TOWNSVILLE CITY COUNCIL

HORSESHOE BAY FLOOD STUDY
BASE-LINE FLOODING ASSESSMENT

AUGUST 2011

Flood Report

103 WALKER STREET, TOWNSVILLE QLD 4810 • PO BOX 1268, TOWNSVILLE QLD 4817

Quality Information

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Prepared by:

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Executive Summary

The *Horseshoe Bay Flood Study – Baseline Flooding Assessment* has been undertaken as part of Townsville City Council's City Wide Flood Constraints Project. The project seeks to develop up to date flood models for the City of Townsville at scales suitable for:

- defining flood levels for most urban properties;
- identifying the flood hazard overlay for the planning scheme;
- evaluating recent and future flood mitigation projects; and
- assisting the disaster management process.

The newly developed flood modelling for Horseshoe Bay was undertaken using XP-RAFTS, a hydrologic runoff routing model, and MIKE FLOOD, a combined 1D and 2D hydraulic model. The models represent Horseshoe Bay's catchments, underground stormwater system, natural open channels, open drains, urban areas, and flood plains. The critical storm duration for the study area was determined to be either 1 or 1.5 hours for most locations.

This study identifies water levels, depths, velocities and flooding extent for storm Average Recurrence Intervals from 2 year to the Probable Maximum Flood. The flooding has been assessed on the basis of land uses as at September 2011 within the study area.

The results of the model provide a detailed understanding of problematic areas including some already known to Council. The following areas were all demonstrated to be significantly affected by flooding and are unlikely to have a low cost solution:

- The trap low point just upstream of Gifford Street at number 40;
- Apjohn Street between Horseshoe Bay Road and the Sandals Development;
- The Corica Crescent Development;
- The lagoon outlet at Horseshoe Bay Road;
- Beeran Creek East upstream of Gifford Street

Horseshoe Bay also has sediment problems at various locations about the study area which all seem to arise from Beeran Creek East upstream of Gifford Street. **Figure 1.2.2** shows the areas mentioned above along with other key locations within Horseshoe Bay.

Potential mitigation options for further investigation within the problems areas mentioned above have been given in **Section 5.8**. This report recommends that an overall solution for flood mitigation of Horseshoe Bay be investigated and that no single mitigation measure be installed without consideration for the overall plan for the study area. It is also recommended that mitigation measures do not hinder the recharge of the underground aquifer system (based on findings in the Horseshoe Bay Drainage Management Plan 2008), and should take into consideration the geomorphic processes within the catchment. Any development application needs to consider its impact on geomorphology and groundwater recharge.

The model was used to demonstrate improvements in flooding upstream of Gifford Street at number 40 due to recent mitigation works. Though flooding in the area has improved, flooding issues still exist.

Flood hazard maps have been developed to assist with floodplain planning. They show hazardous zones that develop in the 100, and 500 Year ARI storms, and in the Probable Maximum Flood. The particularly hazardous areas are (refer to **Figure 1.2.2**):

- Apjohn Street including the intersection of Apjohn Street and Horseshoe Bay Road.
- The Corica Crescent Development.
- The Sandals Development.

For emergency management considerations, the Sewage Treatment Plant on the corner of Apjohn Street and Pollard Street is immune to the Probable Maximum Flood, but inaccessible in less than 2 year ARI storm events. The recreation centre in the park on the corner of Horseshoe Bay Road and Apjohn Street is the only Major Evacuation Centre in Horseshoe Bay however it is a post-impact evacuation centre and is not proposed to be used during flood events. It is likely that only storm events greater than 500 year ARI will cause damages to the centre potentially prevent its use as a post impact evacuation centre.

A review of road closures due to flooding identified points along Apjohn Street and Horseshoe Bay Road as having an immunity equal to or less than a 2 year ARI storm. Flooding can cause evacuation problems for;

- Pacific Drive and Henry Lawson Street;
- The Sandals Development and the Corica Crescent Development; and
- Rural areas west of the Gorge Creek crossing of Apjohn Street.

