HERVEY BAY CITY COUNCIL
FLOOD RISK REDUCTION STUDY
OVERALL STUDY CONSOLIDAQTION REPORT

Appendix B – O'Regans Creek Flood Risk Reduction Study

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HERVEY BAY CITY COUNCIL

O'Regans Creek Flood Risk Reduction Study

Final Report

070048-001

6 March 2008





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HERVEY BAY CITY COUNCIL
O'REGANS CREEK FLOOD RISK REDUCTION STUDY
FINAL REPORT

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PROJECT 070048-001 - O'REGANS CREEK FLOOD RISK REDUCTION STUDY

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EXECUTIVE SUMMARY

In 2007, WORLEYPARSONS was commissioned by Hervey Bay City Council (HBCC) to undertake a Flood Risk Reduction Study for the O'Regans Creek Catchment. The purpose of the analysis is to document existing flooding characteristics within the catchment, classify the flooding risks and assess potential mitigation options for reducing flood risk and to meet HBCC design standards in the area.

The O'Regans catchment is mostly rural with approximately 12 % impervious area considering ultimate landuses and covers approximately 4,100 hectares.

An extensive hydrological model was set-up utilising the XP-RAFTS software package to estimate design flows for a 10, 20, 50 and 100 year ARI event. The Hydraulic model has covered all major waterways through the catchment. This model was verified with the Rational Method and was compared to results of the previous "Strategic Planning Report for the O'Regans Creek Catchment" (Connell Wagner, 1996).

A fully two-dimensional (2D) hydraulic model was set up utilising TUFLOW an Australian developed model that is well known in the industry. The results of the hydraulic model were compared to the previous study (Connell Wagner, 1996).

The hydrological and hydraulic assessment is based on ground level data with varying accuracy. For the lower part of the catchment ALS data was available. For the majority of the catchment (the upper section) 5m contour data was the only available information. Based on this data, the model is suitable for the purpose of this study to assess broad scale regional flooding and flood risk at Pialba Burrum Heads Road. However, more detailed survey should be used for modelling of impacts of localised developments.

Hydrological and hydraulic modelling was undertaken for the design flood events using existing waterway conditions and the ultimate land use scenario as per council Strategic Plan. Hydrological and hydraulic modelling was undertaken for the 10, 20, 50 and 100 year ARI events. The hydraulic model results were mapped and the following information is available digitally and as hard copy for all design events:

1. Flood Extents

2. Flood Levels

3. Water Depth Contours

4. Hazard Regions

The risk assessment shows that the majority of existing flooding issues are classified low risk. However, this study has identified two (2) areas in the catchment where the flooding risk (from road overtopping) is considered high. A total of three (3) mitigation options have been assessed to make the road trafficable and to lower the risk. Once the proposed mitigation works are carried out, the risk at these two (2) locations on Pialba Burrum Heads Road are classified as low risk.

The flood extent shows that approximately 3 properties are inundated during for the 100 year ARI event, however above floor flooding can not be determined due to the absence of floor level information.

A sketch plan of the proposed mitigation works is presented in Figure 8.1 and preliminary cost estimation was undertaken for the preferred mitigation works.

It is expected that this study could be used as guidance for managing existing and future development within the catchment.

It is recommended that Council proceeds with the proposed upgrade for Pialba Burrum Heads Road. At Castle Road, it is also recommended to put flood warning procedures in place during major storm events. The flood warning should inform the public about the high risk at this location during major storm events. This information could be displayed using flood signs.

1. INTRODUCTION

WORLEYPARSONS has been commissioned by Hervey Bay City Council (HBCC) to undertake a Flood Risk Reduction Study for the O'Regans Creek Catchment. The purpose of the analysis is to document existing flooding characteristics within the catchment, assess potential mitigation options for reducing flood risk and meet HBCC design standards in the area. Preliminary cost estimation was undertaken for the preferred mitigation option. The study will be used for managing both existing and future development within the catchment based upon the reduction of flood risk.

In 1995, Council has commissioned a "Strategic Planning Report for the O'Regans Creek Catchment" (Connell Wagner, 1996). This previous report investigated the existing flood behaviour and assessed flood mitigation options. The report utilised existing landuses for the hydrologic model (XP-XP-RAFTS software package) and a one-dimensional (1D) hydraulic model (Mike11 software package).

This current study investigates ultimate landuses for the hydrologic model and a two-dimensional (2D) hydraulic model. The 2D software package utilised is TUFLOW; an industry accepted Australian developed software package. 2D models are preferred in floodplains with complex flow regimes and large storage areas as they consider flow, storage and change in velocities across the floodplain.

The major components of works undertaken for this study have included:

- Definition of sub-catchment boundaries
- The identification of existing drainage patterns including piped systems (trunk drainage)
- Construction of an extensive XP-XP-RAFTS model for the catchment
- Construction of a fully 2-dimensional (2D) TUFLOW hydraulic model
- Hydrological and hydraulic model analysis to define flood levels, flow directions and drainage problems in selected regions of the catchment for the 10, 20,50 and 100 year ARI design flood events
- Analysis of mitigation options for the purposes of flood risk reduction

- Preliminary construction cost estimates for the mitigation options

- Documentation of the study methodology and outcomes as part of a formal report on the investigation including a risk assessment report

The following sections of this report aim to fully document the analysis works undertaken as part of this investigation.

2. STUDY AREA

The O'Regans Creek catchment partly covers Hervey Bay's suburbs Craignish and Takura. The catchment is bounded by Old Toogoom Road in the west, the coastline of Hervey Bay in the north, Torbanlea Pialba Road in the south and Dundowran Road to the east. O'Regans creek discharges into the sea and about one third of the catchment is very low lying. The catchment covers approximately 4,100 hectares.

The O'Regans catchment is mostly rural with approximately 12 % impervious area considering ultimate landuses derived from Councils Planning Scheme (IPA-Zones, 2005).

Figure 2.1 shows the O'Regans Creek catchment boundary and study area.



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Road

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGONS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 2.1

LOCALITY

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3. STUDY DATA

The works undertaken as part of this study, particularly the establishment of the TUFLOW model of the catchment have been prepared based upon a compilation of data sources provided by Hervey Bay City Council and additional survey. Specifically, the models have been developed using a range of data sources and information, each of which are outlined and discussed separately below.

3.1 Topography Data

Council commissioned AAMHATCH to provide digital terrain data from airborne laser scanning (ALS). The data was acquired by AAMHATCH on 6 August 2007 and was provided to WorleyParsons on 3 October 2007. The ALS data covers only approximately 35% of the O'Regans Creek catchment. Therefore, additional topography data was required to cover the entire catchment. Topography data for the catchment was provided in the form of contour information at 1m and 5m increments. A combination of all topographical data with the following priorities has been adopted for this study:

1. ALS data
2. 1m contour data
3. 5m contour data

WorleyParsons have prepared a Digital Terrain Model (DTM) using all of the topography data supplied to accommodate data extraction for the various modelling tasks undertaken as part of this study. The DTM was prepared using the MapInfo Vertical Mapper software is illustrated in Figure 3.1, clearly showing the catchment location and topographical variation.

The 2D modelling approach utilises the entire DTM across the model area. The DTM is sampled at increments corresponding to the 2D hydraulic model grid size chosen. The grid size is described in detail in Section 5.4. Contour information at 1m and 5m is coarse and it is likely that many key drainage features are poorly defined in the DTM. When this data is sampled for the hydraulic model, the definition is lost further. Thus, it is also recommended to collect ALS data for the entire catchment if more detailed modelling is required at a later stage. The data provided is suitable for a broadscale flood study. Any areas that have been identified as needing further ground level information for more detailed modelling have been highlighted throughout this report.

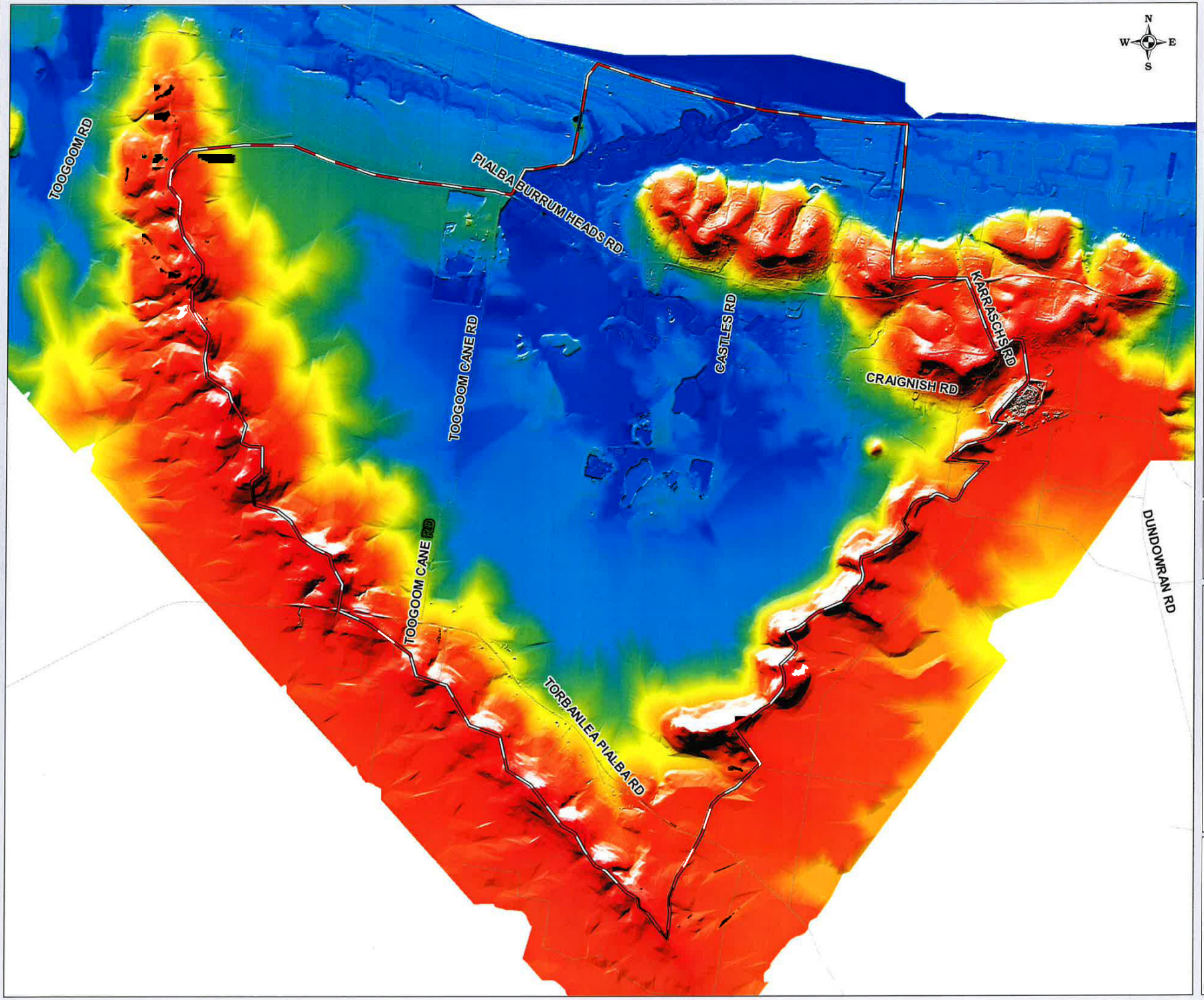
WorleyParsons note that the DTM prepared for the purposes of this study represents an topographic surface based upon contour information of varying accuracy. As such, the DTM prepared for this study is unlikely to be sufficiently accurate to enable more detailed flood analysis works to be performed. The DTM is however suitable and appropriate for the purposes of a broad flood risk study as is the purpose of this study.

3.2 Survey Data

Collection of limited field survey data for the catchment has been undertaken as part of this project. The intent of the field survey data collection was to infill missing information, obtain structure details and to provide more detailed topographical information at discrete and critical locations throughout the study area. Areas where more detailed survey information was required were defined by WORLEYPARSONS following a detailed assessment and review of the information initially provided. As part of the study, WORLEYPARSONS were responsible for management of these works which included the preparation of detailed survey briefs, calling of survey tenders and managing the field collection data.

All detailed survey works collected for this project were undertaken by Surveyors@Work, a locally based and independent survey company in Hervey Bay. This information was collected using both traditional and GPS survey techniques and was provided in a digital AutoCAD format. WORLEYPARSONS utilised this information to update the various drainage network details within the models.

The survey data included spot levels and cross-sections at specific locations in the catchment. As the survey data was only collected at discrete locations the data was not used to update or compile a more accurate DTM for the catchment however, was included in the TUFLOW model to enhance the hydraulic structure representation of the catchment.



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Road

Ground Level (mAHD)

80.0

25.0

15.0

5.0

-1.0

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 3.1

DIGITAL TERRAIN MODEL (DTM)

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File Path: Y:\42Jobs GIS\0270048 003 HBCC ORegans Flood Risk Reduction Study\Figures\Figure 3.1.WOR
Projection Trans. Merc. MGA56(GDA 94)

3.3 Pipe Data

Existing pipe and culvert crossing data throughout the catchment was provided by Council. Details of the existing pipe information were provided through Council supplied GIS data. This data was supplemented using detailed survey information collected at discrete areas, as discussed in Section 3.2.

All the available information as supplied for the study was consolidated to prepare the existing pipe system details within the TUFLOW model. Through liaison with Council it was agreed to model culverts larger than 450mm in diameter.

3.4 Site Inspection

As part of the works for this study, WORLEYPARSONS have undertaken a detailed and comprehensive site inspection of the O'Regans Creek catchment. The site inspection also included an extensive project inception meeting with HBCC.

The site inspection was documented by way of site notes and photographs. Outcomes from the inspection included:

- Assessment of physical catchment parameters including appropriate roughness parameters
- Verification of crossings and existing hydraulic structures
- A comprehensive investigation of the waterway
- Understanding of the flow dynamics of the catchment area and major waterway systems

4. CATCHMENT MODELLING

4.1 Hydrological Modelling

The analysis of runoff from the catchment was performed using the non-linear runoff routing program XP-XP-RAFTS. Hydrographs for design events were produced by lagging rainfall through a series of sub catchments and along channel links to enable flow determination. An average flow velocity of 1 m/s was assumed for lagging rainfall. Hydrographs were produced locally for each XP-XP-RAFTS sub catchment and imported to the hydraulic model.

The total catchment area contributing discharges was found to be 4,100 hectares. The highest elevation of 87m is found in the south of the catchment, whereas the lowest elevation of approximately 1m is at the mouth of O'Regans River discharging into the sea. The slopes in the catchment vary from 3.33% to 0.1%.

The XP-XP-RAFTS analysis involved division of the catchment into twenty three (23) separate sub-catchments, derivation of various physical properties of the sub catchments and assembly of the sub catchments by way of a nodal network. Figure 4.1 illustrates the catchment breakdown and XP-XP-RAFTS schematisation as used for the hydrological modelling of the catchment.

Model parameters for sub catchment characteristics have been selected from recommended design values from the following data sources:

- Impervious and pervious areas – Strategic planning information for the catchment as obtained from HBCC
- Subcatchment slopes – Contour and topographic data provided by HBCC throughout the catchment
- Catchment roughness values – Determined in accordance with the hydrologic parameter values recommended by Council for various landuse classifications, site visit, and aerial photography
- Intensity-Frequency-Duration (IFD) values – HBCC Development Manual

4.2 Design Rainfall

The design rainfall Intensity-Frequency Duration (IFD) data for Hervey Bay was used in the XP-XP-RAFTS model. Design IFD data for Hervey Bay was extracted from the program AUSIFD (Version 2.0). A copy of the HBCC IFD table is attached in Appendix 1.

Rainfall temporal patterns used for the XP-XP-RAFTS analysis were also prepared in accordance with the procedures outlined in AR&R, 2001.

4.3 XP-RAFTS Model Parameters

The adopted percentage impervious and corresponding Manning's roughness parameters for the various land use classifications were supplied by HBCC and are summarised in Table 1 below.

Table 1: Catchment Land Use Parameters

Description	% Impervious	Manning's "n"
Park Residential	20%	0.040
Residential Low Density	45%	0.025
Conservation	0%	0.100
Open Space	10%	0.040
Road	80%	0.020
Rural Land	2%	0.070
Rural Residential	20%	0.040
Special Purpose	20%	0.040

On the basis of HBCC landuse strategic plan and the supplied landuse hydrologic parameters, the areas of various landuse classifications used in the development of the XP-RAFTS model are summarised in Table 2.

Table 2: Summary of Areas for Various Landuse Classifications

Landuse Classification	Impervious Area (ha)	Pervious Area (ha)
Conservation	0.00	89.90
Low Density Residential	12.80	15.64
Open Space	4.11	36.96
Park Residential	64.17	256.67
Road	318.95	79.74
Rural Land	60.91	2984.44
Rural Residential	39.21	156.84
Special Purpose	0.21	0.86
Total	**500.35**	**3621.04**

Rainfall loss on each sub-catchment was applied using an initial and continuing rainfall loss model. Design loss parameters for the XP-XP-RAFTS model were based on guideline values as recommended by HBCC. These loss rates are consistent with AR&R (2001) which recommends a continuing loss of 2.5 mm/hr and an initial loss of between 15-35 mm be applied in eastern Queensland.

The adopted loss parameters applied for the XP-XP-RAFTS model are presented in Table 3.

