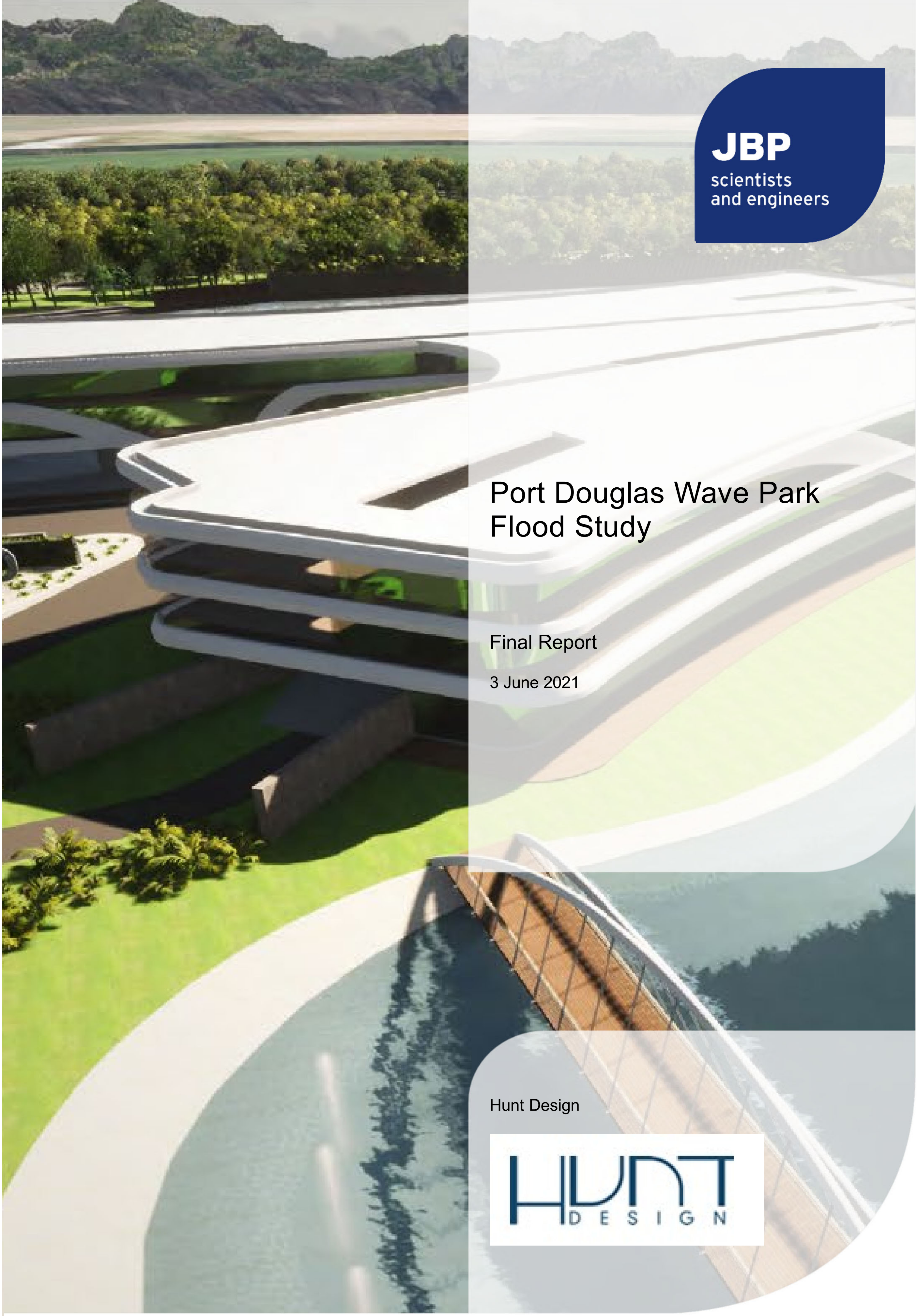

JBP scientists and engineers

Port Douglas Wave Park Flood Study

Final Report

3 June 2021

Hunt Design

HUNT DESIGN

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
S3-P01 / March 2021		JR
S4-P01 / April 2021		JR
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Contract

This report describes work commissioned by Jarrod Ryan on behalf of Hunt Design, Dr Ellie Vahidi of JBP carried out this work.

Prepared by ....Dr Ellie Vahidi PhD, MEng, BEng
Hydraulic Engineer

Reviewed and approved by ....William Prentice BEng, MIEAust, CPEng, NER, FMA
Technical Director

Purpose

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The conclusions and recommendations contained in this report are based upon information provided by others and upon the assumption that all relevant information has been provided by those parties from whom it has been requested and that such information is accurate. Information obtained by JBP has not been independently verified by JBP, unless otherwise stated in the report.

The methodology adopted and the sources of information used by JBP in providing its services are outlined in this report. The work described in this report was undertaken between February 2021 to March 2021 and is based on the conditions encountered and the information available during this period of time. The scope of this report and the services are accordingly factually limited by these circumstances.

Any assessments of works or costs identified in this report are based upon the information available at the time, and where appropriate are subject to further investigations or information which may become available.

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ACN: 610 411 508

Executive Summary

JBPacific were commissioned by Hunt Design to deliver hydrological and hydraulic modelling within the Mowbray River catchment, to support the proposed integrated development of a recreational 'wave park', at Lot 123 on SR687, located 5km south of Port Douglas on the Captain Cook Highway.

An URBS hydrological model was developed estimate rainfall-runoff and streamflow in the Mowbray River catchment. Design flood estimation for the 1% Annual Exceedance Probability (AEP) flood event was completed to provide inflow hydrograph information to the hydraulic modelling.

The hydrodynamic modelling software TUFLOW using its 'Classic' engine was adopted as the basis of the hydraulic analysis. An existing TUFLOW model, developed for Douglas Shire Council as part of the draft Storm Tide Inundation Methodologies Study (JBPacific, 2020) project, was available as basis for modelling the proposed development. The TUFLOW model was modified to ensure that it appropriately simulated river flooding in the vicinity of the proposed development.

The hydraulic modelling was run to simulate both the existing catchment conditions and the post-development scenario. The results of the hydraulic modelling indicate flood impacts are restricted to the portion of the floodplain downstream of the Captain Cook Highway, Mowbray.

Results of the flood study demonstrate:

- The largest flood level impacts are evident to the west (upstream) side of the site between the proponents land and the Highway. The maximum afflux in this location is 183mm, however this is on State-owned conservation land and as such, the flood impacts are not anticipated to result in adverse impacts to people or property.
- There is only a minor increase in inundation extent, to the north of the site on the opposite bank to the proposed development. The minor increase in flood liable land is generally restricted to property zoned for rural uses and a review of available aerial imagery does not indicate the increase in flooded area will impact any existing dwellings in the lower catchment.
- The maximum impact on residential property is 18mm. It should be noted that whilst this land is zoned as low density residential in the Douglas Planning Scheme 2018, aerial imagery indicates it is currently vegetated, undeveloped land. Additionally, flood impacts are limited to an existing low-laying area of lot, which represents approximately 2% of the total lot area.
- Maximum flood impacts on rural land external of the proponents land is 37mm, which is located opposite the proposed development on agricultural land. An increase of 37mm is not expected to adversely affect the existing land owners ability to farm the land.
- Analysis of velocity afflux was conducted to demonstrate the impact the proposed development has on the flood velocity compare to the existing case. There are some increases in flood velocity within the proposed development site (up to 0.5 m/s); however, the maximum velocity change external of the site is less than 0.2 m/s.
- The supplied concept earthwork plan shows the total cut and fill volumes of 165,200m³ and 190,700 m³ respectively, resulting in a nett fill of 25,500 m³. If flood impacts are considered undesirable, reducing the nett fill volume, through further compensatory cut on the western side of the earthworks area will likely reduce post development peak flood levels.

The proposed development has been shown to result in localised increases to 1%AEP peak flood levels external of the site. The maximum afflux of 183mm is located to the south-west of the site immediately adjacent to the proposed development between the site and the Captain Cook Highway. The flood impacts at the location are not considered to result in material nuisance as the lot is State-owned conservation land. The maximum impact to 1%AEP flood event peak water levels on existing residential lots is 18mm.

A 13% increase in nett fill (as a proportion of total proposed fill) on the site is proposed, which will result in a decrease of floodplain storage. The placement (rather than nett volume) of the fill has the most significant impact on modelled post-development flood behaviour, specifically in the vicinity of the cabin/camping area. Filling in this location impacts the out-of-channel flood conveyance in the 1%AEP flood event.

Further modelling was undertaken to investigate if the addition of open channels through the cabin/camping grounds would improve floodplain conveyance and assess the potential benefit of adding a trapezoidal open channel in this location. The objective of testing these design iterations

was to determine if one or two channels - with an indicative 20 metre base, 1:4 sides and 500mm depth - would provide sufficient additional conveyance to compensate for the loss of floodplain conveyance arising from the proposed earthworks. The two design iterations were successful in reducing the maximum peak flood impacts, however they did not show material benefit in flood risk outcomes.

Whilst the design iterations were shown to improve floodplain conveyance and reduce flood level impacts in the post-development scenario, given the initial proposed design has been demonstrated to achieve acceptable flood risk outcomes outlined by the Douglas Planning Scheme, and the need for additional excavation and removal of vegetation to construct the channels, these design options may be contrary to the desired outcomes of the Planning Scheme in maintaining the protective function of existing vegetation.

The Douglas Planning Scheme does not provide a definition of 'acceptable flood impacts', so a risk assessment in line with ISO31000 has been undertaken to demonstrate the proposed development 'avoids an unacceptable increase in severity'. ISO31000 is the international standard for risk management, and defines risk as the consideration of the likelihood of a hazard occurring and the consequence when an event occurs.

The assessment of the potential for damage to other properties was based on the number of properties exposed to flood hazard given a specified likelihood. In this case, the Defined Flood Event of 1%AEP was analysed, with the number of properties at risk external of the development site shown in Table 7-1.

Table 1-1. Summary of at-risk properties by land use

Land Use	Count of properties within the 1%AEP flood extent	
	Existing	Post-development
Conservation	9	9
Environmental Management	1	1
Low Density Residential	1	1
Ocean	1	1
Rural	45*	45
Rural Residential	0	0
Special Purpose	1	1
Total	115	115

*Note: An additional rural property was counted in the existing conditions model on the eastern extremity of the hydraulic model. This was deemed to be an artifact of the flood model itself and was not considered to be a valid inclusion in comparison with post development property exposure.

The exposure analysis shows the existing catchment conditions and post-development catchment conditions result in the same number of properties at risk in the 1%AEP flood event, and as such the proposed development does not significantly increase the potential for damage on the site or other properties.

An analysis of flood hazard, using depth-velocity results from hydraulic modelling of the proposed development was undertaken to gain an understanding of the severity of flood hazard under pre and post development conditions. A comparison of existing and post-development flood hazard based on depth-velocity flood information, shows a minor increase in flood hazard within the channel immediately downstream of the Captain Cook Highway and negligible (+/-0.2m2/s) or minor reduction in depth-velocity product on all existing properties. A review of aerial imagery available from Google and NearMap, indicates there are currently no dwellings located within the mapped flood impact area. Figure 6-1. Comparison of existing and post development depth-velocity flood behaviour

The assessment of potential exposure to flooding and severity of flood hazards analysed using a risk-based approach consistent with ISO31000, which considers the likelihood of flooding and consequence of flooding hazard, has demonstrated the proposed development does not increase existing flood risk in an unacceptable manner.

Contents

List of Figures

List of Tables

Abbreviations

AEP .... Annual Exceedance Probability

AHD .... Australian Height Datum

ARR .... Australian Rainfall and Runoff guidelines 2019

BoM .... Bureau of Meteorology

DEM............................... Digital Elevation Model

GBR............................... Great Barrier Reef

HAT .... Highest Astronomical Tide

LiDAR .... Light Distance and Ranging

JBP .... Jeremy Benn Pacific or JBPacific

NDVI .... Normalised Difference Vegetation Index

QLUMP .... Queensland Land Use Mapping Program

URBS............................. Unified River Basin Simulator

1 Introduction

1.1 Background

JBPacific were commissioned by Hunt Design to deliver hydrological and hydraulic modelling within the Mowbray River catchment, to support the proposed integrated development of a recreational 'wave park', at Lot 123 on SR687, located 5km south of Port Douglas on the Captain Cook Highway.

The site is in located within the Mowbray River catchment which is approximately 115.7km^2. As shown in Figure 1-1, the Mowbray River is predominantly undeveloped with small areas of agricultural land located in the flatter, lower laying areas of the catchment and a coastal village along the coastline. The Mowbray River catchment falls in an easterly direction from its headwaters in the Mowbray National Park 10.5km to the west of the Captain Cook Highway to its outlet at Alexandra Reefs approximately 1 km downstream of the Highway.

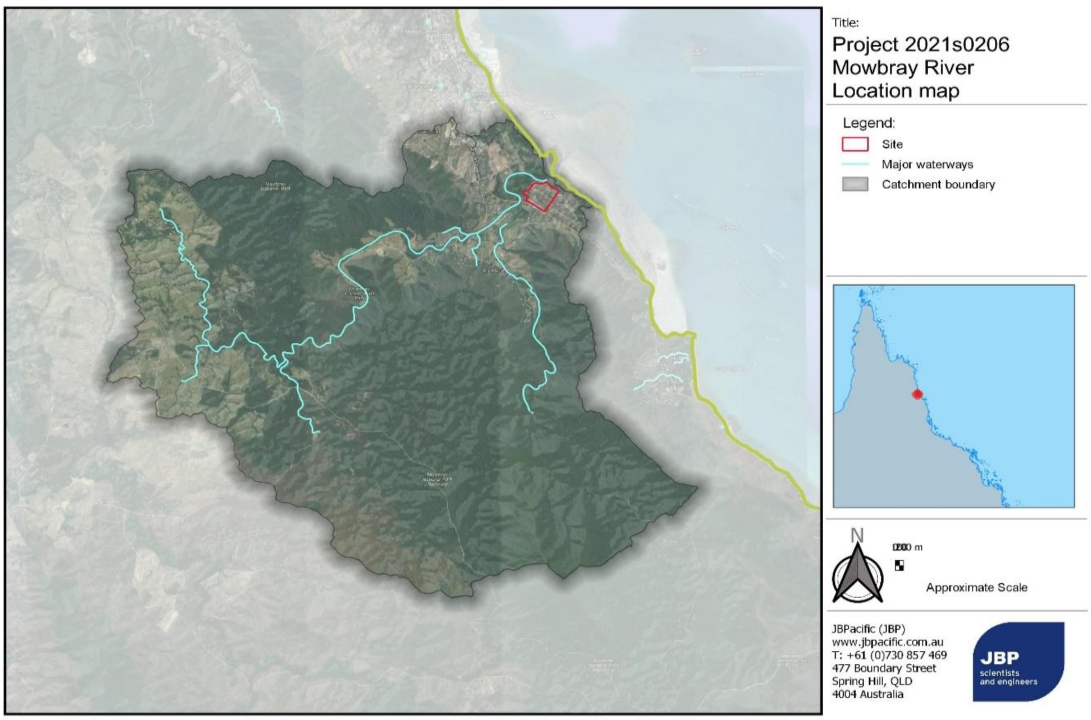


Figure 1-1: Study area

JBPacific's scope of work included hydrologic and hydraulic modelling as the basis for the flooding assessment. This included hydrologic modelling, to estimate design flows within the river. It also included development of a hydraulic model to simulate flood hydrodynamics for existing and post development conditions at the site, to demonstrate any potential impacts to peak flood levels due to the construction of the proposed wave park.

The hydrological model was used to simulate the 1%AEP flows in the Mowbray River catchment for the Defined Flood Event, which is the basis of flood assessments in the Douglas Shire Planning Scheme 2018. The existing hydraulic model from the draft Douglas storm tide study (JBPacific, 2020) was reviewed and updated for the current study proposes.

1.2 Structure of the report

In addition to this introductory chapter, this report contains the following:

- **Section 2:** Available Data
- **Section 3:** Study Methodology
- **Section 4:** Hydraulic Model
- **Section 5:** Flood Impacts
- **Section 6:** Conclusion

2 Available Data

2.1 Topographic data

Elevation data above mean sea level is available through the QLD 5m Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM). The 5m LiDAR DEM has been sourced from more than 200 individual LiDAR surveys conducted between 2001 and 20151. For larger areas where the 5m dataset is not available, the 30m SRTM topographic data has been used. Additional 1m LiDAR tiles have been sourced from the Intergovernmental Committee on Surveying and Mapping (ICSM) for areas where higher-resolution is required.

2.2 Bathymetry data

Offshore bathymetry was obtained between the coastline to the outer GBR by the DeepReef 30m dataset[2]. The GBR30 bathymetric dataset was developed in collaboration between James Cook University, Geoscience Australia, and the Australian Hydrographic Office to compile all available digital bathymetry data to develop regional-scale, 30m resolution grids. This contains deep-water multibeam surveys, airborne lidar bathymetry and chart data, all edited as point clouds to remove noise, and merged into a consistent WGS84 horizontal datum, and an approximate mean sea level vertical datum.

2.3 Hydraulic structures

Details of bridge structures, Mowbray River bridge and Wangetti trail bridge, as shown in Figure 2-1, were obtained from GHD, who have also been engaged by Hunt Design on this project. The details of these structures were modelled in the TUFLOW model. Bridge information such as deck level, thickness, opening dimensions and guardrail height were estimated from supplied engineering drawings. The drawings are contained in Appendix – As Constructed Drawings.