An assessment of the impacts of sea-level rise due to climate change on flooding has been completed on Horseshoe Bay. The areas that exhibit flood level changes due to sea-level rise are the Lagoon, the outlet of Endeavour and Gorge Creeks, and the swale behind the primary sand dune. 2 properties on Henry Lawson Street, 11 properties on Pacific Drive, 5 properties within the Corica Crescent Development, and 11 properties with the Sandals Development are affected by increased flood levels due to sea-level rise.

Glossary

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff (1998)
AusIFD	A program to calculate average rainfall intensities and temporal patterns within Australia
DCC	Department of Climate Change and Energy Efficiency – Australian Government
DEM	Digital Elevation Model
DFE	Defined Flood Event
GSDM	General Short Duration Method – A method of calculating Probable Maximum Precipitation
GSS	Geospatial Solutions Unit
HAT	Highest Astronomical Tide - The highest level of water which can be predicted to occur under any combination of astronomical conditions.
HBDMP	Horseshoe Bay Drainage Management Plan
HBFS	Horseshoe Bay Flood Study
HEC-RAS	Steady State One Dimensional Hydraulic Model
IFD	Intensity Frequency Distribution
IPCC	International Panel on Climate Change
LiDAR	Light Detection and Ranging (Aerial Laser Survey)
MHWS	Mean High Water Springs - The average height of the high waters of spring tides
MIKE11	Fully Dynamic One Dimensional Hydraulic Model
MIKE21	Fully Dynamic Two Dimensional Hydraulic Model
MIKE FLOOD	Fully Dynamic Coupled One & Two Dimensional Hydraulic Model
MLWS	Mean Low Water Springs
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QUDM	Queensland Urban Drainage Manual
Spring Tides	The tide that rises highest and falls lowest from the mean sea level within a lunar cycle.
TFHAS	Townsville Flood Hazard Assessment Study
XP-RAFTS	An urban and rural runoff routing application

1.0 Introduction

1.1 Overview

The *Horseshoe Bay Flood Study – Baseline Flooding Assessment* has been undertaken as part of Townsville City Council's City Wide Flood Constraints Project. The project seeks to develop up to date flood models for the City of Townsville at scales suitable for:

- defining flood levels for most urban properties;
- identifying the flood hazard overlay for the planning scheme;
- evaluating recent and future flood mitigation projects; and
- assisting the disaster management process.

This study incorporates, the latest Light Detection and Ranging (LiDAR) topographic data, as well as the most recent infrastructure survey to develop up to date hydrologic and hydraulic flood models for Horseshoe Bay.

1.2 Study Area

The Horseshoe Bay study covers the creeks that discharge into Horseshoe Bay on the northern side of Magnetic Island. Horseshoe Bay is home to around 27% of the population on Magnetic Island with a population of approximately 743 as at November 2011. It is also a popular tourist destination

Horseshoe Bay contains 2 major outlets, one through Beeran Creek on the eastern side of the bay, and one through Endeavour Creek on the western side. Most of the development in Horseshoe Bay exists in the Beeran Creek catchment.

The total catchment size of the study area is 1205 Ha. The catchment of Endeavour Creek and its Gorge Creek tributary occupy most of the study area with a total size of 824 Ha.

Horseshoe Bay consists of mainly two land types. Firstly, there is the mountainous upper reaches of the catchment, the majority of which is part of the Magnetic Island National Park. Those mountainous parts that are not National Park are designated green space, and are very steep. These areas are unlikely to be built upon in the short to medium future. The other land type is in the lower reaches and contains the flood plains for the local creeks. This area is flat and contains several residential developments. Most of the land is undeveloped as at August 2011 but could become developed as the city grows. The Horseshoe Bay hydrologic and hydraulic models represent the study area with the most up to date information available.