Table 3: Adopted Rainfall Loss Parameters used in the XP-XP-RAFTS Model

Pervious Area (non sand)		Pervious Area (sand)		Impervious Area	
Initial Loss (mm/hr)	Continuing Loss (mm)	Initial Loss (mm/hr)	Continuing Loss (mm)	Initial Loss (mm/hr)	**Continuing Loss (mm)**
15	**2.5**	**35**	**2.5**	**0**	**0**

The storage coefficient multiplication factor (Bx) in the XP-RAFTS model uniformly modifies the basic calculated sub-catchment storage delay values. The factor represents the dampening effect of the catchment on the excess rainfall. The default Bx value of one (1) was adopted in the XP-RAFTS models.

4.4 Hydrological Flow Verification

As calibration of the hydrological models to recorded data was not possible, Rational Method flow calculations have been undertaken at key locations for comparison and verification with the XP-RAFTS results. The comparison of total flow results for the 100 year ARI storm event at key catchment locations are summarised in Table 4 under ultimate catchment conditions. The locations of these XP-RAFTS nodes are shown on Figure 4.1. Appendix 2 presents the total flows for each sub catchment for the 10, 20, 50, and 100 year ARI event for varying critical storm durations.

Comparisons between peak flows at a range of locations throughout the catchment calculated using the XP-RAFTS model and the Rational Method have identified that the difference of peak flows between the two methods is generally within the order of 10%. Therefore, the XP-RAFTS model is considered to predict flows to an acceptable level of accuracy and has been adopted for the purposes of this assessment.

Table 4: Comparison of Hydrologic Results for the 100 year ARI Storm Event at key catchment locations (Ultimate Development Conditions)

Location	XP-RAFTS Node	Area (ha)	Rational Flow (m^3/s)	XP-RAFTS Flow (m^3/s)	Percentage Difference (%)
Toogoom Cane Road	4	720	111.4	123.2	**10.6%**
Castle Road	19	510	57.8	53.4	**-7.7%**
Pialba Burrum Heads Road	21	3500	289.0	260.9	**-9.7%**

The design total flows were also compared to the previous strategic planning report (Connell Wagner, 1996) and are represented in Table 5. The comparison indicated that the flows of this current XP-RAFTS model match the flows from the previous study very well. The difference between flows is within 2% for the 100 year ARI event.

The previous study was based on existing landuse and this current study is based on ultimate landuses. The comparison of the two studies shows that the impervious area within the catchment has not increased significantly between 1996 and 2007.

Table 5: Comparison of Hydrologic Results for the 100 year ARI Storm Event between the Previous Report (Connell Wagner, 1996) and this current study

Location	100 year ARI Storm Event		
	Existing XP-RAFTS Model (m^3/s)	Connell Wagner Report (1996) (m^3/s)	Difference (%)
Castle Road	53.4	50.6	**+1.1**
Pialba Burrum Heads Road	260.9	270.5	**-1.0**

The hydraulic

TUFLOW model was set-up to utilise local flows for each subcatchment in the O'Regans Creek catchment. Therefore, the hydrologic assessment for the critical storm duration was undertaken by assessing local flows. The estimated peak discharges and critical durations for the 100 year ARI storm durations for all catchments are summarised in the in Appendix 2 of this report.

The hydrologic assessment indicates that the 60 minutes storm duration dominates for local flows throughout the catchment for the 100 year ARI flood event. At Pialba Burrum Heads Road, which is the location main focus of this current study, the XP-RAFTS model predicts that the 60min storm duration is the critical duration.

As a result, the 60 minute storm duration has been adopted for the generation of local boundary conditions for incorporation into the hydraulic model.



HERVEY BAY CITY COUNCIL

LEGEND

- DCDB
- Road
- Study Boundary
- Rafts Subcatchment
- Rafts Node
- Rafts Link

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 4.1

RAFTS MODEL LAYOUT

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5. HYDRAULIC MODELLING

5.1 General Overview

WorleyParsons have undertaken detailed 2 Dimensional (2D), hydrodynamic flood modelling of the catchment in order to provide accurate and detailed flood information for the entire waterway system. The following information provides details of the software, topographic data and other parameters used in the hydraulic modelling of the catchment.

5.2 Modelling Software

Hydraulic analysis of the study area has been undertaken using the coupled one dimensional (1D) and two dimensional (2D) finite difference model TUFLOW, an industry accepted, Australian owned and commercially available software package highly suited to the investigation of flood behaviour in complex flow scenarios. The model can simulate unsteady hydrodynamic flow in two directions on a rectilinear grid as well as one dimensional unsteady hydrodynamic flow through waterway structures such as culverts. The model is based on a robust finite difference solution scheme able to compute both sub critical and supercritical flow regimes.

The TUFLOW 1D/2D model is suited to simulation of dynamic hydraulic behaviour of overland flow in both rural and urban areas. Based on this and TUFLOW's ability to couple hydraulic structures such as culverts and bridges at road crossings in a stable and verified manner, the modelling system was considered the most appropriate investigative tool for the characteristics of O'Regans Creek and the surrounding rural areas.

Major advantages of a combined 1D and 2D modelling approach over traditional 1D approaches include:

- Full topographic survey terrain models are used, rather than selected, discrete cross sections
- Flow patterns are dictated by the influence of topography and surface roughness conditions rather than by 'forced' flow paths, as used in quasi-two-dimensional networks
- Flow directions and paths can vary with stage and flow conditions (c/f 'rigid' networks forcing flow paths in quasi-two-dimensional models)

- Production of detailed output of flow patterns, flood rise and fall animations, and output suitable for direct GIS interfacing. This allows production of accurate depth of flooding, velocity and hazard maps as well as area of influence maps

Major advantages of a combined 1D and 2D approach over an exclusive 2D approach include:

- Regions lying outside the area of interest that have to be modelled (e.g. to apply boundary conditions) do not necessarily have to be modelled in full 2D. This dramatically decreases the required computational time, leaving more room for detailed modelling of the area of interest

- The behaviour of hydraulic structures such as culverts and bridges can be simulated in a more detailed and robust way using a traditional 1D approach. Also, overtopping of bridges can be reliably modelled as the weir flow component of flood flow including the blockage of handrails at crossings can take place within the 2D environment whereas the flow through the hydraulic structure can be modelled in 1D

5.3 Model Construction

The 2 dimensional TUFLOW model constructed for O'Regans Creek consists of the following elements, each of which are described in more detail in the sections of this report which follow:

- A two-dimensional (2D) curvilinear grid representing the topographic levels within the area of interest extracted directly from the DTM constructed using supplied contour data as outlined in Section 3.1

- One-dimensional (1D) elements within the 2D grid extent that represent hydraulic structures

- Downstream water level boundary applied at the model outlet

- Rainfall boundary conditions simulating the local sub-catchment response within the 2D modelling area

Figure 5-1 illustrates the layout and extent of the hydraulic model constructed for this study.

5.4 2D Topographic Grid

The 2D model topography was derived using the Digital Terrain Model (DTM) constructed from contour data as supplied by Council (Refer Section 3.1). A balance between the number of computational

points, level of modelling detail and model run times was required to deliver suitably accurate outcomes in a timely and efficient manner. The decision on the grid spacing to adopt in the 2D model is critical and is based on knowledge of the catchment, the pertinent drainage areas, and previous experience. A grid size of 10m was selected. This grid size reflects the accuracy of the base survey data and optimises runtimes. The extent of hydraulic modelling is shown in Figure 5-1.

Real world co-ordinate systems have been used for all modelling. The 2D hydraulic model is based on MGA94 Zone 56 horizontally and AHD vertically.

5.5 1D Hydraulic Structure Elements

In a full 2D modelling environment it is often not possible to accurately describe the hydraulic behaviour of structures such as culverts and bridges. This is due to the fact that grid cell sizes often exceed the dimensions of various structures in addition with the grid cells only representing bottom friction and consequently no roof friction or specific hydraulic structure losses. As a result, hydraulic structures are typically more accurately modelled in a 1D modelling environment, thus allowing prescriptive modelling of the exact characteristics of the various structures.

Within the 2D model, 1D elements have been introduced in order to enable the prescriptive modelling of various floodplain structures. The waterway crossings and pipe network with diameters of larger than 450mm have been included in the model as 1D elements throughout the study area and are presented in Table 6 (Refer Figure 5-1 for structure locations). Table 6 also summarises the structure details at each locations.

Table 6: Structure Details

Culvert ID	Invert Level upstream (mAHD)	Road Name	Structure Name in Hydraulic model	Description
1	0.4	Pialba Burrum Heads Road	Pialba Burrum Heads Road 1 (most western location)	3 x 0.6m circular pipes
2	0.4	Pialba Burrum Heads Road	Pialba Burrum Heads Road 2	4 box culvert 3.6m wide x 1.2 high
3	1.7	Pialba Burrum Heads Road	Pialba Burrum Heads Road 3	2 x 0.6m circular pipes
4	1.3	Pialba Burrum Heads Road	Pialba Burrum Heads Road 4 (most eastern location)	6 x 0.6m circular pipes
5	3.9	Toogoom Cane Road	Toogoom Cane Road 1 (most northern location)	2 x 0.45m circular pipes

Culvert ID	Invert Level upstream (mAHD)	Road Name	Structure Name in Hydraulic model	Description
6	1.4	Toogoom Cane Road	Toogoom Cane Road 2	1 x 0.9m circular pipes
7	1.4	Toogoom Cane Road	Toogoom Cane Road 3 (most southern location)	2 x 1.2m circular pipes
8	1.5	Castle Road	Castle Road 1	26 x 0.6m circular pipes
9	1.7	Crooks Road	Crooks Road	3 x 0.75m circular pipes
10	1.9	Dublin Road	Castle Road 2	1 x 0.6m circular pipes
11	1.7	Dublin Road	Castle Road 3	1 x 0.6m circular pipes

Each of the structures detailed in Table 6 have been prescriptively modelled based on the following data sources:

- Council's pipe network information GIS layers
- Verification of some structure details and configurations by way of a detailed site inspection by WORLEYPARSONS

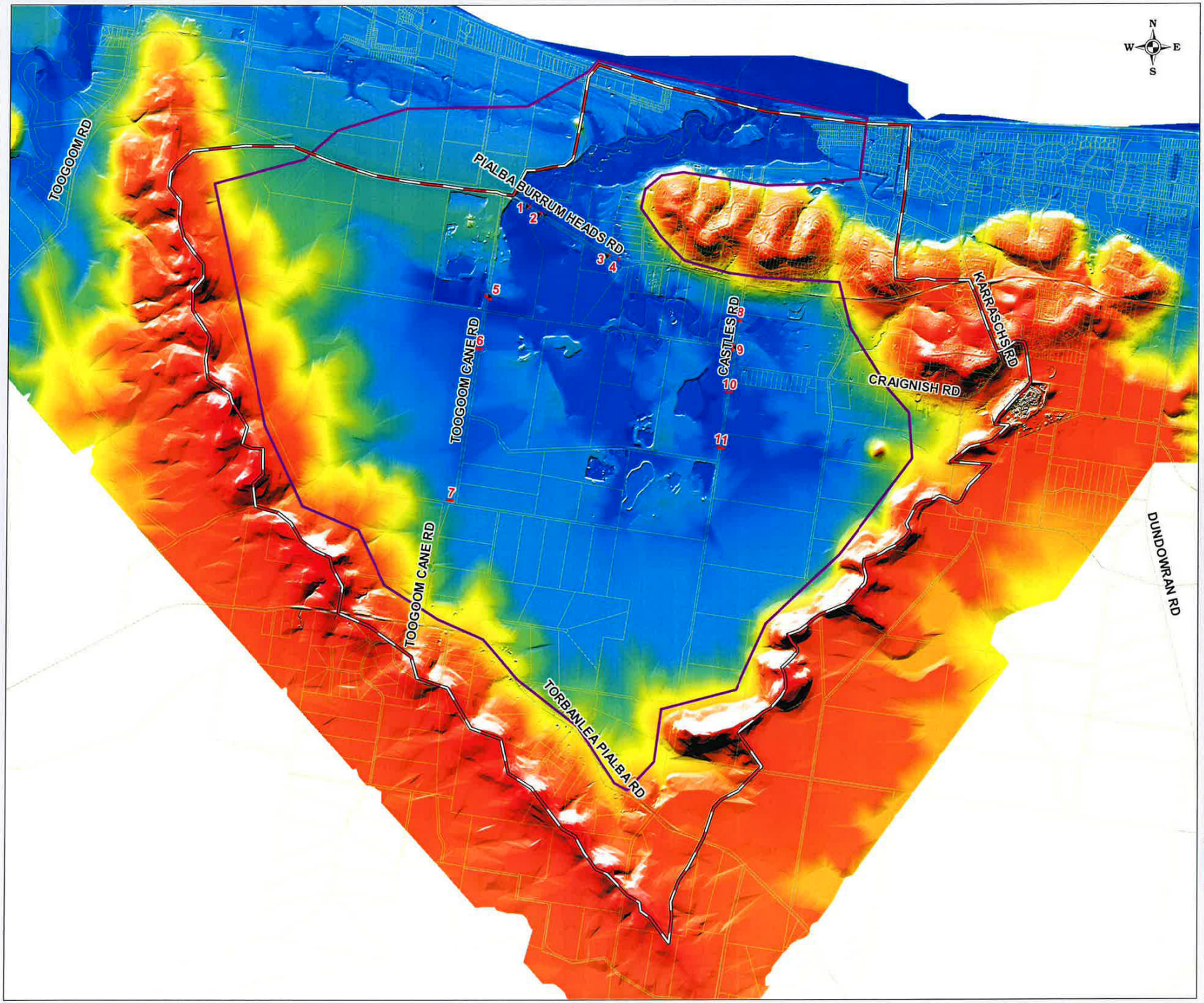
All structures have been represented using a combination of 1D and 2D domains. Flow through the culverts is modelled using the 1D component of TUFLOW whilst the overland and weir flow, both around the structure and over the road, are modelled purely in the 2D scheme.

5.6 Model Boundary Conditions

Two types of boundaries have been applied to the model. The first, flows derived from the XP-RAFTS model, are applied across the model in various locations representing the sub catchments defined from the hydrologic analysis. Flows have been applied across areas (rather than at point locations). This allows TUFLOW to assign the flow to the lowest cell in each area first and then distribute the flow to wet cells as the flood event progresses.

The second, tail water boundaries have been applied to the downstream edge of the model. For all design events, a Highest Astronomical Tide (HAT) level of 2.15 mAHD has been applied and was determined from review of Semidiurnal Tidal Planes 2007.

A sensitivity analysis of the model boundary condition was required as part of this study and this has been undertaken and discussed separately in Section 6 of this report.



HERVEY BAY CITY COUNCIL

LEGEND

DCDB

Study Boundary

TUFLOW Boundary

Pipe Network

1 Structure ID

Ground Level (mAHD)

80.0
25.0
15.0
5.0
-1.0

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 5.1

HYDRAULIC MODEL LAYOUT

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5.7 2D Model Roughness

A GIS land use map covering the entire study area was created for the purposes of defining the hydraulic roughness across the floodplain. Each grid cell is assigned a Manning's 'n' roughness value based upon land use defined on the map. The GIS layer of ultimate land use was generated using Councils Planning Scheme and aerial photography.

Roughness values for each land use type were assigned based on site observations and using previous experience in 2D hydraulic modelling applications. The Manning's "n" roughness parameters adopted in the model ranged from 0.015 for open water bodies through to 0.1 for residential areas with ineffective flow paths blocked by buildings, fences and other obstructions. These values are typical of those adopted for floodplain roughness for studies of this nature, and are in accordance with those supplied by HBCC in the brief for this study. Table 7 documents roughness parameters assigned to each land use.

Table 7: Adopted Roughness Parameters

Land Use Type	Manning's "n" Roughness Parameter
Water Body	0.02
Park residential	0.050
Residential low density	0.10
Residential medium density	0.10
Residential high density	0.10
Active open space	0.035
Short Grass	0.030
Trees, high vegetation	0.070
Road	0.015
Sugar Cane	0.060

5.8 Model Design Runs

The TUFLOW hydraulic model was analysed for the 10, 20, 50 and 100 year ARI design flood events for the critical storm event. The results from the analysis for the ultimate case (ultimate conditions) model are discussed separately in the following section of this report.

6. EXISTING CASE ANALYSIS RESULTS (ULTIMATE HYRDOLOGY)

6.1 Verification of Model to Previous Study Results

A process of verification was undertaken to ensure that the model constructed as part of this assessment was behaving in an appropriate manner. Peak flood levels for the 100 year ARI event with a varying downstream boundary levels were compared at a number of key locations throughout the study area to previous modelling undertaken by Connell Wagner in 1996 using XP- RAFTS and the MIKE11 1D modelling package. Table 8 presents comparisons between flood levels reported in the "Strategic Planning Report for the O'Regans Creek Catchment", 1996 and levels obtained using two (2) hydraulic model constructed for use in this study with varying tail water level of 2.15 m AHD and 2.45 m AHD. Figure 6-1 shows the location of the comparison points and the difference in water levels.

Table 8: Comparison of Peak Flood Level, 100 year ARI

Location	100 year ARI Flood Levels (m AHD)				
	Connell Wagner Strategic Planning Report for O'Regans Creek Catchment (1996)	Existing TUFLOW Model with TW=2.15 m AHD	Difference model with TW=2.15 (m)	Existing TUFLOW model with TW=2.45 m AHD	Difference model with TW=2.45 (m)
1	2.48	2.15	-0.33	2.45	-0.03
2	2.59	2.18	-0.41	2.49	-0.10
3	2.96	2.23	-0.73	2.53	-0.43
4	3.05	2.41	-0.64	2.63	-0.42
5	3.09	2.42	-0.67	2.63	-0.46
6	3.15	2.43	-0.72	2.64	-0.51

Location	100 year ARI Flood Levels (m AHD)				
	Connell Wagner Strategic Planning Report for O'Regans Creek Catchment (1996)	Existing TUFLOW Model with TW=2.15 m AHD	Difference model with TW=2.15 (m)	Existing TUFLOW model with TW=2.45 m AHD	Difference model with TW=2.45 (m)
7	3.14	2.44	-0.70	2.64	-0.50
8	3.31	2.52	-0.79	2.7	-0.61
8	3.33	2.67	-0.66	2.75	-0.58
9	3.32	2.56	-0.76	2.72	-0.60
10	3.34	3.04	-0.30	3.07	-0.27

Table 8 demonstrates that flood levels obtained using the newly constructed model with a tail water level of 2.45m AHD are lower ranging from 0.03m to 0.6m difference. There are following three (3) reasons for this:

1. The 2D modelling approach compared to 1D modelling
2. 2m and 5m contour data utilised in the upper catchment in this current study
3. Available survey data for cross sections in the previous Study (Connell Wagner, 1996)

Differences between the studies are likely to be due to storage effects in the different model approaches (1D, 2D) and the available ground level information of both studies.