Figure 2-1. Mowbray River bridge and Wangetti trail bridge

2.4 Tide information

The dynamic time varying tidal boundary was adopted to represent sinusoidal water level patterns with a peak level equivalent to a Highest Astronomical Tide (HAT), estimated at 1.78mAHD for present day (2021).

2.5 Gauge data

The catchment is currently ungauged and as such, data on historical river heights and rainfall in the catchment are currently unavailable.

1 Geoscience Australia 2015. Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid. Geoscience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/89644

2 Beaman, R.J. (2018) "100/30 m-resolution bathymetry grids for the Great Barrier Reef", SSSI Hydrography Commission Seminar, March 2018. Surveying and Spatial Sciences Institute (SSSI), Canberra, Australia.

3 Study Methodology

3.1 Hydrologic model development

A hydrologic model has been developed to estimate rainfall-runoff and streamflow throughout the Mowbray River catchment. The Unified River Basin Simulator (URBS) model adopted for this project is a semi-distributed nonlinear rainfall-runoff model. The URBS model has been applied in a 'split' mode, where the effects of the sub-catchment and channel routing are calculated separately. First, the excess rainfall on a sub-catchment is routed to the creek channel, with the inflow assumed to occur at the centroid of the sub-catchment. The lag of the sub-catchment storage is assumed proportional to the square root of the sub-catchment area. Next, the inflow is routed along a reach using a linear Muskingum method, where lag time is assumed to be proportional to the length of the reach.

Catchment delineation within the model has been based on a 30 metre Digital Elevation Model (DEM). The catchment was divided into 112 sub-catchments, ranging between 1 and 2 km^2. The catchment delineation is shown in Figure 3-1.

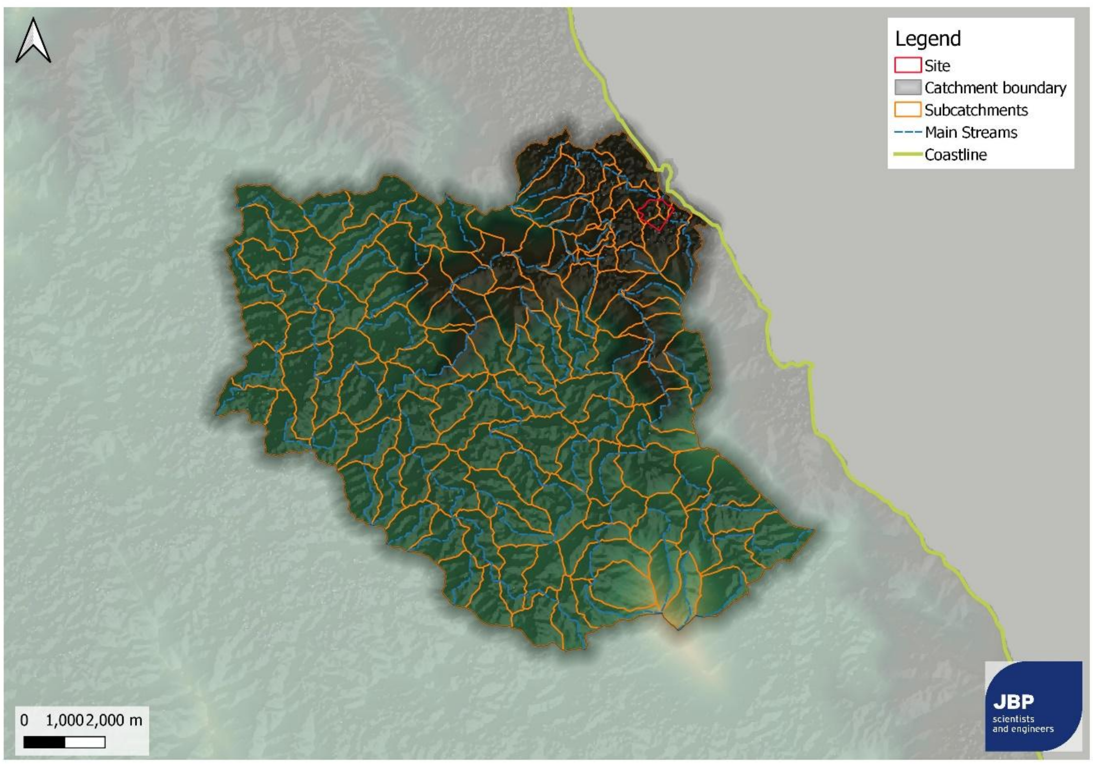


Figure 3-1. Mowbray River sub-catchment delineation

Given the absence of gauging station in the study area, a review of hydrological modelling of nearby catchments was undertaken. JBPacific has completed comprehensive, calibrated hydrologic modelling of the nearby adjoining Mossman River catchment. The Mossman River outlet is located approximately 14km to the north of the mouth of the Mowbray River. The two catchments have similar fan-shapes and are both small-medium catchments with comparative areas approximately 208km^2 and 116km^2 respectively.

The initial hydrologic model build used the same URBS model parameters as for the Mossman River and was jointly-validated by comparing hydrological results with obtained results from the TUFLOW hydraulic model. The validation resulted in a refining of the alpha parameter, which decreased from 0.3 to 0.2. This is a reasonable change as decreasing the alpha value results in faster flood wave celerity which is likely given the shorter, smaller catchment. The adopted URBS parameters are summarised in Table 3-1.

Table 3-1: Adopted URBS model parameters

Parameter	Mowbray River
Number of sub-catchments	112
Initial Loss	16
Continuing Loss	3.5 mm/hr
Alpha, α	0.2
m	0.8
Beta, β	1.2

3.1.1 Design inputs

The hydrological model was used to simulate the 1%AEP flows in the Mowbray River catchment. Design hydrographs were estimated at the upstream boundary of the TUFLOW model, representing the inflow of the Mowbray River and Spring Creek. Local catchment runoff was calculated at the outlet of the rest of the sub-catchments in the study area. Rainfall data was downloaded from the Australian Rainfall and Runoff (ARR2019) data hub.

3.1.2 Intensity-Frequency-Duration (IFD) Curves

Due to the topographic variability and size of the catchment, it was deemed that using one IFD would not accurately represent the catchment, and on the other end of the spectrum, it was not considered practical, or necessary to generate an IFD for 112 individual sub-catchments. As displayed in Figure 3-2 the catchment was delineated into six regions, with the centroids of each IFD region used to download the Bureau of Meteorology's (BoM's) IFD data.

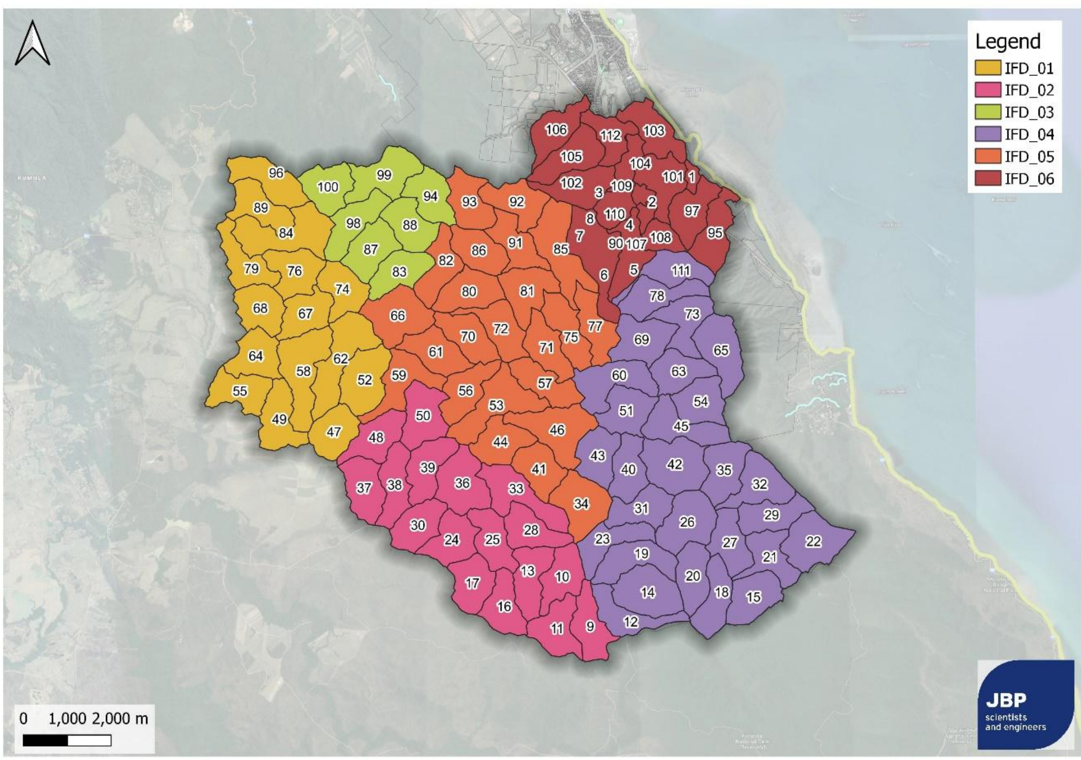


Figure 3-2. Application of IFDs to hydrological modelling across the catchment

3.1.3 Temporal Patterns

The ARR DataHub was used to obtain temporal pattern ensembles for the catchment. Two sets of temporal patterns were obtained which represent “rare” events and events within the areal “North East Coast” region for the catchment. The rare temporal pattern sets contained storm durations of 4.5 hours, 6 hours, 9 hours, 12 hours, 18 hours, 24 hours, 30 hours, 36 hours, 48 hours, 72 hours, 96 hours and 120 hours while the areal set contained storm durations of 12hours, 18 hours, 24 hours, 36 hours, 48 hours, 72 hours, 96 hours and 120 hours. Each of the two temporal pattern sets contained 10 ensembles for each duration.

3.1.4 URBS ARR19 Results

Given the lack of stream gauges within the Mowbray River, the URBS model cannot be formally calibrated. Instead, in line with Australian Rainfall and Runoff (ARR2019) guidelines a validation of the URBS model using an analytical approach, regional flood frequency estimation and generalised rational method was undertaken.

Various duration hydrographs from 6 hour to 120 hours were assessed to determine the critical duration for each sub-catchment. The approach adopted for the design flood estimation was to select the pattern and duration that was closest to the median (or one higher than the median) as an input to the hydraulic model. Figure 3-3 shows the ensemble results for each duration and 1%AEP as box and whisker plot for catchment outlet. Critical inflow duration for that location was 48 hours. It is noted that these critical durations may differ from the hydraulic model critical durations as any floodplain storage will be more accurately modelled in the hydraulic model. The validity of estimated peak flood discharge at the catchment outlet was investigated by Regional Flood Frequency Estimation Model, ARR, which the results show consistency with lower confidence limit of 1%AEP peak flow.

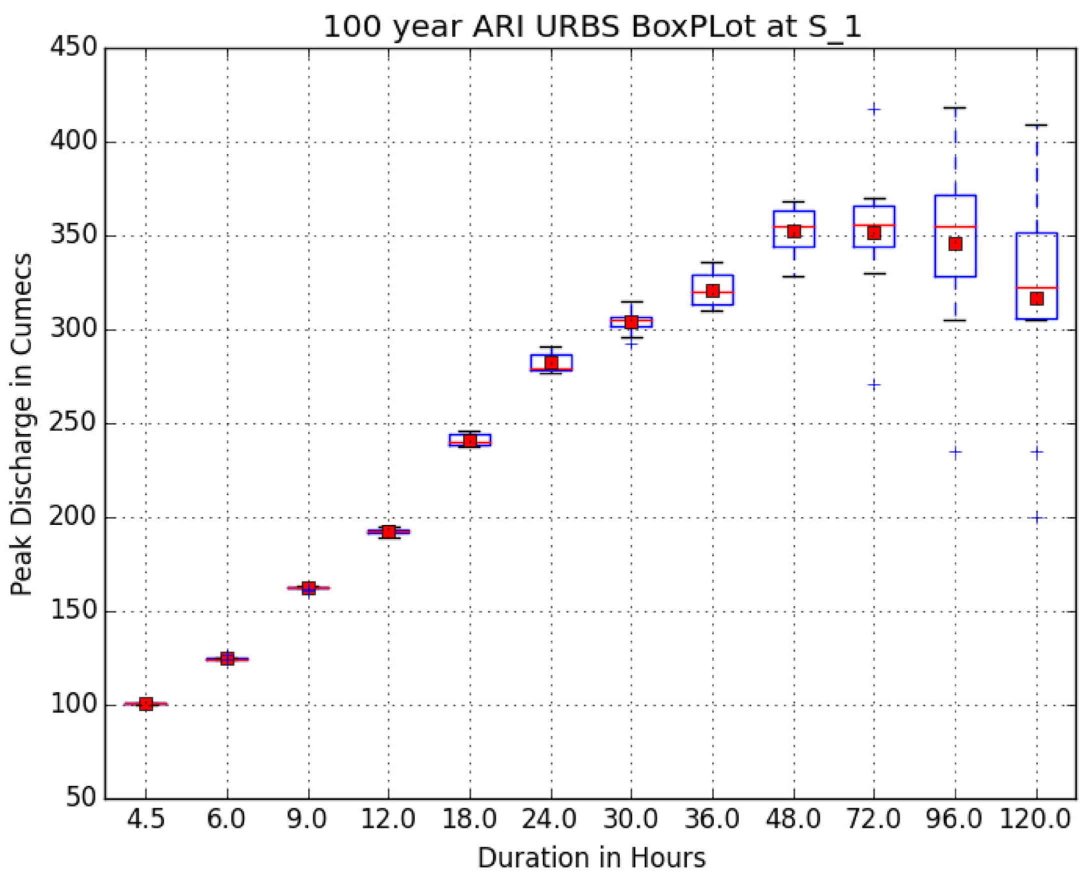


Figure 3-3. Box and whisker plot of ensemble temporal patterns modelled in the URBS hydrological model. Reported at river outlet (sub-catchemnt1)

3.2 Hydraulic model development

3.2.1 Overview

The existing 2-dimensional hydrodynamic TUFLOW model developed as part of the draft Storm Tide Inundation Methodologies Study (JBPacific, 2020) was used as a basis for the hydraulic modelling undertaken in this project. The model was updated to ensure it was fit-for-purpose for this current study and run to simulate flood behaviour at the site for the 1%AEP flood event.

3.2.2 Model extent

A schematic of the hydraulic model domain is shown in Figure 3-4, showing the TUFLOW model covers an area of approximately 12.89 km^2 with a downstream boundary located along the tidal waters offshore of the Mowbray River mouth. The tidal boundary was positioned at the -3mAHD depth contour and adopted a dynamic time varying tidal boundary with a peak value equivalent to Highest Astronomical Tide (HAT).

Three inflow location were included in the model, they were schematised to represent:

- the Mowbray River inflow from the west
- the Spring Creek inflow from the south and
- a local catchment inflow from the north.

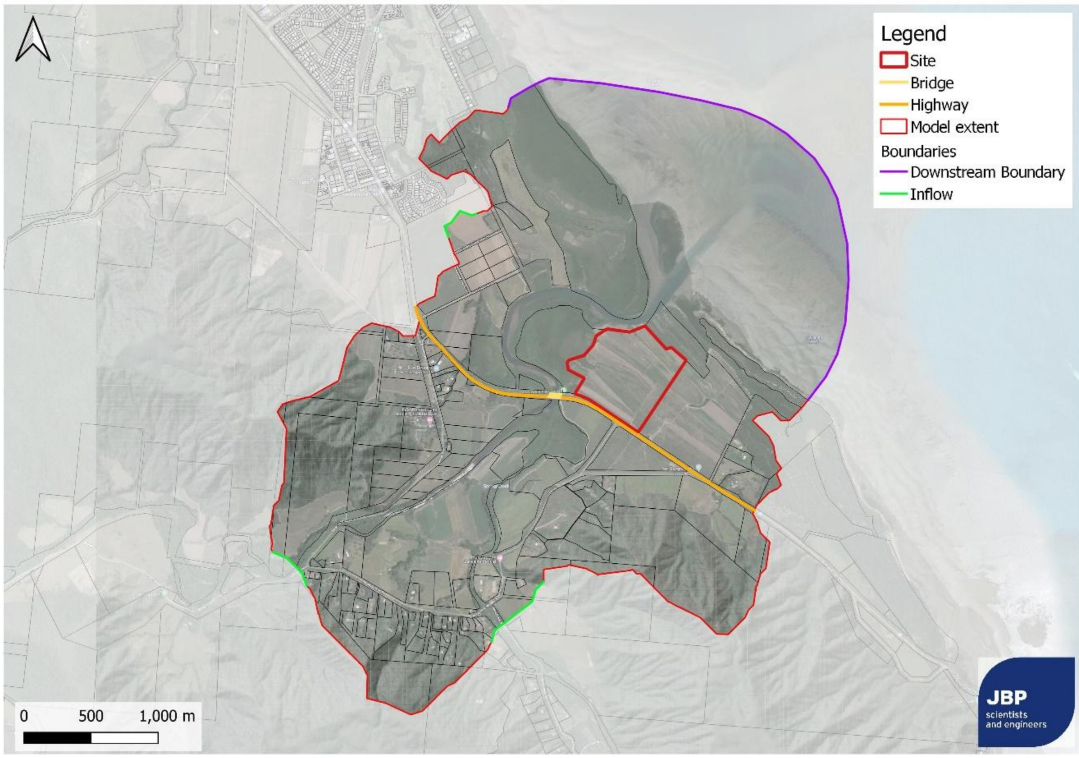


Figure 3-4. TUFLOW model configuration

3.2.3 Topography and bathymetry data

The existing case digital elevation model (DEM) was derived by merging the available topography and bathymetry data as described in Section 2-1.