Figure 1.2.1 and 1.2.2 show the Horseshoe Bay Study Area

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

2009 Contours

Elevation [m]

0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6.000
6.500
7.000
7.500
8.000

City of Townsville

320 160 0
Meters

SCALE: 1:10,000 @ A3

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Figure 1.2.1: Study Area

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Waterways

290 145 0

Meters

SCALE: 1:9,000 @ A3

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**Figure 1.2.2:
Study Area**

1.3 Scope of Works

In 2005, the TFHAS study was completed which covered the suburb of Horseshoe Bay. Since that time development has occurred, new modelling techniques have emerged, and there has been updated LiDAR and aerial photography. This flood model will allow better representation of the study area, and has the flexibility required to assess future mitigation options. The scope of works for this *Baseline Flooding Assessment* includes:

- review of previous engineering reports and data;
- collation of relevant data including rainfall, construction drawings, and topographic survey;
- identification of a suitable approach for hydraulic and hydrologic modelling;
- development and calibration of hydrologic and hydraulic models; and
- identification of the base-line flooding issues for Horseshoe Bay.

1.4 Study Approach

The flood model is the key tool used in completing a flood study. It is used to numerically simulate flooding to create flood maps, determine velocities, determine road closures, assess mitigation options, and classify the flood immunity of properties and structures. There is no interaction with other study areas of the City Wide Flood Constraints Project has been considered.

XP-RAFTS is the hydrologic model used to determine inflows into the hydraulic models. The hydrologic model converts rainfall to runoff.

The MIKE FLOOD hydraulic model uses input from the hydrologic model and the available data listed in **Chapter 2**. It provides results as areas of inundation, water depths, flood levels, and velocities. These results are then used to make conclusions about the base-line flooding within the study area.

