time step using the angle of the entry and exit culverts, water levels and flow distributions.

Surface Roughness

Within TUFLOW, a materials layer is utilised to define surface roughness information in the model. The adopted Manning's "n" values in the model were applied based on the LIST land use layer and are summarised in Table 3.5. Manning's "n" roughness values have been selected based upon consistency with industry standard values, such as Chow (1959) and recommendations made in AR&R 2019 for urban hydraulic modelling. Note that the values for residential values are high to replicate the obstructions that buildings, fences, vegetation etc. cause in residential areas.

Table 3.5 TUFLOW Surface Roughness

LIST Land Use Type	Manning's "n" Value
General Residential	0.35
Low Density Residential	0.15
Environmental Living	0.15
Community Purpose	0.06
Recreation	0.05
Open Space	0.06
Local Business	0.35
Utilities	0.05
Environmental Management	0.08

1D Boundary Conditions

The 1D boundary condition layer (1d_bc) has been used to read in XPRAFTS inflow hydrographs for the individual sub-catchments.

Some sub-catchments do not contain any pits and therefore flow cannot be applied to the model using 1D boundary conditions. In these instances, 2D source areas (2d_sa) were utilised.

2D Boundary Conditions

As part of the 1D network, 2D SX (source of flow from a 1D model) boundaries were assigned to the pits to allow surcharge of water from the pipe network to the 2D surface.

The downstream boundary of the model has been set as a HT (head versus time relationship) type. The level set at this downstream boundary was 0 m AHD, to allow free-flow conditions at the downstream boundary.

3.4 Base Case Results

The hydraulic and hydrologic models were simulated for the 5% and 1% AEP flood events, for durations ranging from 10 minutes to 180 minutes, for the full suite of ten ensemble temporal patterns as recommended by AR&R 2019.

Base case flood depth mapping is provided in Appendix A, and discussion of hotspot identification is provided in Section 4. A filtering process has been applied to the base case scenario results in order to improve the legibility of the overland flow path mapping. The filtering criteria was as follows:

- Exclude flood depth x velocity products <0.02 m^2/s
- Exclude flood depths <0.05 m
- Exclude ponds <500 m^2 in area.

3.4.1 Summary of Catchment Behaviour

Hydraulic modelling has identified the following flooding behaviour characteristics in the Blackmans Bay catchment:

- Peak flood conditions occur in the catchment during short, high intensity storms. An inspection of the results indicated that the critical duration is predominantly 30 minutes for the 1% AEP storm. This is due to the small and steep nature of catchments in Blackmans Bay.

- Commonly, the capacity of the underground pipe network is exceeded in both the 5% and 1% AEP flood events and significant overland flow of significant depth and hazard is observed through properties, where no drainage easement or channel is present.
- In numerous locations where flow is contained with the road reserve, flood hazard and depth exceed safe vehicle trafficability limits for both the 5% AEP and 1% AEP flood events.
- Generally, flood risk increases towards the bottom of the localised catchments. Specifically, identified hotspots are discussed in Section 4.3.1.

3.4.2 Summary of 2018 Flood Event Behaviour

On the 11th May 2018, 140 millimetres was recorded at the Blackmans Bay Treatment Plant gauge (094163). Analysis of the rainfall IFD information indicated that this event was approximately between a 5% AEP and 2% AEP flood event if considering the 24-hour rainfall. However, this event was an extreme flash flooding event and the 24-hour rainfall may not adequately represent the intensity of the event. As a comparison, the pluviograph site at Hobart recorded a 2-hour rainfall that was approximately a 0.05% AEP event. The 24-hour rainfall total at Blackmans Bay was larger than that recorded at Hobart. As such, the flood impact experienced on May 2018 may have been greater than the 1% AEP event.

3.5 Calibration

Inspection of available rainfall pluviograph stations revealed that there are no stations within a suitable distance of the Blackmans Bay catchment that allows for adequate replication of the identified May 2018 flood event. Additionally, there were no available flood height records from the event. Without the availability of suitable rainfall and flood level/depth records, hydrologic/hydraulic model calibration could not be undertaken.

3.6 Sensitivity and Climate Change Analyses

The following sections outline the sensitivity analyses performed on the model. Of the climate change analysis and the two sensitivity analyses undertaken, the model appears to be most sensitive to climate change (increase in rainfall intensity).

3.6.1 Climate Change Analysis

A climate change scenario of 30% increase in rainfall intensity was modelled for the 1% AEP flood event. This selection has been informed by modelling undertaken for Climate Futures Tasmania (White et.al., 2012) which indicated that the intensity of the 1% AEP 24 hour rainfall event may increase by 10-30% by 2100 and is also consistent with the Browns River Flood Study and other studies in Tasmania. This climate change analysis has only considered increase in flood risk due to increased rainfall and does not take into account sea level rise.

Flood mapping for the climate change scenario (shown as flood afflux from the base case scenario) is provided in Appendix B. The effects of increased rainfall are more predominant in the lower portions of Blackmans Bay catchment, where flood depths are greater. Flood depths are expected to increase from anywhere in the range of 15 mm (roads, upper catchment) to 200 mm (lower catchment, deeper base case depths).

3.6.2 Sensitivity Analyses

Two separate sensitivity analyses have been undertaken using the 1% AEP base case hydraulic model to assess uncertainty in the modelling assumptions. These scenarios were as follows:

- Increase in model domain roughness. This has been applied as a 20% increase to the Manning's "n" roughness values.
- A blockage factor for hydraulic structures (i.e. pits). Guidance in Book 9 of AR&R 2019 states that a blockage factor of 50% is generally applied for sag pits where experimental or observational data is not available. This value can be reduced for on-grade pits, however, for the purpose of the sensitivity analysis a value of 50% has been adopted, which is reasonable given the presence of vegetation observed in the catchment.

Flood mapping for the sensitivity analysis scenarios (shown as flood afflux from the base case scenario) are provided in Appendix B. The blockage scenario causes greater increases in flood depths than the increase in Manning's "n" roughness values. Under the increase in model roughness scenario, increases in flood depth of only up to 20 mm are observed, with no clear determining factor for larger increases in flood depth. For blockage, larger increase in flood depth are observed in the lower catchment, with increases across the entirety of the catchment ranging from 15 mm to 150 mm.

4. FLOOD MITIGATION MEASURES

Managing stormwater and any associated flood risk is important to improve community resilience to flooding and limiting flood risk growth which may occur from increased development and climate changes. Achieving effective management within the Kingborough Council LGA should involve encouraging or promoting the:

- Inclusion of stormwater management outcomes in policies, planning instruments and forward plans.
- Management of existing, future and residual flood risk for the local community using a range of suitable measures.
- Engagement with, and active participation of, the local community in managing the flood risks they face.
- Identification, assessment and implementation of feasible, practical and effective options to treat intolerable risks to the existing community, considering their social, environmental and economic benefits and costs, and their sustainability.

Generally, flood risk management opportunities are broadly separated into three (3) categories; property modification measures, response modification measures and flood behaviour modification measures.

Effective strategies often include a combination of measures rather than focusing only on the most favoured measure. Details regarding the potential implication of each measure is discussed, along with its suitability to Blackmans Bay. A full range of flood mitigation measures were considered as summarised below.

4.1 Flood Response Modification

The suitable flood response modification measures, referred to herein as emergency management measures, suitable to the Blackmans Bay catchment are outlined as follows.

4.1.1 EM1: Flash Flood Warning System

Flash flood warning systems are utilised to provide advanced warning that flooding is expected to occur in a defined area as a result of forecasted extreme rainfall. They can be utilised in areas such as Blackmans Bay where the advance warning time for flood conditions is short due to the small, steep catchments present in the area.

The suitability or ability for a flash flood warning system to be utilised in Blackmans Bay requires significant analysis of available gauging and historical hydrologic behaviour. Another driving aspect for consideration is whether appropriate communication system infrastructure is available (i.e. phone, SMS) to disseminate flood warnings. A summary of the investigations that would need to be completed to determine whether a flash flood warning system is suitable includes:

- Collation and review of all available historical rainfall records and available flood surveys (i.e. debris survey).
- Review of government-provided rainfall warning information.
- Review of Council infrastructure available or to be acquired in order to disseminate flash flood warnings.
- Detailed combined hydrologic and hydraulic modelling of historical events, investigating response times between rainfall event start and corresponding flooding.
- Recommendation for development of a flash flood warning system to be based upon if suitable delay is present between start of rainfall events and observed flooding in the catchment.
- Consideration of capital expenditure required.

A clear recommendation for a flash flood warning system cannot be made based upon the current available information, however, a further detailed investigation into the suitability of a flash flood warning system should be considered by Council, with consideration of outcomes from the Multi-Criteria Analysis as presented in Section 6.2.

4.1.2 EM2: Evacuation and Emergency Access

Assessment and provision of information regarding the preferred key evacuation routes from the most flood affected areas of Blackmans Bay should be made available to emergency services and the public via an online platform. Identification of localities vulnerable individuals (such as the elderly or disabled) could contribute to suitable evacuation routes.

To provide comprehensive evacuation and access information, the flood modelling undertaken for this report should be expanded to cover a magnitude of AEPs, in order to provide sufficient information linking flood/rainfall magnitude to expected inundation depths and access road immunity. With road immunity information, preferred access routes can be marked either via mapping or physically via street signage.