3.2.4 Grid and Timestep

A 5m model grid resolution was used for the existing hydraulic model. Considering the topography is generally defined by widespread agricultural land and scattered to dense vegetation with a wide floodplain this grid resolution is considered appropriate for the floodplain areas of the catchment. The TUFLOW model was developed as a classic model with the timestep of 2 seconds to produce reasonable hydraulic model simulation times.

3.2.5 Roughness

Surface roughness conditions have been represented through the application of Manning's 'n' values. The Douglas Shire contains estuaries, mangrove forest and rivers, which each can influence the extent and depth of flooding. The Manning values were adopted from DRAFT Storm Tide Inundation Methodologies Study (JBPacific, 2020) which, were mapped from the combination of Queensland Land Use Mapping Program (QLUMP) and NDVI vegetation analysis. The adopted roughness values are shown in Table 3-1.

Table 3-2. Model roughness

Vegetation class	Mannings 'n;
Dense vegetation/mangrove	0.120
Other minimal use	0.120
Residential and farm infrastructure	0.040
Grazing native vegetation	0.035
Managed vegetation	0.030
River channel	0.030
Open water	0.030
Sandy beach	0.025

3.2.6 Existing Structures

Bridge structures were represented in the TUFLOW model. Details of these structures were obtained from GHD for the Wangetti trail bridge and included in the TUFLOW model. The modelled bridges are indicated on Figure 3-4. Bridge information such as deck level, thickness, opening dimensions and guardrail height were estimated from provided engineering drawings (Appendix – As Constructed Drawings). Bridges were modelled as 2d structures, which is common practice on the main watercourses.

3.2.7 Boundaries

Four boundaries have been established:

- A inflow Q-T boundary, as a time-varying hydrograph, representing the Mowbray river flows;
- A inflow Q-T boundary, as a time-varying hydrograph, representing the Spring Creek flows;
- A inflow Q-T boundary, as a time-varying hydrograph, representing a minor catchment inflow from the north of the catchment.; and
- A H-T tailwater boundary at the ocean.

Local sub-catchment inflows were included in the hydraulic model setup for more accurate simulation of hydrological process in the study area.

The downstream boundary has been established along the eastern seaboard of the TUFLOW model approximately 1.5 km offshore from the river mouth. As shown in Figure 3-5, the dynamic time varying tidal boundary was adopted to represent sinusoidal water level patterns with a peak value equivalent to an estimated Highest Astronomical Tide (HAT) level of 1.78mAHD for present day (2021). Three days of the tidal cycles were modelled with the present time timeframe. The flood wave from Mowbray river will coincide with a peak of highest tide of the second cycle as a conservative approach.

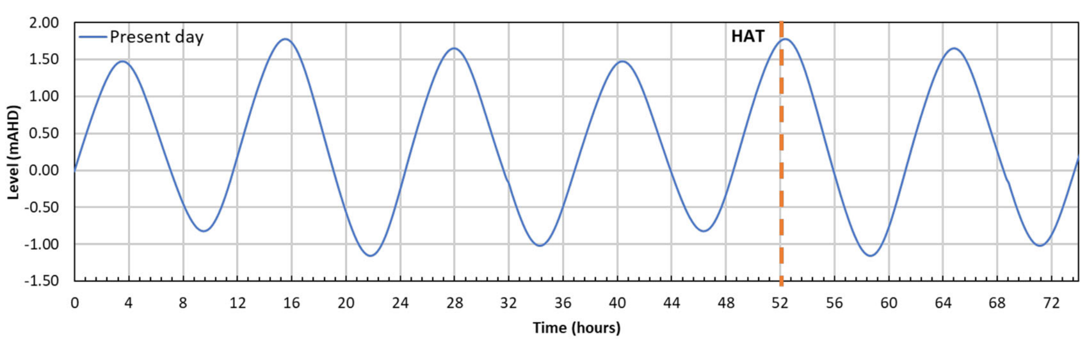


Figure 3-5. Tidal signature for present day

4 Hydraulic Model

As required by the Douglas Planning Scheme 2018, the Defined Flood Event or 1% Annual Exceedance Probability (AEP) flood event was the focus of the hydraulic model simulation.

4.1 Base case model

Once the TUFLOW Classic hydraulic model was setup, a base case scenario was established. The purpose of the base case was to establish flood behaviour in the catchment and vicinity of the site for existing catchment conditions.

As discussed in Section 3-1, the estimated inflow hydrographs were extracted from the hydrological model at the TUFLOW model inflow locations. Reporting location nearby the site and downstream of the bridge were used to compare the results between the hydrological and hydraulic models, for evaluating the performance of the hydraulic mode. As shown in Figure 4-1, a comparison of hydrologic and hydraulic model results, show good agreement between the two model. The small differences in the hydrograph shape and peak are most likely related to the fact that floodplain storages are more accurately modelled in the hydraulic model.

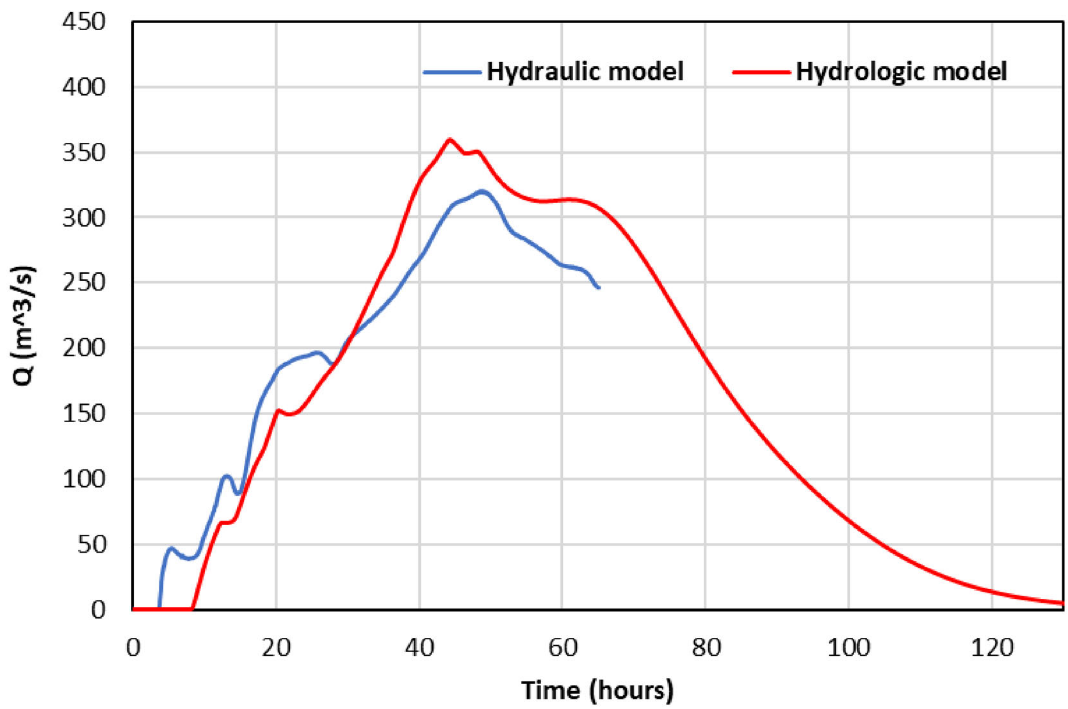


Figure 4-1. Comparison between hydrological and hydraulic model results near the site.

4.1.1 Base case results

The existing case flooding characteristics for the 1% AEP flood event in the vicinity of the site are described below:

- Hydraulic modelling indicates peak water levels within the lot subject to the development application, range from approximately 2.6 mAHD in the west side nearest the Mowbray River to approximately 2 mAHD in the north, as shown in Figure 4-2.
- The water depth ranges from 1.1m in the in the west side of the lot subject to the development application to 0.01m in the north of the site as shown in Figure 4-3.

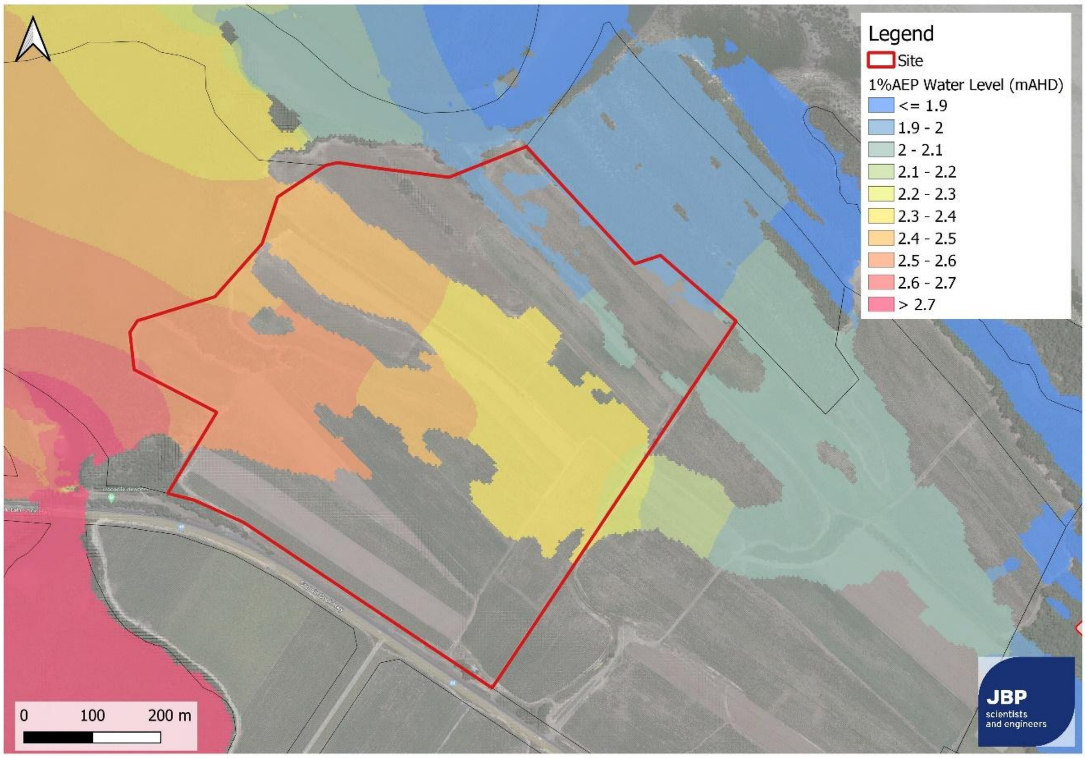


Figure 4-2. Peak water surface level in the 1%AEP flood for existing case

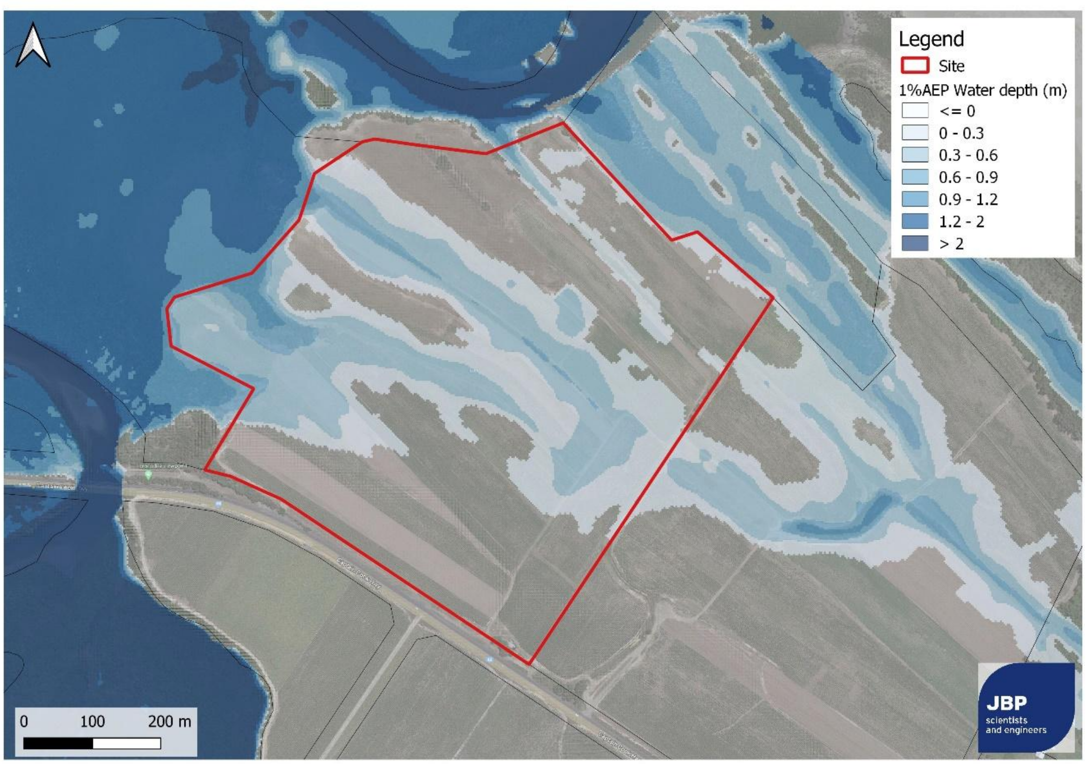


Figure 4-3. Peak flood depth in the 1%AEP flood for existing case

4.2 Post-development model

The hydraulic model was used to simulate the proposed (post-development) scenario and assess impacts on flood behaviour in the vicinity of the proposed development. Results of the post-development and analysis of flood impacts are provided in Section 5 of this report.

4.2.1 Development footprint

The proposed development was modelled by using the preliminary digital train model provided by Hunt Design as shown in Figure 4-4. The surface roughness information was mapped and updated to the new development footprint. Consideration was not given to detailed elements for mapping the roughness as it was out of scope of this study.

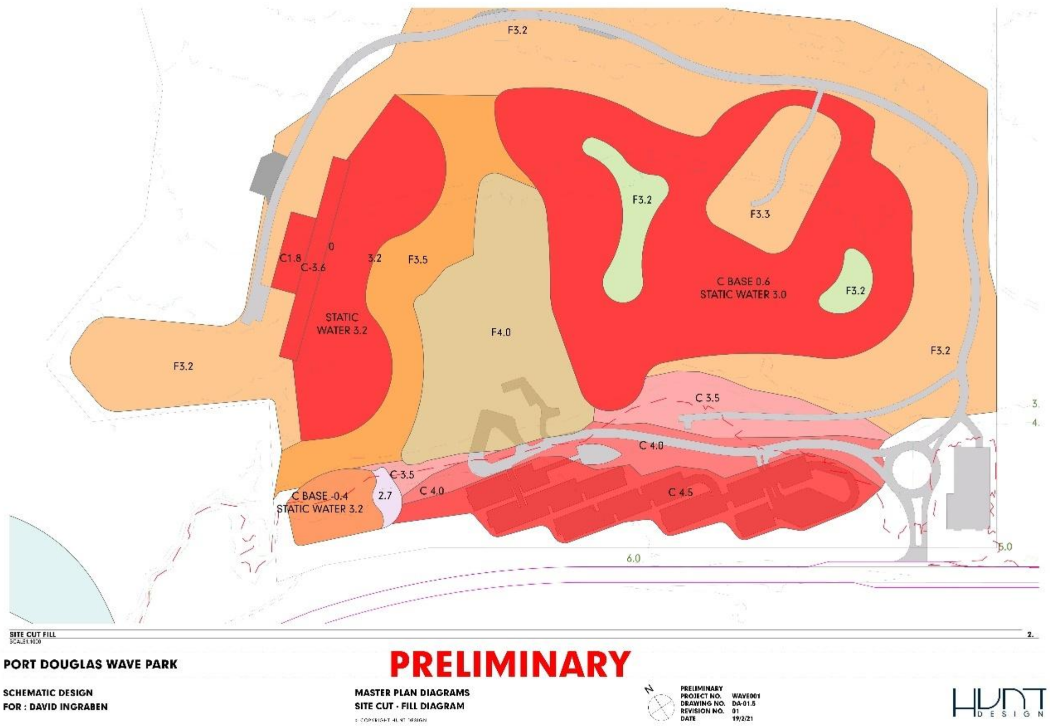


Figure 4-4. Configuration of preliminary earthwork

4.2.2 Developed case results

The developed case flooding characteristics for the 1% AEP flood event in the vicinity of the site are described below:

- Hydraulic modelling indicates peak water levels within the lot subject to the development application, range from approximately 2.7 mAHD in the west side nearest the Mowbray River to approximately 2 mAHD in the north, as shown in Figure 4-5
- The water depth ranges from 1.1m in the in the west side of the lot subject to the development application to 0.01m in the north of the site as shown in Figure 4-6.