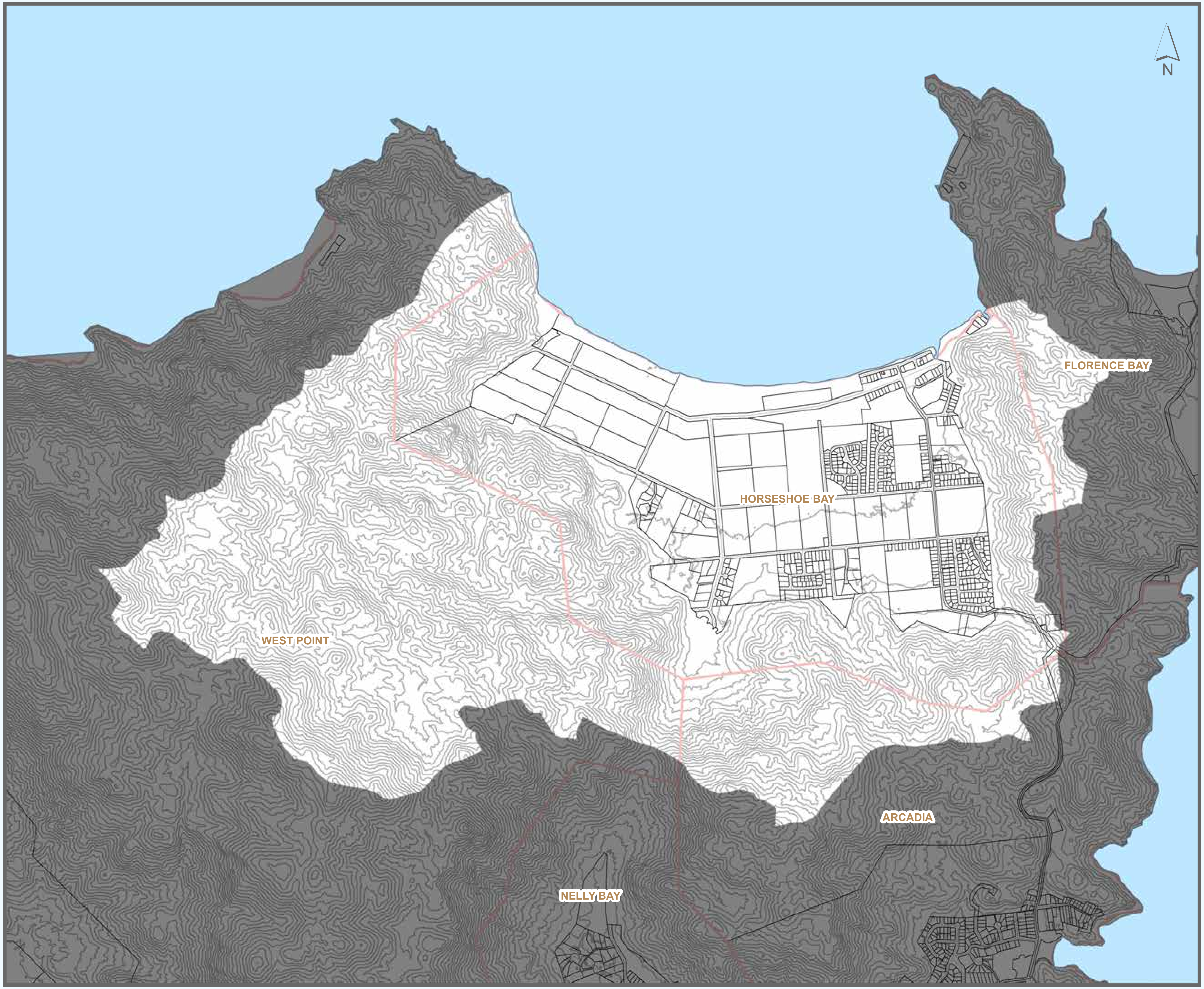
2.0 Available Data

2.1 Topographic Data

The main topographic data used in modelling Horseshoe Bay was Townsville City Council LiDAR. LiDAR (aerial survey) was used for determining catchment delineation, sub-catchment slope, sub-catchment routing, and for generating the bathymetry of the model.

A potential issue exists at the outlet of Beeran Creek as sand bank topography tends to change seasonally. It is understood the aerial survey was undertaken towards the end of the dry season. Towards the end of the dry season is when the sand bar at the mouth is most likely to be at its highest level as it would not be washed away with flood flows. To include the sand bar in the hydraulic model in this state would represent a conservative approach, as the flood flows would erode the sand bar. In the absence of any detailed records of the sand bar in flood conditions, the sand bar was included as per the topographic survey with no accounting for the erosion of the sandbar. An assessment of the sandbar erosion was beyond the scope of this study.

Figure 2.1.1 shows the LiDAR data in the form of contours over the Horseshoe Bay study area.



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

2009 Contours

0.5m intervals

700 350 0
Meters

SCALE: 1:20,000 @ A3

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Figure 2.1.1: Topographic Data

2.2 Stormwater Network

Stormwater Network Data was available on Council's GIS and Mosaic software systems for the construction of the flood model. As-Constructed plans from the plan index were used to determine details of the culverts under Apjohn Street and the drop structures in the downstream channel (plan numbers 9110/1-7, 9110/1-8, and 9110/1-9, 5022-C , 5022-C20, and 5022-C21).

Figure 2.2.1 shows the available stormwater network. **Figure 2.2.2 A and B** shows the culvert structures that were represented in the model.

2.3 Historical Flooding Information

The Horseshoe Bay study area is a stand alone catchment with 2 outlets to the bay and no stream gauges. No historical flood levels were available to use for calibration. Anecdotal accounts of some of the flow paths within Horseshoe Bay are available from council officers and from the Horseshoe Bay Drainage Improvements Report January 2011. Evidence, like sediment deposits, obtained from site inspections indicated flow paths in certain areas. This data was the only historic flood information available for the Horseshoe Bay Study Area.

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LEGEND

Pipe Diameter [mm]

1500

900

40 20 0

Meters

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Figure 2.2.1: Stormwater Network