Utilising the results from the flood modelling undertaken for this study, preferred access routes surrounding areas of high flood risk during a 1% AEP flood event have been identified as indicated on Figure 4.1. On this figure, road locations along the key routes (roads classified as arterial road, collector road in road hierarchy) where the flood hazard rating becomes non-trafficable (ZAEM1 classification of H2) in a standard 30 minute storm (critical duration for the catchment) have been identified, and the approximate duration for which the road remains non-trafficable. Generally, given the small, steep catchments of Blackmans Bay, it is expected that periods where key access routes are non-trafficable are expected to be short (<40 minutes).

This mitigation option could be further enhanced by the installation of live-feed cameras located at crossings where high flood hazard occurs, in order for the public to view the flooding conditions on their access routes via an on-line portal and dashboard and seek alternative access. The recommended locations for these cameras are identified on Figure 4.1; which are Algona Road, Roslyn Avenue and Pearsall Avenue.

An online platform containing information regarding key evacuation routes should be considered by Council, with consideration of outcomes from the Multi-Criteria Analysis as presented in Section 6.2.

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ENGENY WATER MANAGEMENT

Kingborough

0 75 150 225 300 m

Scale in metres (1:7000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 56

Blackmans Bay
Catchment Resilience Program

Figure 4.1
Access Route Assessment

Job Number: M91000_002
Revision: 0
Drawn: JH
Checked: KM
Date: 27/2/2020

4.1.3 EM3: Increase Community Flood Awareness

A requirement of the Urban Drainage Act 2013 is for Council to maintain publicly available maps showing all public stormwater systems. To meet the requirements of the Act, Council should therefore:

1. Consider making flood mapping and the stormwater network layers available in hard copy form at key Council locations including the Civic Centre.

2. Integrate the Council GIS system with interactive online mapping to ensure information is available, consistent and up to date.

Further, community information sessions or a flood awareness campaign (such as sending out letters, pamphlets) held in advance of the wet season should be considered to increase flood awareness. These sessions could also be utilised to identify vulnerable populations, with specific flood advice to be disseminated to these people. Increasing community awareness should be undertaken by Council, with consideration of the outcomes from the Multi-Criteria Analysis as presented in Section 6.2.

4.1.4 EM4: Provide Email Address for the Community to Submit Flood Event Information

The accuracy of flood models is generally limited by the availability of historical flood data. An email address for the community to submit photos and videos of storm events or any other information should be setup to assist in any future flood risk investigations. This email should be disseminated to the community via letters and pamphlets. The intent of this information is for internal Council information only. Any improved flood information resulting from the submission of information should be disseminated as part of Measure EM3.

4.2 Property Modification

The applicable property modification measures, referred to herein as land use planning and development control measures, applicable to the Blackmans Bay catchment are outlined below.

Flood behaviour through the Blackmans Bay catchment is characterised by overland flow through residential properties, where stormwater infrastructure upgrades and flood modification are not possible. Alternatively, property modification measures look at reducing exposure of buildings and population to flood risk.

4.2.1 LP1: Zoning and Development Control

Ensure stormwater systems for new development are designed in accordance with the Tasmanian Subdivision Guidelines (LGAT, 2013) or a Kingborough Council Stormwater Code (which should be developed). Improving the design of new stormwater systems is significantly more cost effective than rectifying poorly designed stormwater systems. The Tasmanian Subdivision Guidelines (LGAT, 2013) provides guidance on stormwater design

in Tasmania, however it is also strongly recommended that Council consider adopting a stormwater management guideline/code or policy to support the planning scheme in managing future development.

Based on the drainage issues identified in the existing stormwater system, the key design considerations which should be formalised in a stormwater management code are as follows:

- Ensure provision of overland flow paths for major events to ensure that provision is made to allow stormwater flow up to a 1% AEP storm to flow overland within an easement without undue inundation to any properties.
- Potential locations where Council could consider easement acquisition where significant flood hazard is present, and where built obstructions are minimal, are identified on Figure 4.2 and Figure 4.3.
- Ensure minimum pipe sizes, pit sizes and pit depths. Based on the specified minimum pipe size of 375 mm for the Kingborough Council amendment in the IPWEA standard drawings, 375 mm would be considered appropriate.
- Ensure pipes are located on public property or within dedicated easements. This should be enforced for future development and high risk uncontrolled overland flow through existing private properties should be identified and considered for voluntary or compulsory easement acquisition. More detailed investigation and hydraulic modelling is likely to be required to enable this determination.
- Utilise the outputs from this study as a trigger to identify development that may be subject to overland flow and trigger the requirement to manage overland flow accordingly. For example, if a proposed development involves building or earthworks within the development trigger, a detailed overland flow path assessment (i.e. hydrologic and hydraulic analysis) may be required. This is to assess the impacts the proposed development may have on the existing overland flow path extent.

Council should consider developing a stormwater code which can refer to the Tasmanian Subdivision Guidelines or Kingborough Council specific requirements with consideration for best stormwater management practice including reference to QUDM and other industry leading guidelines.

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ENGENY WATER MANAGEMENT

Kingborough

0 50 100 150 200 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 56

Blackmans Bay
Catchment Resilience Program

Figure 4.2
Potential Easement Acquisition - North

Job Number: M91000_002
Revision: 0
Drawn: JH
Checked: KM
Date: 29/1/2020

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Kingborough

0 50 100 150 200 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 56

Blackmans Bay
Catchment Resilience Program

Figure 4.3
Potential Easement Acquisition - South

Job Number: M91000_002
Revision: 0
Drawn: JH
Checked: KM
Date: 29/1/2020

4.2.2 LP2: Flood Proofing of Buildings

Flood proofing is a mitigation measure that can reduce flood consequence at the worst affected properties. However, residual flood risk still exists at the property following flood proofing of the house. Examples of flood proofing include:

- Raising key appliances, such as air conditioning units, hot water systems, washing machines.
- Separating lower floor and upper floor electricity and raising power outlets.
- Install flood resilient flooring, with skirtings, and flood resilient cabinetry.
- Install water resistant external wall cladding and lining. Replace cavity walls with water-resistant non-cavity walls.

Given that flood proofing significantly modifies private buildings, it is considered a measure for private property owners rather than Council.

4.2.3 LP3: House Raising

House raising is a potential measure to reduce flood risk, however, with many flood affected buildings being generally slab-on-ground structures, house raising is not practical from a cost or constructability perspective. Additionally, residual flood risk still exists at the property following raising of the house. House raising could be considered by private owners, though is not a viable measure for Council to consider.

4.2.4 LP4: Property Buy-Back

Consideration of purchase of properties that experience both high likelihood and consequence of flooding is a potential land use planning measure. Properties where the assessment indicated a high flood hazard (ZAEM1 classification of H3 over the building footprint) included the following:

- Unit 2/158C Roslyn Avenue
- 6 Pearsall Avenue
- 28 Blowhole Road
- 36 Blowhole Road
- 41 Wells Parade.

Council has not previously adopted any property buy-back scheme, and would only consider such an option where, in its opinion, it was appropriate, necessary and provided a tangible benefit to the community.