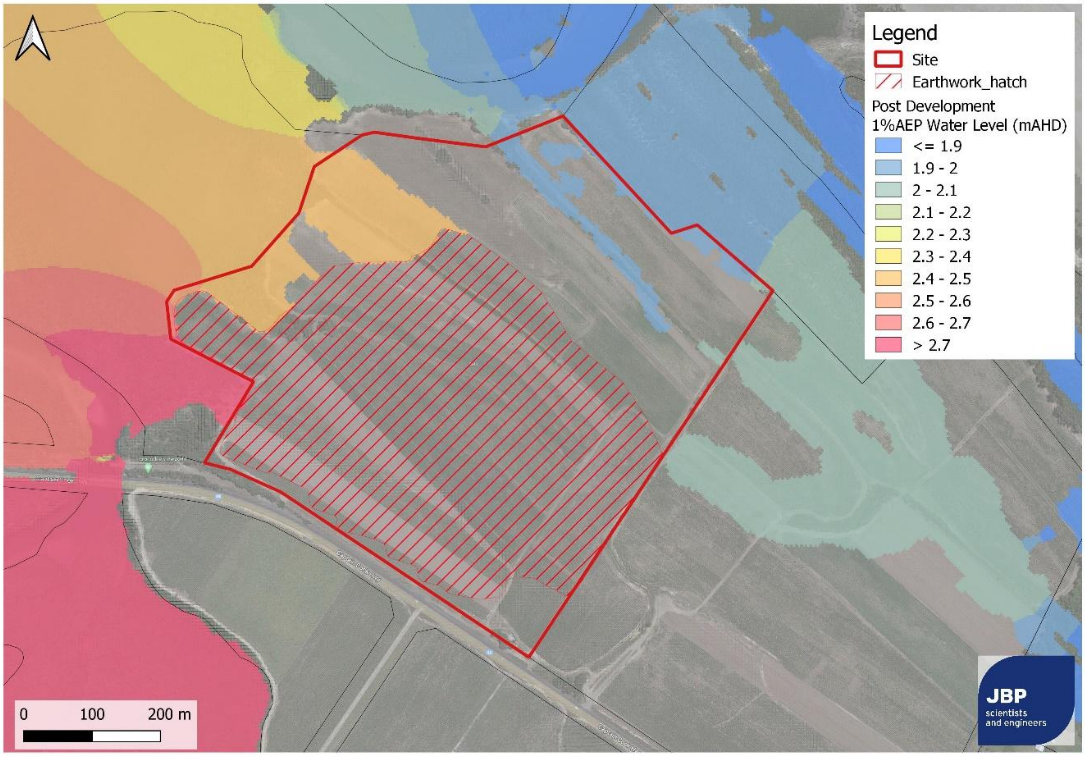


Figure 4-5. Post development 1%AEP peak water surface level

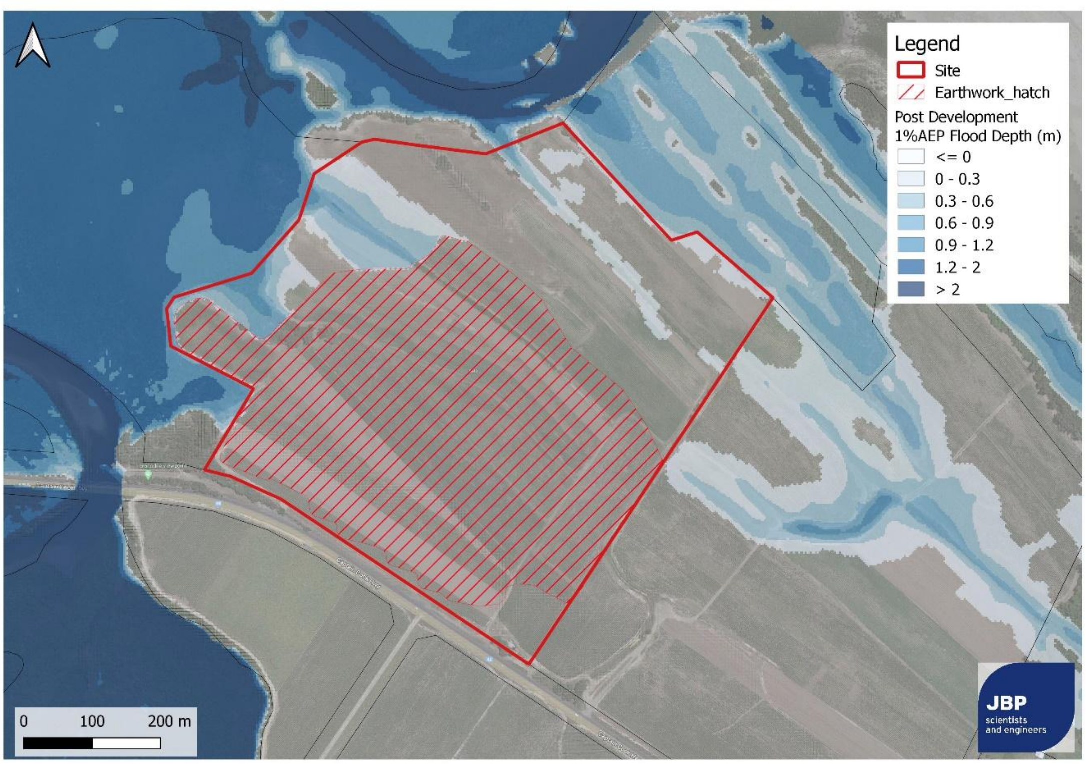


Figure 4-6. Post development 1%AEP peak flood depth

5 Flood Impacts

The hydraulic model was used to assess the possible impacts to the existing flood conditions for the proposed development.

Consideration was given to a range of flooding characteristics, including:

- Flood level impacts
- Flood velocity impacts
- Floodplain storage

5.1 Flood level impacts

Hydraulic model results for the post-development condition were compared to the pre-development, existing case flood results. As shown in Figure 5-1, the largest flood level impacts are generally observed in the immediate vicinity of the proposed development, with the greatest flood level impact of 183mm occurring adjacent to the lot subject of the development application.

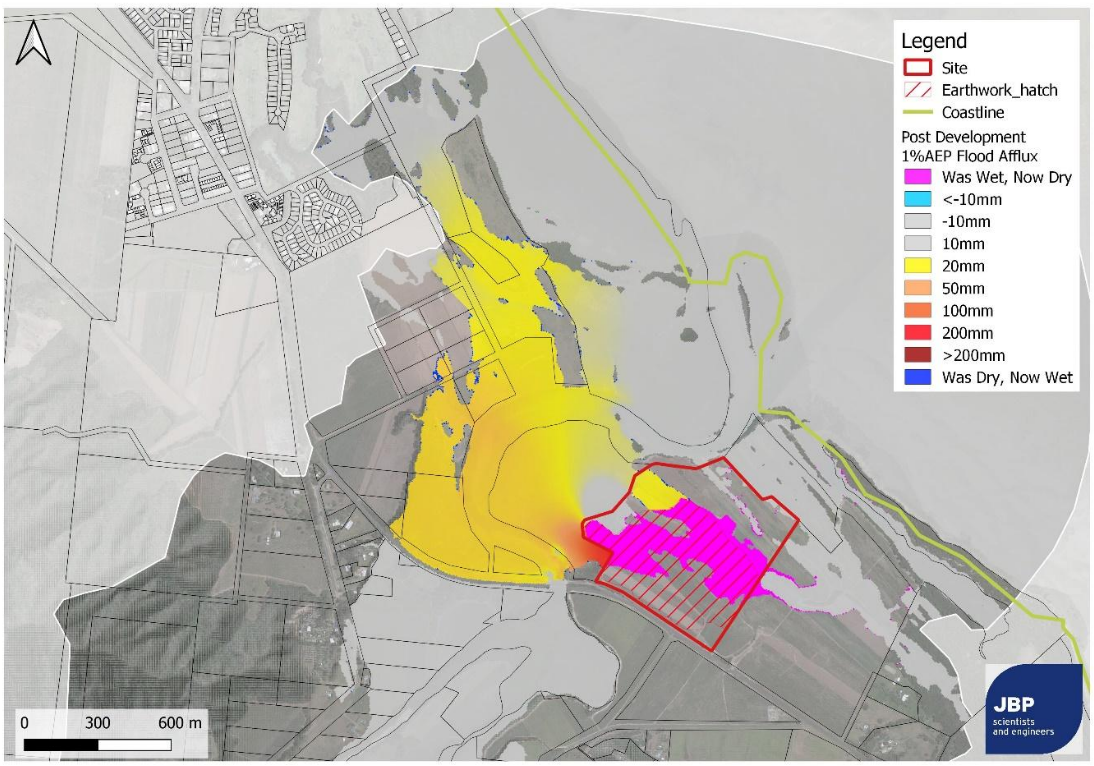


Figure 5-1. Flood level impacts in the 1%AEP flood event

The flood modelling indicates flood impacts are restricted to the portion of the floodplain downstream of the Captain Cook Highway, Mowbray. The largest flood level impacts are evident to the west (upstream) side of the site between the proponents land and the Highway. The maximum afflux in this location is 183mm, however this is on State-owned conservation land and as such, the flood impacts are not anticipated to result in adverse impacts to people or property.

There is only a minor increase in inundation extent, to the north of the site on the opposite bank to the proposed development. The minor increase in flood liable land is generally restricted to property zoned for rural uses and a review of available aerial imagery does not indicate this is will impact existing dwellings in the lower catchment.

As shown in Figure 5-1, flood impacts in the 1%AEP flood event are limited to downstream of the Captain Cook Highway. Given the modelling results indicate there is potentially some impact to peak flood levels, a further analysis of peak flood levels was undertaken at a lot scale. The results of this analysis are summarised in Table 5-1.

Table 5-1. Summary of peak flood impacts (by land use)

Lot	1%AEP Maximum Afflux (m)
Low Density Residential	0.018
Rural	0.037
Environmental Management	0.021
Conservation	0.183
Special Purpose	<0.001

Table 5-1 indicates the maximum impact on residential property is 18mm. It should be noted that whilst this land is zoned as low density residential in the Douglas Planning Scheme 2018, aerial imagery indicates it is currently vegetated, undeveloped land. Additionally, flood impacts are limited to an existing low-laying area of lot, which represents approximately 2% of the total lot area.

Maximum flood impacts on rural land external of the proponents land is 37mm, which is located opposite the proposed development on agricultural land. An increase of 37mm is not expected to adversely affect the existing land owners ability to farm the land.

5.2 Flood velocity impacts

Analysis of velocity afflux was conducted to demonstrate the impact the proposed development has on the flood velocity compare to the existing case. Figure 5-2 shows there are some increases in flood velocity in the west side of proposed development lot (up to 0.5 m/s), however, the maximum velocity afflux external of the site is less than 0.2 m/s.

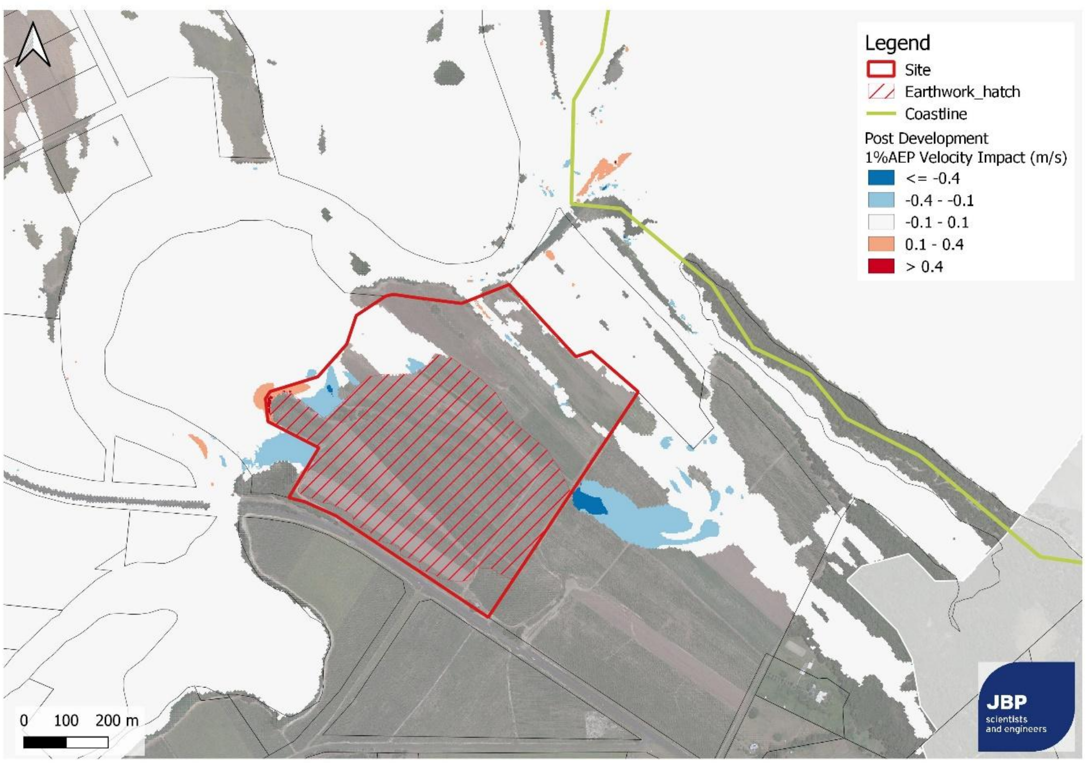


Figure 5-2. Flood velocity impact in the 1%AEP flood event

5.3 Floodplain storage

The purpose of this hydraulic impact assessment was to assess the impact on flooding behaviour resulting from the proposed development. The earthworks cut and fill balance has been provided by GHD in Figure 5-3.

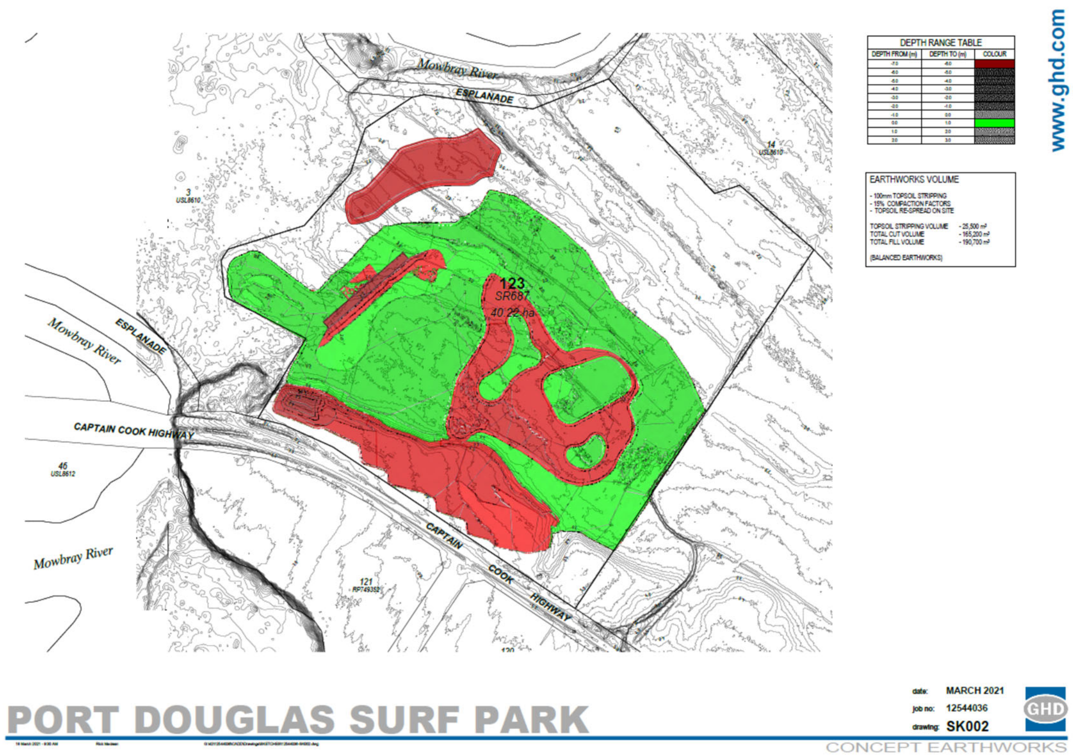


Figure 5-3. Earthworks plan

The earthwork concept design shows the total cut and fill are 165,200 m³ and 190,700 m³ respectively, with total balance value of 25,500 m³, excess of fill over cut, (Table 5-2). This loss of floodplain capacity is shown to affect flood levels on the areas immediately upstream of the proposed development (160mm) and slight effect on rural lots (summarised in Table 5-1). In general, reducing floodplain capacity cause upstream and downstream impacts, therefore any development should balance cut and fill by creating additional volume adjacent filling site to approach minimum impact to the floodplain.

Table 5-2. Summary of cut and fill (provided by Hunt Design Consultants)

Total Cut (m³)	Total Fill (m³)	Total Balance (m³)
165,200	190,700	25,500 fill

5.4 Design iterations

The initial proposed design, was shown to result in increased flood levels in the 1%AEP flood event of up to 18mm on residential zone lot-type parcels, 37mm on rural zone lot-type parcels and a maximum peak flood level increase of 183mm on conservation zone land. The highest impacts were shown in Figure 5-1 to occur immediately upstream of the site, in an area of filling that created a 'right angle of fill', reducing the cross-sectional area for floodplain conveyance in comparison to the existing catchment conditions. Reactivating the floodplain conveyance by including an open channel through the proposed development in the vicinity of the 'cabin park' on the south west of the site near the Wangetti Trail.

5.4.1 Single open channel

To improve floodplain conveyance through the site a single trapezoidal open channel with typical geometry, as shown in Figure 5-4, was added to the hydraulic model. The channel had a base width of 20m and a depth of 500mm, with 1:4 slope batters. The channel design adopted a longitudinal slope of 0.006 m/m (0.6%), which is slightly steeper than the existing ground levels and would require additional minor excavation on the downstream end of the channel. The additional gradient was required to improve flow in the channel, given the ground levels on the neighbouring property at the upstream end of the channel are the limiting natural ground level for the indicative design of the open channel.

The alignment of the single open channel tested in the design iteration is shown in Figure 5-5, with resulting flood impacts shown in Figure 5-6.