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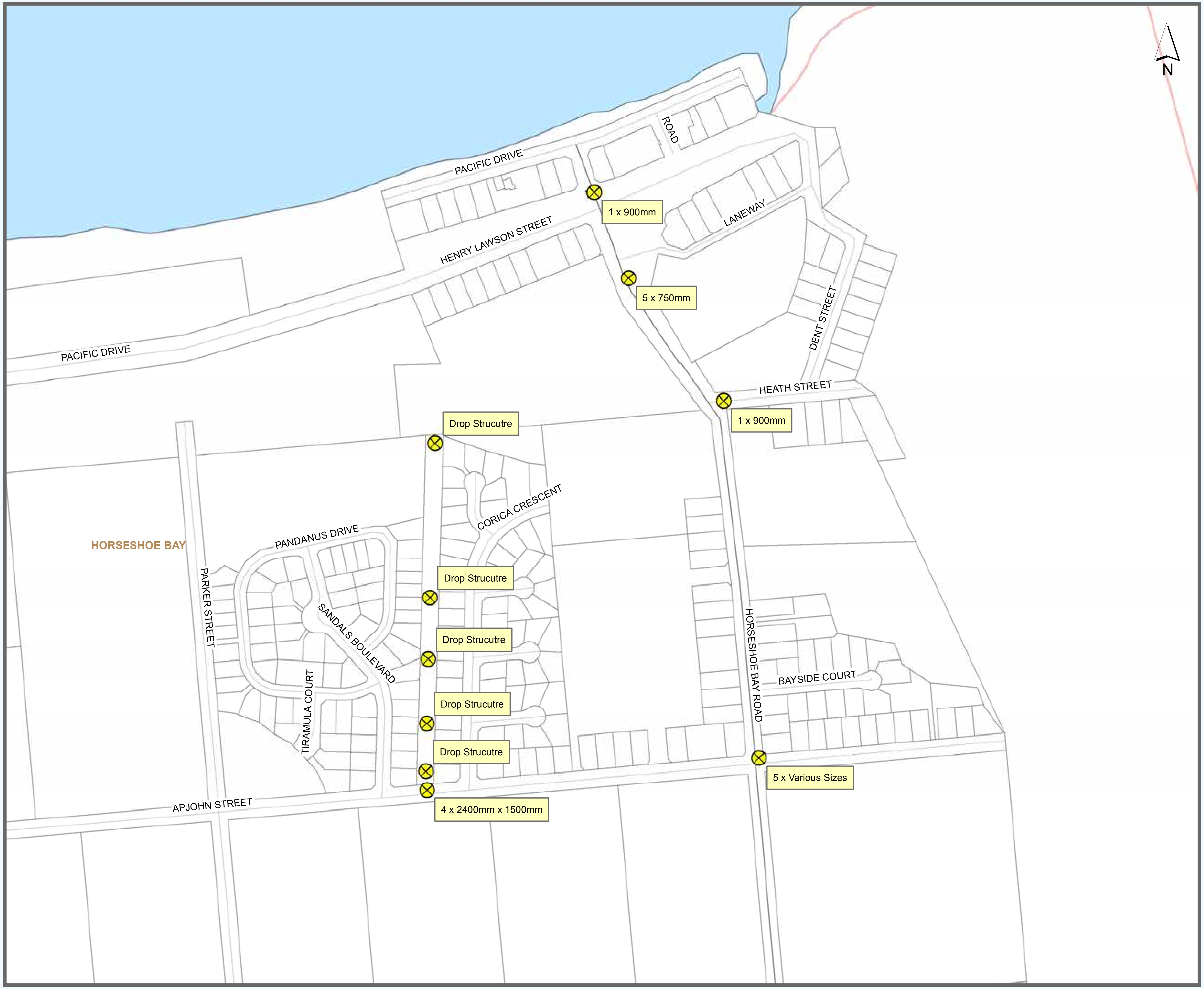
STUDY AREA



LEGEND

Structures

80 40 0
Meters

SCALE: 1:4,000 @ A3

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Figure 2.2.2 A: Stormwater Network

TOWNSVILLE CITY COUNCIL
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STUDY AREA

LEGEND

Structures

60 30 0
Meters

SCALE: 1:3,000 @ A3

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Figure 2.2.2 B: Stormwater Network

2.4 Historical Rainfall

Rainfall gauges do exist on Magnetic Island in Nelly and Picnic bays, but because there was no quantitative historic flood information, historical rainfall data was not used for calibrating the hydrological model.