4.3 Flood Behaviour Modification

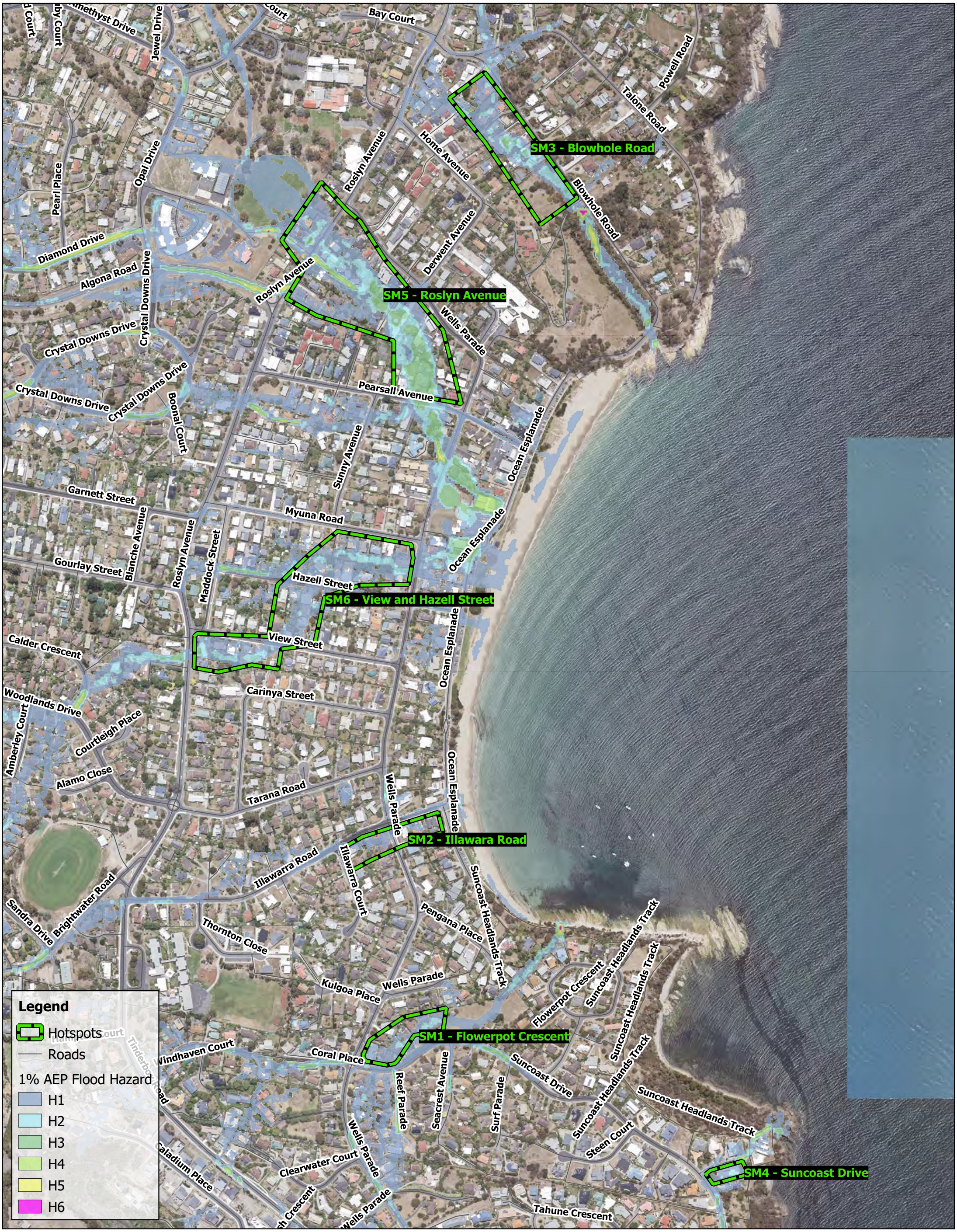
4.3.1 Identification of Hotspots

The identification of flooding hotspot areas where flood behaviour modification measures may be beneficial, herein referred to as structural management measures, were identified in the *Kingborough SSMP* (Engeny, 2020), and confirmed through the updated hydrologic and hydraulic modelling undertaken in the CRP. The measures identified in the SSMP have been further investigated with consideration for residual flood hazard present following inclusion of the stormwater network in the hydraulic model. The measures have been further advanced with specification of conceptual dimensions for the upgrade and have been included in the hydraulic model to approximately measure the improvement following construction of the measure.

The six locations where structural management measures were considered, as discussed and approved with Council, are as follows:

- System 1 – Flowerpot Crescent
- System 2 – Illawarra Road
- System 3 – Blowhole Road
- System 4 – Suncoast Drive
- System 5 – Roslyn Avenue
- System 6 – View and Hazell Street.

Roslyn Avenue and Flowerpot Crescent (referred to as Suncoast Drive in the SSMP) were two Blackmans Bay hotspots identified in the SSMP as prioritised hotspots and have thus been included. Illawarra Road, Hazel Street, and Blowhole Road were also identified as hotspots in the SSMP. Following discussion with Council, Suncoast Drive was added as a hotspot requiring further investigation. The hotspot locations are shown on Figure 4.4.



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ENGENY WATER MANAGEMENT

Kingborough

0 50 100 150 200 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 56

Blackmans Bay
Catchment Resilience Program

Figure 4.4
Flood Mitigation Hotspots

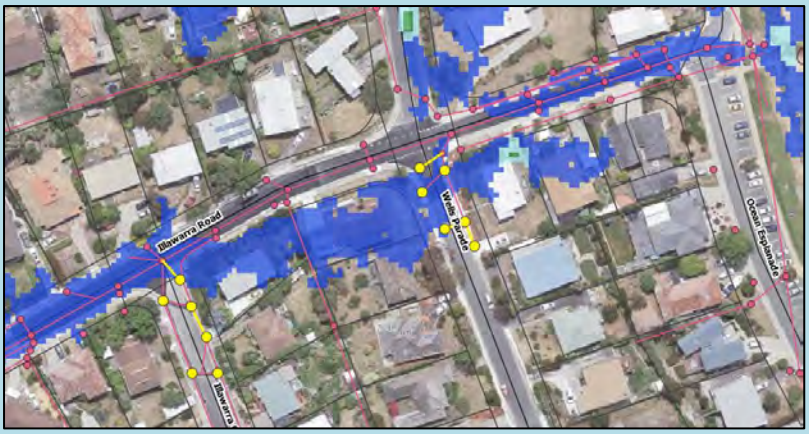
Job Number:
M91000_002
Revision: 0
Drawn: JH
Checked: KM
Date: 6/4/2020

4.3.2 Mitigation Measures

Structural management measures identified to improve flooding issues at the six key hotspot locations (as summarised in Section 4.3.1) are provided in Table 4.1 (in no particular order), along with the conceptual layout of each measure and the existing case scenario 1:100 AEP flood hazard overlay.

Table 4.1 Structural Mitigation Details

Mitigation ID	Mitigation Hotspot Location	Summary of Upgrade
SM1	System 1 - Flowerpot Crescent	Flow originating from both the catchment located between Reef Parade and Wells Parade, and south-west of the Coral Place cul-de-sac exceeds the capacity of the current stormwater network located adjacent to Suncoast Drive. This flow breaks out from the road reserve and flows through 8 properties on Suncoast Drive. The overland flow path then formalises into a defined flow path along the rear of properties at Flowerpot Crescent. The proposed upgrade includes additional pits in Suncoast Drive and upgrade of the pipe system from Coral Place through to the open space adjacent to the impacted properties. Previous discussions have been held with Council regarding reducing the length of the upgrade by out-letting to a detention basin (surcharge pit) located on Council land immediately downstream of the impacted properties. Due to topographic constraints within the park, the detention volume is limited and initial modelling of the minor detention system indicated that the basin would cause adverse impacts and therefore has not been included in the proposed conceptual upgrade for this system. The modelled upgrade consists of the following: - 3 new inlet pits with minor pipe connection - 6 m of new DN375 mm RCP (Connect adjacent GYT42 to system) - 17 m of DN450 mm RCP (Connect adjacent GXZ76 to system) - 200 m of DN1200 mm RCP (US Wells Parade through to system outlet).

Mitigation ID	Mitigation Hotspot Location	Summary of Upgrade
		
SM2	System 2 - Illawarra Road	The stormwater network located along Illawarra Road, including the systems in Wells Parade and Illawarra Road, has spare capacity in the 5% AEP flood event. However, flow is observed to break out from Illawarra Road and Wells Parade and cause inundation of five properties along Illawarra Road. To provide mitigation for this issue, upgrades to the pits and construction of small pipe connections in Wells Parade and Illawarra Road are proposed. The modelled upgrade consists of the following: - Additional pits equivalent 13 x Tasmanian IPWEA standard with minor pipe connections. 

Mitigation ID	Mitigation Hotspot Location	Summary of Upgrade
SM3	System 3 - Blowhole Road	Flow from the catchment located upstream of Talone Road exceeds the capacity of the stormwater network located within properties on Blowhole Road, causing significant overland flow to affect these properties. Upgrading the network through the existing properties is likely unfeasible from both a political and construction point of view. Therefore, a new stormwater line is proposed along Blowhole Road and out-letting on Council land at a similar location as the existing network. However, such an upgrade would need to consider outlet design requirements for increased discharge to an environmentally sensitive area. Inspection of hazard and velocity results at the outlet would have to be undertaken, and incorporation of energy dissipation into the outlet design would be necessary. The modelled upgrade consists of the following: - 8 m of DN650 mm RCP (U/S to D/S Blowhole Road) - 270 m of DN750 mm RCP (D/S Blowhole Road through to system outlet) - 2 additional inlet pits. 

Mitigation ID	Mitigation Hotspot Location	Summary of Upgrade
SM4	System 4 - Suncoast Drive	A property on Suncoast Drive experiences overland flow caused by exceedance of the stormwater network system directly upstream of the property that is intended to provide relief of ponding in a localised sag in Suncoast Drive. Previous discussions held with Council regarding this locality have been centred around upgrading the pit capacity in isolation. However, inspection of the hydraulic modelling results indicated that this network is at capacity in the 5% AEP event and therefore increasing the pit capacity is unlikely to provide the required mitigation. Hence, a stormwater pipe upgrade for the upstream-most network has been proposed for consideration. The modelled upgrade consists of the following: - 3 inlet pits with minor pipe connection - 70 m of DN600 mm RCP (D/S Suncoast Drive along access road). 
SM5	System 5 - Roslyn Avenue	The existing issue at Roslyn Avenue is multi-faceted and extensive. Significant flooding exists at properties on Wells Parade due to the catchment located upstream of the school and directly east exceeding the existing stormwater network capacity and overtopping Roslyn Avenue. Formalising a detention basin at the school oval has been discussed with Council, but due to introduction of risk associated with a regulated structure and construction limitations, this measure has not been investigated further. Additionally, underground tanks are likely to be cost prohibitive and unsupported by the government/school.