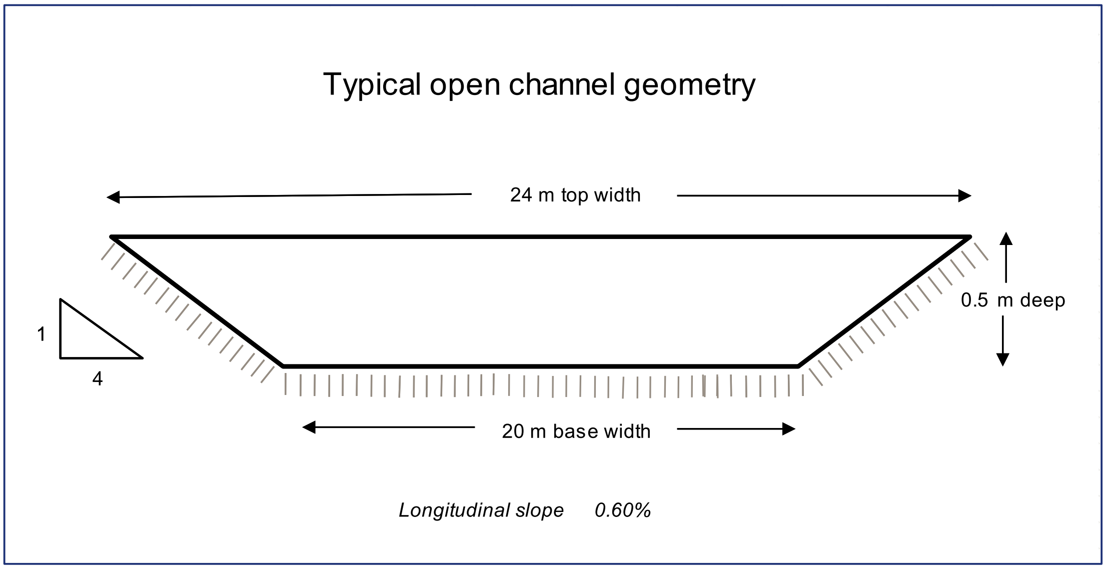


Figure 5-4. Typical section of indicative open channel

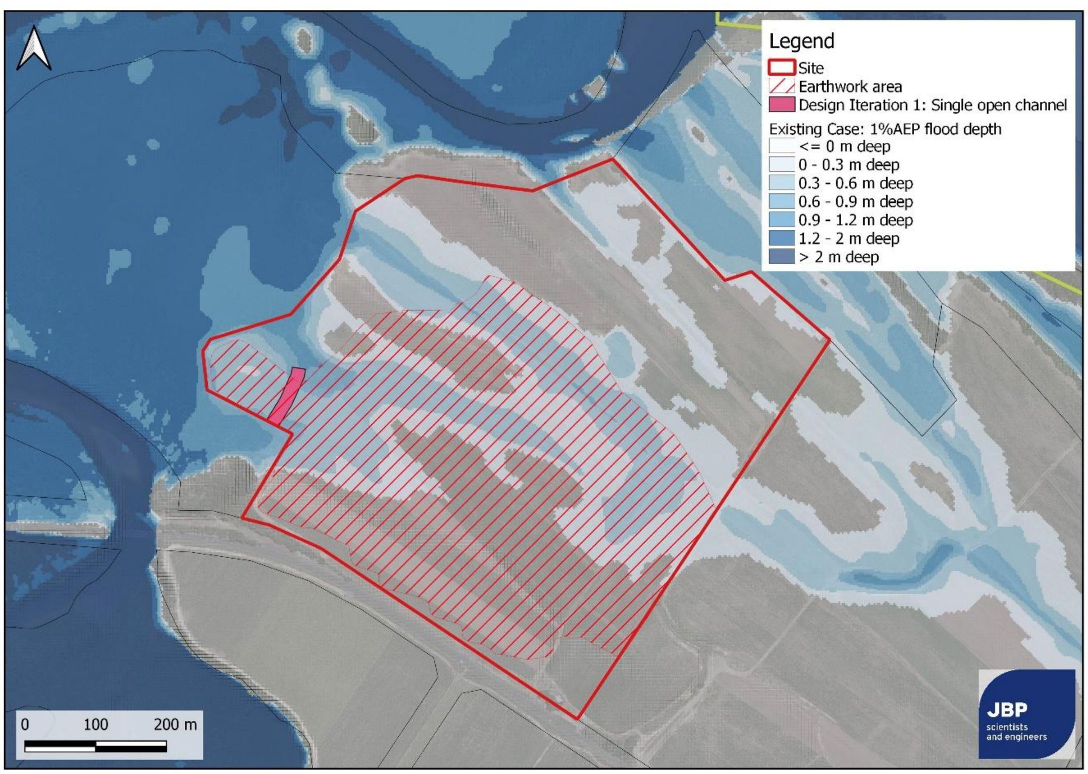


Figure 5-5. Location of indicative single open channel

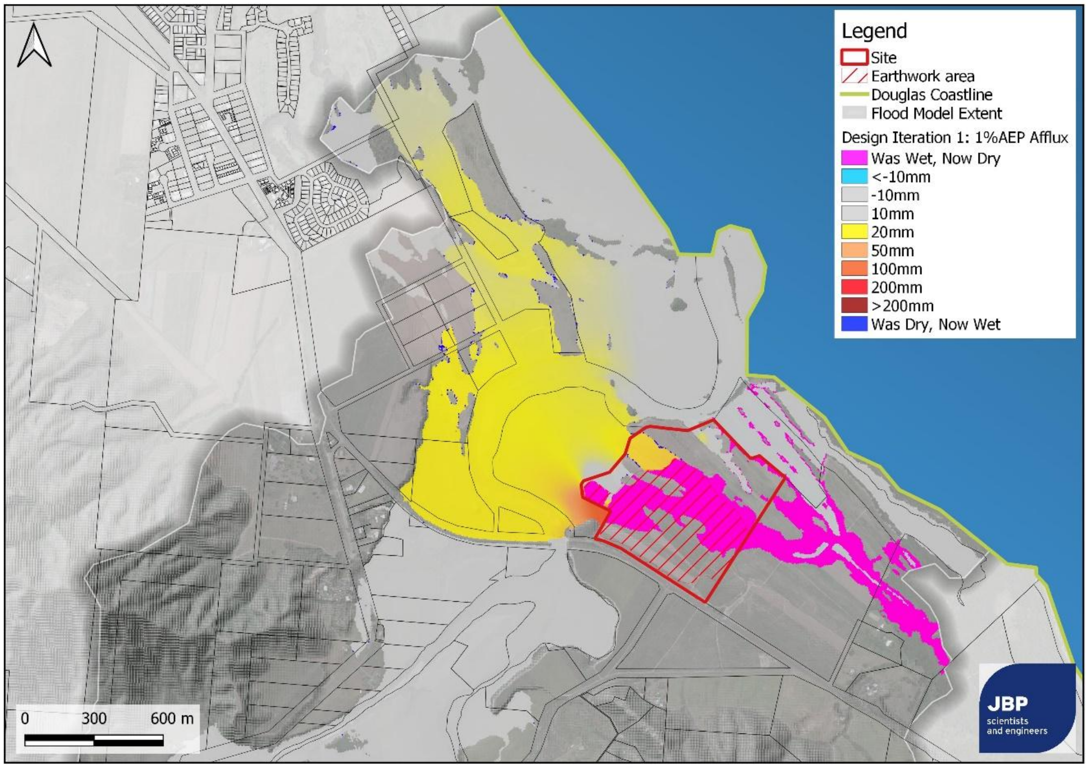


Figure 5-6. Flood impacts associated with indicative single open channel

The results of the design iteration incorporating the single trapezoidal open channel is summarised in Table 5-3, shows peak flood impacts external of the site are generally reduced, in comparison to the initial design, by the inclusion of the single open channel. Figure 5-6 shows the maximum flood level impact of 127mm is located on conservation land immediately upstream of the site between the proposed cabin/camp facilities and the Wangetti Trail.

Table 5-3 indicates the maximum impact on residential property is 15mm. It should be noted that whilst this land is zoned as low density residential in the Douglas Planning Scheme 2018, aerial imagery indicates it is currently vegetated, undeveloped land. Additionally, flood impacts are limited to an existing low-laying area of lot, which represents approximately 2% of the total lot area.

Maximum flood impacts on rural land external of the proponents land is 25mm, which is located opposite the proposed development on agricultural land. An increase of 25mm is not expected to adversely affect the existing land owners ability to farm the land.

Table 5-3. Summary of peak flood impacts (by land use)

Lot	Initial Design 1%AEP Maximum Afflux (m)	Design Iteration 1 (single channel) 1%AEP Maximum afflux (m)	Change in modelled 1%AEP flood impacts
Low Density Residential	0.018	0.015	3mm reduction
Rural	0.037	0.025	12mm reduction
Environmental Management	0.021	0.018	3 mm reduction
Conservation	0.183	0.127	56mm reduction
Special Purpose	<0.001	<0.001	negligible

5.4.2 Dual open channel

To improve floodplain conveyance through the site dual trapezoidal open channels with typical geometry, as shown in Figure 5-7Figure 5-4, was added to the hydraulic model. The channel had a base width of 20m and a depth of 500mm, with 1:4 slope batters. The channel design adopted a longitudinal slope of 0.006 m/m (0.6%), which is slightly steeper than the existing ground levels and would require additional minor excavation on the downstream end of the channel. The additional gradient was required to improve flow in the channel, given the ground levels on the neighbouring property at the upstream end of the channel are the limiting natural ground level for the indicative design of the open channel.

The alignment of the single open channel tested in the design iteration is shown in Figure 5-8, with resulting flood impacts shown in Figure 5-9.

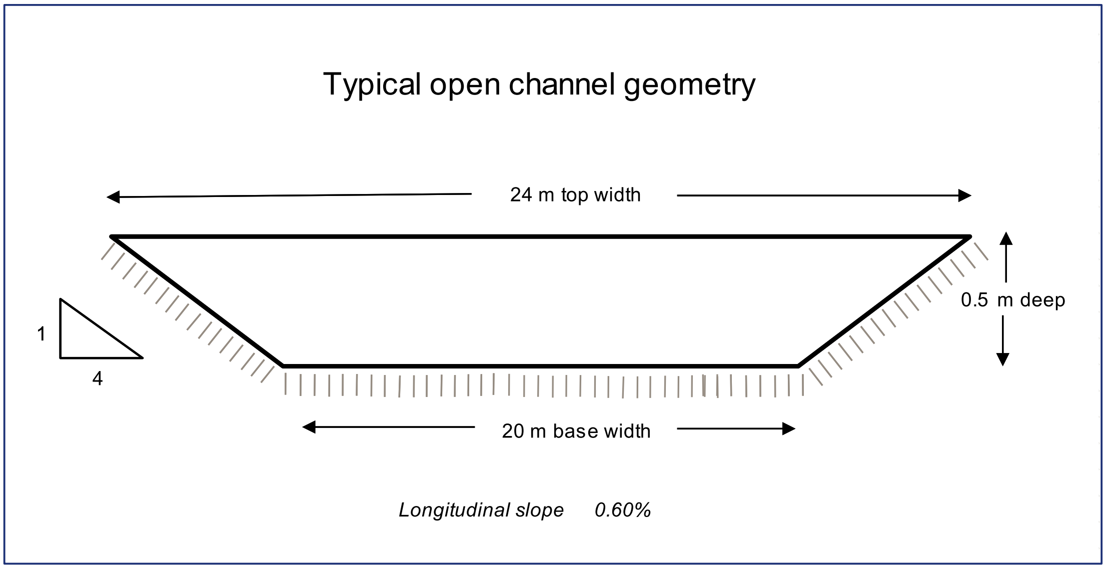


Figure 5-7. Typical section of indicative open channel

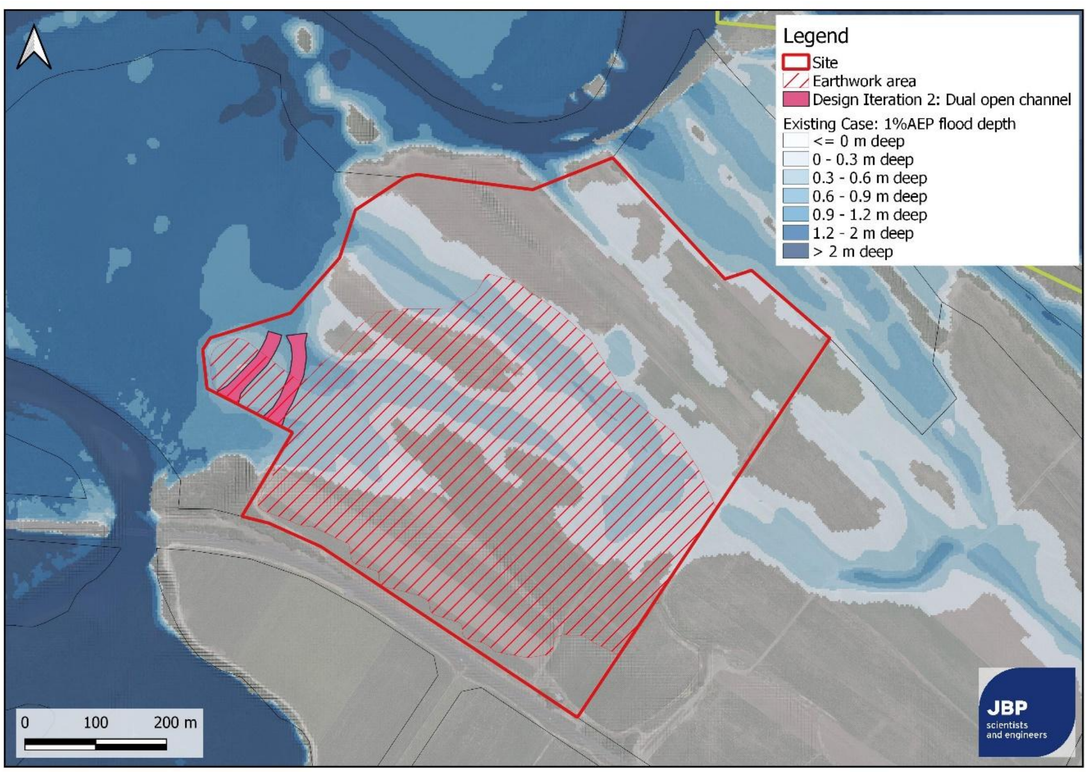


Figure 5-8. Location of indicative dual open channel

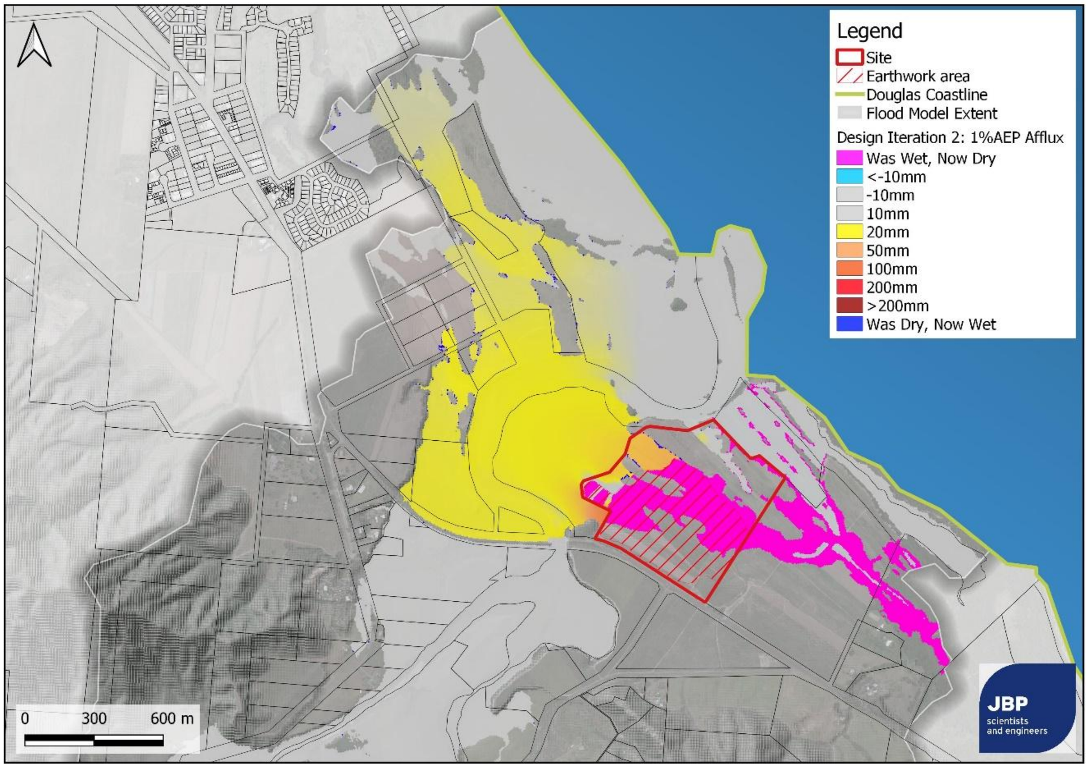


Figure 5-9. Flood impacts associated with indicative dual open channel

The results of the design iteration incorporating the single trapezoidal open channel is summarised in Table 5-4, shows peak flood impacts external of the site are generally reduced, in comparison to the initial design, by the inclusion of the single open channel. Figure 5-9 shows the maximum flood level impact of 88mm is located on conservation land immediately upstream of the site between the proposed cabin/camp facilities and the Wangetti Trail.

Table 5-4 indicates the maximum impact on residential property is 15mm. It should be noted that whilst this land is zoned as low density residential in the Douglas Planning Scheme 2018, aerial imagery indicates it is currently vegetated, undeveloped land. Additionally, flood impacts are limited to an existing low-laying area of lot, which represents approximately 2% of the total lot area.

Maximum flood impacts on rural land external of the proponents land is 25mm, which is located opposite the proposed development on agricultural land. An increase of 25mm is not expected to adversely affect the existing land owners ability to farm the land.