The 2D TUFLOW model is suitable for this study and has been adopted for the determination of flooding behaviour within the study area.

6.2 Boundary Condition Sensitivity Analysis

A sensitivity analysis has been undertaken on the tidal levels adopted at the downstream boundary of the models.

The sensitivity analysis was undertaken for the 100 year ARI event using the HAT tidal level and a ±0.3m variation (RL 2.15 m AHD and RL 2.45 / 1.85m AHD respectively) based on the critical duration storm event. Figures 6.2 and 6.3 show the extent of impact predicted as a result of varying the ocean boundary condition. Peak water surface levels for both sensitivity model runs have been extracted at approximately 50 locations across the catchment. The Water surface levels are presented in Appendix 3 and the locations of the reporting points are presented in Figure 6.4.

The modelling demonstrates that the impacts from varying the tail water levels extend across the majority of the catchment. The sensitivity analysis shows that the low lying areas of O'Regans Creek Catchment are very sensitive to the tail water levels.



HERVEY BAY CITY COUNCIL

LEGEND

- Road
- Study Boundary
- 01 — Point ID
- - 0.02 — Difference (m) from previous Connel Wagner, 1996) Study

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.1

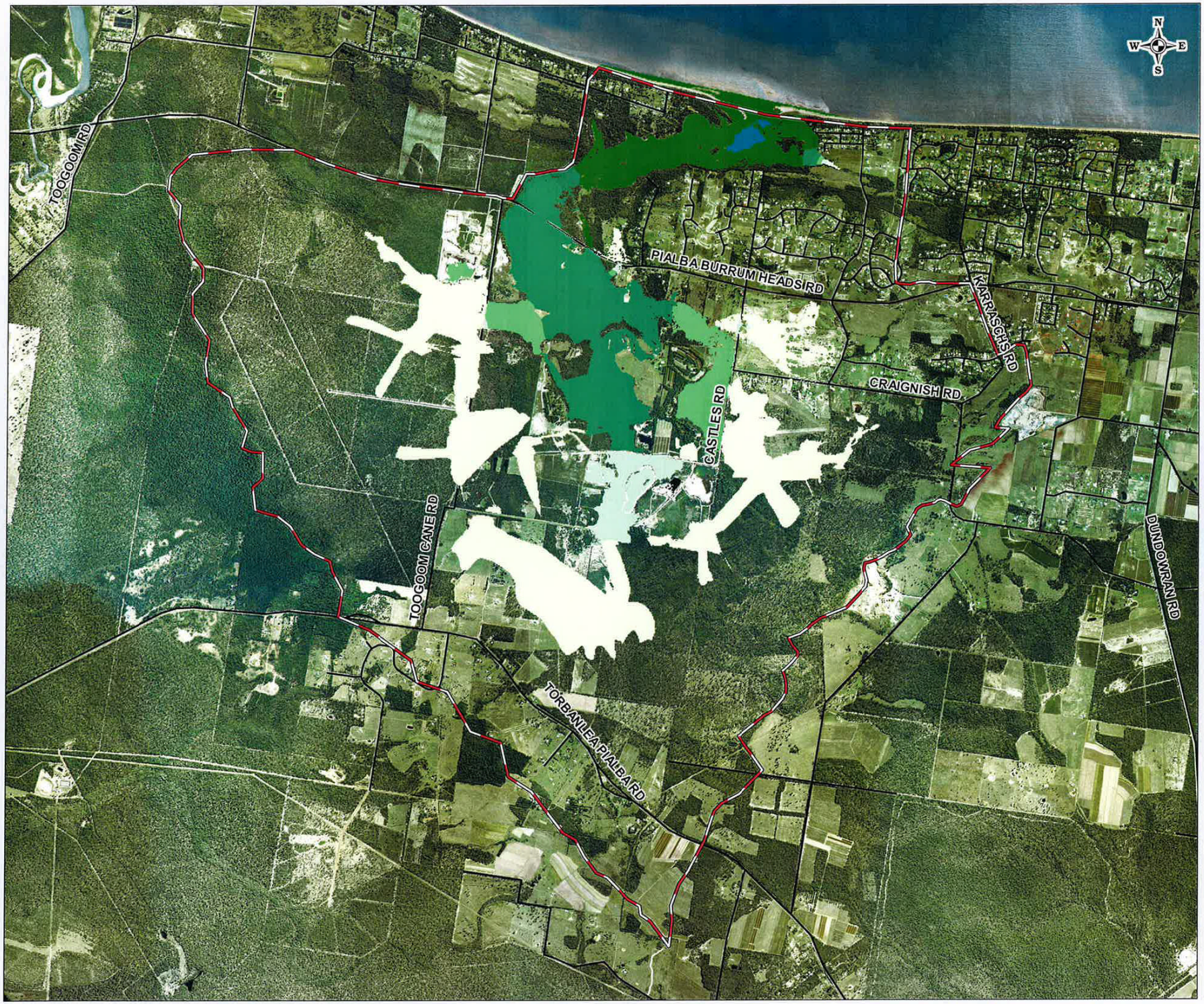
STUDY COMPARISON

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LEGEND

Study Boundary

Difference (m)

- -1 to -0.5
- -0.5 to -0.20
- -0.2 to -0.15
- -0.15 to -0.1
- -0.1 to -0.05
- -0.05 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.5
- 0.5 to 10

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.2

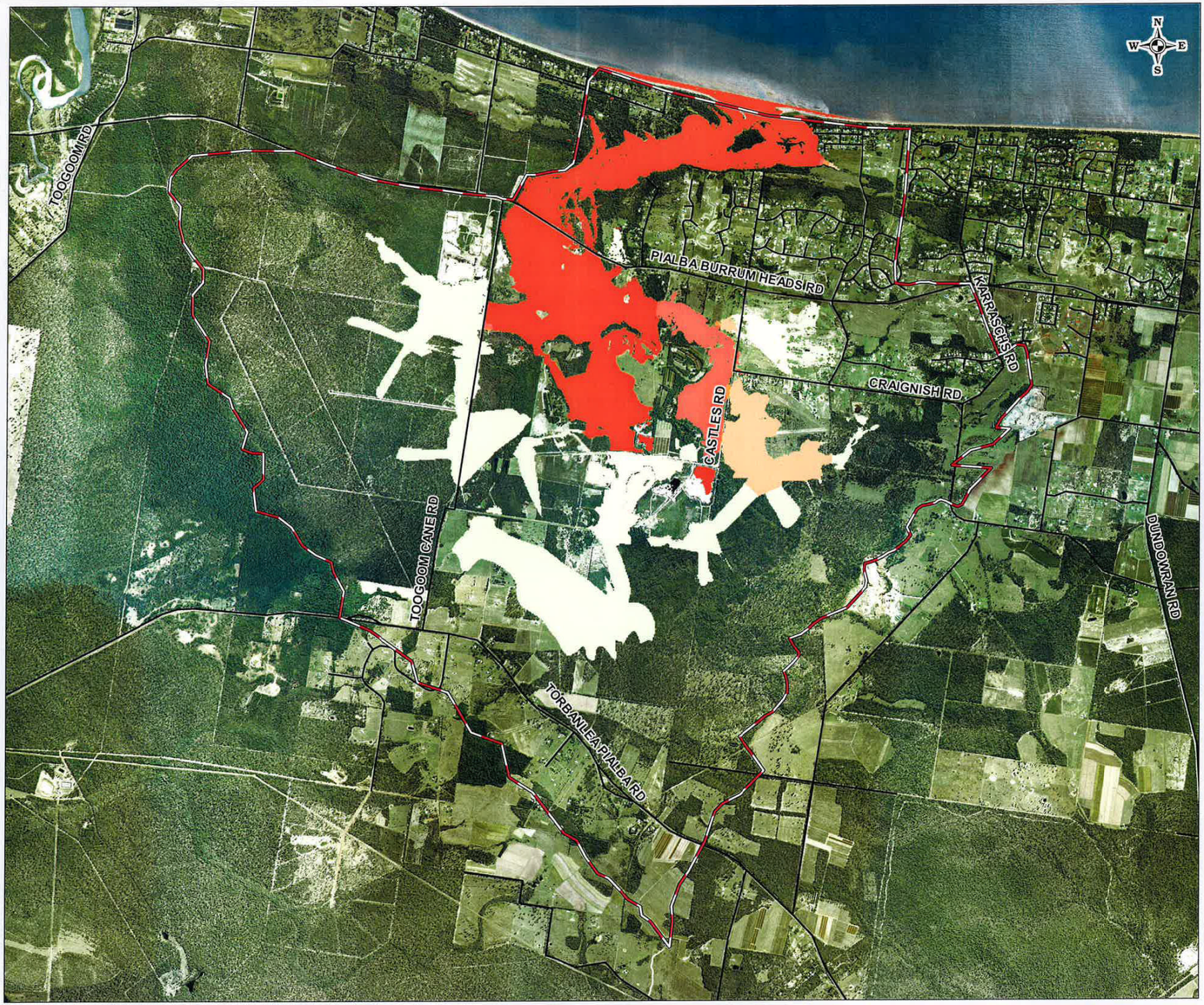
TAILWATER SENSITIVITY ANALYSIS

Q100 YEAR ARI 1.85M BOUNDARY

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HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Difference (m)

- -1 to -0.5
- -0.5 to -0.20
- -0.2 to -0.15
- -0.15 to -0.1
- -0.1 to -0.05
- -0.05 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.5
- 0.5 to 10

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.3

TAILWATER SENSITIVITY ANALYSIS

Q100 YEAR ARI 2.45M BOUNDARY

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6.3 Model Results and Flood Mapping

The TUFLOW, 2D model was adopted for the purposes of estimating flood levels and flood inundation throughout the study area under the 10, 20, 50 and 100 year ARI design flood events. These analyses were undertaken using the existing site topography which excluded any proposed flood mitigation works. The results therefore represent the "existing case" model results.

The model results have been mapped using MapInfo and Vertical Mapper (Version 9.0). Peak water levels have been extracted for approximately 50 reporting locations across the catchment. Figure 6.4 illustrates the flood reporting locations. Peak water levels at each reporting location for the 10, 20, 50 and 100 year ARI event are presented in Appendix C. It should be noted that the flood level data for reporting points 20 to 47 are at locations where 5m contour data was the only available ground level information. Therefore, the flood levels at these locations do not represent high accuracy.

The results of the existing case (with ultimate catchment conditions) model are provided in this report. The results provided include the following flood reporting information:

- Flood inundation extents for all events
- Flood levels for all events
- Flood depths for all events
- Hazard (as the product of depth and velocity) for all events

A total of sixteen (16) flood plans have been prepared as part of this study. Flood extent plans for all events are presented in Figures 6.5 to 6.9, Flood levels are illustrated in Figures 6.9 to 6.12. The flood depths for all events are presented in Figures 6.13 to 6.17 and the hazard is presented in Figures 6.18 to 6.20.

The flood inundation mapping prepared as part of this study is subject to the following notations:

1. The flood extent and associated flood data prepared as part of this study is based on available survey data as supplied by Hervey Bay City Council. This includes aerial photogrammetric survey, limited field validation survey and stormwater pipe and pit information. The flood extents and flood results will therefore be subject to the accuracy and detail of the background study information. Drainage conditions may also have changed since the collection of the survey information.

2. A buffer of 0.1m has been applied to the derivation of the flood extent such that, depths less than 0.1m are not shown. This has been done to remove the local drainage and sheet flow that is outside the scope and detail of the study.

3. All flood extents prepared as part of this study have been prepared based upon the DTM formed for the study area. The accuracy of the flood extents prepared from this study is subject to the accuracy of the topographical representation contained within the DEM.



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Q100 Flood Extent

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.4

REPORTING LOCATIONS

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Projection Trans. Merc. MGA56(GDA 94)



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LEGEND

- Study Boundary
- Q10 Flood Extent

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

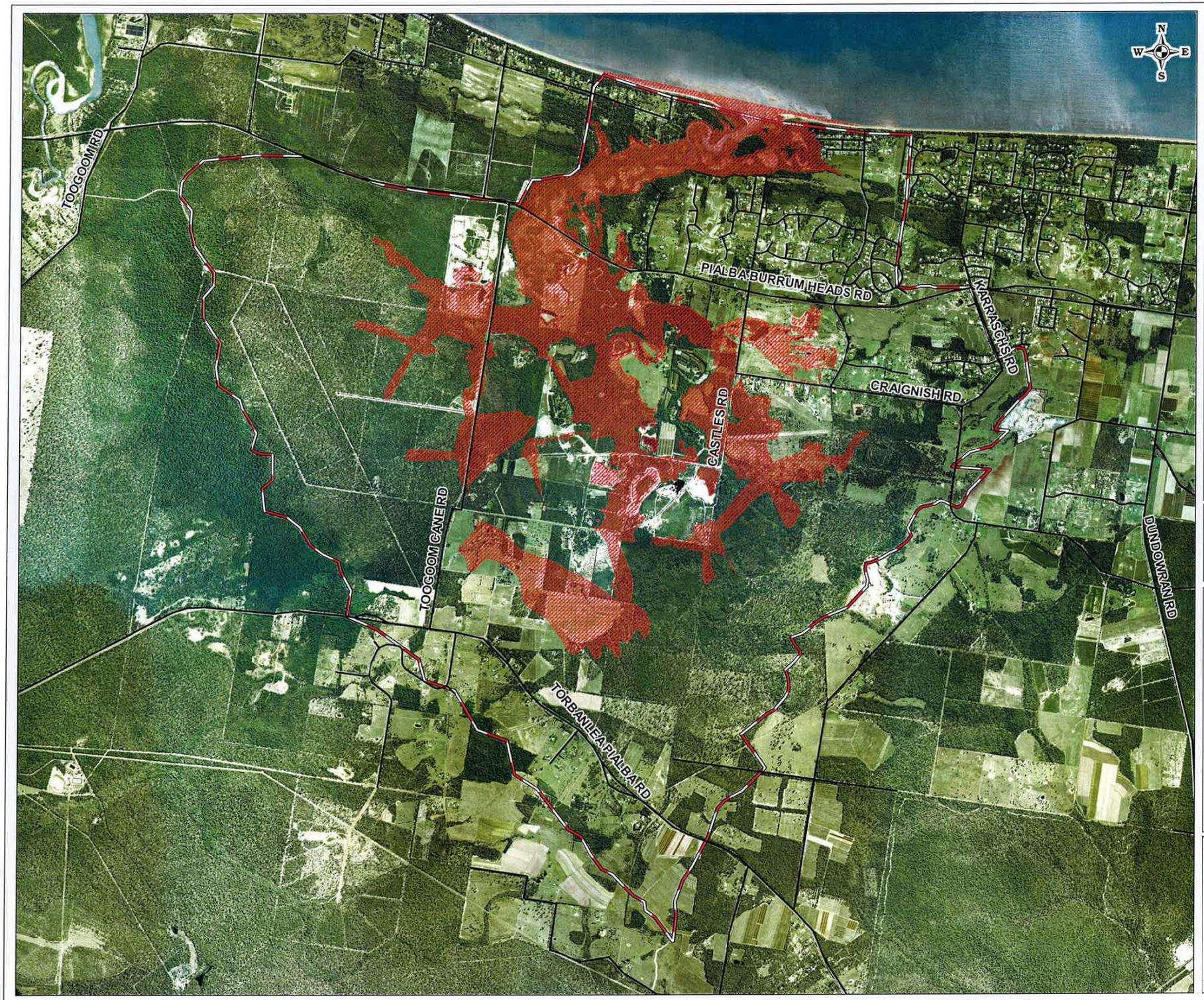
FIGURE 6.5

10 YEAR ARI FLOOD EXTENT

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LEGEND

- Study Boundary
- Q20 Flood Extent

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.6

20 YEAR ARI FLOOD EXTENT

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LEGEND

Study Boundary

Q50 Flood Extent

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.7

50 YEAR ARI FLOOD EXTENT

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HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Q100 Flood Extent

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.8

Q100 FLOOD EXTENT

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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Flood Surface Level (m)

7.25
6.50
5.00
3.50
3.00
2.50
2.15

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.9

10 YEAR ARI FLOOD LEVEL

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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Flood Surface Level (m)

7.50
6.50
5.00
3.50
3.00
2.50
2.15

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.10

20 YEAR ARI FLOOD LEVEL

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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Flood Surface Level (m)

7.50
6.50
5.00
3.50
3.00
2.50
2.15

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.11

50 YEAR ARI FLOOD LEVEL

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HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Flood Surface Level (m)

7.50
6.50
5.00
3.50
3.00
2.50
2.15

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.12

100 YEAR ARI FLOOD LEVEL

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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Depth (m)

- 0.1 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.13

10 YEAR ARI FLOOD DEPTH

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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Depth (m)

- 0.1 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.14

20 YEAR ARI FLOOD DEPTH

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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Depth (m)

- 0.1 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.15

50 YEAR ARI FLOOD DEPTH

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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Depth (m)