Mitigation ID	Mitigation Hotspot Location	Summary of Upgrade
		Smaller, terraced basins located through the open space corridor upstream of Opal Drive, in addition to the existing minor basins, is proposed as the mitigation option for this hotspot. Upgrade of the existing stormwater network located underneath Roslyn Ave and Pearsall Ave is considered unfeasible as this network is not located within an easement and there are existing dwellings constructed over the network. Additionally, construction of a new stormwater pipe alignment along Wells Parade is also not feasible due to the cut required to achieve a free-draining system. Therefore, no current stormwater pipe upgrade is proposed in this location. The modelled upgrade consists of the following: - 2 x minor detention 90 m^3 (closest to Opal Drive) - 2 x minor detention 180 m^3 (furthest from Opal Drive). 
SM6	System 6 – View and Hazell Street	Overland flow from upstream of Roslyn Avenue exceeds the capacity of the existing stormwater network located underneath properties on View and Hazell Streets, resulting in a significant overland flow path in this location. The proposed mitigation option in this location is comprised of a combination of upgraded and new stormwater network from Roslyn Avenue, along View Street and Wells Parade, before joining with an upgraded system along Hazell Street. The modelled upgrade consists of the following:

Mitigation ID	Mitigation Hotspot Location	Summary of Upgrade
		- 9 inlet pits with minor pipe connection - 490 m of DN900 mm RCP (U/S Roslyn Avenue, along View Street and U/S Roslyn Avenue along Hazell Street through to adjacent GXQ04. Duplication of existing DN900 for section from U/S Roslyn Avenue through to adjacent GXZ71) - 365 m of DN1200 mm RCP (Along Wells Parade and duplication of existing DN1200 from adjacent GXQ04 through to system outlet). 

4.3.3 Hydraulic Assessment of Structural Mitigation Measures

The six structural mitigation measures summarised in Table 4.1 have been represented in the TUFLOW hydraulic model. The 5% AEP and 1% AEP events were analysed and a comparison between the base case and post-mitigation flood hazard ratings was undertaken. Flood afflux maps illustrating the comparison are provided in Appendix C. A summary of the observed improvements to flooding from the incorporation of the structural options are summarised in Table 4.2. The hydraulic assessment results have formed the basis of inputs into the Multi-Criteria Analysis summarised in Section 6.

Table 4.2 Summary of Hydraulic Assessment of Structural Mitigation Measures

Mitigation Measure ID	5% AEP Observations	1% AEP Observations
SM1 – Flowerpot Crescent	Reduction in flood depth of up to 20 mm at two properties. Reduction in flood depth of 40 mm at one property. Reduction in flood depth of up to 50 mm on Flowerpot Crescent.	Reduction in flood depth of up to 30 mm at three properties. Reduction in flood depth of up to 50 mm at three properties. Reduction in flood depth of up between 15 and 30 mm on Flowerpot Crescent.
SM2 – Illawarra Road	No improvement.	Reduction in flood depth of 18 mm at one property.
SM3 – Blowhole Road	Reductions in flood depth of up to 150 mm at four properties. Reductions in flood depth of up to 15 mm at two properties. Reductions in flood depth of up to 80 mm at four properties. Reduction in flood depth of 25 mm on Blowhole Road. Reduction of ZAEM1 flood hazard classification H2 to H1 over two properties.	Reductions in flood depth of up to 120 mm at four properties. Reductions in flood depth of up to 70 mm at four properties. Reduction in flood depth of 25 mm on Blowhole Road. Reduction of ZAEM1 flood hazard classification H3 to H2 over three properties. Reduction of ZAEM1 flood hazard classification H2 to H1 over three properties.
SM4 – Suncoast Drive	Reduction in flood depth of 30 mm on Suncoast Drive.	Reduction in flood depth of 50 mm at one property. Reduction in flood depth of 30 mm on Suncoast Drive. Reduction in ZAEM1 flood hazard classification on access road from H5 to H3.

Mitigation Measure ID	5% AEP Observations	1% AEP Observations
SM5 – Roslyn Avenue	Reductions in flood depth of up to 50 mm at two properties. Reduction of flood depth up to 15 mm at one property.	Reduction of flood depth on school oval of up to 15 mm. Reduction in flood depth of up to 30 mm at 22 properties. Reduction of flood depth at Roslyn Avenue of 25 mm. Reduction of flood depth of up to 15 mm at Pearsall Avenue and Wells Parade.
SM6 – View and Hazell Street	Reduction in flood depth of up to 30 mm at Roslyn Avenue and Wells Parade. Reduction in flood depth of up to 20 mm on Hazell Street and Ocean Esplanade. Reduction in flood depth of up to 70 mm at five properties. Reduction in flood depth of 150 mm at one property. Reduction of flood depth of 350 mm at one property. Reduction in ZAEM1 flood hazard classification of H3 to H1 at one property. Reduction in ZAEM1 flood hazard classification of H2 to H1 at one property.	Reduction in flood depth of up to 40 mm at Roslyn Avenue, View Street, Hazell Street, Wells Parade and Ocean Esplanade. Reduction in flood depth of up to 150 mm at six properties. Reduction of up to 80 mm at five properties. Reduction in flood depth of up to 40 mm at four properties. Reduction in ZAEM1 flood hazard classification of H2 to H1 at four properties.

Note: A "property" is considered to experience a reduction in flood depth or hazard only if that reduction in flood depth or hazard is observed over the building footprint.

5. COST ESTIMATES

5.1 Methodology and Assumptions

Preliminary cost estimates were undertaken for the structural management measures outlined in Section 4.1. Costs for non-structural management measures have not been estimated as these measures largely consist of Council staff time. Preliminary cost estimates were undertaken based on the following:

- Indirect costs (Survey, detailed design, contractor preliminaries, Council project management, etc.) were assumed to be approximately 40% of direct costs.
- A contingency factor of 20% was applied to total costs.
- Construction rates were sourced from cost-estimates from similar projects and other Tasmanian local government sources.

The preliminary cost estimates are shown in Table 5.1.

Table 5.1 Preliminary Cost Estimates

Mitigation Measure ID	Mitigation Measure Hotspot Location	Capital Cost Estimate
SM1	System 1 - Flowerpot Crescent	$920,000
SM2	System 2 - Illawarra Road	$177,000
SM3	System 3 - Blowhole Road	$619,000
SM4	System 4 - Suncoast Drive	$196,000
SM5	System 5 - Roslyn Avenue	$128,000
SM6	System 6 – View and Hazell Street	$2,250,000

6. PRIORITISATION

6.1 Methodology

The flood mitigation measures as discussed in Section 4 have been prioritised through a Multi-Criteria Analysis (MCA). The categories included within the MCA are:

- Economic benefit and considerations
- Social benefit and considerations
- Environmental benefit and considerations
- Governance benefit and considerations.

It is noted that the benefits of non-structural mitigation measures can be difficult to quantify. Therefore, the MCA scores are to be interpreted cautiously. The summary of the MCA is provided in Table 6.1. The scoring system utilised, with justification of scoring for each criterion is provided in Appendix E. A scoring system utilising values from -2 through to +2 has been utilised in order to produce a final MCA score that is either negative or positive. A positive MCA score indicates a mitigation option that is viable, whereas a negative MCA indicates that the option is likely to not be viable.

6.2 Multi-Criteria Assessment

Table 6.1 Multi-Criteria Assessment

Category	Category Weighting	Criteria Weighting	Relative Weighting	Criteria	SM1: Flowerpot Crescent	SM2: Illawarra Road	SM3: Blowhole Road	SM4: Suncoast Drive	SM5: Roslyn Avenue	SM6: View and Hazell Street
Economic	50%	30%	15%	Life Cycle Capital Cost	-1	1	-1	1	1	-2
		50%	25%	Reduce Flood Damage	1	0	1	0	2	2
		20%	10%	Feasibility	-1	0	0	-1	1	0
Social	20%	100%	20%	Improved evacuation and emergency access	1	0	1	1	1	1
Environmental	20%	50%	10%	Recreation and Flora / Fauna Impacts	-1	0	-2	0	-1	0
		50%	10%	Visual Impact or Public Domain	0	0	0	0	-1	0
Governance	10%	20%	2%	Community and Stakeholder Support	0	0	0	0	0	0
		30%	3%	Compatible with Policies and Plans	0	0	0	0	0	0
		50%	5%	Funding Opportunity	0	0	0	0	0	0
CATEGORY WEIGHTED SCORE - ECONOMIC					0.0	0.2	0.1	0.1	0.8	0.2
CATEGORY WEIGHTED SCORE - SOCIAL					0.2	0.0	0.2	0.2	0.2	0.2
CATEGORY WEIGHTED SCORE - ENVIRONMENTAL					-0.1	0.0	-0.2	0.0	-0.2	0.0
CATEGORY WEIGHTED SCORE - GOVERNANCE					0.0	0.0	0.0	0.0	0.0	0.0
TOTAL MCA SCORE					0.10	0.15	0.10	0.25	0.75	0.40

Category	Category Weighting	Criteria Weighting	Relative Weighting	Criteria	EM1: Flash Flood Warning Systems	EM2: Evacuation and Emergency Access Assessment	EM3: Increase Community Flood Awareness	EM4: Provide Email Address for the Community to Submit Flood Event Information	LP1: Zoning and Development Control	LP2: Flood Proofing of Buildings	LP3: House Raising	LP4: Property Buy-Back
Economic	50%	30%	15%	Life Cycle Capital Cost	0	2	2	2	2	-1	-2	-2
		50%	25%	Reduce Flood Damage	0	0	0	0	0	0	1	1
		20%	10%	Feasibility	-2	2	2	2	1	-1	-2	-2
Social	20%	100%	20%	Improved evacuation and emergency access	0	0	0	0	0	0	0	0
Environmental	20%	50%	10%	Recreation and Flora / Fauna Impacts	0	0	0	0	0	0	0	0
		50%	10%	Visual Impact or Public Domain	0	0	0	0	0	0	0	0
Governance	10%	20%	2%	Community and Stakeholder Support	0	0	0	0	0	-1	-1	-2
		30%	3%	Compatible with Policies and Plans	0	0	0	0	0	0	0	0
		50%	5%	Funding Opportunity	0	0	0	0	0	0	0	0
CATEGORY WEIGHTED SCORE - ECONOMIC					-0.2	0.5	0.5	0.5	0.4	-0.3	-0.3	-0.3
CATEGORY WEIGHTED SCORE - SOCIAL					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CATEGORY WEIGHTED SCORE - ENVIRONMENTAL					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CATEGORY WEIGHTED SCORE - GOVERNANCE					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL MCA SCORE					-0.20	0.50	0.50	0.50	0.40	-0.27	-0.27	-0.29

6.3 Prioritisation

A prioritisation based purely on the outcomes of the MCA is provided in Table 6.2. It is noted that the measures were only prioritised relative to other shortlisted measures in this study.