2.5 Design Rainfall

Design storms are specified from IFD input data. IFD input parameters for Townsville can be found in Council's Handbook for Drainage Design. The IFD input parameters used for this study were taken from the Bureau of Meteorology website which references Australian Rainfall and Runoff, 1987, Volume 2. These values were more site specific than the values given by the Handbook for Drainage Design and differ slightly in that the Horseshoe Bay study area is subject to higher intensity rainfall for shorter, more extreme events. For more frequent and longer duration events, rainfall intensities for Horseshoe Bay are less than the generalised values given in the Handbook for Drainage Design. **Table 2.5.1** shows the IFD input data. The actual IFD data used to derive rainfall intensities for each ARI and duration is shown below in **Table 2.5.2**.

Table 2.5.1: IFD Input Data for Horseshoe Bay

Parameter	Value
Latitude [° E]	19.125
Longitude [° S]	146.85
1 hour, 2 year intensity [mm/h]	52
12 hour, 2 year intensity [mm/h]	10.8
72 hour, 2 year intensity [mm/h]	3.48
1 hour, 50 year intensity [mm/h]	112
12 hour, 50 year intensity [mm/h]	23.3
72 hour, 50 year intensity [mm/h]	9
Average Regional Skewness, G	0.06
Geographical Factor, F2	3.93
Geographical Factor, F50	17.15

Table 2.5.2: Rainfall Intensity Frequency Duration data for; Horseshoe Bay Qld							
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	111	145	193	222	261	312	352
5.5	108	141	188	216	253	303	342
6	105	137	183	210	246	295	333
6.5	102	134	178	205	240	287	324
7	100	130	174	200	234	281	317
7.5	97	127	170	195	229	274	310
8	95	125	166	191	224	268	303
8.5	93	122	162	187	220	263	297
9	91	119	159	184	215	258	291
9.5	90	117	156	180	211	253	285
10	88	115	153	177	207	248	280
11	85	111	148	171	200	240	271
12	82	107	143	165	194	232	262
13	80	104	139	160	188	225	254
14	77	101	135	155	182	219	247
15	75	98	131	151	177	213	240
16	73	96	128	147	173	207	234
17	71	93	125	144	169	202	228
18	70	91	122	140	165	197	223
19	68	89	119	137	161	193	218
20	67	87	116	134	158	189	213
21	65	85	114	131	154	185	209
22	64	83	112	129	151	181	205
23	63	82	109	126	148	178	201
24	61	80	107	124	146	175	197
25	60	79	105	122	143	172	194
26	59	77	104	120	141	169	190
27	58	76	102	118	138	166	187
28	57	75	100	116	136	163	184
29	56	74	99	114	134	160	181
30	55	73	97	112	132	158	179
32	54	70	94	109	128	153	173
34	52	68	92	106	124	149	169
36	51	67	89	103	121	145	164
38	49.5	65	87	100	118	142	160
40	48.3	63	85	98	115	138	156
45	45.6	60	80	93	109	131	148
50	43.3	57	76	88	103	124	140
55	41.3	54	73	84	99	119	134
60	39.5	52	69	80	95	114	128
75	34.5	45.2	61	70	82	99	112
90	30.8	40.3	54	63	74	88	100
105	27.9	36.6	49.1	57	67	80	91
120	25.7	33.7	45.2	52	61	74	84
135	23.8	31.2	41.9	48.5	57	69	78
150	22.3	29.2	39.2	45.4	53	64	73
165	21	27.5	36.9	42.7	50	60	68
180	19.8	26	34.9	40.4	47.5	57	65
195	18.9	24.7	33.2	38.4	45.1	54	61
210	18	23.6	31.6	36.6	43.1	52	59
225	17.2	22.6	30.3	35	41.2	49.5	56
240	16.5	21.6	29.1	33.6	39.5	47.5	54
270	15.3	20.1	26.9	31.2	36.7	44.1	49.9
300	14.3	18.8	25.2	29.2	34.3	41.2	46.6
360	12.7	16.7	22.4	26	30.5	36.7	41.5
420	11.6	15.1	20.3	23.5	27.7	33.3	37.6
480	10.6	13.9	18.7	21.6	25.4	30.6	34.6
540	9.85	12.9	17.3	20.1	23.6	28.4	32.1
600	9.21	12.1	16.2	18.8	22.1	26.5	30
660	8.67	11.4	15.3	17.7	20.8	25	28.2
720	8.21	10.8	14.4	16.7	19.7	23.6	26.7
840	7.47	9.81	13.3	15.4	18.2	21.9	24.8
960	6.89	9.07	12.3	14.3	16.9	20.5	23.3
1080	6.41	8.45	11.5	13.5	15.9	19.3	22
1200	6.01	7.93	10.9	12.7	15.1	18.3	20.9
1320	5.67	7.49	10.3	12.1	14.4	17.5	19.9
1440	5.37	7.11	9.81	11.5	13.7	16.7	19.1
1800	4.67	6.2	8.63	10.2	12.2	14.9	17.1
2160	4.15	5.53	7.76	9.19	11	13.5	15.5
2520	3.75	5.01	7.07	8.41	10.1	12.5	14.3
2880	3.43	4.59	6.52	7.77	9.37	11.6	13.4
3240	3.16	4.24	6.05	7.24	8.75	10.8	12.5
3600	2.94	3.94	5.66	6.78	8.21	10.2	11.8
3960	2.74	3.69	5.31	6.38	7.75	9.64	11.2
4320	2.57	3.46	5.01	6.03	7.33	9.15	10.6