- 0.1 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.16

100 YEAR ARI FLOOD DEPTH

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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Flood Hazard Legend

2.00
1.00
0.10
0.08
0.06
0.04
0.02
0.00
0.10
0.00

m^2/Second

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.17

10 YEAR ARI HAZARD

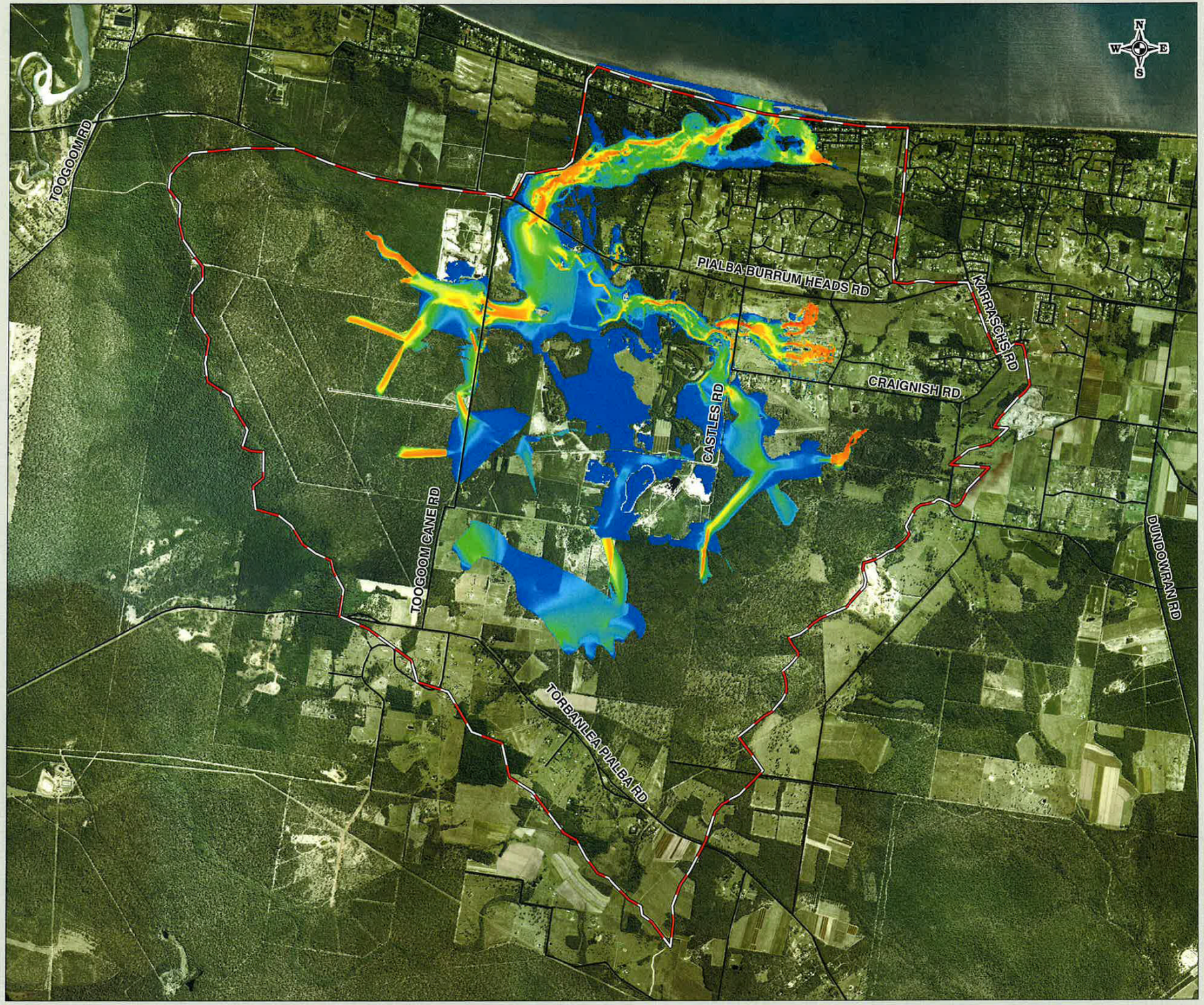
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File Path: Y:\42jobs\GIS\QGIS\001 HBCC - ORegans Flood Risk Reduction Study\Figures\Figure 6.17 Q10 Hazard.MXD

Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Flood Hazard Legend

2.00
1.00
0.10
0.08
0.06
0.04
0.02
0.00
0.10
0.00

m^2/Second

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.18

20 YEAR ARI HAZARD

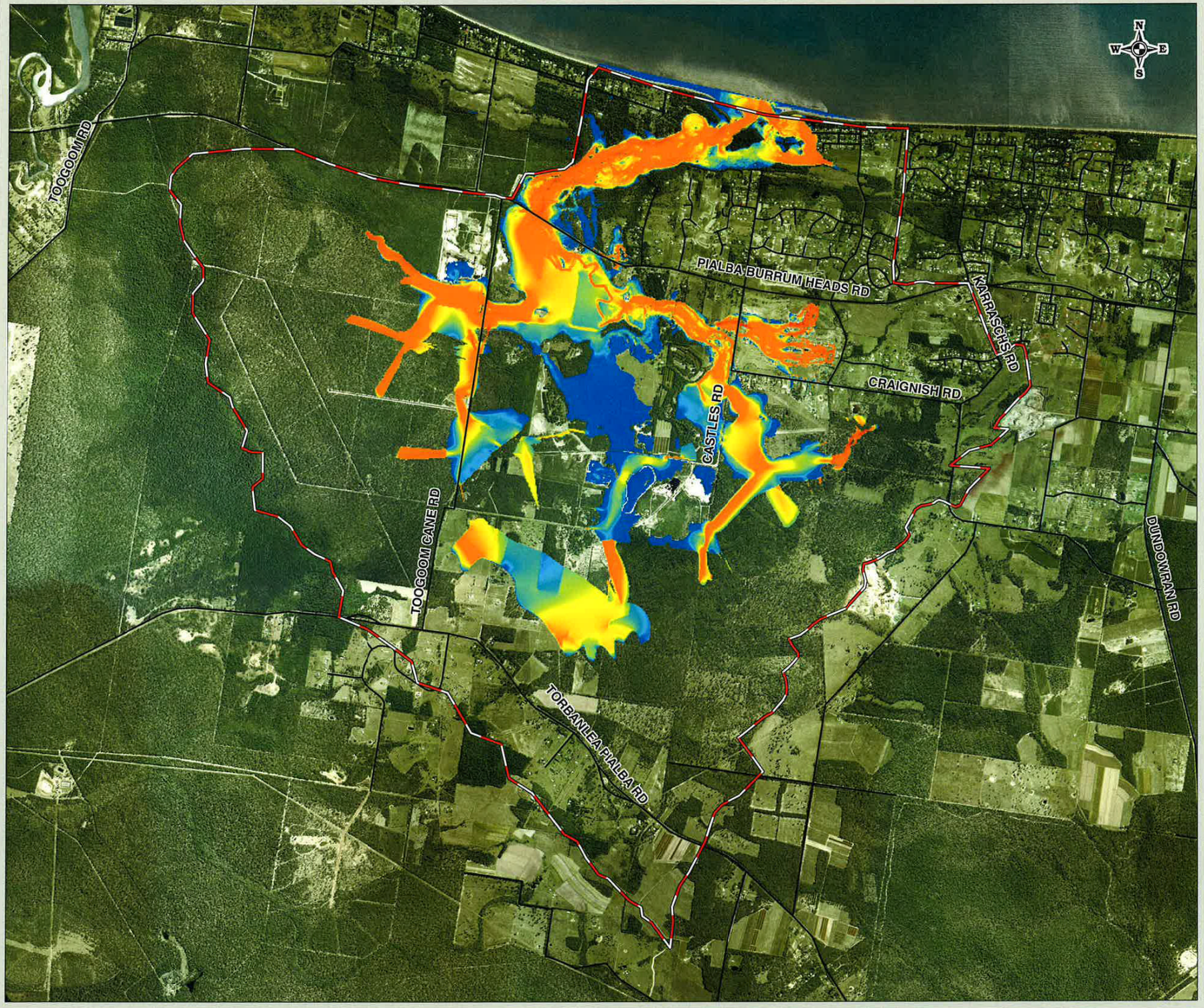
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resources & energy

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ABN 61 001 279 812
PO Box 81, Albert Street QLD 4002, Australia
Ph. +61 7 3221 7444 Fax. +61 7 3221 7791

File Path: Y:\42\jobs GIS\W70048 001 HBCC ORegans Flood Risk Reduction Study\Pictures\Figure 6.18 020 Hazard.WOR

Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Flood Hazard Legend

2.00
1.00
0.10
0.08
0.06
0.04
0.02
0.00
0.10
0.00

m^2/Second

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.19

50 YEAR ARI HAZARD

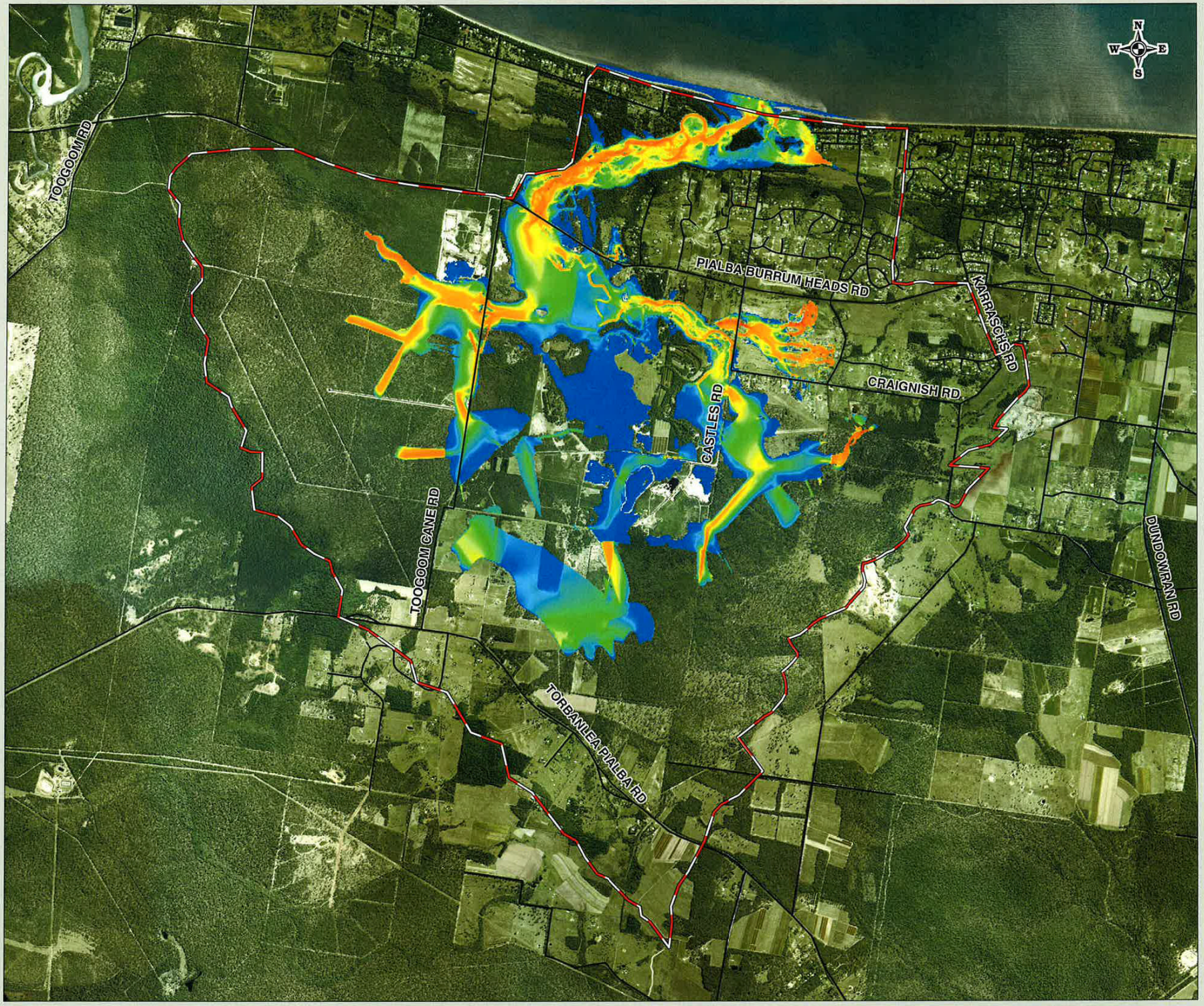
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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Flood Hazard Legend

2.00
1.00
0.10
0.08
0.06
0.04
0.02
0.00
0.10
0.00

m^2/Second

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.20

100 YEAR ARI HAZARD

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Projection Trans. Merc. MGA56(GDA 94)

7. EXISTING SCENARIO RISK IDENTIFICATION & PRIORITISATION

7.1 Risk Identification Methodology

In liaison with HBCC a procedure for the evaluation and prioritisation of risks was developed. Risks are evaluated and prioritised using two methodologies, Queensland Urban Drainage Manual (QUDM) and the risk ranking matrix according to Councils Disaster Mitigation Plan. Identification of overtopping and hazard at road crossings was defined using the QUDM design criteria for roads as shown in Table 9. Major roads have been assessed for the 50 year ARI event and minor roads have been assessed for the 10 year ARI event.

Table 9: QUDM design criteria for roads

Criteria	Limit
For Vehicle and Pedestrian Safety	0.6m^2/s (0.4 m^2/s if the area is known to have high pedestrian usage or has safety issues)
Maximum depth of flow on any Road	300mm

Prioritisation and risk for the identified crossings was evaluated using the risk ranking matrix. The risk ranking matrix considers the likelihood and consequence of the risk occurring and defines a risk ranking for each risk. Table 10 and 11 provides the classification of likelihood and consequence respectively. Table 12 shows the resulting risk ranking derived from the relationship of likelihood and consequence.

Table 10: Likelihood parameters

Almost certain	A 99.5% chance of a hazard being exceeded in a 50 year period – a 1 in 10 year event
Likely	Probability of exceedance is greater than 50% in a 50 year period, but less than 99.5% - a 1 in 50 year event

Possible	Probability of exceedance is greater than 20% in a 50 year period, but less than 50% - a 1 in 100 – 200 year event
Unlikely	Probability of exceedance is greater than 5% in a 50 year period. but less than 20% - a 1 in 500 year event
Rare	Probability of exceedance is less than 5% in a 50 year period - a 1 in 500 year event

Table 11: Consequence parameters (based on 2000 AU$)

Insignificant	Natural hazards are experienced and cause some stress on community lifelines. Community agencies cope with some effort and total community financial loss is less than $1.0m
Minor	No disaster is officially declared and effects lead to temporary failure of lifelines other than energy supply for up to 24 hours. Total community financial loss is less than $10m
Moderate	Disruption lasts for more than 5 days including energy disruption. Recovery takes 14 – 21 days. Vulnerable elements are severely affected and all major agencies are involved. Hospitalisation of victims occurs and total community financial loss is less than $50m. State of emergency is declared during the event.
Major	All lifelines affected. Energy is disrupted for up to 14 days. Recovery takes 4 – 6 weeks. At least one death is suffered and temporary evacuation of area is required. State of Disaster is declared and total community loss is up to $200m.
Catastrophic	Effects are severe and all lifelines are affected. No energy for up to 8 weeks and recovery takes 6 – 24 months. At least 10 deaths suffered and significant evacuation required. Total community financial loss in hundreds of millions.

Table 12: Risk Ranking

Return period	Consequence / Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
10	Almost certain	H	H	E	E	E
50	Likely	M	H	H	E	E
100/200	Possible	L	M	H	E	E
500	Unlikely	L	L	M	H	E
1000	Rare	L	L	M	H	H

Where: E = extreme risk H = high risk M = moderate risk L = low risk

In addition to infrastructure lifelines, risk parameters for people, buildings, economic loss and loss of the natural environment are proposed as shown in Table 13.