Table 6.2 Prioritised Management Measures

Priority	Measure	MCA Score
1	SM5: Roslyn Avenue	0.75
2	EM2: Evacuation and Emergency Access Assessment	0.50
3	EM3: Increase Community Flood Awareness	0.50
4	EM4: Provide Email Address for the Community to Submit Flood Event Information	0.50
5	LP1: Zoning and Development Control	0.40
6	SM6: View and Hazell Street	0.40
7	SM4: Suncoast Drive	0.25
8	SM2: Illawarra Road	0.15
9	SM3: Blowhole Road	0.10
10	SM1: Flowerpot Crescent	0.10
11	EM1: Flash Flood Warning Systems	-0.20
12	LP2: Flood Proofing of Buildings	-0.27
13	LP3: House Raising	-0.27
14	LP4: Property Buy-Back	-0.29

7. SUMMARY

The key outcomes from the Blackmans Bay Catchment Resilience Project have been summarised below.

7.1 Updated Hydraulic and Hydrologic Modelling

Building upon previous high-level modelling completed for the SSMP, updated hydrologic and hydraulic modelling was completed for the Blackmans Bay catchment. In summary, the process undertaken included:

- Development of a hydrologic model representing the entirety of the Blackmans Bay catchment, with application of ARR19 rainfall.
- Development of a hydraulic model, inclusive of all stormwater pits and pipes.
- Simulation of the 5% and 1% AEP flood events for durations ranging from 15 minutes to 3 hours.

Key outcomes from the simulation of the existing scenario modelling were:

- Peak flood conditions occur in the catchment during short, high intensity storms. An inspection of the results indicated that predominantly the critical duration is 30 minutes for the 1% AEP storm. This is due to the small and steep nature of catchments in Blackmans Bay.
- Commonly, the capacity of the underground pipe network is exceeded and significant overland flow of significant depth and hazard is observed through properties, where no drainage easement or channel is present.
- In numerous locations where flow is contained with the road reserve, flood hazard and depth exceed safe vehicle trafficability limits.
- Generally, flood risk increases towards the bottom of the localised catchments, with six hotpots included for identification of flood mitigation measures.

7.2 Flood Mitigation Measures

Three broad categories of flood mitigation measures were considered for the Blackmans Bay catchment dependent on applicability. These are as follows:

- Flood Response Modification, also referred to as emergency management measures
  - EM1: Flash Flood Warning System
  - EM2: Evacuation and Emergency Access
  - EM3: Increase Community Flood Awareness
  - EM4: Provide Email Address for the Community to Submit Flood Event Information.

- Property Modification, also referred to as land use planning measures
  - LP1: Zoning and Development Control
  - LP2: Flood Proofing of Buildings
  - LP3: House Raising
  - LP4: Property Buy-Back.

- Flood Behaviour Modification, also referred to as structural measures
  - System 1 – Flowerpot Crescent
  - System 2 – Illawarra Road
  - System 3 – Blowhole Road
  - System 4 – Suncoast Drive
  - System 5 – Roslyn Avenue.
  - System 6 – View Street and Hazel Street.

7.3 Prioritisation Approach

In order to provide recommendations to Council for flood mitigation measures that should be considered for the Blackmans Bay catchment, the following process of costing, followed by multi-criteria analysis (MCA) and finally prioritisation was undertaken:

- Conceptual-level capital cost estimates were undertaken for the structural measures only. Accurate cost-estimates for the land use planning measures and non-structural measures were unable to be undertaken, with determination of broad expected envelope of cost taken into account within the multi-criteria analysis.

- A MCA was performed on all options considered in the CRP. The scoring system utilised in the MCA is provided in Appendix E. The factors considered in the MCA included:
  - Economic – cost, feasibility, benefit-cost ratio and reduction in flood damage.
  - Social – reduction in risk to like, improved access, social disruption.
  - Environmental – Impacts on flora and fauna, visual impact.
  - Governance – community and stakeholder support, compatibility with policies/plans, funding opportunities (very little detail can be provided for this category and it is recommended that Council revise these scorings following stakeholder engagement).

- A final prioritisation of flood mitigations options for the Blackmans Bay catchment was provided based on the outcome of the MCA. Implementation of the measures should be considered by Council in respect to the prioritisation provided, community support and available budget.

8. RECOMMENDATIONS

All flood mitigation measures were assessed through an MCA, with the resulting prioritisation summarised in Table 8.1.

Table 8.1 Prioritisation of Flood Mitigation Measures

Priority	Measure	MCA
1	SM5: Roslyn Avenue	0.75
2	EM2: Evacuation and Emergency Access Assessment	0.50
3	EM3: Increase Community Flood Awareness	0.50
4	EM4: Provide Email Address for the Community to Submit Flood Event Information	0.50
5	LP1: Zoning and Development Control	0.40
6	SM6: View and Hazell Street	0.40
7	SM4: Suncoast Drive	0.25
8	SM2: Illawarra Road	0.15
9	SM3: Blowhole Road	0.10
10	SM1: Flowerpot Crescent	0.10
11	EM1: Flash Flood Warning Systems	-0.20
12	LP2: Flood Proofing of Buildings	-0.27
13	LP3: House Raising	-0.27
14	LP4: Property Buy-Back	-0.29

From the above MCA outcome, the recommended flood mitigation measures for Council to consider implementing are summarised below. Available capital budget and stakeholder support will influence the viability of each measure.

8.1 Emergency Management Measures

The following emergency management measures should be considered for adoption by Council, the details of which are described further in Section 4.1.

- EM2: Evacuation and Emergency Access

- EM3: Increase Community Flood Awareness
- EM4: Provide Email Address for the Community to Submit Flood Event Information.

8.2 Land Use Planning Measures

The following land use planning measures should be considered for adoption by Council, the details of which are described further in Section 4.2.

- LP1: Zoning and Development Control

8.3 Structural Measures

All structural measures are shown to be viable utilising the MCA scores. The two highest scoring options are below, the details of which are described further in Section 4.3.

- SM5: Roslyn Avenue.
- SM6: View and Hazell Street.

8.4 Key Actions

The key actions recommended for Council to undertake to reduce flood risk in Blackmans Bay is summarised in Table 8.1.

Table 8.2 Summary of Key Actions from CRP

Action/Strategy	Scope	Priority	Timeline
Stormwater management policy	Develop a stormwater management policy to support the planning scheme in managing future development. A review of development assessment considerations relating to stormwater management should also be undertaken.	High	FY 2020/2021
Community awareness program	Develop a community awareness program. The community awareness program should serve to increase flood risk awareness as well as promote the mitigation measures proposed to reduce risk.	High	FY 2020/2021 (the awareness programs needs to be submitted and endorsed by Council prior to engagement with the community)
Assessment and provision of information regarding	Information regarding preferred key evacuation routes from the most flood affected areas of Blackmans Bay are to	High	FY 2020/2021

Action/Strategy	Scope	Priority	Timeline
evacuation and emergency access	be made available to emergency services and the public via an online platform. Commence study in to the feasibility of installation of live-feed cameras, with a connected web portal and dashboard.		
Concept design and financial feasibility studies for recommended structural measures	Further design to be undertaken regarding proposed stormwater pit and pipe network upgrades at Roslyn Avenue and View and Hazell Streets.	Medium	FY 2021/2022 (pending budget allocations)
Collection of observed flood information	Provide email address to assist with the collection of flood information from the community for past and future flood events.	Medium	FY 2020/2021

9. REFERENCES

Ball, et. al. (2019), *Australian Rainfall and Runoff: A Guide to Flood Estimation.*

Chow (1959), *Open Channel Hydraulics.*

Cordery and Pilgrim (1983), *On the Lack of Dependence of Losses from Flood Runoff on Soil and Cover Characteristics.* International Association for Hydrologic Sciences.

Engeny (2020), *Kingborough Council Stormwater System Management Plan.*

10. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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g. This report does not provide legal advice.