Table 5-4. Summary of peak flood impacts (by land use)

Lot	Initial Design 1%AEP Maximum Afflux (m)	Design Iteration 2 (dual channels) 1%AEP Maximum afflux (m)	Change in modelled 1%AEP flood impacts
Low Density Residential	0.018	0.015	3mm reduction
Rural	0.037	0.025	12mm reduction
Environmental Management	0.021	0.018	3 mm reduction
Conservation	0.183	0.088	95mm reduction
Special Purpose	<0.001	<0.001	negligible

5.4.3 Results of design iterations

Two design iterations were investigated to identify if potential changes to the proposed earthworks may reduce modelled flood impacts.

Only a minor reduction of 3mm in flood impacts was observed on low density residential and environmental management zoned land. A moderate reduction of 12mm was observed for rural zoned land, bringing peak flood level impacts down from 37mm to 25mm. These results were consistent for the single open channel and dual open channel scenarios.

The 1%AEP flood impacts observed on conservation land immediately upstream of the site, on the south west of the proposed development near the Wangetti Trail were reduced from 183mm to 127mm (a 56mm reduction) for the single open channel scenario and from 183mm to 88mm (a reduction of 95mm) for the dual open channel scenario.

6 Flood risk assessment

The Douglas Planning Scheme 2018 does not provide guidance on acceptable levels of afflux in the Defined Flood Event (1%AEP flood event), but rather the purpose of the flood hazard overlay code will be achieved through the following overall outcomes:

a. development siting, layout and access responds to the risk of the natural hazard and minimises risk to personal safety;
b. development achieves an acceptable or tolerable risk level, based on a fit for purpose risk assessment;
c. the development is resilient to natural hazard events by ensuring siting and design accounts for the potential risks of natural hazards to property;
d. the development supports, and does not unduly burden disaster management response or recovery capacity and capabilities;
e. the development directly, indirectly and cumulatively avoids an unacceptable increase in severity of the natural hazards and does not significantly increase the potential for damage on site or to other properties;
f. the development avoids the release of hazardous materials as a result of a natural hazard event;
g. natural processes and the protective function of landforms and/or vegetation are maintained in natural hazard areas;
h. community infrastructure is located and designed to maintain the required level of functionality during and immediately after a hazard event.

The proposed development has demonstrated that the development siting, layout and access is above the 1%AEP flood level and is not anticipated to expose people to flood inundation in the 1%AEP flood event by providing a development footprint above the 1%AEP flood level, thus achieving acceptable flood risk and enabling a resilient design.

The two outcomes that required further analysis were:

- the development directly, indirectly and cumulatively avoids an unacceptable increase in severity of the natural hazards and does not significantly increase the potential for damage on site or to other properties;
- natural processes and the protective function of landforms and/or vegetation are maintained in natural hazard areas;

6.1.1 Development avoids an unacceptable increase in severity of the natural hazards and does not significantly increase the potential for damage on site or to other properties

The State Planning Policy defines 'acceptable risk' as "*a risk that, following an understanding of the likelihood and consequences, is sufficiently low to require no new treatments or actions to reduce risk further. Individuals and society can live with this risk without feeling the necessity to reduce the risk any further.*"[3]

As noted above, the Douglas Planning Scheme does not provide a definition of 'acceptable flood impacts', so a risk assessment in line with ISO31000 has been undertaken to demonstrate the proposed development 'avoids an unacceptable increase in severity'. ISO31000 is the international standard for risk management, and defines risk as the consideration of the likelihood of a hazard occurring and the consequence when an event occurs.

The assessment of the potential for damage to other properties was based on the number of properties exposed to flood hazard given a specified likelihood. In this case, the Defined Flood

3 Natural hazards, risks and resilience - Flood, The State of Queensland, Department of Infrastructure, Local Government and Planning, (2017)

Event of 1%AEP was analysed, with the number of properties at risk external of the development site shown in Table 6-1.

Table 6-1. Summary of at-risk properties by land use

Land Use	Count of properties within the 1%AEP flood extent	
	Existing	Post-development
Conservation	9	9
Environmental Management	1	1
Low Density Residential	1	1
Ocean	1	1
Rural	45*	45
Rural Residential	0	0
Special Purpose	1	1
Total	115	115

*Note: An additional rural property was counted in the existing results on the eastern extremity of the hydraulic model. This was deemed to be an artifact of the flood model itself and was not considered to be a valid inclusion in comparison with post development property exposure.

Table 6-1 shows the existing catchment conditions and post-development catchment conditions result in the same number of properties at risk in the 1%AEP flood event, and as such the proposed development does not significantly increase the potential for damage on the site or other properties.

An analysis of flood hazard, using depth-velocity results from the hydraulic modelling of the proposed development was undertaken to gain an understanding of the severity of flood hazard under pre and post development conditions. A comparison of flood hazard is provided in Figure 6-1, which shows a minor increase in flood hazard within the channel immediately downstream of the Captain Cook Highway and negligible (+/-0.2m2/s) or minor reduction in depth-velocity product on all existing properties. A review of aerial imagery available from Google and NearMap, indicates there are currently no dwellings located within the mapped flood impact area. Figure 6-1. Comparison of existing and post development depth-velocity flood behaviour

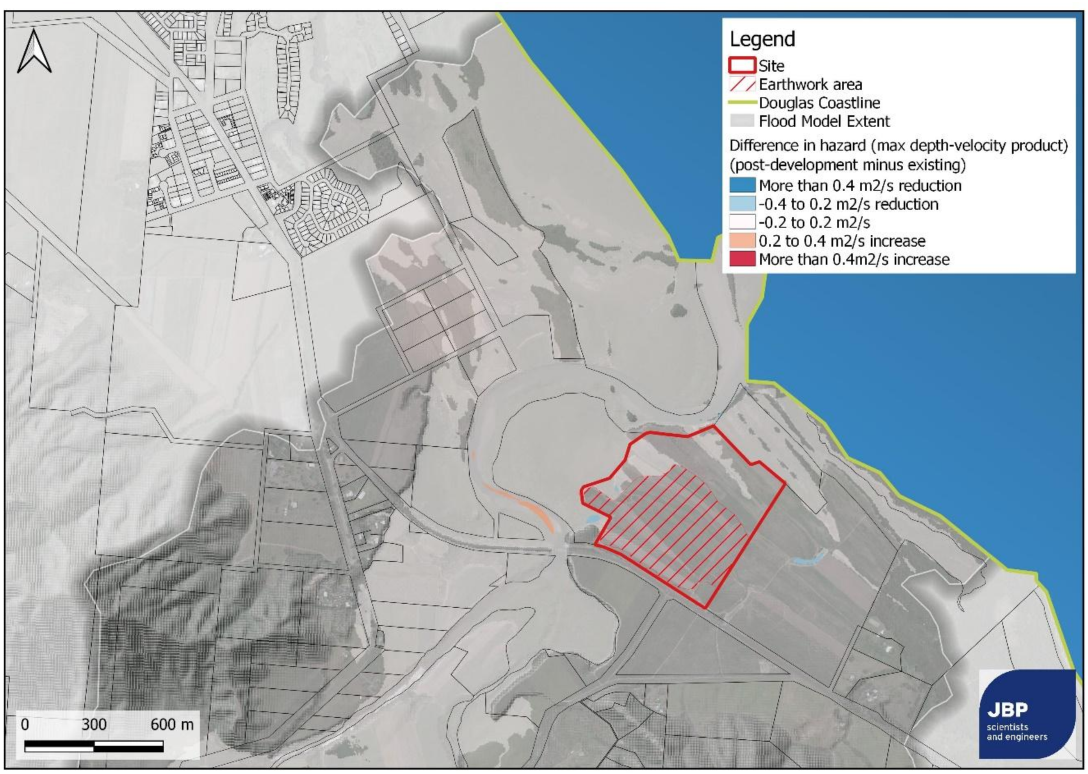


Figure 6-1. Comparison of existing and post development depth-velocity flood behaviour

The assessment of potential exposure to flooding and severity of flood hazards analysed using a risk-based approach consistent with ISO31000, which considers the likelihood of flooding and consequence of flooding hazard, has demonstrated the proposed development does not increase existing flood risk in an unacceptable manner.

6.1.2 Natural processes and the protective function of landforms and/or vegetation are maintained in natural hazard areas

The natural flood behaviour has been described throughout this report. It has been shown there is a 13% increase in nett fill (as a proportion of proposed fill) on the site, which will result in a small decrease of floodplain storage.

The placement of the fill has the most significant impact on modelled post-development flood behaviour, specifically in the vicinity of the cabin/camping area, which impacts the out-of-channel flood conveyance in the 1%AEP flood event. This has been demonstrated to have an impact on existing peak flood levels of up to 183mm on conservation land, and up to 18mm on residential-zoned land, currently undeveloped to the north of the site.

A flood risk assessment was undertaken to investigate the implication of the modelled flood impacts, which has shown the proposed development:

- will not increase the number of properties at risk of flood inundation in the 1%AEP
- will not significantly impact flood hazard
- will not adversely impact existing dwellings.

Further modelling was undertaken to investigate if the addition of open channels through the cabin/camping grounds would improve floodplain conveyance. Whilst the design iterations were shown to improve floodplain conveyance and reduce flood level impacts in the post-development scenario, given the initial proposed design has been demonstrated to achieve acceptable flood risk outcomes outlined by the Douglas Planning Scheme, and the need for additional excavation and removal of vegetation to construct the channels, these design options may be contrary to the desired outcomes of the Planning Scheme in maintaining the protective function of existing vegetation.

7 Conclusion

JBPacific were commissioned by Hunt Design to deliver hydrological and hydraulic modelling within the Mowbray River catchment, to support the proposed integrated development of a recreational 'wave park', at Lot 123 on SR687, located 5km south of Port Douglas on the Captain Cook Highway.

An URBS hydrological model was developed estimate rainfall-runoff and streamflow in the Mowbray River catchment. Design flood estimation for the 1% Annual Exceedance Probability (AEP) flood event was completed to provide inflow hydrograph information to the hydraulic modelling.

The hydrodynamic modelling software TUFLOW using its 'Classic' engine was adopted as the basis of the hydraulic analysis. An existing TUFLOW model, developed for Douglas Shire Council as part of the draft Storm Tide Inundation Methodologies Study (JBPacific, 2020) project, was available as basis for modelling the proposed development. The TUFLOW model was modified to ensure that it appropriately simulated river flooding in the vicinity of the proposed development.

The hydraulic modelling was run to simulate both the existing catchment conditions and the post-development scenario. The results of the hydraulic modelling indicate flood impacts are restricted to the portion of the floodplain downstream of the Captain Cook Highway, Mowbray.

Results of the flood study demonstrate:

- The largest flood level impacts are evident to the west (upstream) side of the site between the proponents land and the Highway. The maximum afflux in this location is 183mm, however this is on State-owned conservation land and as such, the flood impacts are not anticipated to result in adverse impacts to people or property.
- There is only a minor increase in inundation extent, to the north of the site on the opposite bank to the proposed development. The minor increase in flood liable land is generally restricted to property zoned for rural uses and a review of available aerial imagery does not indicate the increase in flooded area will impact any existing dwellings in the lower catchment.
- The maximum impact on residential property is 18mm. It should be noted that whilst this land is zoned as low density residential in the Douglas Planning Scheme 2018, aerial imagery indicates it is currently vegetated, undeveloped land. Additionally, flood impacts are limited to an existing low-laying area of lot, which represents approximately 2% of the total lot area.
- Maximum flood impacts on rural land external of the proponents land is 37mm, which is located opposite the proposed development on agricultural land. An increase of 37mm is not expected to adversely affect the existing land owners ability to farm the land.
- Analysis of velocity afflux was conducted to demonstrate the impact the proposed development has on the flood velocity compare to the existing case. There are some increases in flood velocity within the proposed development site (up to 0.5 m/s); however, the maximum velocity change external of the site is less than 0.2 m/s.
- The supplied concept earthwork plan shows the total cut and fill volumes of 165,200m³ and 190,700 m³ respectively, resulting in a nett fill of 25,500 m³. If flood impacts are considered undesirable, reducing the nett fill volume, through further compensatory cut on the western side of the earthworks area will likely reduce post development peak flood levels.

The proposed development has been shown to result in localised increases to 1%AEP peak flood levels external of the site. The maximum afflux of 183mm is located to the south-west of the site immediately adjacent to the proposed development between the site and the Captain Cook Highway. The flood impacts at the location are not considered to result in material nuisance as the lot is State-owned conservation land. The maximum impact to 1%AEP flood event peak water levels on existing residential lots is 18mm.

A 13% increase in nett fill (as a proportion of total proposed fill) on the site is proposed, which will result in a decrease of floodplain storage. The placement (rather than nett volume) of the fill has the most significant impact on modelled post-development flood behaviour, specifically in the vicinity of the cabin/camping area. Filling in this location impacts the out-of-channel flood conveyance in the 1%AEP flood event.

Further modelling was undertaken to investigate if the addition of open channels through the cabin/camping grounds would improve floodplain conveyance and assess the potential benefit of adding a trapezoidal open channel in this location. The objective of testing these design iterations was to determine if one or two channels - with an indicative 20 metre base, 1:4 sides and 500mm depth - would provide sufficient additional conveyance to compensate for the loss of floodplain conveyance arising from the proposed earthworks. The two design iterations were successful in reducing the maximum peak flood impacts, however they did not show material benefit in flood risk outcomes.

Whilst the design iterations were shown to improve floodplain conveyance and reduce flood level impacts in the post-development scenario, given the initial proposed design has been demonstrated to achieve acceptable flood risk outcomes outlined by the Douglas Planning Scheme, and the need for additional excavation and removal of vegetation to construct the channels, these design options may be contrary to the desired outcomes of the Planning Scheme in maintaining the protective function of existing vegetation.

The Douglas Planning Scheme does not provide a definition of 'acceptable flood impacts', so a risk assessment in line with ISO31000 has been undertaken to demonstrate the proposed development 'avoids an unacceptable increase in severity'. ISO31000 is the international standard for risk management, and defines risk as the consideration of the likelihood of a hazard occurring and the consequence when an event occurs.

The assessment of the potential for damage to other properties was based on the number of properties exposed to flood hazard given a specified likelihood. In this case, the Defined Flood Event of 1%AEP was analysed, with the number of properties at risk external of the development site shown in Table 7-1.

Table 7-1. Summary of at-risk properties by land use

Land Use	Count of properties within the 1%AEP flood extent	
	Existing	Post-development
Conservation	9	9
Environmental Management	1	1
Low Density Residential	1	1
Ocean	1	1
Rural	45*	45
Rural Residential	0	0
Special Purpose	1	1
Total	115	115

*Note: An additional rural property was counted in the existing conditions model on the eastern extremity of the hydraulic model. This was deemed to be an artifact of the flood model itself and was not considered to be a valid inclusion in comparison with post development property exposure.

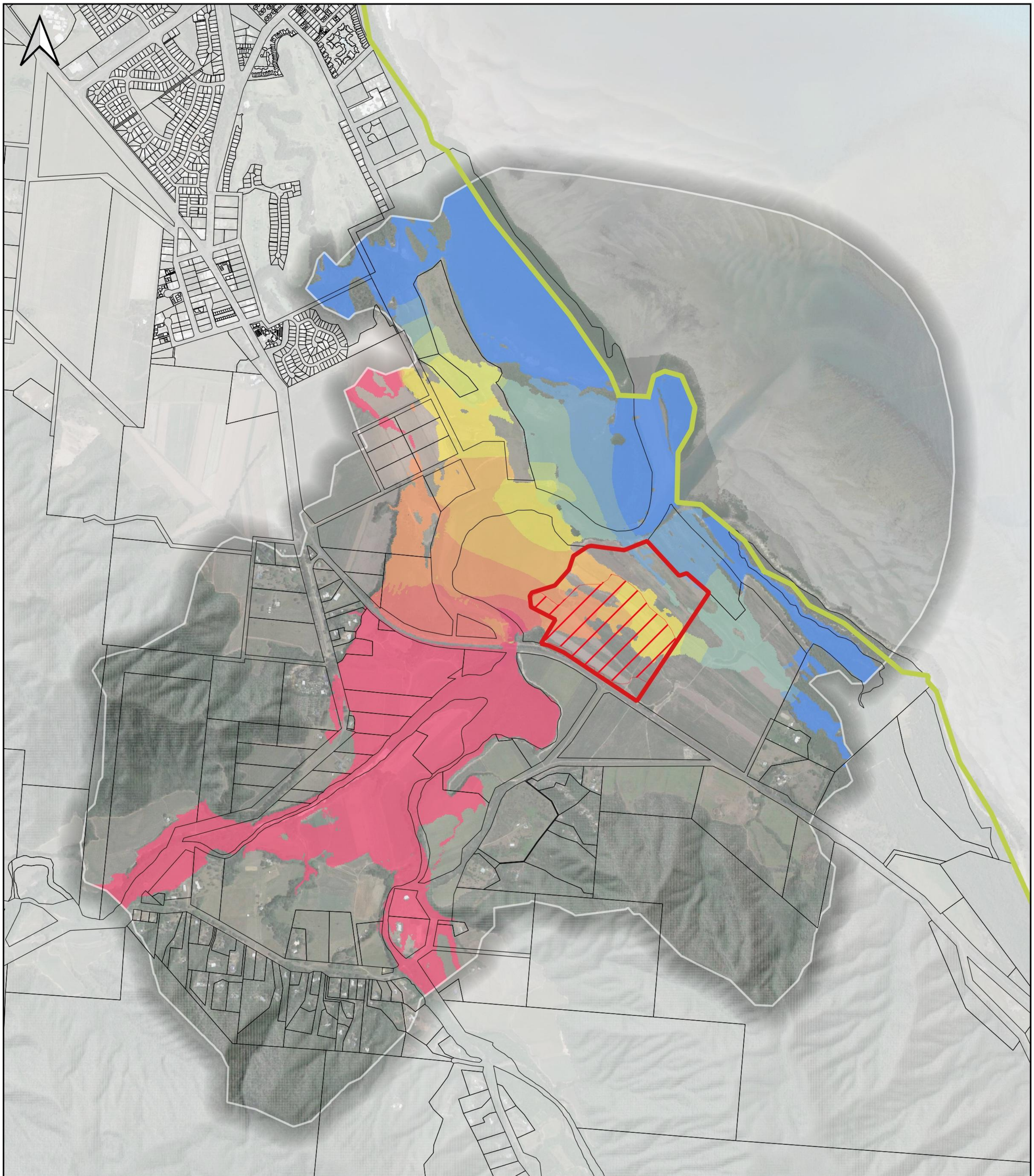
The exposure analysis shows the existing catchment conditions and post-development catchment conditions result in the same number of properties at risk in the 1%AEP flood event, and as such the proposed development does not significantly increase the potential for damage on the site or other properties.