Table 13: Risk Parameters for People, Buildings, Economic Loss and Natural Environment

Risk element	Extreme (unacceptable) risk
People	Vulnerability to natural hazards is generally measured by the risk to life and property from known hazards. An area may be prone to a known hazard, but if there is no possible risk to life or property, the vulnerability is low. Where life and property are at risk, the magnitude and likelihood of the hazard combine to create a measure of vulnerability. **Unacceptable risks are death, serious injury and major health hazard.**
Buildings	The built environment is at risk from a number of known hazards in Hervey Bay. Various regulations have been developed locally (e.g. Local Laws) and at a wider scale (e.g. the Building Code of Australia) to minimise the risk of damage to the built environment. All of these regulations are based on an acceptable level of risk which has been determined either by Council or a wider community of interest (e.g. 1:100 flood immunity). Inevitably there will be extreme events which go beyond the acceptable level of immunity and the only possible way to immunise against these events is avoidance. **Unacceptable risks are collapse or damage to buildings requiring demolition.**
Economic loss	In all disaster events there is bound to be some form of economic loss. The Federal Government under the Natural Disaster Relief Arrangements provides funding to victims of disaster events. This funding is generally short term and designed to minimise immediate suffering and loss. Businesses need to make their own assessment of potential economic loss through a natural disaster event and make plans accordingly. These would range from building construction, to choice of location to insurance. **Unacceptable risks are loss of livelihood for more than 10% of the working community.**
Natural environment	The natural environment is at risk from a number of known hazards in Hervey Bay. **Unacceptable risks are loss of ecological systems, major habitats or conservation areas. Significant disruption to natural drainage systems.**

Risk escalation	Risk escalation is likely to happen when initial risk minimisation programs or event response mechanisms do not achieve their intended purpose. The risks outlined in this document may have follow-on or secondary effects (e.g. an earthquake may lead to a dam break, which may lead to flooding, which may lead to injury or isolation). **Unacceptable risks arise from the failure of initial risk minimisation and response mechanisms.**
Risk frequency	Risks to physical infrastructure are usually incorporated in design parameters (e.g. bridges are designed to withstand certain loads; drains are designed to accommodate mathematically derived flood levels). These are generally based on industry standards of acceptable levels of risk. These standards have until recently had very little legislative basis. The recent adoption of *State Planning 1/03 - Mitigating the adverse impacts of Flood, Bushfire and Landslide* introduces risk frequency levels (e.g., 1:100 years) which are required to be accommodated in planning and design documents (e.g. planning schemes and infrastructure codes). **Unacceptable risks are events which occur within the design capacity of infrastructure or industry accepted measures.**
Legal and social justice implications	Risk management is applied by Council across all parts of its jurisdiction in an equal manner and includes all persons. Council is required to make decisions on an annual basis about prioritising its expenditure on various competing items. Expenditure on risk minimisation is incorporated in most capital works projects by way of an in-built design standard. **Unacceptable risks are deliberate inequality of expenditure against any one group, or any one part of the city.**
Political implications	Council's decisions are subject to scrutiny and influence from various elements and sectors of the community. It is Council's role to make informed and un-biased decisions. **Unacceptable risks are decisions made which reflect unlawful political bias.**

For the O'Regans Creek Flood Risk Reduction Study, specific flood risks were identified through use of the above risk matrix and examination of modelling results as discussed in Chapter 6. Where modelling identified a hazard, an analysis of the various risk elements was undertaken using the risk matrix above. A risk ranking for the hazard was determined based on the likelihood and the consequences of the hazard occurring. For elements such as people, not only the potential to suffer injury or death as a result of property inundation was analysed, but also the ease of egress from the property through the determination of velocity x depth products and road overtopping as defined in the (QUDM). These parameters are shown in Table 13.

A risk ranking for each specific flooding risk was determined. This risk ranking can be used to prioritise mitigation options within the total catchment and is discussed in more detail in Chapter 8. A description of flooding and risk ranking for key areas across the catchment is provided in the following text. Based on the derived risk ranking and the flooding characteristics of each location the upgrade and immunity requirements are presented in Table 16.

Risk elements were further defined by flood hazard and road overtopping. The following sections provide existing case flooding information for key areas across the catchment. These areas include road overtopping and areas of inundation. Road overtopping has been assessed in accordance with the Queensland Urban Drainage Manual (QUDM), 1992.

7.2 Risk Identification

All locations of key risk areas have been mapped and are illustrated in Figure 7.1. Risks have been identified based on the QUDM road design guidelines and the risk ranking matrix. Key risk elements are defined in the following sections.

7.2.1 QUDM Classification

As discussed in the previous section, QUDM defines road trafficability based on the depth of inundation and the velocity x depth product across the road. All crossings in the catchment have been assessed against these parameters and the outcomes are shown in Table 14.

7.2.2 Risk Ranking Matrix

All crossings and key areas were assessed to define the risk ranking. Table 12 shows the risk ranking matrix.

Table 14: QUDM Road Trafficability Assessment

Location Id and Name	Road Type	Q10 Depth	Q20 Depth	Q50 Depth	Q100 Depth	Q10 vxd	Q20 vxd	Q50 vxd	Q100 vxd
1 Pialba Burrum Heads Road	Major	0.25	0.3	0.35	0.40	0.10	0.14	0.18	0.22
2 Pialba Burrum Heads Road	Major	0.20	0.25	0.30	0.32	0.05	0.08	0.12	0.19
3 Toogoom Cane Road	Minor	0.15	0.19	0.21	0.24	0.17	0.25	0.32	0.38
4 Castle Road	Minor	0.30	0.35	0.38	0.40	0.30	0.37	0.42	0.48
*5 Dublin Road**	*Minor*	*0.08*	*0.12*	*0.18*	*0.25*	*0.02*	*0.04*	*0.06*	*0.09*
6a Castle Road	Minor	0.17	0.2	0.23	0.25	0.09	0.11	0.13	0.14
6b Castle Road	Minor	NA	NA	NA	0.12	NA	NA	NA	0.07

*Road Level has not been surveyed and therefore water depth and d*v values are not of high accuracy. Yellow marked fields show water depths of 0.3m and greater.

Table 15: Flood Risk Analysis

Location/Flooding Hot Spot ID (Refer Figure 7.1)	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Upgrade recommended
Pialba Burrum Heads Road 1	People - drowning	No resultant deaths, injuries or major health hazards	✓	Possible	Minor	**Moderate**	×
	People - ease of egress	DV Product <0.6 D<300mm	×	Likely	Minor	**High**	✓
	Buildings	Q100 immunity	✓	Unlikely	Minor	**Low**	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×
Pialba Burrum Heads Road 2	People - drowning	No resultant deaths, injuries or major health hazards	✓	Possible	Minor	**Moderate**	✓
	People - ease of egress	DV Product <0.6 D<300mm	×	Likely	Minor	**High**	✓
	Buildings	Q100 immunity	✓	Unlikely	Minor	**Low**	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×

Location/Flooding Hot Spot ID (Refer Figure 7.1)	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Upgrade recommended
Toogoom Cane Road 3	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Minor	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	✓	Unlikely	Minor	**Low**	×
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	**Low**	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×
Castle Road 4	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	×	Almost Certain	Insignificant	**High**	✓
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	**Low**	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×

Location/Flooding Hot Spot ID (Refer Figure 7.1)	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Upgrade recommended
Dublin Road 5	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	✓	Unlikely	Insignificant	**Low**	×
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	**Low**	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×
Castle Road 6a	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	✓	Unlikely	Insignificant	**Low**	×
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	**Low**	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×

Location/Flooding Hot Spot ID (Refer Figure 7.1)	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Upgrade recommended
Castle Road 6b	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	✓	Unlikely	Insignificant	**Low**	×
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	**Low**	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×

7.2.3 Key Risk Elements

Modelling of the O'Regans Creek catchment identified a number of key risk elements as outlined in Sections 7.2.4 – 7.2.7.

7.2.4 Pialba Burrum Heads Road ID 1

Pialba Burrum Heads Road is predicted to be overtopped for all design events. The road trafficability of Pialba Burrum Heads Road has been assessed for the 50 year ARI event, as it is a major road.

Where the major culverts are located (refer location 1 in Figure 7.1), the road is predicted to be inundated by more than 300mm, however the velocity x depth product is predicted to be below 0.3m^2/s for all design events. Table 16 demonstrates that based on QUDM, Pialba Burrum Heads Road is not trafficable in events greater than and including the 20 year ARI event.

WORLEYPARSONS also noted that Pialba Burrum Heads Road is an Evacuation Route during Emergency. Therefore, this location was identified high risk, as presented in Table 15.

It is recommended that Pialba Burrum Heads Road ID 1be assessed for upgrade.

Table 16: Inundation depths on Pialba Burrum Heads Road ID 1

Design Event	Depth of Inundation (mm)
10	250
20	300
50	350
100	400

7.2.5 Pialba Burrum Heads Road ID 2

Pialba Burrum Heads Road ID 2 is located to the east of ID 1(Refer location 2 in Figure 7.1). At this location the modelling predicts, the road will be overtopped for all design events. During the 50 year ARI event, the road at this location is predicted to be inundated by approximately 300mm. The velocity x depth product is predicted to be below 0.3m^2/s for all design events.

Table 17 demonstrates that based on QUDM, Pialba Burrum Heads Road is not trafficable in events greater than and including the 50 year ARI event. In accordance with Table 15 Pialba Burrum Heads Road was classified as high risk.

It is recommended that Pialba Burrum Heads Road ID 2be assessed for upgrade.

Table 17: Inundation depths on Pialba Burrum Heads Road 2

Design Event	Depth of Inundation (mm)
10	200
20	250
50	300
100	320

7.2.6 Toogoom Cane Road

Toogoom Cane Road (location 3) is predicted to be overtopped in all design events. The road trafficability of Toogoom Cane Road has been assessed for the 10 year ARI event, as it is a minor road. In a 10 year ARI event the road is predicted to be inundated by 150mm and the velocity x depth product is predicted to be below 0.3m^2/s.

Table 18 demonstrates that based on QUDM, Pialba Burrum Heads Road is trafficable in all design events.

Based on the classification of low risk, Toogoom Cane Road is not recommended to be assessed for upgrade.

Table 18: Inundation depths on Toogoom Cane Road

Design Event	Depth of Inundation (mm)
10	150
20	190
50	210
100	240

7.2.7 Castle Road

Three (3) locations have been assessed at Castle Road. Refer Figure 7.1 for these three locations (location 4, 6a and 6b). Castle Road is a minor road and road trafficability has therefore been assessed for the 10 year ARI event.

At location 4, overtopping of Castle Road is predicted in the 10 year ARI event and greater. Table 19 presents that Castle Road is predicted to be not trafficable in all design events. This location was classified high risk according to Table 15.

However, after discussion with Council it was determined that other roads can be used for evacuation during major storm events. Residents will not be trapped in the event of an emergency. Therefore, these locations are not recommended for upgrade analysis.

Table 19: Inundation depths on Castle Road ID 4

Design Event	Depth of Inundation (mm)
10	300
20	350
50	380
100	400

Castle Road at location 6a is predicted to be overtopped for all design events; however the road is predicted to be trafficable for all design events (water depth is less than 300mm). Therefore, this location is identified with low risk and is not included in the mitigation assessment.

Castle Road at location 6b is predicted to be overtopped in the 100 year ARI event only. The velocity x depth product is predicted to be below 0.3m^2/s (refer Table 14). This location is identified with low risk and mitigation options have not been assessed.

7.2.8 Dublin Road

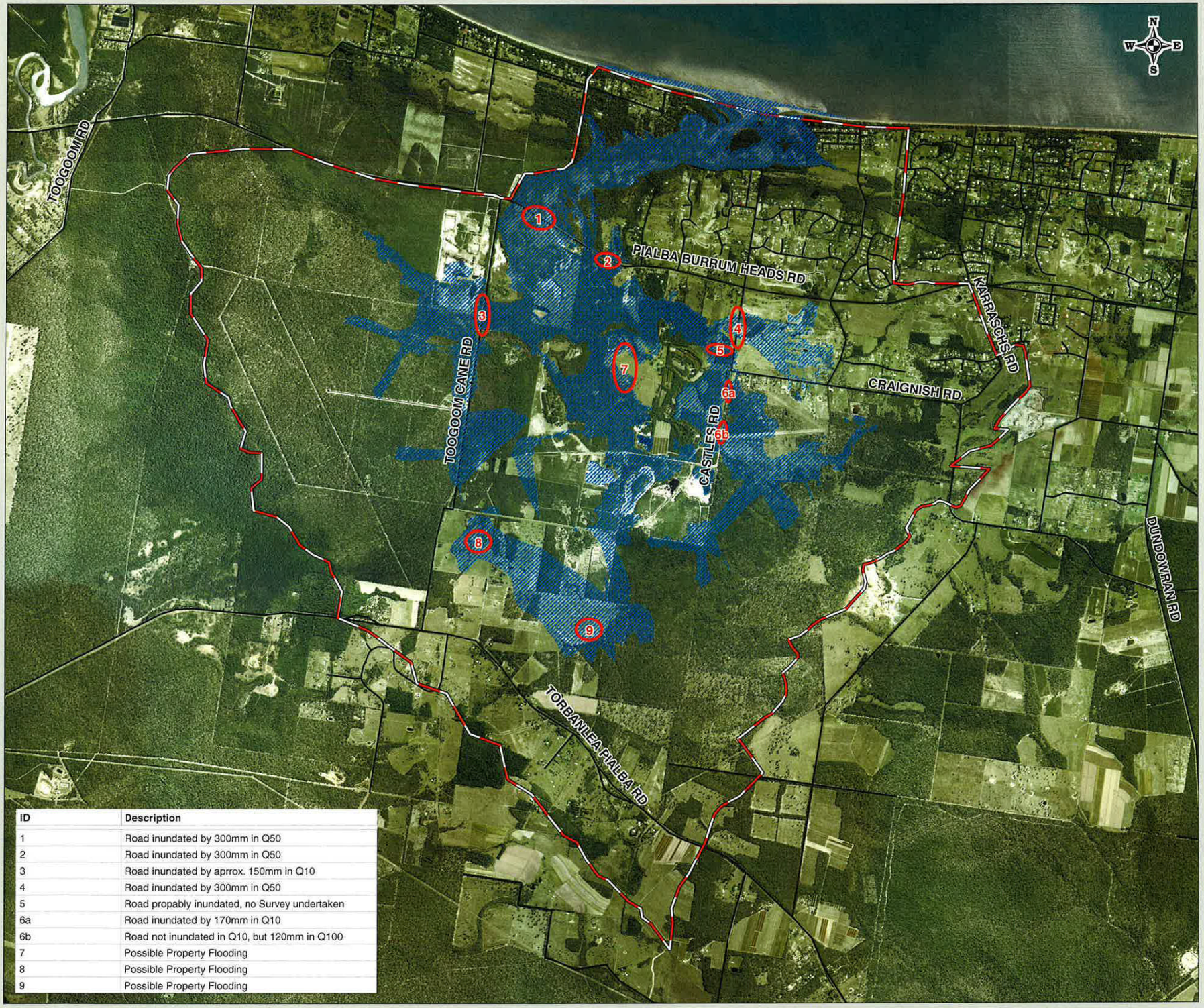
Location 5 in Figure 7.1 is located on Dublin Road, which is a minor road. This road has not been surveyed as part of this study. Therefore, the water depth on the road is based on the DTM derived from 5m contour data. This means that water depth and the velocity x depth product cannot be predicted with high accuracy.

In liaison with Council it was determined that no mitigation options will be modelled at this location. If assessment of this road is required in the future it is recommended that more detailed ground level information be collected.

7.2.9 Possible Property Flooding

Location 7, 8 and 9 illustrated in Figure 7.1 have been identified as areas with possible property flooding. This preliminary assessment is based on aerial photography only; floor levels have not been surveyed and no additional information is available. It should also be noted that the DTM at these locations is based on a 5m contour data and therefore, has limited accuracy.

No upgrades are recommended as part of this study. If further analysis is carried out on these locations, it is recommended that more detailed ground survey be collected.



ID	Description
1	Road inundated by 300mm in Q50
2	Road inundated by 300mm in Q50
3	Road inundated by aprrox. 150mm in Q10
4	Road inundated by 300mm in Q50
5	Road propably inundated, no Survey undertaken
6a	Road inundated by 170mm in Q10
6b	Road not inundated in Q10, but 120mm in Q100
7	Possible Property Flooding
8	Possible Property Flooding
9	Possible Property Flooding

HERVEY BAY CITY COUNCIL

LEGEND

- Study Boundary
- Q100 Flood Extent
- Locations With Flooding Issues

350 0 350 700 1050

Metres

Scale: 1:35,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 7.1

FLOODING HOT SPOTS

WorleyParsons
resources & energy

OneWay

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File Path: Y:\42\lots GIS\070048 001 HBCC - ORegans Flood Risk Reduction Study\Figures\Figure 7.1.WOR

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8. FLOODING MITIGATION OPTIONS AND COST ESTIMATION

8.1 Risk Treatment Options

Treatment of flooding risks as identified in Chapter 7 of this report has been investigated and summarised below. Specifically, flooding areas that were identified as high risk were mitigated by means of drainage augmentation such as raising roads or the installation of flood gates with the aim of an overall reduction of the flooding risk. Where flow depths were identified as failing to meet Council design guidelines and QUDM design requirements, mitigation options are suggested in this section.

Mitigation options have only been considered where necessary and to provide a beneficial outcome in terms of reducing flooding and flood risks. At this point, limited consideration has been given to the likely cost implications associated with these options. A brief description and costing of each of these options is provided below. Detailed design of the mitigation works is not included and is outside the scope of works of this study. Figure 8.1 illustrates the locations of the proposed drainage mitigation work investigated as part of this study.

8.1.1 Pialba Burrum Heads Road

To meet QUDM and Councils design requirements Pialba Burrum Heads Road should be trafficable (i.e., flood depth less than 300mm and V x D product < 0.6m²/s) in a 50 year ARI event. An analysis has been carried out to determine the mitigation works required to convey flow beneath Pialba Burrum Heads Road in the 50 year ARI event.

LOCATION 1 AT PIALBA BURRUM HEADS ROAD

The following three (3) mitigation options have been modelled:

1. Flood gates at the main structures (ID 1 and 2) on Pialba Burrum Heads Road
2. Raising the road by 300mm
3. Raising the road by 500mm

Modelling of flood gates predicts that the road does not achieve road trafficability in the 50 year ARI event. The road still overtops with a water depth of approximately 350mm.

Preliminary analysis of raising the road by 300mm does not achieve the required road trafficability. This model run predicts to over top the road with a water depth of approximately 340mm.

The mitigation option where Pialba Burrum Heads is raised by 500mm predicts that the road is flood immune in a 50 year ARI event and therefore achieves the required standard. Even in the 100 year ARI event the model predicts that Pialba Burrum Heads Road is flood immune.

This option has been selected as the preferred option and has been included in the model for the mitigated case for all design events.

LOCATION 2 AT PIALBA BURRUM HEADS ROAD

The following two (2) mitigation options have been modeled:

1. Raising the road by 300mm
2. Raising the road by 500mm

The modelling of raising the road by 300mm predicts that the road is still overtopping and not trafficable for the 50 year ARI event.

The simulation of raising the road by 500mm predicts that the road is flood immune in the 50 year event and achieves the required standard. The road is also flood immune in the 100 year ARI event.