APPENDIX A

Base Case Flood Mapping

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PO Box 10183 Brisbane
www.engeny.com.au
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ENGENY WATER MANAGEMENT

Kingborough

0 170 340 510 m

Scale in metres (1:10000@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP

Figure A1

Reference Map

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Depth (m)

0.00 - 0.10

0.10 - 0.20

0.20 - 0.50

0.50 - 1.00

> 1

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stirling Avenue
Stratford Place
Carita Road
Roslyn Avenue
Mirramar Park
Mirramar Park
Mirramar Park
Mirramar Park
Tingira Road
Hillside Drive
Kiama Place
Honeysuckle Drive
Melaleuca Drive
Hiern Road
Powell Road
Timbertop Drive
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Pearl Place
Diamond Drive
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Ocean Esplanade
Woodlands Drive
Calder Crescent
View Street
Darville Court
Roslyn Avenue
Carinya Street

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure A2
5% AEP Flood Depth
Base Case

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Depth (m)

0.00 - 0.10

0.10 - 0.20

0.20 - 0.50

0.50 - 1.00

> 1

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stirling Avenue
Stratford Place
Carita Road
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Hillside Drive
Kiama Place
Mirramar Park
Mirramar Park
Honeysuckle Drive
Melaleuca Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Pearl Place
Diamond Drive
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Darville Court
Roslyn Avenue

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure A3
1% AEP Flood Depth
Base Case

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Depth (m)

- 0.00 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- > 1

Algona Road
Crystal Downs Drive
Crystal Downs Drive
Crystal Downs Drive
Wells Parade
Blowhole Road
Pearsall Avenue
Sunny Avenue
Ocean Esplanade
Edison Avenue
Garnett Street
Montego Court
Myuna Road
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Daryille Court
Roslyn Avenue
Tarana Road
Illawarra Road
Wells Parade
Sandra Drive
Thornton Close
Pengana Place
Windhaven Court
Wells Parade
Reef Parade
Seacrest Avenue
Surf Parade
Suncoast Headlands Track
Steen Court
Burwood Drive
Caladium Place
Tinderbox Road
Clearwater Court
Wells Parade
Tahune Crescent
Jodie Court
Suncoast Headlands Track
Suncoast Drive
Brightwater Road
Estuary Drive
Bluebush Crescent

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure A4
5% AEP Flood Depth
Base Case

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

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0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure A5
1% AEP Flood Depth
Base Case

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Velocity (m/s)

- <= 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 1.5
- > 1.5

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stratford Place
Carita Road
Stirling Avenue
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Kiama Place
Hillside Drive
Mirramar Park
Mirramar Park
Honeysuckle Drive
Melaleuca Drive
Hiern Road
Powell Road
Timbertop Drive
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Diamond Drive
Pearl Place
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Darville Court
Roslyn Avenue
Carinya Street

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure A6
5% AEP Flood Velocity
Base Case

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Velocity (m/s)

- <= 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 1.5
- > 1.5

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stirling Avenue
Stratford Place
Carita Road
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Kiama Place
Hillside Drive
Honeysuckle Drive
Melaleuca Drive
Mirramar Park
Mirramar Park
Hiern Road
Powell Road
Timbertop Drive
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Diamond Drive
Pearl Place
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Roslyn Avenue
Darville Court

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure A7
1% AEP Flood Velocity
Base Case

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure A8
5% AEP Flood Velocity
Base Case

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Velocity (m/s)

- <= 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 1.5
- > 1.5

Algona Road
Crystal Downs Drive
Crystal Downs Drive
Crystal Downs Drive
Wells Parade
Blowhole Road
Pearsall Avenue
Sunny Avenue
Ocean Esplanade
Edison Avenue
Montego Court
Garnett Street
Myuna Road
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Roslyn Avenue
Tarana Road
Illawarra Road
Wells Parade
Sandra Drive
Thornton Close
Pengana Place
Windhaven Court
Wells Parade
Reef Parade
Seacrest Avenue
Surf Parade
Suncoast Headlands Track
Steen Court
Burwood Drive
Caladium Place
Tinderbox Road
Clearwater Court
Wells Parade
Tahune Crescent
Jodie Court
Suncoast Headlands Track
Suncoast Drive
Brightwater Road
Estuary Drive
Bluebush Crescent

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure A9
1% AEP Flood Velocity
Base Case

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Height (m)

0

40

80

120

14

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stirling Avenue
Stratford Place
Carita Road
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Kiama Place
Hillside Drive
Honeysuckle Drive
Mirramar Park
Mirramar Park
Melaleuca Drive
Hiern Road
Powell Road
Timbertop Drive
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Pearl Place
Diamond Drive
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Roslyn Avenue
Carinya Street
Darville Court

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure A10
5% AEP Flood Level
Base Case

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Height (m)

0

40

80

120

14

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stirling Avenue
Stratford Place
Carita Road
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Hillside Drive
Kiama Place
Mirramar Park
Mirramar Park
Honeysuckle Drive
Melaleuca Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Pearl Place
Diamond Drive
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Montego Court
Garnett Street
Sunny Avenue
Ocean Esplanade
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Roslyn Avenue
Darville Court

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure A11
1% AEP Flood Level
Base Case

Job Number:
M91000_002
Revision: 1
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Checked: KM
Date: 10/3/2020

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP South

Figure A12
5% AEP Flood Level
Base Case

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Height (m)

0

40

80

120

14

Algona Road

Crystal Downs Drive

Crystal Downs Drive

Crystal Downs Drive

Wells Parade

Blowhole Road

Pearsall Avenue

Ocean Esplanade

Edison Avenue

Sunny Avenue

Garnett Street

Myuna Road

Montego Court

Roslyn Avenue

Maddock Street

Gourlay Street

Hazell Street

Woodlands Drive

Calder Crescent

View Street

Esplanade

Carinya Street

Darville Court

Roslyn Avenue

Tarana Road

Ocean Esplanade

Illawarra Road

Wells Parade

Sandra Drive

Thornton Close

Pengana Place

Windhaven Court

Wells Parade

Reef Parade

Seacrest Avenue

Surf Parade

Suncoast Headlands Track

Burwood Drive

Caladium Place

Tinderbox Road

Clearwater Court

Steen Court

Wells Parade

Tahune Crescent

Jodie Court

Suncoast Headlands Track

Brightwater Road

Bluebush Crescent

Suncoast Drive

Estuary Drive

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure A13
1% AEP Flood Level
Base Case

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stirling Avenue
Stratford Place
Carita Road
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Kiama Place
Hillside Drive
Mirramar Park
Mirramar Park
Honeysuckle Drive
Melaleuca Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Pearl Place
Diamond Drive
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Garnett Street
Montego Court
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Roslyn Avenue
Darville Court

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure A14
5% AEP Flood Hazard (ZAEM1)
Base Case

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Protea Place

Jindabyne Road

Aldinga Street

Boronia Hill Flora Track

Tingira Road

Stirling Avenue

Stratford Place

Carita Road

Roslyn Avenue

Mirramar Park

Mirramar Park

Tingira Road

Honeysuckle Drive

Hillside Drive

Kiama Place

Mirramar Park

Mirramar Park

Melaleuca Drive

Timbertop Drive

Hiern Road

Powell Road

Amethyst Drive

Bay Court

Opal Drive

Roslyn Avenue

Home Avenue

Talone Road

Pearl Place

Diamond Drive

Derwent Avenue

Blowhole Road

Crystal Downs Drive

Algona Road

Crystal Downs Drive

Crystal Downs Drive

Illira Way

Crystal Downs Drive

Pearsall Avenue

Ashley Court

Edison Avenue

Sunny Avenue

Ocean Esplanade

Garnett Street

Montego Court

Myuna Road

Wells Parade

Roslyn Avenue

Maddock Street

Gourlay Street

Hazell Street

Woodlands Drive

Calder Crescent

View Street

Ocean Esplanade

Darville Court

Roslyn Avenue

Carinya Street

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure A15
1% AEP Flood Hazard (ZAEM1)
Base Case

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Algona Road
Crystal Downs Drive
Crystal Downs Drive
Crystal Downs Drive
Wells Parade
Blowhole Road
Pearsall Avenue
Sunny Avenue
Ocean Esplanade
Edison Avenue
Montego Court
Garnett Street
Myuna Road
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Darville Court
Roslyn Avenue
Tarana Road
Illawarra Road
Wells Parade
Sandra Drive
Thornton Close
Pengana Place
Windhaven Court
Wells Parade
Reef Parade
Seacrest Avenue
Surf Parade
Suncoast Headlands Track
Steen Court
Burwood Drive
Caladium Place
Tinderbox Road
Clearwater Court
Bluebush Crescent
Wells Parade
Tahune Crescent
Jodie Court
Suncoast Headlands Track
Brightwater Road
Estuary Drive
Suncoast Drive

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure A16
5% AEP Flood Hazard (ZAEM1)
Base Case

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Algona Road
Crystal Downs Drive
Crystal Downs Drive
Crystal Downs Drive
Wells Parade
Blowhole Road
Pearsall Avenue
Sunny Avenue
Ocean Esplanade
Edison Avenue
Garnett Street
Montego Court
Myuna Road
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Darville Court
Roslyn Avenue
Tarana Road
Illawarra Road
Wells Parade
Sandra Drive
Thornton Close
Pengana Place
Windhaven Court
Wells Parade
Reef Parade
Seacrest Avenue
Surf Parade
Suncoast Headlands Track
Burwood Drive
Caladium Place
Tinderbox Road
Clearwater Court
Steen Court
Bluebush Crescent
Wells Parade
Tahune Crescent
Jodie Court
Suncoast Headlands Track
Suncoast Drive
Brightwater Road
Estuary Drive