2.6 GIS Layers

A number of standard base GIS layers were used to create this model. The Stormwater Infrastructure layers were used to create structure and pipes in the hydraulic model. Aerial survey layers were used to create bathymetry and cross sectional data, as well as helping to determine sub-catchment break-up. To see the resulting model setup from GIS layers, refer to **Section 4.3**.

2.7 Previous Reports

Horseshoe Bay Drainage Improvements Report

In January 2011, Council completed the Horseshoe Bay Drainage Improvements Report for the purpose of identifying existing stormwater issues within Horseshoe Bay, and suggesting possible mitigation options. The report was utilised in this study to verify flow paths and problematic areas that were identified through the flood model. The report also contained recommendations for flood mitigation that were reviewed

Townsville Flood Hazard Assessment Study

The Townsville Flood Hazard Assessment Study was undertaken in 2005 by Maunsell on behalf of Council. The study aimed to quantify flood inundation, determine the flood hazards and the vulnerability of community and infrastructure, and identify possible risk mitigation measures and strategies to allow proper and effective management of the identified risks. The study was used to verify quantitative results of the Horseshoe Bay Flood Model.

Horseshoe Bay Drainage Management Plan

The Horseshoe Bay Drainage Management Plan – Phase 1 and Phase 2 Reports contains important information about catchment characteristics that were taken into account when choosing loss parameter values for the Horseshoe Bay Flood Model. The report brings up flooding issues and makes recommendations that were reviewed in **Chapter 5.9** – Potential Mitigation Options.

3.0 Hydrological Assessment

3.1 Overview

Horseshoe Bay was divided up into two main catchments: the Endeavour Creek catchment on the western side and the Beeran Creek catchment on the eastern side. Each catchment was then divided up into sub-catchments based on topography to allow for appropriate representation of flows within the study area. A total of 125 sub-catchments were used for the Horseshoe Bay model. XP-RAFTS was used to create a hydrologic model of the study area which was verified to the Rational Method. The calibrated model then was used to determine flows from design storm events.