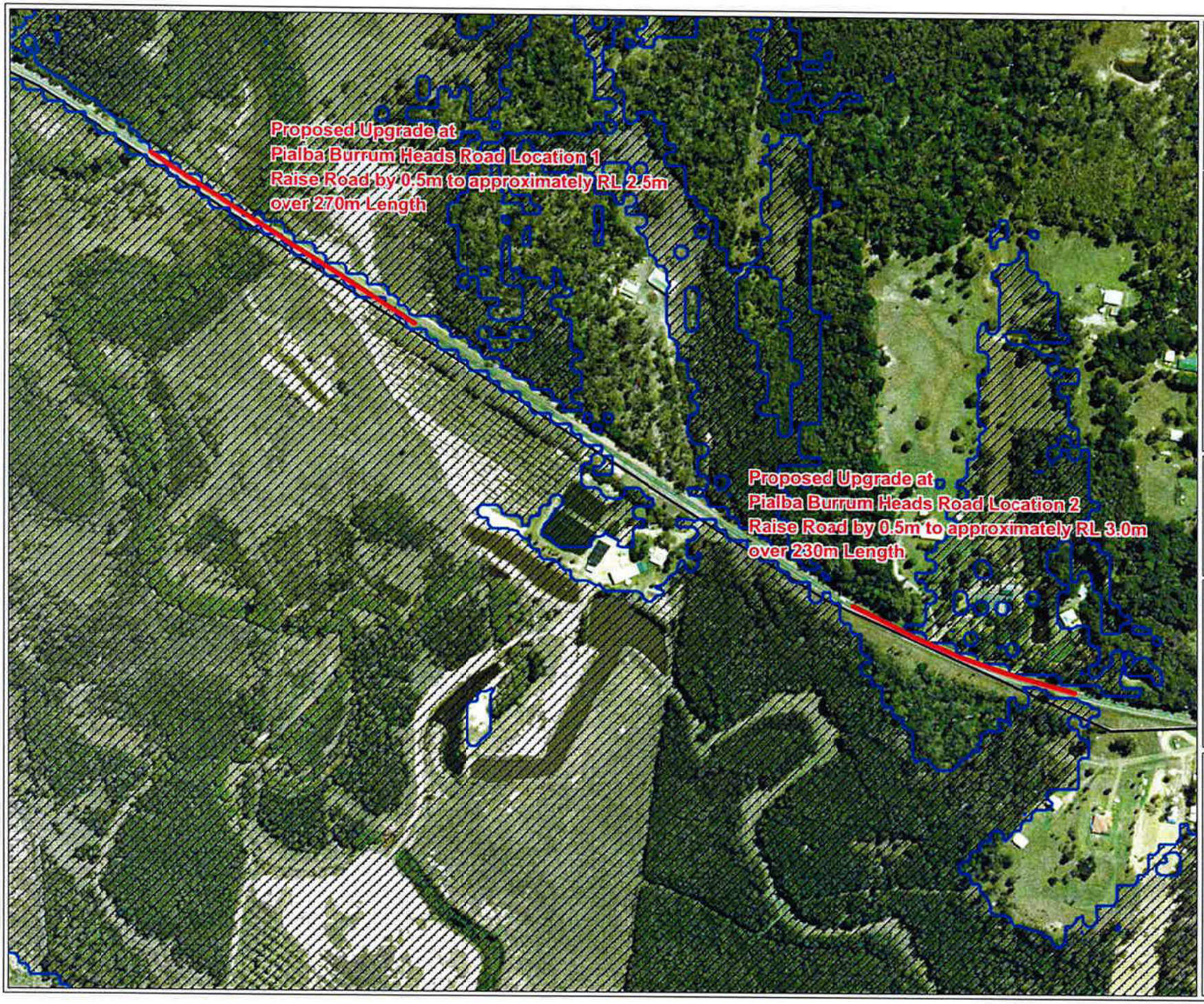
Therefore, this option and has been adopted as preferred mitigation option at this location and was included in the model for the mitigated case.

8.2 Risk Treatment Summary

Generally, a vast majority of the flooding identified throughout the O'Regans Creek catchment is largely nuisance flooding and was classified as low risk areas. These areas have not been included in the mitigation option assessment.

However, this study has identified two (2) areas in the catchment where the flooding risk (from road overtopping) is considered high. Mitigation options have been assessed to make the road trafficable and to lower the risk at these locations. Once the proposed mitigation works are carried out, the risk at the two (2) locations on Pialba Burrm Heads Road will be classified as low risk.

Existing water surface levels and water surface levels for the model including all proposed mitigation works are presented at the reporting locations in Appendix 4. Refer Figure 6.4 for the location of these reporting points. Figures 8.2 to 8.5 show the water depth for the model including all proposed the mitigation works in the 10, 20, 50 and 100 year ARI event.



N
W E
S

LEGEND

Q100 Flood Extent
Mitigated Condition

Road Upgrade

1 0 1 2 3

Kilometres

Scale: 1:100,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

Figure 8.1

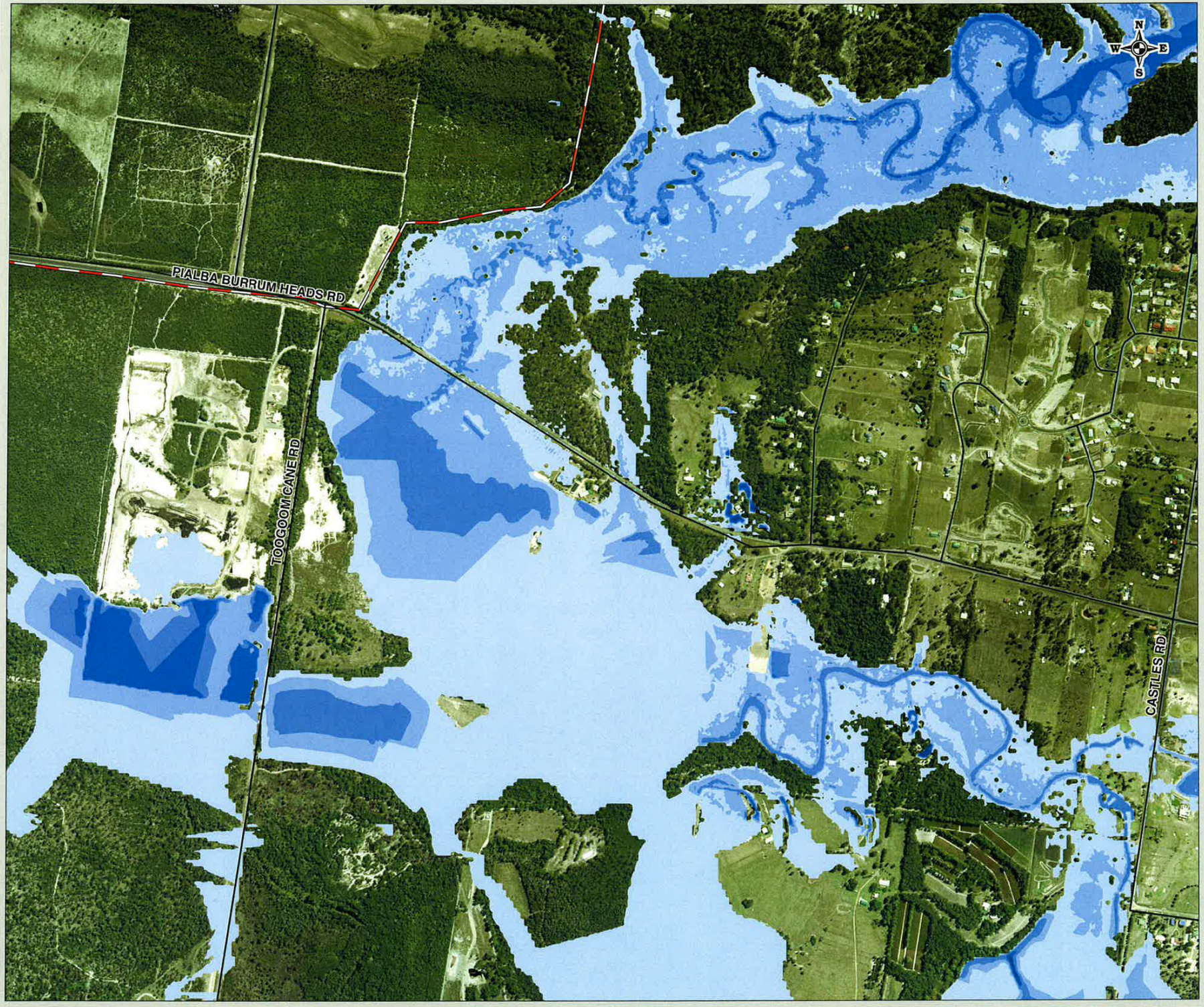
Mitigation Works

HERVEY BAY CITY COUNCIL

WorleyParsons
resources & energy

OneWay

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HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Depth (m)

- 0.1 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0

100 0 100 200 300

Metres

Scale: 1:10,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 8.2

MITIGATED CASE 10 YEAR ARI FLOOD DEPTH

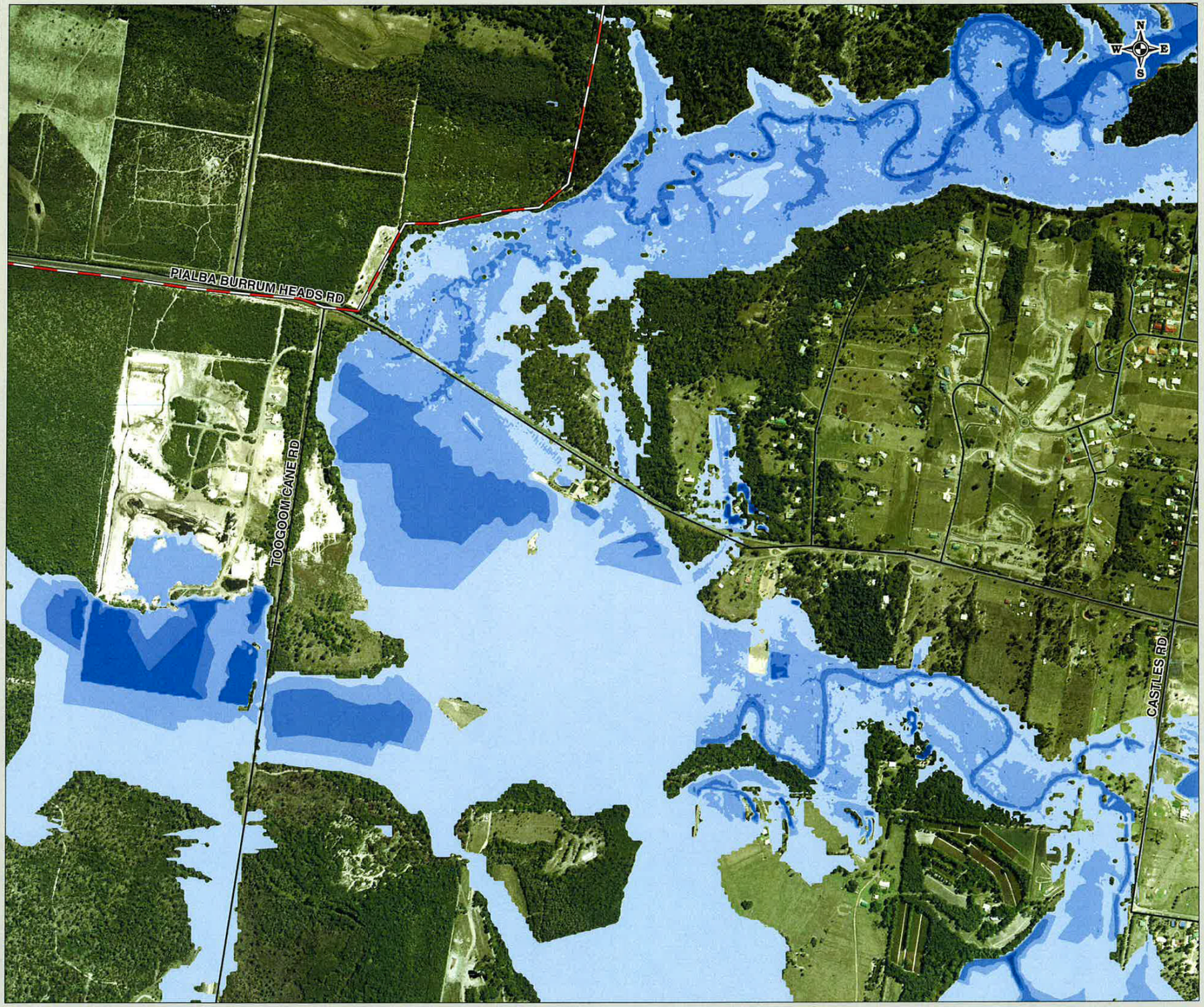
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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Depth (m)

- 0.1 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0

100 0 100 200 300

Metres

Scale: 1:10,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 8.3

MITIGATED CASE 20 YEAR ARI FLOOD DEPTH

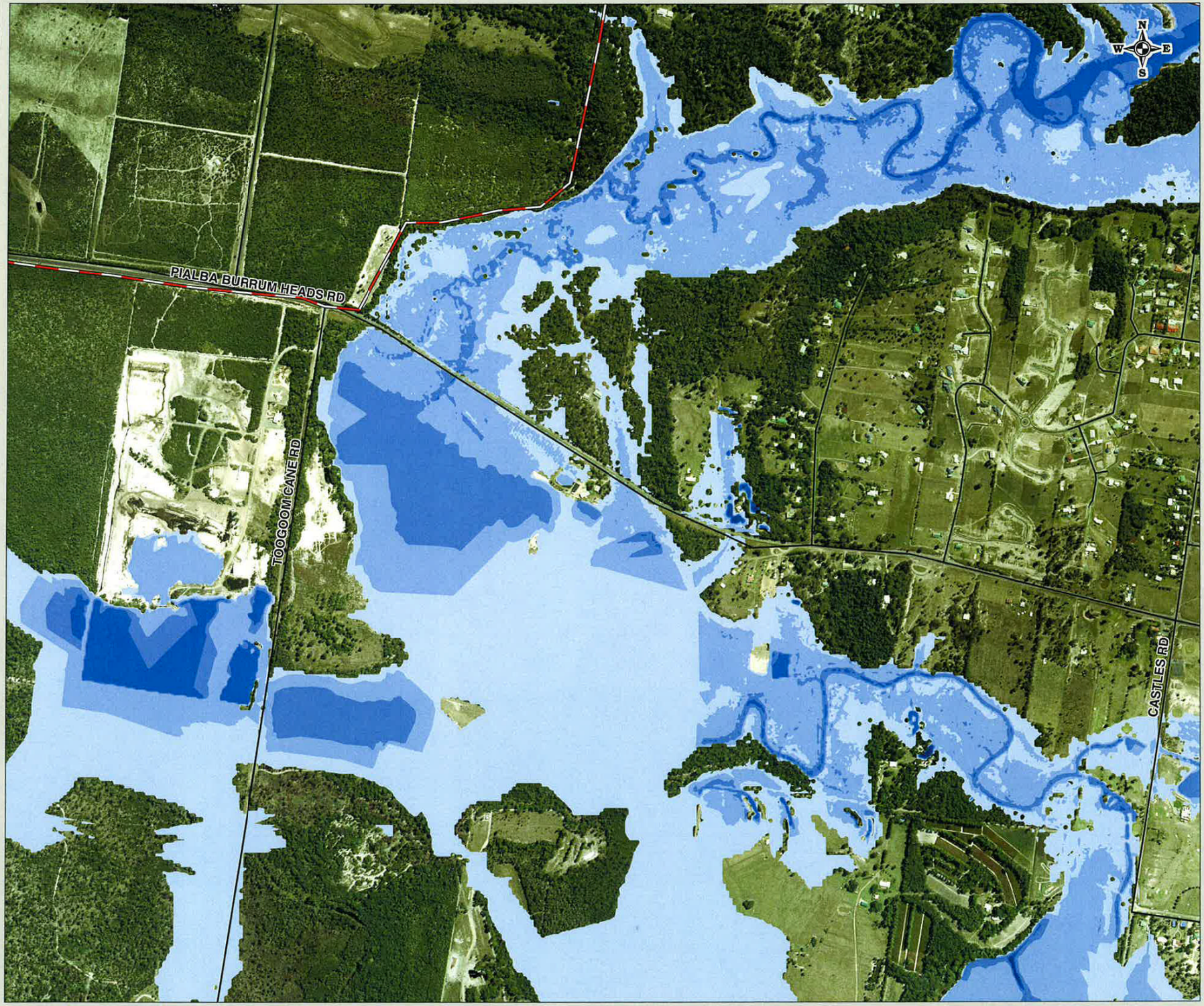
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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Depth (m)