An analysis of flood hazard, using depth-velocity results from hydraulic modelling of the proposed development was undertaken to gain an understanding of the severity of flood hazard under pre and post development conditions. A comparison of existing and post-development flood hazard based on depth-velocity flood information, shows a minor increase in flood hazard within the channel immediately downstream of the Captain Cook Highway and negligible (+/-0.2m2/s) or minor reduction in depth-velocity product on all existing properties. A review of aerial imagery available from Google and NearMap, indicates there are currently no dwellings located within the mapped flood impact area. Figure 6-1. Comparison of existing and post development depth-velocity flood behaviour

The assessment of potential exposure to flooding and severity of flood hazards analysed using a risk-based approach consistent with ISO31000, which considers the likelihood of flooding and consequence of flooding hazard, has demonstrated the proposed development does not increase existing flood risk in an unacceptable manner.

Appendices

A Appendix – Base Case Flood Model Results



jbpacific.com.au
+61 (0)7 3085 7469
477 Boundary Street
Spring Hill
QLD 4004

Scale

0 0.5 1 km

Date
18/03/2021

Legend

Earthwork_hatch
Site

Peak Flood Level (mAHD)

- <= 1.9
- 1.9 - 2
- 2 - 2.1
- 2.1 - 2.2
- 2.2 - 2.3
- 2.3 - 2.4
- 2.4 - 2.5
- 2.5 - 2.6
- 2.6 - 2.7
- > 2.7

Title
Existing - 1%AEP Peak Water Level

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Scale

0 0.5 1 km

Date
18/03/2021

Legend

- Earthwork_hatch
- Site

Peak flood depth (m)

- <= 0
- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 0.9
- 0.9 - 1.2
- 1.2 - 2
- > 2

Title
Existing - 1%AEP Peak flood depth

Project
2021s0206 - Mowbray Wave Park Flood Study

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Hunt Design

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Scale

0 0.5 1 km

Date
18/03/2021

Legend

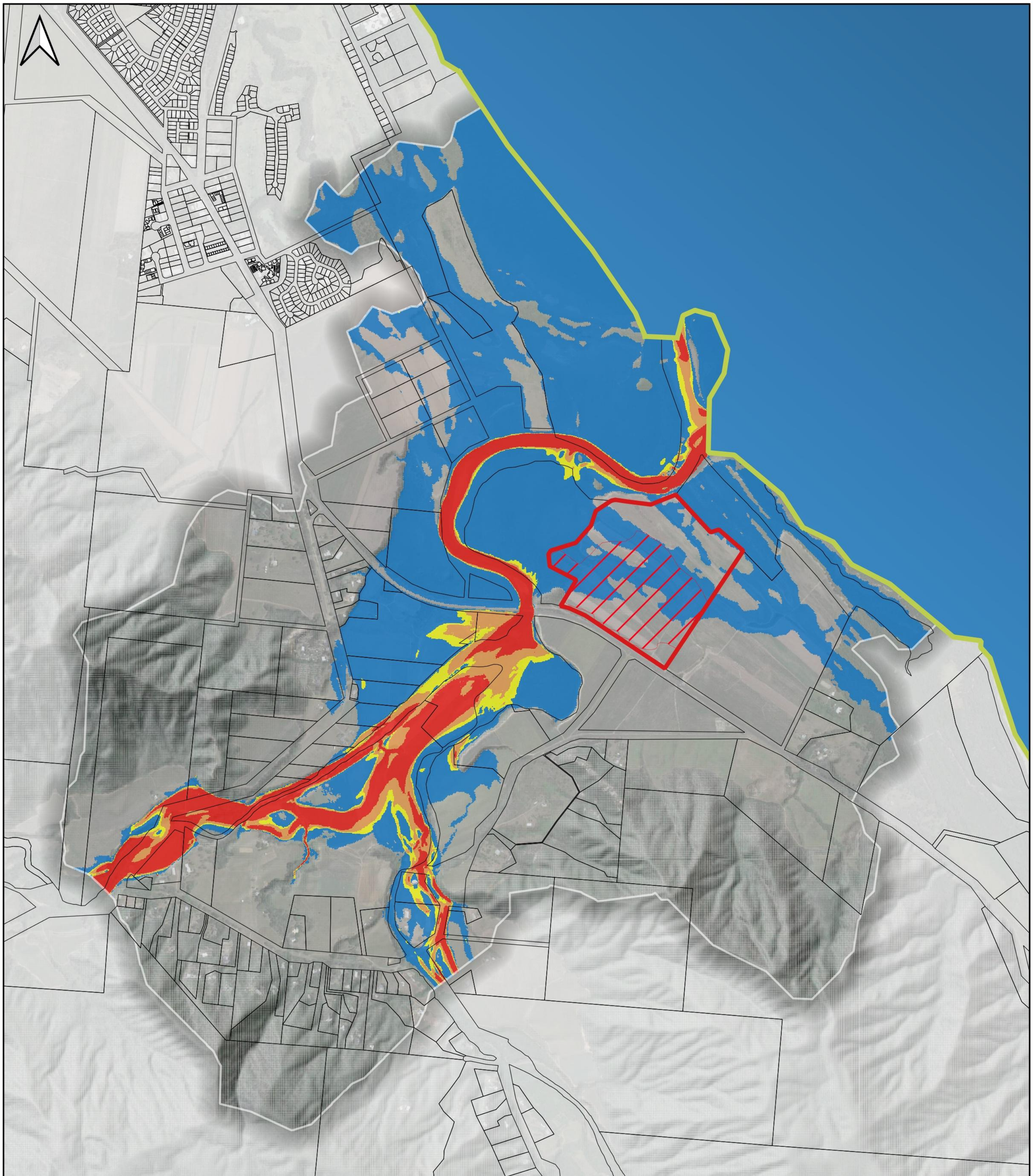
Earthwork_hatch
Site

Peak velocity (m/s)
- <= 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 2.5
- > 2.5

Title
Existing - 1%AEP Peak flood velocity

Project
2021s0206 - Mowbray Wave Park Flood Study

Client
Hunt Design



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JBP scientists and engineers

Legend

- Earthwork_hatch
- Site
- Flood model extent
- Coastline

Depth-velocity hazard

- Low
- Significant
- High
- Extreme

Scale

0 0.5 1 km

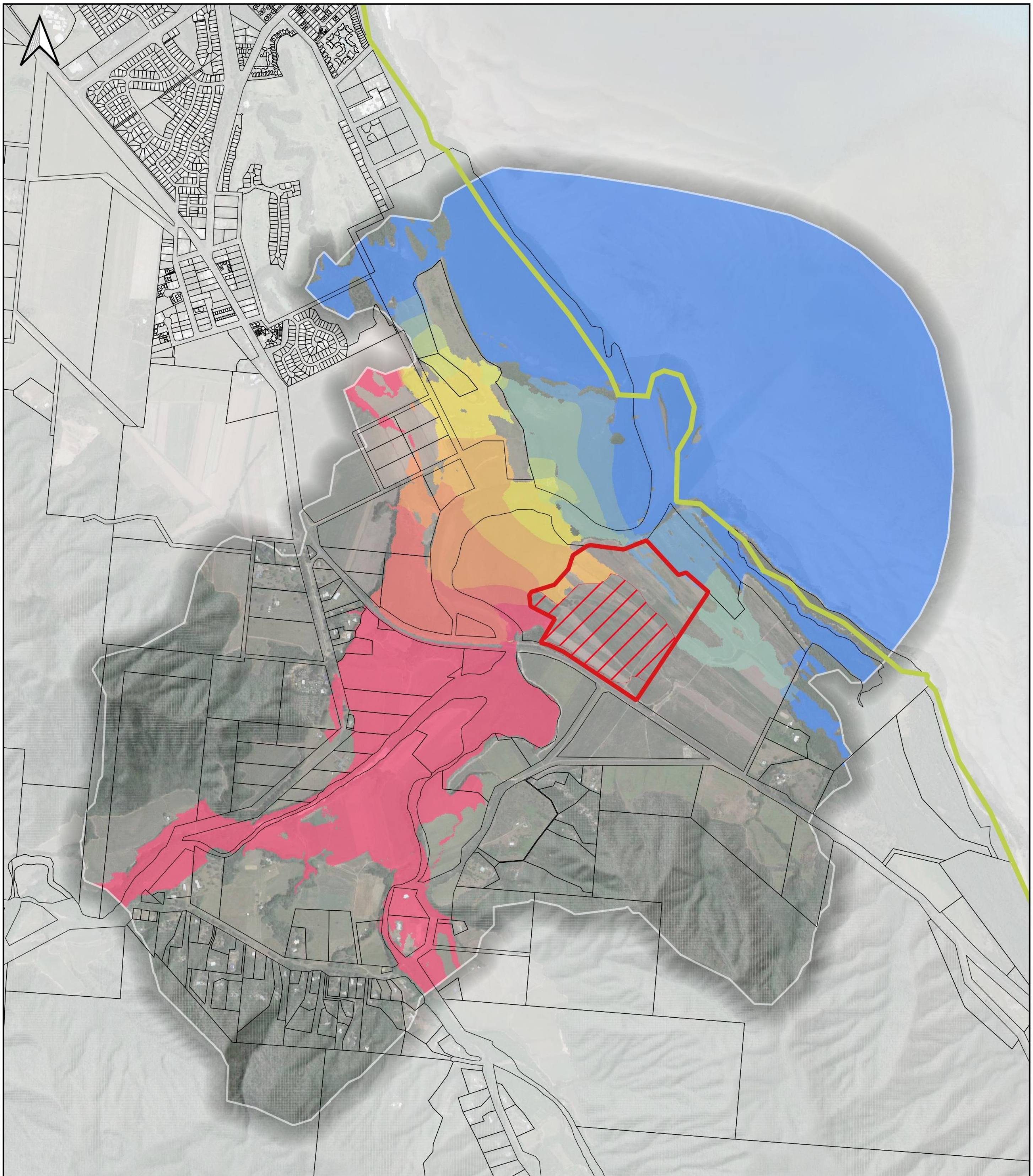
Date
14/04/2021

Title
Existing case: 1%AEP flood depth-velocity hazard

Project
2021s0206 - Mowbray Wave Park Flood Study

Client
Hunt Design

B Appendix – Design Case Flood Model Results



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Spring Hill
QLD 4004

Scale

0 0.5 1 km

Date
18/03/2021

Legend

Earthwork_hatch
Site

Peak flood level (mAHD)

- <= 1.9
- 1.9 - 2
- 2 - 2.1
- 2.1 - 2.2
- 2.2 - 2.3
- 2.3 - 2.4
- 2.4 - 2.5
- 2.5 - 2.6
- 2.6 - 2.7
- > 2.7

Title
Post development - 1%AEP Peak flood level

Project
2021s0206 - Mowbray Wave Park Flood Study

Client
Hunt Design

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477 Boundary Street
Spring Hill
QLD 4004

Scale

0 0.5 1 km

Date
18/03/2021

Legend

- Earthwork_hatch
- Site

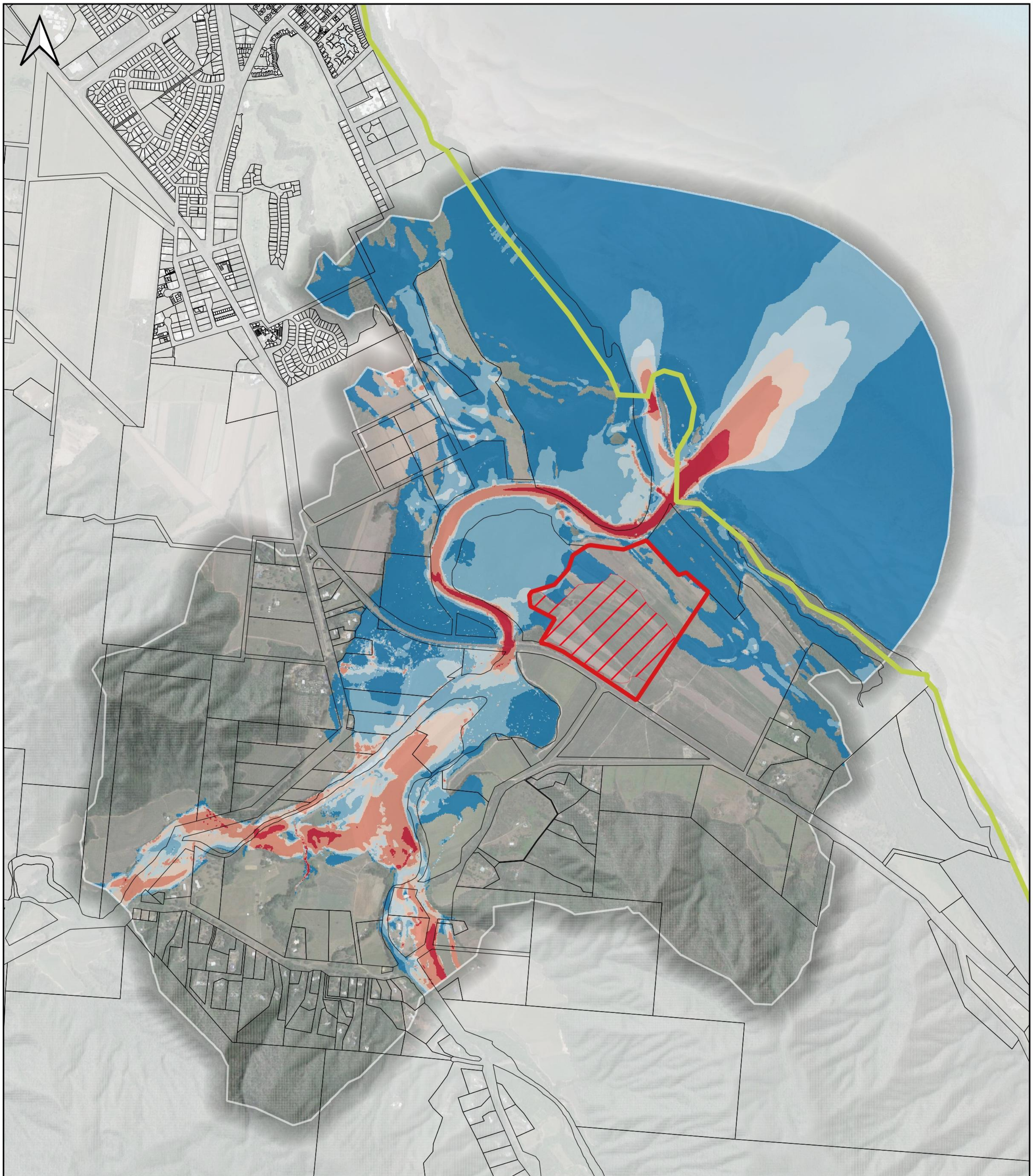
Peak flood depth (m)

- <= 0
- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 0.9
- 0.9 - 1.2
- 1.2 - 2
- > 2

Title
Post development - 1%AEP Peak flood depth

Project
2021s0206 - Mowbray Wave Park Flood Study

Client
Hunt Design



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QLD 4004

JBP scientists and engineers

Scale

0 0.5 1 km

Date
18/03/2021

Legend

Earthwork_hatch
Site

Peak velocity (m/s)
- <= 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 2.5
- > 2.5