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure A17
1% AEP Flood Hazard (ZAEM1)
Base Case

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

APPENDIX B

Climate Change and Sensitivities Flood Mapping

Legend

Cadastre Boundaries

Flood Afflux (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stirling Avenue
Stratford Place
Carita Road
Roslyn Avenue
Mirramar Park
Tingira Road
Kiama Place
Hillside Drive
Honeysuckle Drive
Melaleuca Drive
Hiern Road
Powell Road
Timbertop Drive
Amethyst Drive
Bay Court
Opal Drive
Home Avenue
Talone Road
Pearl Place
Diamond Drive
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Illira Way
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Myuna Road
Wells Parade
Gourlay Street
Maddock Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Darville Court
Carinya Street

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure B1
1% AEP Flood Level Afflux
Climate Change

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Protea Place

Jindabyne Road

Aldinga Street

Boronia Hill Flora Track

Tingira Road

Stirling Avenue

Stratford Place

Carita Road

Roslyn Avenue

Mirramar Park

Mirramar Park

Tingira Road

Honeysuckle Drive

Hillside Drive

Kiama Place

Mirramar Park

Mirramar Park

Melaleuca Drive

Timbertop Drive

Hiern Road

Powell Road

Amethyst Drive

Bay Court

Opal Drive

Roslyn Avenue

Home Avenue

Talone Road

Pearl Place

Diamond Drive

Derwent Avenue

Blowhole Road

Crystal Downs Drive

Algona Road

Crystal Downs Drive

Crystal Downs Drive

Illira Way

Crystal Downs Drive

Pearsall Avenue

Ashley Court

Edison Avenue

Garnett Street

Sunny Avenue

Ocean Esplanade

Montego Court

Myuna Road

Wells Parade

Roslyn Avenue

Maddock Street

Gourlay Street

Hazell Street

Woodlands Drive

Calder Crescent

View Street

Ocean Esplanade

Darville Court

Roslyn Avenue

Carinya Street

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure B2
1% AEP Flood Hazard (ZAEM1)
Climate Change

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure B3
1% AEP Flood Level Afflux
Climate Change

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Algona Road

Crystal Downs Drive

Crystal Downs Drive

Crystal Downs Drive

Wells Parade

Blowhole Road

Pearsall Avenue

Sunny Avenue

Ocean Esplanade

Edison Avenue

Montego Court

Garnett Street

Myuna Road

Roslyn Avenue

Maddock Street

Gourlay Street

Hazell Street

Woodlands Drive

Calder Crescent

View Street

Ocean Esplanade

Carinya Street

Darville Court

Roslyn Avenue

Tarana Road

Illawarra Road

Wells Parade

Sandra Drive

Thornton Close

Pengana Place

Windhaven Court

Wells Parade

Reef Parade

Seacrest Avenue

Surf Parade

Suncoast Headlands Track

Steen Court

Burwood Drive

Caladium Place

Tinderbox Road

Clearwater Court

Wells Parade

Tahune Crescent

Jodie Court

Suncoast Headlands Track

Suncoast Drive

Brightwater Road

Bluebush Crescent

Estuary Drive

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure B4
1% AEP Flood Hazard (ZAEM1)
Climate Change

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Afflux (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stratford Place
Carita Road
Stirling Avenue
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Hillside Drive
Kiama Place
Mirramar Park
Mirramar Park
Honeysuckle Drive
Melaleuca Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Diamond Drive
Pearl Place
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Garnett Street
Montego Court
Myuna Road
Wells Parade
Roslyn Avenue
Gourlay Street
Maddock Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Roslyn Avenue
Carinya Street
Darville Court

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure B5
1% AEP Flood Level Afflux
Increased Roughness

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stratford Place
Carita Road
Mirramar Park
Stirling Avenue
Roslyn Avenue
Mirramar Park
Tingira Road
Honeysuckle Drive
Hillside Drive
Kiama Place
Mirramar Park
Mirramar Park
Melaleuca Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Diamond Drive
Pearl Place
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Darville Court
Roslyn Avenue
Carinya Street

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure B6
1% AEP Flood Hazard (ZAEM1)
Increased Roughness

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure B7
1% AEP Flood Level Afflux
Increased Roughness

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Algona Road

Crystal Downs Drive

Crystal Downs Drive

Crystal Downs Drive

Wells Parade

Blowhole Road

Pearsall Avenue

Sunny Avenue

Ocean Esplanade

Edison Avenue

Garnett Street

Montego Court

Myuna Road

Roslyn Avenue

Maddock Street

Gourlay Street

Hazell Street

Woodlands Drive

Calder Crescent

View Street

Ocean Esplanade

Carinya Street

Darville Court

Roslyn Avenue

Tarana Road

Illawarra Road

Wells Parade

Sandra Drive

Thornton Close

Pengana Place

Windhaven Court

Wells Parade

Reef Parade

Seacrest Avenue

Surf Parade

Suncoast Headlands Track

Steen Court

Burwood Drive

Caladium Place

Tinderbox Road

Clearwater Court

Wells Parade

Tahune Crescent

Jodie Court

Suncoast Headlands Track

Suncoast Drive

Brightwater Road

Bluebush Crescent

Estuary Drive

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure B8
1% AEP Flood Hazard (ZAEM1)
Increased Roughness

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Afflux (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stratford Place
Carita Road
Stirling Avenue
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Kiama Place
Hillside Drive
Honeysuckle Drive
Mirramar Park
Mirramar Park
Melaleuca Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Pearl Place
Diamond Drive
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Wells Parade
Myuna Road
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Roslyn Avenue
Darville Court

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Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure B9
1% AEP Flood Level Afflux
Network Blockage

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stratford Place
Carita Road
Mirramar Park
Stirling Avenue
Roslyn Avenue
Mirramar Park
Tingira Road
Honeysuckle Drive
Hillside Drive
Kiama Place
Mirramar Park
Mirramar Park
Melaleuca Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Pearl Place
Derwent Avenue
Blowhole Road
Diamond Drive
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Darville Court
Roslyn Avenue
Carinya Street

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure B10
1% AEP Flood Hazard (ZAEM1)
Network Blockage

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Afflux (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5

Algona Road
Crystal Downs Drive
Crystal Downs Drive
Crystal Downs Drive
Edison Avenue
Morego Court
Garnett Street
Gourlay Street
Woodlands Drive
Calder Crescent
Daryille Court
Roslyn Avenue
Maddock Street
Myuna Road
Hazell Street
View Street
Carinya Street
Tarana Road
Wells Parade
Sunny Avenue
Pearsall Avenue
Ocean Esplanade
Blowhole Road
Ocean Esplanade
Illawarra Road
Sandra Drive
Thornton Close
Windhaven Court
Wells Parade
Pengana Place
Reef Parade
Seacrest Avenue
Surf Parade
Suncoast Headlands Track
Steen Court
Tinderbox Road
Caladium Place
Clearwater Court
Bluebush Crescent
Wells Parade
Tahune Crescent
Jodie Court
Suncoast Drive
Suncoast Headlands Track
Burwood Drive
Brightwater Road
Estuary Drive

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Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Algona Road

Crystal Downs Drive

Crystal Downs Drive

Crystal Downs Drive

Wells Parade

Blowhole Road

Pearsall Avenue

Sunny Avenue

Ocean Esplanade

Edison Avenue

Garnett Street

Montego Court

Myuna Road

Roslyn Avenue

Maddock Street

Gourlay Street

Hazell Street

Woodlands Drive

Calder Crescent

View Street

Ocean Esplanade

Carinya Street

Darville Court

Roslyn Avenue

Tarana Road

Illawarra Road

Wells Parade

Sandra Drive

Thornton Close

Pengana Place

Windhaven Court

Wells Parade

Reef Parade

Seacrest Avenue

Surf Parade

Suncoast Headlands Track

Steen Court

Burwood Drive

Caladium Place

Tinderbox Road

Clearwater Court

Wells Parade

Tahune Crescent

Jodie Court

Suncoast Headlands Track

Suncoast Drive

Brightwater Road

Bluebush Crescent

Estuary Drive

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure B12
1% AEP Flood Hazard (ZAEM1)
Network Blockage

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

APPENDIX C

Structural Mitigation Measure Flood Mapping

Legend

Cadastre Boundaries

Flood Afflux (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- Was wet now dry
- Was dry now wet

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stratford Place
Carita Road
Stirling Avenue
Roslyn Avenue
Mirramar Park
Tingira Road
Kiama Place
Hillside Drive
Melaleuca Drive
Hiern Road
Powell Road
Timbertop Drive
Amethyst Drive
Bay Court
Opal Drive
Home Avenue
Talone Road
Pearl Place
Diamond Drive
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Illira Way
Pearsall Avenue
Ashley Court
Edison Avenue
Montego Court
Garnett Street
Sunny Avenue
Ocean Esplanade
Myuna Road
Wells Parade
Gourlay Street
Maddock Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Darville Court
Carinya Street

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure C1
5% AEP Flood Level Afflux
Mitigation Option