- 0.1 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0

100 0 100 200 300

Metres

Scale: 1:10,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 8.4

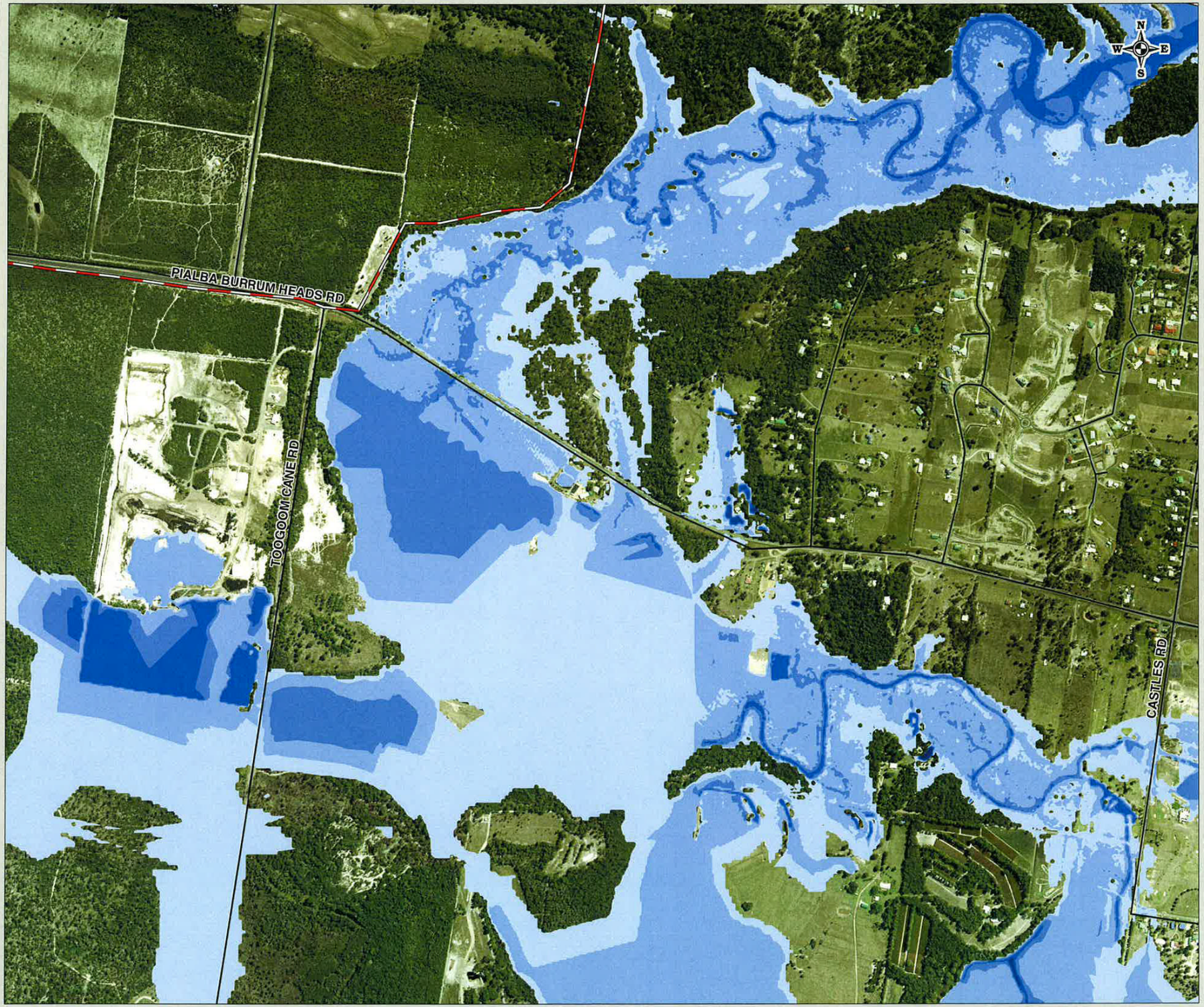
MITIGATED CASE 50 YEAR ARI FLOOD DEPTH

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Projection Trans. Merc. MGA56(GDA 94)



HERVEY BAY CITY COUNCIL

LEGEND

Study Boundary

Depth (m)

- 0.1 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0

100 0 100 200 300

Metres

Scale: 1:10,000

O'REGANS CREEK FLOOD RISK REDUCTION STUDY

FIGURE 8.5

MITIGATED CASE 100 YEAR ARI FLOOD DEPTH

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File Path : Y:\42\nbs_GIS\070048_001 HBCC - ORegans Flood Risk Reduction Study\Figures\Figure Figure 8.5_Q100_Mit_Depth.WOR

Projection Trans. Merc. MGA56(GDA 94)

9. COSTING ESTIMATION

A cost estimate was undertaken for the proposed mitigation works. This cost estimate is preliminary only as neither conceptual nor detailed design has been undertaken. The cost for location 1 and location 2 at Pialba Burrum Head Road is estimated to be $ 330,000 and $ 300,000, respectively. A detailed breakdown of the costs at each location is presented in Appendix 5.

10. CONCLUSIONS

This study has assessed the existing flood behaviour and classified associated risks within the O'Regans Creek catchment. Specifically, the works completed have included:

- The assessment and identification of existing drainage capacities, flow paths and flood information for the 10, 20, 50 and 100 year ARI design flood events
- Preparation of detailed flood data outputs to fully document the outcomes from the analysis works including flood summary data and flood extent plans;
- A sensitivity analysis on the tail water level from the catchment including the analysis of a HAT ± 0.3m;
- Assessment of flood risk and the preparation of flood risk summaries;
- Identification of flood mitigation options for the catchment;
- Hydraulic assessment of the agreed drainage augmentation options for the catchment including the preparation of detailed outputs to fully document the outcomes from the mitigation works;
- Identification of a preferred flood mitigation option for the catchment which has be shown to provide a beneficial outcome for the study in terms of reducing flood inundation of roads and consequently flood risk;
- Preparation of preliminary cost estimates for the preferred mitigation works;
- Preparation of summary tables, models, flood extents, and GIS mapping to formally document the outcomes of the study.

It should be noted that the hydrological and hydraulic assessment is based on ground level data with varying accuracy. For the lower part of the catchment ALS data was available. For the majority of the catchment (the upper section) 5m contour data was the only available information. Based on this data, the model is suitable for the purpose of this study to assess broad scale regional flooding and flood risk at Pialba Burrum Heads Road. However, more detailed survey should be used for modelling of impacts of localised developments.

11. RECOMMENDATIONS

WORLEYPARSONS recommends that Council utilises the outcomes from this Flood Risk Reduction Study for the O'Regans Creek catchment in the management of existing and future development within the catchment in terms of reducing flood risk to an acceptable and manageable standard.

It is also recommended that further works be investigated to proceed with the detailed design of the preferred mitigation works. These mitigation works will reduce high flood risks throughout the catchment significantly. This would also include programming these works and securing future allocations under Council's Capital Works Program or alternatively through other funding arrangements.

Three locations have been identified as high risk areas. For two of these locations, both on Pialba Burrum Heads Road, flood mitigation works have been assessed and are predicted to reduce the risk. The third location on Castle Road (Figure 7.1, location 4) was also identified with high risk. However, in consultation with Council no mitigation options were assessed as this location can be avoided by the public by using alternative routes in an emergency situation. Therefore, it is recommended to put flood warning procedures in place during major storm events. The flood warning should inform the public about the high risk at this location during major storm events. This information could be displayed using flood signs.

In addition, it is recommended to update and redefine the hydraulic model with more detailed ground level information, when this data becomes available. This can be done with Airborne Laser Scan (ALS) data for the entire catchment. This current study utilised ALS data in the lower part of the catchment and ground level data derived from 5m contour lines in the upper part of the catchment.

12. REFERENCES

1. Strategic Planning report for the O'Regans Creek Catchment (Connell Wagner, 1996)
2. The Queensland Urban Drainage Manual (QUDM)
3. Australian Rainfall and Runoff (AR&R - 2001 edition)
4. Pulgul Creek Catchment Flood Risk Reduction Study (JWP, 2006)
5. Semidiurnal Tidal Planes, 2007

13. QUALIFICATION

1. In preparing the report and estimate of costs WORLEYPARSONS has exercised the degree of skill and care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering design principles.

2. WORLEYPARSONS has used all reasonable endeavours to inform itself of the parameters and requirements of the project and has taken all reasonable steps to ensure that the report and costs estimate is as accurate and comprehensive as possible given the information upon which it is based.

3. It is not intended that this report and costs estimate represent a final assessment of the feasibility of the project.

4. WORLEYPARSONS reserves the right to review and amend all calculations, cost estimates and/or opinions included or referred to in the report if:

   (a) Additional sources of information not presently available (for whatever reason) are provided or become known to WORLEYPARSONS; or

   (b) WORLEYPARSONS considers it prudent to revise the estimate in light of any information which becomes known to it after the date of submission.

5. WORLEYPARSONS does not give any warranty nor accept any liability in relation to the completeness or accuracy of the report and cost estimate.

6. If any warranty would be implied whether by law, custom or otherwise, that warranty is to the full extent permitted by law excluded.

7. All limitations of liability shall apply for the benefit of the employees, agents and representatives of WORLEYPARSONS to the same extent that they apply for the benefit of WORLEYPARSONS.

8. This report and cost estimate is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report and cost estimate.

9. If any claim or demand is made by any person against WORLEYPARSONS on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report and cost estimate or information therein, WORLEYPARSONS will rely upon this provision as a defence to any such claim or demand.

Appendix 1– Intensity-Frenquency-Duration table for O'Regans Creek Catchment

Rainfall Intensity Frequency Duration data for; Hervay Bay Qld

Geographic Location: 22 Deg. South 153 Deg. East

AUSIFD Version 2.0 10-Feb 2006

Duration (mins)	1 Year ARI (mm/hour)	2 Year ARI (mm/hour)	5 Year ARI (mm/hour)	10 Year ARI (mm/hour)	20 Year ARI (mm/hour)	50 Year ARI (mm/hour)	100 Year ARI (mm/hour)
5	115	148	186	209	239	280	311
5.5	112	143	180	202	232	270	300
6	108	139	175	196	224	262	291
6.5	105	135	170	190	218	254	282
7	102	131	165	185	212	247	275
7.5	100	128	161	180	206	241	267
8	97	125	157	176	201	235	261
8.5	95	122	153	171	196	229	254
9	93	119	150	168	192	224	248
9.5	91	116	146	164	188	219	243
10	89	114	143	160	184	214	238
11	85	109	138	154	176	206	228
12	82	105	132	148	170	198	220
13	80	102	128	143	164	191	212
14	77	98	124	138	158	185	205
15	75	95	120	134	153	179	198
16	72	93	116	130	149	174	193
17	70	90	113	126	145	169	187
18	69	88	110	123	141	164	182
19	67	85	107	120	137	160	177
20	65	83	105	117	134	156	173
21	64	81	102	114	131	152	169
22	62	80	100	112	128	149	165
23	61	78	98	109	125	145	161
24	60	76	95	107	122	142	158
25	58	75	94	105	120	139	154
26	57	73	92	102	117	136	151
27	56	72	90	100	115	134	148
28	55	70	88	99	113	131	145
29	54	69	87	97	111	129	143
30	53	68	85	95	109	127	140
32	51	66	82	92	105	122	135
34	49.8	64	80	89	102	118	131
36	48.3	62	77	86	99	115	127
38	46.9	60	75	84	96	111	123
40	45.6	58	73	81	93	108	120
45	42.8	55	68	76	87	101	112
50	40.4	52	64	72	82	96	106
55	38.3	48.9	61	68	78	90	100
60	36.5	46.5	58	65	74	86	95
75	31.7	40.5	51	57	65	75	83
90	28.2	36	45.2	51	58	67	75
105	25.5	32.6	41	45.9	53	61	68
120	23.4	29.9	37.7	42.2	48.3	56	63
135	21.6	27.7	34.9	39.1	44.9	52	58
150	20.2	25.9	32.7	36.6	42	49	54
165	19	24.3	30.7	34.5	39.5	46.2	51

Rainfall Intensity Frequency Duration data for; Hervay Bay Qld

Geographic Location: 22 Deg. South 153 Deg. East

AUSIFD Version 2.0 10-Feb 2006

Duration (mins)	1 Year ARI (mm/hour)	2 Year ARI (mm/hour)	5 Year ARI (mm/hour)	10 Year ARI (mm/hour)	20 Year ARI (mm/hour)	50 Year ARI (mm/hour)	100 Year ARI (mm/hour)
180	17.9	23	29	32.6	37.4	43.8	48.6
195	17	21.8	27.6	31	35.6	41.6	46.3
210	16.2	20.8	26.3	29.5	33.9	39.7	44.2
225	15.5	19.9	25.2	28.3	32.5	38	42.3
240	14.8	19	24.1	27.1	31.2	36.5	40.6
270	13.7	17.6	22.4	25.2	28.9	33.9	37.8
300	12.8	16.4	20.9	23.5	27.1	31.7	35.4
360	11.4	14.6	18.6	21	24.1	28.3	31.6
420	10.3	13.2	16.8	19	21.9	25.7	28.7
480	9.4	12.1	15.5	17.4	20.1	23.7	26.4
540	8.7	11.2	14.3	16.2	18.7	22	24.5
600	8.12	10.5	13.4	15.1	17.5	20.6	23
660	7.63	9.83	12.6	14.3	16.5	19.4	21.7
720	7.21	9.29	11.9	13.5	15.6	18.4	20.5
840	6.52	8.43	10.9	12.4	14.4	17	19.1
960	5.97	7.75	10.1	11.5	13.4	15.9	17.9
1080	5.53	7.19	9.44	10.8	12.6	15	16.9
1200	5.15	6.72	8.88	10.2	11.9	14.3	16.1
1320	4.84	6.32	8.4	9.68	11.4	13.6	15.4
1440	4.57	5.98	7.98	9.22	10.8	13	14.8
1800	3.93	5.17	6.99	8.13	9.62	11.6	13.2
2160	3.46	4.57	6.25	7.32	8.7	10.6	12.1
2520	3.11	4.12	5.68	6.69	7.98	9.76	11.2
2880	2.82	3.75	5.22	6.17	7.39	9.08	10.4
3240	2.58	3.45	4.83	5.74	6.89	8.5	9.79
3600	2.39	3.19	4.5	5.37	6.47	8.01	9.24
3960	2.22	2.97	4.22	5.04	6.1	7.57	8.76
4320	2.07	2.78	3.97	4.76	5.77	7.19	8.34

Appendix 2– Summary of peak discharges and critical durations for all storm durations and all subcatchments

Summary of peak total flows for the 10, 20, 50 and 100 year ARI event at the critical strom duration

	Q10	Q20	Q50	Q100
NODE	Maximum Flow (m^3/s)	Maximum Flow (m^3/s)	Maximum Flow (m^3/s)	Maximum Flow (m^3/s)
1A	10.6	13.6	16.1	19.0
1B	8.6	11.0	13.2	15.6
2	25.4	32.6	38.5	45.5
3	9.3	11.8	14.4	16.7
4A	52.0	65.5	79.2	91.2
4B	70.3	88.5	106.7	123.2
5	12.2	15.4	18.5	22.2
6A	14.7	18.3	21.9	26.3
6B	18.5	23.0	27.2	31.4
7	14.9	18.2	20.1	23.1
8	16.8	20.6	23.0	26.6
9	17.0	20.8	22.8	26.4
10	18.2	22.3	24.7	29.1
11	18.2	21.6	23.6	27.0
12	24.7	30.5	36.8	42.2
13	28.2	35.1	42.3	48.7
14	9.0	11.4	13.7	15.8
15	22.6	28.2	34.3	39.6
16	14.1	16.9	18.4	21.3
17	15.5	18.6	20.9	24.2
18A	19.4	23.9	26.1	30.2
18B	23.7	29.9	32.9	38.3
19	34.6	41.6	47.2	53.4
20	81.2	101.6	122.6	142.2
21A	9.3	11.9	13.1	15.5
21B	85.7	106.8	127.7	148.0
21C	152.8	189.2	226.5	260.9
22	168.3	207.5	245.1	281.1
23	17.2	19.7	21.5	23.9
OUT	168.3	207.5	245.1	281.1

			Local flows for each subcatchment for the 100 year ARI event									
NODE	Maximum Flow (m^3/s)	Critical Duration	30 mins	45 mins	60 mins	90 mins	120 mins	180 mins	270 mins	360 mins	difference critical duration - 120min	difference critical duration - 180min
1A	19.0	120 mins	10.7	14.2	16.5	18.8	19.0	17.8	16.1	13.9	-2.5	-1.3
1B	15.6	120 mins	7.6	10.5	12.9	15.0	15.6	14.8	13.2	12.4	-2.7	-2.0
2	14.3	270min	9.2	7.8	9.9	9.5	11.0	13.3	14.3	14.2	-1.1	-3.4
3	16.7	180 mins	7.0	9.3	11.3	14.2	16.1	16.7	15.6	15.2	-4.8	-5.5
4A	6.9	360min	6.5	5.7	6.8	5.8	5.3	5.7	6.6	6.9	1.6	1.1
4B	5.0	60min	4.9	4.5	5.0	4.1	3.8	3.0	2.8	2.7	1.2	2.0
5	22.1	120 mins	13.8	15.1	17.5	20.9	22.1	21.2	18.8	18.2	-4.7	-3.7
6A	5.1	270 mins	1.8	2.4	2.8	3.5	4.2	4.9	5.1	4.9	-1.3	-2.1
6B	7.2	60 mins	6.8	6.0	7.2	6.2	5.7	6.1	6.5	6.2	1.5	1.0
7	23.1	60 mins	21.2	17.8	23.1	21.5	22.0	20.8	18.8	17.7	1.0	2.3
8	7.8	60 mins	7.5	6.7	7.8	6.5	6.0	5.0	5.6	5.7	1.8	2.8
9	26.4	120 mins	24.2	20.4	26.4	24.9	26.4	25.4	22.7	22.3	-0.1	1.0
10	5.2	60 mins	5.2	4.6	5.2	4.3	3.9	3.4	3.7	4.1	1.3	1.7
11	27.0	60 mins	25.4	22.3	27.0	23.5	22.3	24.7	25.8	24.8	4.7	2.2
12	19.2	270 mins	12.3	11.3	13.3	15.0	17.2	19.0	19.2	18.5	-4.0	-5.7
13	7.4	60 mins	7.1	6.3	7.4	6.1	5.6	5.5	6.4	7.0	1.7	1.9
14	15.8	180 mins	7.9	9.6	11.4	14.1	15.6	15.8	13.9	14.0	-4.2	-4.4
15	2.7	360 mins	1.4	1.2	1.5	1.4	1.6	2.0	2.5	2.7	-0.1	-0.5
16	21.3	60 mins	19.7	17.0	21.3	18.9	20.3	21.2	19.5	19.0	1.0	0.0
17	4.5	60 mins	4.0	4.0	4.5	4.1	3.8	3.4	3.4	3.6	0.7	1.0
18A	30.2	60 mins	27.6	23.1	30.2	27.3	24.2	25.1	22.0	22.2	6.0	5.1
18B	38.3	60 mins	33.4	31.0	38.3	35.7	31.2	29.3	27.2	22.2	7.1	9.0
19	5.3	60 mins	5.0	4.3	5.3	4.8	4.8	5.0	4.5	4.4	0.5	0.4
20	26.3	60 mins	26.0	23.8	26.3	21.3	19.7	15.3	14.6	15.5	6.6	11.0
21A	15.5	60 mins	13.0	13.5	15.5	14.7	13.2	12.6	11.7	9.7	2.3	2.9
21B	7.6	60 mins	7.2	6.3	7.6	6.7	6.4	7.2	7.5	7.2	1.2	0.4
21C	10.1	60 mins	9.9	9.1	10.1	8.4	7.8	6.1	6.6	6.2	2.4	4.0
22	55.3	60 mins	54.2	50.3	55.3	45.1	42.3	31.5	27.5	24.1	13.0	23.7
23	23.6	60min	22.4	20.4	23.6	20.2	18.1	16.9	14.5	14.5	5.5	6.7
									Standard Deviation		3.9	5.7