Title
Post development - 1%AEP Peak flood velocity

Project
2021s0206 - Mowbray Wave Park Flood Study

Client
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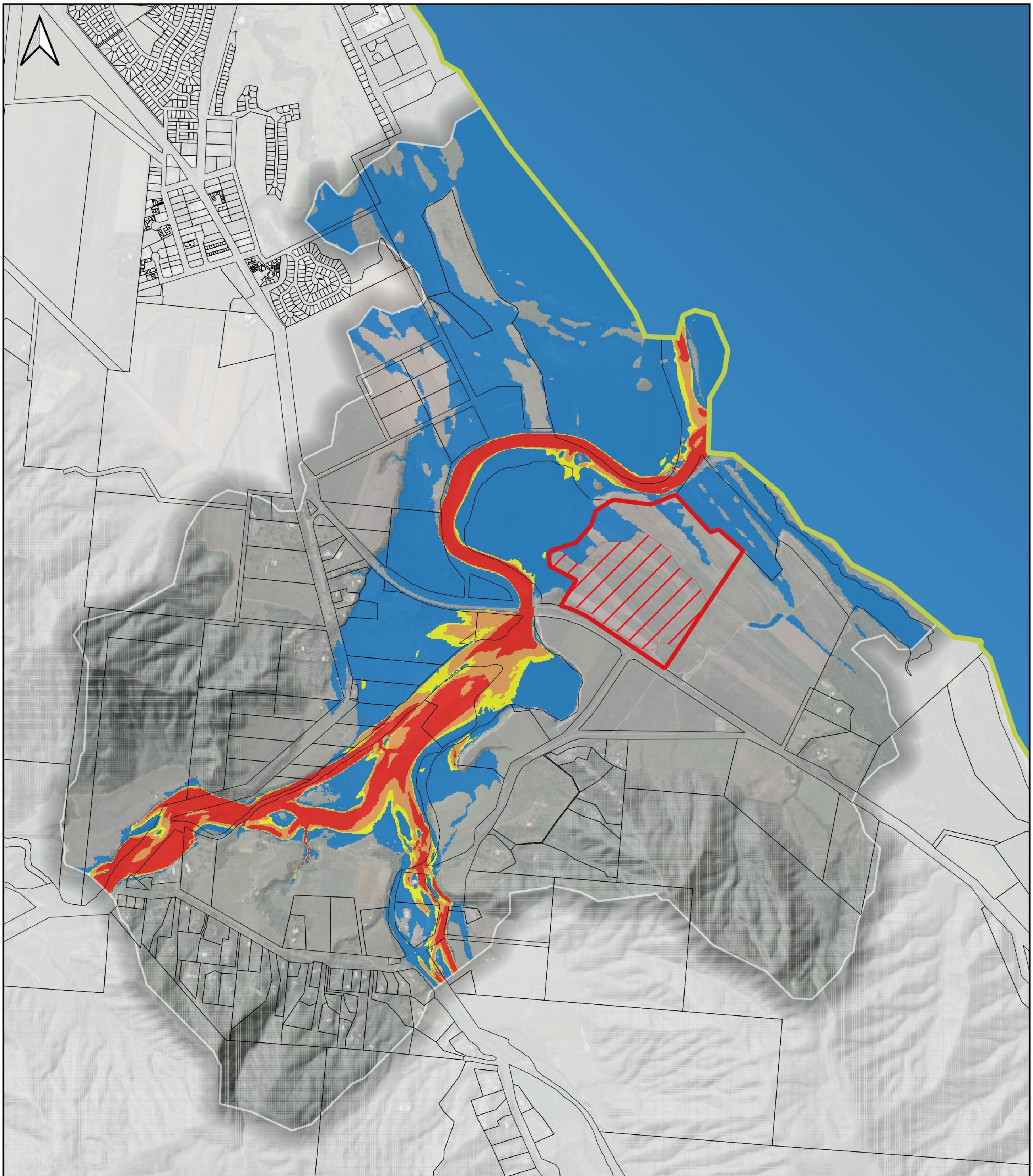

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Scale

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Date
14/04/2021

Legend

- Earthwork_hatch
- Site
- Flood model extent
- Coastline

Depth-velocity hazard

- Low
- Significant
- High
- Extreme

Title

Post-development case: 1%AEP flood depth-velocity hazard

Project

2021s0206 - Mowbray Wave Park Flood Study

Client

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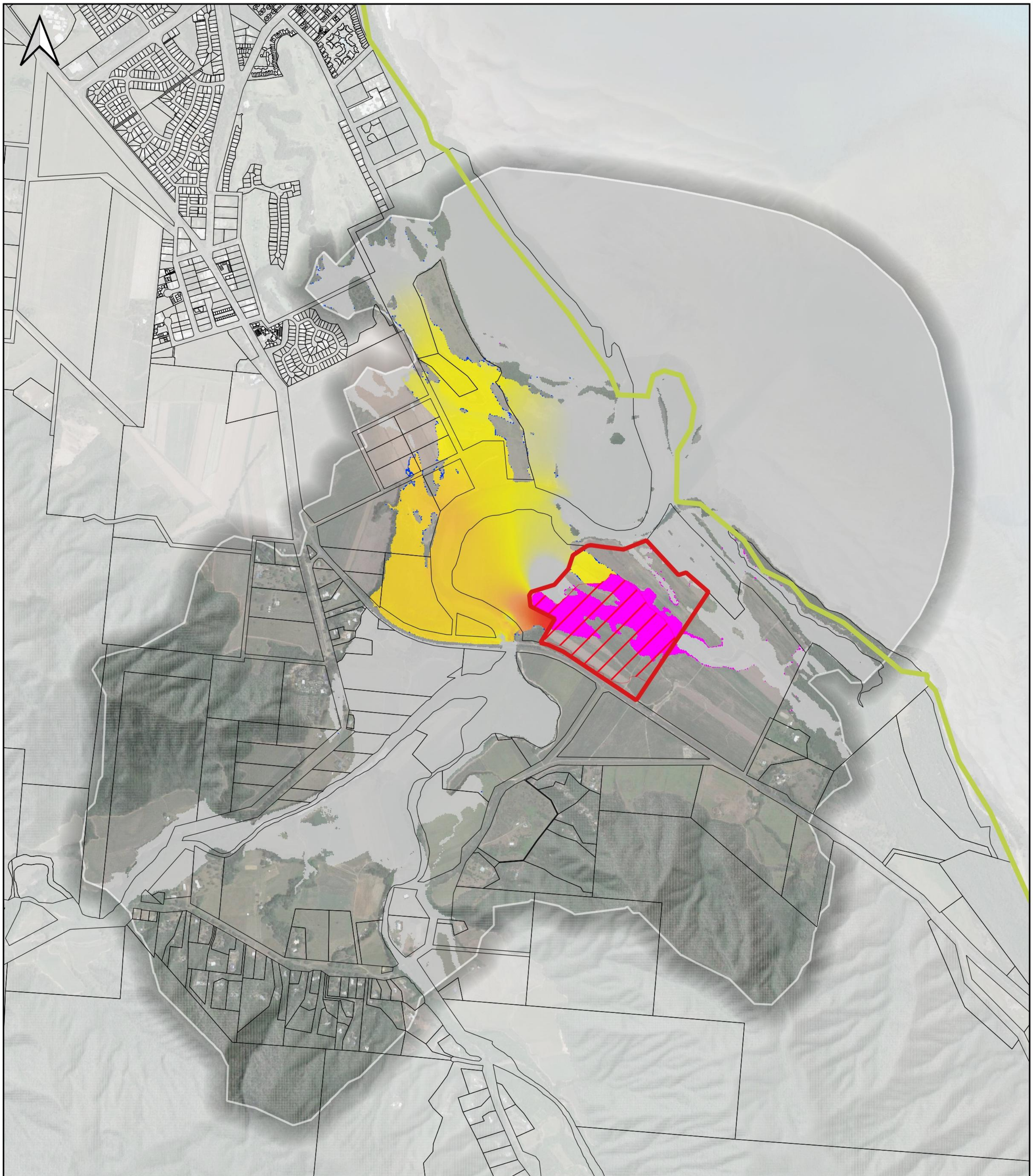
C Appendix - Flood Impact maps



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Scale

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Date
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Legend

Earthwork_hatch
Site

Afflux (mm)

- Was Wet, Now Dry
- <-10mm
- -10mm
- 10mm
- 20mm
- 50mm
- 100mm
- 200mm
- >200mm
- Was Dry, Now Wet

Title
Post development - 1%AEP Peak flood afflux

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- Earthwork_hatch
- Site

Velocity change (m/s)

- <= -0.4
- -0.4 - -0.1
- -0.1 - 0.1
- 0.1 - 0.4
- > 0.4

Title
Post development - 1%AEP Peak flood velocity impacts

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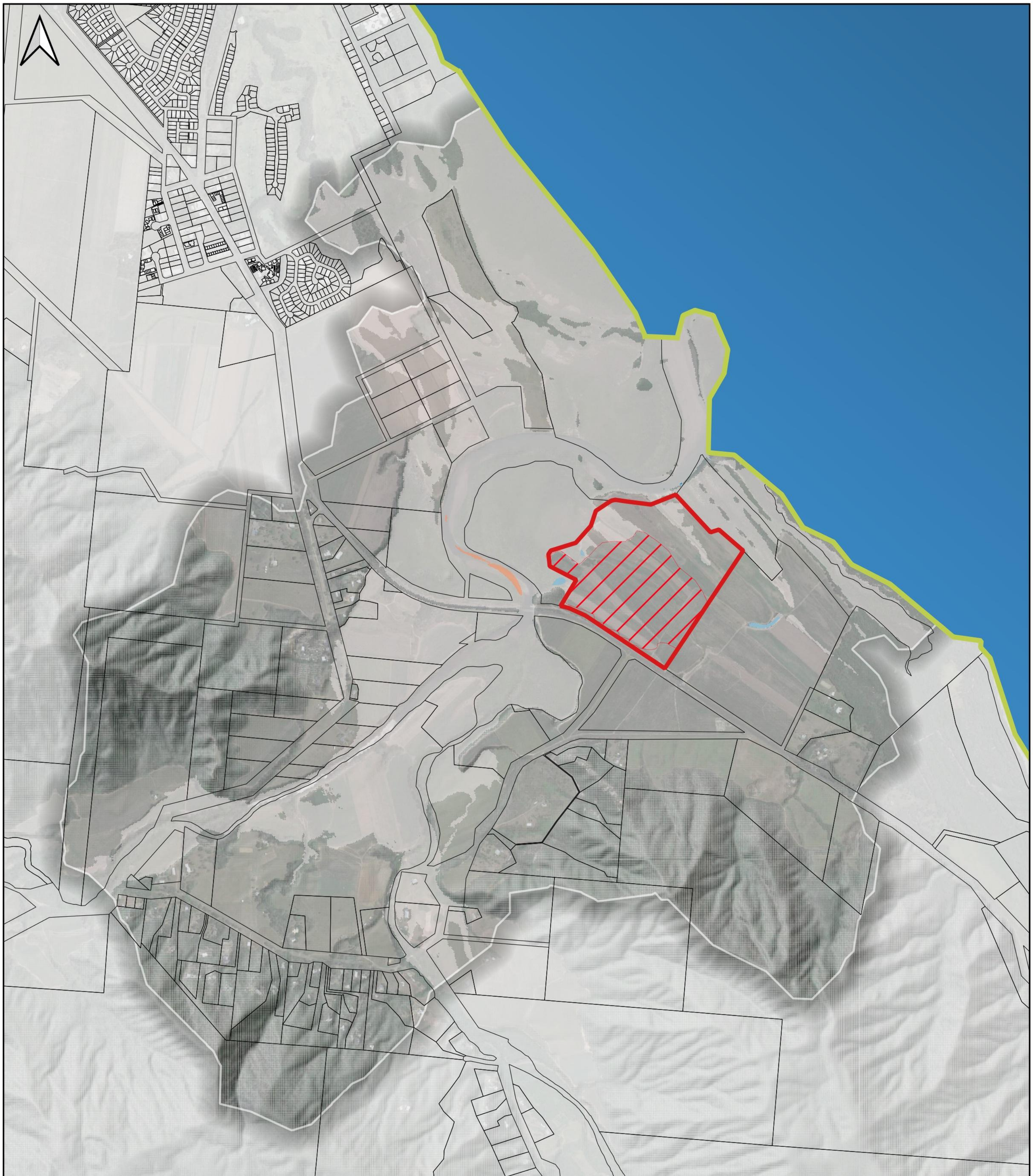

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Scale

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Date
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Legend

- Earthwork_hatch
- Site
- Flood model extent
- Coastline

Change in depth-velocity

- More than 0.4 m2/s reduction
- -0.4 to 0.2 m2/s reduction
- -0.2 to 0.2 m2/s
- 0.2 to 0.4 m2/s increase
- More than 0.4m2/s increase

Title
Change in 1%AEP flood depth-velocity (post-development minus existing case)

Project
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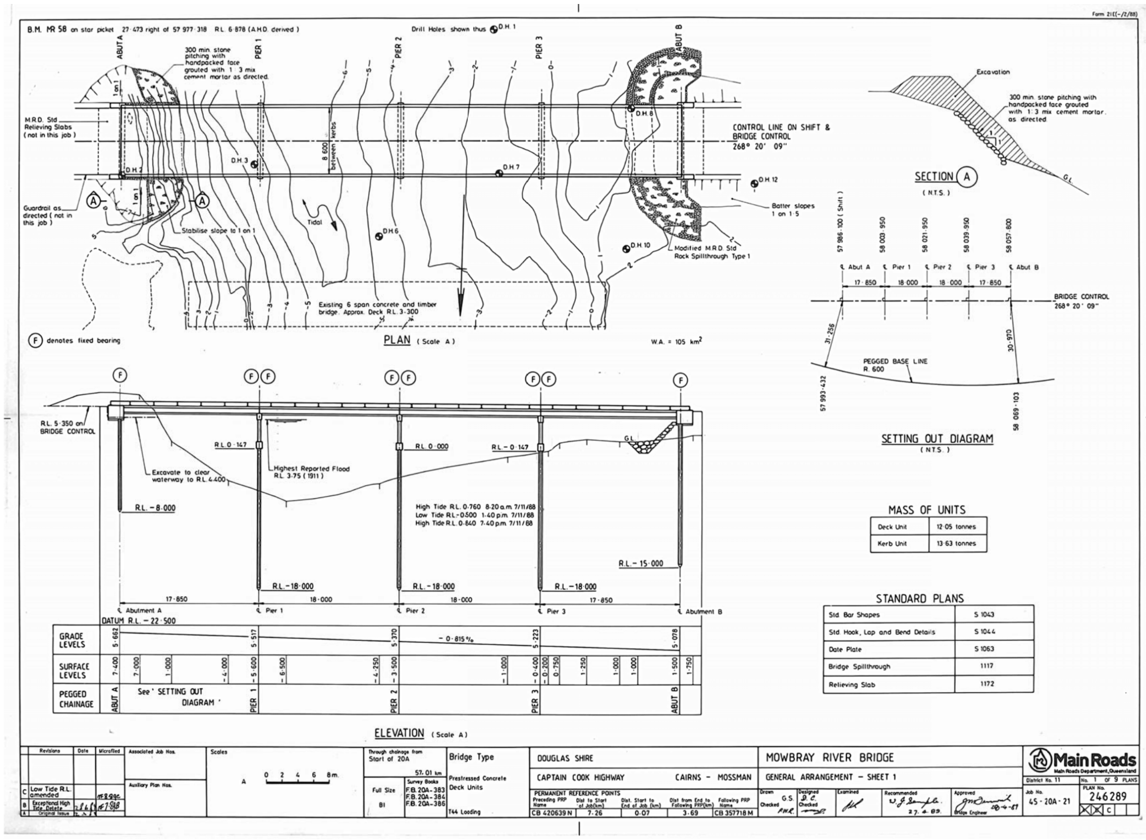
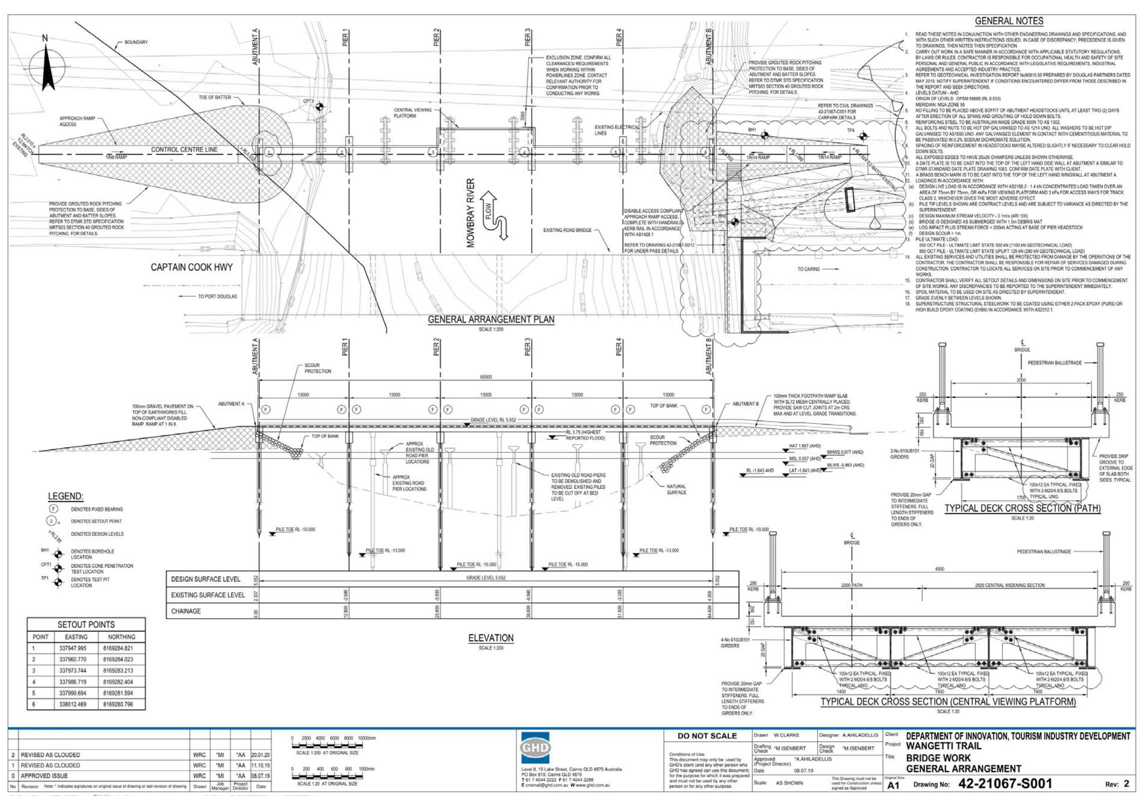
D Appendix – As Constructed Drawings





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