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stirling Avenue
Stratford Place
Carita Road
Roslyn Avenue
Mirramar Park
Mirramar Park
Honeysuckle Drive
Hillside Drive
Kiama Place
Tingira Road
Mirramar Park
Mirramar Park
Melaleuca Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Diamond Drive
Pearl Place
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Montego Court
Garnett Street
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Darville Court
Roslyn Avenue
Carinya Street

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure C2
5% AEP Flood Hazard (ZAEM1)
Mitigation Option

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Afflux (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- Was wet now dry
- Was dry now wet

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stratford Place
Carita Road
Stirling Avenue
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Hillside Drive
Kiama Place
Mirramar Park
Mirramar Park
Melaleuca Drive
Honeysuckle Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Diamond Drive
Pearl Place
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Sunny Avenue
Ocean Esplanade
Garnett Street
Montego Court
Myuna Road
Wells Parade
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Carinya Street
Roslyn Avenue
Darville Court

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure C3
1% AEP Flood Level Afflux
Mitigation Option

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Protea Place
Jindabyne Road
Aldinga Street
Boronia Hill Flora Track
Tingira Road
Stirling Avenue
Stratford Place
Carita Road
Roslyn Avenue
Mirramar Park
Mirramar Park
Tingira Road
Kiama Place
Hillside Drive
Mirramar Park
Mirramar Park
Honeysuckle Drive
Melaleuca Drive
Timbertop Drive
Hiern Road
Powell Road
Amethyst Drive
Bay Court
Opal Drive
Roslyn Avenue
Home Avenue
Talone Road
Pearl Place
Diamond Drive
Derwent Avenue
Blowhole Road
Crystal Downs Drive
Algona Road
Crystal Downs Drive
Crystal Downs Drive
Illira Way
Crystal Downs Drive
Pearsall Avenue
Ashley Court
Edison Avenue
Montego Court
Garnett Street
Sunny Avenue
Wells Parade
Ocean Esplanade
Myuna Road
Roslyn Avenue
Maddock Street
Gourlay Street
Hazell Street
Woodlands Drive
Calder Crescent
View Street
Ocean Esplanade
Darville Court
Roslyn Avenue
Carinya Street

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
North

Figure C4
1% AEP Flood Hazard (ZAEM1)
Mitigation Option

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

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ENGENY WATER MANAGEMENT
Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure C5
5% AEP Flood Level Afflux
Mitigation Option

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Algona Road

Crystal Downs Drive

Crystal Downs Drive

Crystal Downs Drive

Wells Parade

Blowhole Road

Pearsall Avenue

Sunny Avenue

Ocean Esplanade

Edison Avenue

Montego Court

Garnett Street

Myuna Road

Roslyn Avenue

Maddock Street

Gourlay Street

Hazell Street

Woodlands Drive

Calder Crescent

View Street

Ocean Esplanade

Carinya Street

Darville Court

Roslyn Avenue

Tarana Road

Illawarra Road

Wells Parade

Sandra Drive

Thornton Close

Pengana Place

Windhaven Court

Wells Parade

Reef Parade

Seacrest Avenue

Surf Parade

Suncoast Headlands Track

Steen Court

Burwood Drive

Caladium Place

Tinderbox Road

Clearwater Court

Bluebush Crescent

Wells Parade

Tahune Crescent

Jodie Court

Suncoast Headlands Track

Brightwater Road

Estuary Drive

Suncoast Drive

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure C6
5% AEP Flood Hazard (ZAEM1)
Mitigation Option

Job Number:
M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Afflux (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- Was wet now dry
- Was dry now wet

Algona Road
Crystal Downs Drive
Crystal Downs Drive
Crystal Downs Drive
Edison Avenue
Morego Court
Garnett Street
Gourlay Street
Roslyn Avenue
Maddock Street
Myuna Road
Sunny Avenue
Wells Parade
Pearsall Avenue
Ocean Esplanade
Blowhole Road
Hazell Street
View Street
Calder Crescent
Carinya Street
Ocean Esplanade
Darville Court
Roslyn Avenue
Tarana Road
Illawarra Road
Wells Parade
Sandra Drive
Thornton Close
Pengana Place
Windhaven Court
Wells Parade
Reef Parade
Seacrest Avenue
Surf Parade
Suncoast Headlands Track
Steen Court
Burwood Drive
Caladium Place
Tinderbox Road
Clearwater Court
Wells Parade
Tahune Crescent
Jodie Court
Suncoast Drive
Brightwater Road
Estuary Drive
Bluebush Crescent

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure C7
1% AEP Flood Level Afflux
Mitigation Option

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

Legend

Cadastre Boundaries

Flood Hazard

H1

H2

H3

H4

H5

H6

Algona Road

Crystal Downs Drive

Crystal Downs Drive

Crystal Downs Drive

Wells Parade

Blowhole Road

Pearsall Avenue

Sunny Avenue

Ocean Esplanade

Edison Avenue

Garnett Street

Montego Court

Myuna Road

Roslyn Avenue

Maddock Street

Gourlay Street

Hazell Street

Woodlands Drive

Calder Crescent

View Street

Ocean Esplanade

Carinya Street

Darville Court

Roslyn Avenue

Tarana Road

Illawarra Road

Wells Parade

Sandra Drive

Thornton Close

Pengana Place

Windhaven Court

Wells Parade

Reef Parade

Seacrest Avenue

Surf Parade

Suncoast Headlands Track

Steen Court

Burwood Drive

Caladium Place

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Jodie Court

Suncoast Headlands Track

Suncoast Drive

Brightwater Road

Bluebush Crescent

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ENGENY WATER MANAGEMENT

Kingborough

0 85 170 255 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia Zone 55

Blackmans Bay CRP
South

Figure C8
1% AEP Flood Hazard (ZAEM1)
Mitigation Option

Job Number: M91000_002
Revision: 1
Drawn: JN
Checked: KM
Date: 10/3/2020

APPENDIX D

Cost-Estimates

Engeny Cost Estimate Form
Kingborough Council - Blackmans Bay CRP Mitigation Options

Summary

Project:	M91000_002
Date:	10/03/2020
Revision:	1
Work By:	KM
Reviewed:	MP

		Total	
		Capital Cost	**Capital Cost (Rounded)**
1	SM1 - Flowerpot Crescent	$ 920,236	$ 920,000
2	SM2 - Illawarra Road	$ 177,350	$ 177,000
3	SM3 - Blowhole Road	$ 619,303	$ 619,000
4	SM4 - Suncoast Drive	$ 196,474	$ 196,000
5	SM5 - Rosyln Avenue	$ 127,911	$ 128,000
6	SM6 - View and Hazell Street	$ 2,250,357	$ 2,250,000

Notes:

No allowance has been made for service relocation
No allowance has been made for trench bedding replacement
No allowance has been made for trench excavation in rock
Preliminary estimate only

APPENDIX E

Multi-Criteria Analysis Scoring System

Category	Criteria	Metric	-2	-1	0	1	2
Economic	Life cycle capital cost	Construction and maintenance cost to Council over the life cycle of the measure	> $1million	$500k to $1million	$250k to $500k	$100k to $250k	$0 to $100k
	Reduction in flood damages	Reduction in flooding observed in a 1% AEP event	Impacts to >10 properties	Impacts to 2 to 10 properties	Reduction or impacts to 0-1 property	Reduction to 2 to 10 properties	Reduction to >10 properties
	Feasibility	Establishes the feasibility of options based on constructability, costs and bureaucratic difficulties such as land acquisition and agreements with external agencies	There are a number of factors that pose a significant impact on the feasibility of the project	There is a factor that poses a potential impact on the feasibility of the project	May or may not be feasible	Likely to be feasible	Very likely to be feasible
Social	Improved evacuation and emergency access	Flood depth and duration changes for critical transport routes in 1% AEP event	Key access roads become flooded that were previously flood free	Increase in local or main road flooding	No Change	Decrease in local or main road flooding	All roads flood free in vicinity of option
Environmental	Recreation and Flora / Fauna Impacts including Street Trees	Impacts or benefits to flora / fauna or passive/active recreational areas	Likely vegetation / habitat impacts and/or impact on recreation areas	Removal of isolated trees, minor landscaping and/or minor impact on recreation areas	No impact	Restoration of small areas of habitat	Restoration of large areas of habitat

Category	Criteria	Metric	-2	-1	0	1	2
	Visual Impact	Impact of completed works on visual amenity or function of public domain	Significant loss of existing visual amenity or public domain	Minor to moderate loss of existing valued visual amenity or public domain	No Change	Minor to moderate improvement to visual amenity or public domain	Significant improvement to visual amenity or public domain
Governance	Community and Stakeholder Support	Level of agreement from community, Council and related agencies	Strong disagreement	Disagreement	Neutral / No Response	Support	Strong Support
	Compatible with Policies and Plans	The compatibility with Council's policies and plans	Amendment required to either Council's current policies or plans	Slightly incompatible with Council's current policies or plans	Slightly incompatible with Council's current policies or plans, but could be grounds for reviewing policies or plans	Compatible with both Council's policies and plans	In line with and supported by Council's current policies or plans
	Funding Opportunity	Funding opportunity available from Federal, State or Territory	NA	NA	1 to 10% funding available	10% to 25% funding available	>25% funding available