Appendix 3– Peak water levels at each reporting location for the 10, 20, 50 and 100 year ARI event and for the 100 year sensitivity analysis

Water Surface Levels at Reporting Points for the 10, 20, 50 and 100 year ARI event and for the Sensitivity Analysis, 100 year ARI event

ID	Q10 WSL Existing Case	Q20 WSL Existing Case	Q50 WSL Existing Case	Q100 WSL Existing Case	Q100 WSL Sensitivity Analysis TW=1.85	Q100 WSL Sensitivity Analysis TW=2.45
1	2.16	2.16	2.16	2.16	1.86	2.46
2	2.17	2.17	2.17	2.18	1.91	2.48
3	2.17	2.18	2.19	2.21	1.96	2.51
4	2.18	2.19	2.22	2.24	2.03	2.54
5	2.21	2.25	2.28	2.33	2.17	2.58
6	2.24	2.29	2.34	2.39	2.25	2.62
7	2.25	2.31	2.36	2.41	2.28	2.63
8	2.24	2.29	2.34	2.4	2.26	2.62
9	2.25	2.3	2.35	2.41	2.28	2.63
10	2.72	2.79	2.83	2.86	2.85	2.89
11	2.35	2.39	2.45	2.47	2.4	2.64
12	2.71	2.76	2.81	2.84	2.83	2.87
13	2.31	2.33	2.37	2.42	2.37	2.63
14	2.25	2.31	2.36	2.41	2.28	2.63
15	2.25	2.31	2.36	2.41	2.28	2.63
16	2.25	2.31	2.36	2.42	2.29	2.63
17	2.26	2.32	2.38	2.43	2.31	2.64
18	2.27	2.33	2.39	2.44	2.33	2.64
19	2.29	2.37	2.44	2.5	2.4	2.68
20	2.57	2.62	2.67	2.72	2.7	2.77
21	2.84	2.92	2.98	3.03	3.02	3.07
22	2.35	2.42	2.48	2.54	2.46	2.71
23	2.38	2.43	2.49	2.56	2.48	2.72
24	2.39	2.45	2.52	2.58	2.51	2.74
25	2.57	2.61	2.64	2.67	2.65	2.75
26	2.39	2.45	2.52	2.58	2.51	2.74
27	2.57	2.62	2.64	2.67	2.66	2.75
28	2.39	2.45	2.52	2.58	2.51	2.74
29	2.57	2.62	2.65	2.68	2.66	2.75
30	2.27	2.32	2.38	2.43	2.3	2.64
31	2.27	2.33	2.38	2.43	2.3	2.64
32	2.27	2.33	2.38	2.44	2.3	2.64
33	3.2	3.33	3.4	3.46	3.44	3.49
34	3.2	3.33	3.4	3.46	3.44	3.49
35	3.4	3.42	3.44	3.47	3.46	3.49
36	2.62	2.66	2.69	2.72	2.71	2.74
37	2.62	2.66	2.69	2.72	2.71	2.74
38	2.62	2.66	2.69	2.72	2.71	2.73
39	2.29	2.34	2.39	2.43	2.38	2.64
40	2.68	2.72	2.75	2.79	2.79	2.78
41	2.68	2.72	2.75	2.79	2.79	2.78
42	3.33	3.39	3.43	3.47	3.47	3.47
43	5.13	5.15	5.17	5.18	5.18	5.18
44	5.1	5.12	5.14	5.15	5.15	5.15
45	5.13	5.16	5.17	5.19	5.19	5.19
46	5.14	5.16	5.17	5.19	5.19	5.19
47	4.81	4.84	4.85	4.87	4.87	4.87
15A	2.25	2.31	2.36	2.41	2.28	2.63
15B	2.26	2.31	2.37	2.42	2.3	2.63
16A	2.26	2.32	2.37	2.42	2.3	2.64
21A	2.84	2.92	2.98	3.03	3.02	3.07
21B	4.26	4.28	4.29	4.3	4.3	4.3
21C	4.64	4.65	4.66	4.67	4.68	4.68
29A	2.57	2.62	2.65	2.68	2.66	2.75
31A	2.27	2.33	2.38	2.43	2.3	2.64

Refer Figure 6.4 for Reporting Point Locations

Appendix 4– Existing and mitigated peak water surface levels at each reporting location

Water Surface Levels for the Mitigated Case at Reporting Points for the 10 year, 20 year, 50 year and 100 year ARI event

ID	Q10 Existing Case	Q10 Mitigated Case	Difference (Mitigation - Existing	Q20 Existing Case	Q20 Mitigated Case	Difference (Mitigation - Existing	Q50 Existing Case	Q50 Mitigated Case	Difference (Mitigation - Existing	Q100 Existing Case	Q100 Mitigated Case	Difference (Mitigation - Existing
1	2.16	2.16	0.00	2.16	2.16	0.00	2.16	2.16	0.00	2.16	2.16	0.00
2	2.17	2.17	0.00	2.17	2.17	0.00	2.17	2.17	0.00	2.18	2.17	-0.01
3	2.17	2.17	0.00	2.18	2.18	0.00	2.19	2.18	-0.01	2.21	2.19	-0.02
4	2.18	2.18	0.00	2.19	2.18	-0.01	2.22	2.20	-0.02	2.24	2.21	-0.03
5	2.21	2.19	-0.02	2.25	2.22	-0.03	2.28	2.25	-0.03	2.33	2.28	-0.05
6	2.24	2.22	-0.02	2.29	2.26	-0.03	2.34	2.29	-0.05	2.39	2.33	-0.06
7	2.25	2.27	0.02	2.31	2.35	0.04	2.36	2.42	0.06	2.41	2.49	0.08
8	2.24	2.22	-0.02	2.29	2.26	-0.03	2.34	2.29	-0.05	2.40	2.34	-0.06
9	2.25	2.27	0.02	2.30	2.35	0.05	2.35	2.42	0.07	2.41	2.49	0.08
10	2.72	2.75	0.03	2.79	2.84	0.05	2.83	2.91	0.08	2.86	2.97	0.11
11	2.35	2.15	-0.20	2.39	2.36	-0.03	2.45	2.43	-0.02	2.47	2.49	0.02
12	2.71	2.74	0.03	2.76	2.83	0.07	2.81	2.91	0.10	2.84	2.97	0.13
13	2.31	2.31	0.00	2.33	2.36	0.03	2.37	2.43	0.06	2.42	2.49	0.07
14	2.25	2.27	0.02	2.31	2.35	0.04	2.36	2.42	0.06	2.41	2.49	0.08
15	2.25	2.27	0.02	2.31	2.35	0.04	2.36	2.42	0.06	2.41	2.49	0.08
16	2.25	2.28	0.03	2.31	2.35	0.04	2.36	2.42	0.06	2.42	2.49	0.07
17	2.26	2.28	0.02	2.32	2.36	0.04	2.38	2.43	0.05	2.43	2.50	0.07
18	2.27	2.29	0.02	2.33	2.37	0.04	2.39	2.43	0.04	2.44	2.50	0.06
19	2.29	2.31	0.02	2.37	2.39	0.02	2.44	2.46	0.02	2.50	2.53	0.03
20	2.57	2.57	0.00	2.62	2.62	0.00	2.67	2.67	0.00	2.72	2.72	0.00
21	2.84	2.84	0.00	2.92	2.92	0.00	2.98	2.98	0.00	3.03	3.03	0.00
22	2.35	2.36	0.01	2.42	2.43	0.01	2.48	2.50	0.02	2.54	2.56	0.02
23	2.38	2.38	0.00	2.43	2.44	0.01	2.49	2.51	0.02	2.56	2.57	0.01
24	2.39	2.39	0.00	2.45	2.46	0.01	2.52	2.53	0.01	2.58	2.60	0.02
25	2.57	2.57	0.00	2.61	2.61	0.00	2.64	2.64	0.00	2.67	2.67	0.00
26	2.39	2.39	0.00	2.45	2.46	0.01	2.52	2.53	0.01	2.58	2.60	0.02
27	2.57	2.57	0.00	2.62	2.62	0.00	2.64	2.65	0.01	2.67	2.68	0.01
28	2.39	2.39	0.00	2.45	2.46	0.01	2.52	2.53	0.01	2.58	2.60	0.02
29	2.57	2.57	0.00	2.62	2.62	0.00	2.65	2.65	0.00	2.68	2.68	0.00
30	2.27	2.28	0.01	2.32	2.36	0.04	2.38	2.43	0.05	2.43	2.50	0.07
31	2.27	2.28	0.01	2.33	2.36	0.03	2.38	2.43	0.05	2.43	2.50	0.07
32	2.27	2.28	0.01	2.33	2.36	0.03	2.38	2.43	0.05	2.44	2.50	0.06
33	3.20	3.20	0.00	3.33	3.33	0.00	3.40	3.40	0.00	3.46	3.45	-0.01
34	3.20	3.20	0.00	3.33	3.33	0.00	3.40	3.40	0.00	3.46	3.45	-0.01
35	3.40	3.40	0.00	3.42	3.42	0.00	3.44	3.44	0.00	3.47	3.47	0.00
36	2.62	2.62	0.00	2.66	2.66	0.00	2.69	2.69	0.00	2.72	2.72	0.00
37	2.62	2.62	0.00	2.66	2.66	0.00	2.69	2.69	0.00	2.72	2.72	0.00
38	2.62	2.62	0.00	2.66	2.66	0.00	2.69	2.69	0.00	2.72	2.72	0.00
39	2.29	2.29	0.00	2.34	2.36	0.02	2.39	2.43	0.04	2.43	2.50	0.07
40	2.68	2.68	0.00	2.72	2.72	0.00	2.75	2.75	0.00	2.79	2.79	0.00

Water Surface Levels for the Mitigated Case at Reporting Points for the 10 year, 20 year, 50 year and 100 year ARI event

ID	Q10 Existing Case	Q10 Mitigated Case	Difference (Mitigation - Existing	Q20 Existing Case	Q20 Mitigated Case	Difference (Mitigation - Existing	Q50 Existing Case	Q50 Mitigated Case	Difference (Mitigation - Existing	Q100 Existing Case	Q100 Mitigated Case	Difference (Mitigation - Existing
41	2.68	2.68	0.00	2.72	2.72	0.00	2.75	2.75	0.00	2.79	2.79	0.00
42	3.33	3.33	0.00	3.39	3.39	0.00	3.43	3.43	0.00	3.47	3.47	0.00
43	5.13	5.13	0.00	5.15	5.15	0.00	5.17	5.17	0.00	5.18	5.18	0.00
44	5.10	5.10	0.00	5.12	5.12	0.00	5.14	5.14	0.00	5.15	5.15	0.00
45	5.13	5.13	0.00	5.16	5.16	0.00	5.17	5.17	0.00	5.19	5.19	0.00
46	5.14	5.14	0.00	5.16	5.16	0.00	5.17	5.17	0.00	5.19	5.19	0.00
47	4.81	4.81	0.00	4.84	4.83	-0.01	4.85	4.85	0.00	4.87	4.87	0.00
15A	2.25	2.27	0.02	2.31	2.35	0.04	2.36	2.42	0.06	2.41	2.49	0.08
15B	2.26	2.28	0.02	2.31	2.35	0.04	2.37	2.42	0.05	2.42	2.49	0.07
16A	2.26	2.28	0.02	2.32	2.36	0.04	2.37	2.43	0.06	2.42	2.50	0.08
21A	2.84	2.84	0.00	2.92	2.92	0.00	2.98	2.98	0.00	3.03	3.03	0.00
21B	4.26	4.26	0.00	4.28	4.28	0.00	4.29	4.29	0.00	4.30	4.30	0.00
21C	4.64	4.63	-0.01	4.65	4.66	0.01	4.66	4.66	0.00	4.67	4.68	0.01
29A	2.57	2.57	0.00	2.62	2.62	0.00	2.65	2.65	0.00	2.68	2.68	0.00
31A	2.27	2.28	0.01	2.33	2.36	0.03	2.38	2.43	0.05	2.43	2.50	0.07
	Minimum Difference		-0.2	Minimum Difference		-0.03	Minimum Difference		-0.05	Minimum Difference		-0.06
	Maximum Difference		0.03	Maximum Difference		0.07	Maximum Difference		0.1	Maximum Difference		0.13

Refer Figure 6.4 for reporting locations

Appendix 5– Detailed breakdown of the costs for each mitigation work

O'Regans Flood Mitigation Study - Pialba Burrum Heads Road Location1

Preliminary Cost Estimate				
Description	Unit	Rate	Quantity	Cost
Project Establishment				**$45,000.00**
Site Establishment	Item	$15,000.00	1	$15,000.00
Provision for Traffic	Item	$20,000.00	1	$20,000.00
Soil Testing for Road Pavement Design	Item	$5,000.00	1	$5,000.00
Potholing of Existing Services	Item	$5,000.00	1	$5,000.00
Site Preparation				**$4,000.00**
Clearing & Grubbing	Item	$2,000.00	1	$2,000.00
Stockpile Topsoil on Site for Later Reinstatement	Item	$2,000.00	1	$2,000.00
Earthworks				**$42,400.00**
Excavation Through Road and Stockpile	m^3	$40.00	810	$32,400.00
Allowance for Disposal of Material Off-Site	Item	$10,000.00	1	$10,000.00
Pavements / Surfacing				**$82,350.00**
Grade, Compact and Form Road 270m x 10m x 0.5m)	m^3	$25.00	1350	$33,750.00
2 Coat bitumen surfacing (270m x 10m)	m^2	$18.00	2700	$48,600.00
Landscaping				**$19,500.00**
Seeding & Hydromulch	Item	$4,500.00	1	$4,500.00
Allowance for Re-vegetation	Item	$10,000.00	1	$10,000.00
Maintenance of Vegetation Works (during establishment period)	Item	$5,000.00	1	$5,000.00
Miscelaneous				**$29,500.00**
Provision for Sediment & Erosion Control During Construction	Item	$10,000	1	$10,000.00
Allowance for Survey Setout of Works	Item	$10,000	1	$10,000.00
Survey and As Constructed Plans	Item	$9,500	1	$9,500.00
Sub-Total				**$222,750.00**
Project Management and Design at 15%				$33,412.50
Contingencies at 30%				$66,825.00
Total for Works (Excl. GST)				**$322,987.50**
SAY				**$330,000.00**

O'Regans Flood Mitigation Study - Pialba Burrum Heads Road Location 2

Preliminary Cost Estimate				
Description	Unit	Rate	Quantity	Cost
Project Establishment				**$45,000.00**
Site Establishment	Item	$15,000.00	1	$15,000.00
Provision for Traffic	Item	$20,000.00	1	$20,000.00
Soil Testing for Road Pavement Design	Item	$5,000.00	1	$5,000.00
Potholing of Existing Services	Item	$5,000.00	1	$5,000.00
Site Preparation				**$4,000.00**
Clearing & Grubbing	Item	$2,000.00	1	$2,000.00
Stockpile Topsoil on Site for Later Reinstatement	Item	$2,000.00	1	$2,000.00
Earthworks				**$37,600.00**
Excavation Through Road and Stockpile	m^3	$40.00	690	$27,600.00
Allowance for Disposal of Material Off-Site	Item	$10,000.00	1	$10,000.00
Pavements / Surfacing				**$70,150.00**
Grade, Compact and Form Road 230m x 10m x 0.5m)	m^3	$25.00	1150	$28,750.00
2 Coat bitumen surfacing (230m x 10m)	m^2	$18.00	2300	$41,400.00
Landscaping				**$19,500.00**
Seeding & Hydromulch	Item	$4,500.00	1	$4,500.00
Allowance for Re-vegetation	Item	$10,000.00	1	$10,000.00
Maintenance of Vegetation Works (during establishment period)	Item	$5,000.00	1	$5,000.00
Miscelaneous				**$29,500.00**
Provision for Sediment & Erosion Control During Construction	Item	$10,000	1	$10,000.00
Allowance for Survey Setout of Works	Item	$10,000	1	$10,000.00
Survey and As Constructed Plans	Item	$9,500	1	$9,500.00
Sub-Total				**$205,750.00**
Project Management and Design at 15%				$30,862.50
Contingencies at 30%				$61,725.00
Total for Works (Excl. GST)				**$298,337.50**
SAY				**$300,000.00**