3.2 XP-RAFTS

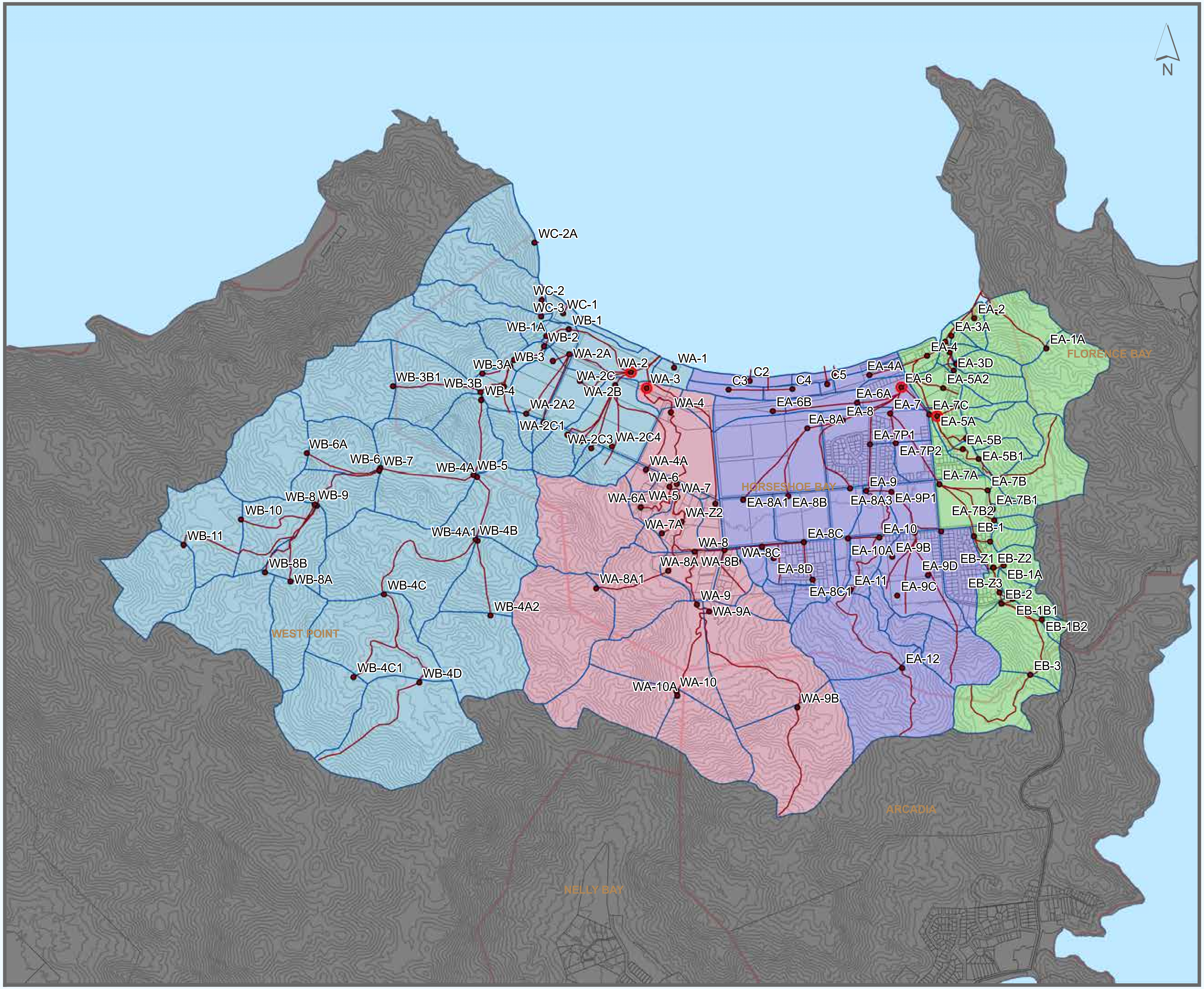
XP-RAFTS from XP Software is a runoff routing model that is used for hydrologic analysis of catchment systems. XP-RAFTS uses the Laurenson non-linear runoff routing procedure to develop stormwater runoff hydrographs. Hydrographs can be generated from either an actual event (recorded rainfall time series) or a design storm utilizing Intensity-Frequency-Duration data together with storm temporal patterns based on standard ARR 1987 data.

3.3 Catchment

The Horseshoe Bay Study Area includes a large portion of the Magnetic Island National Park. It mainly covers the suburb of Horseshoe Bay, but also includes parts of the suburbs of Florence Bay, Arcadia, and West Point on Magnetic Island and has a total area of 1205 Ha.

Horseshoe Bay is partially developed in the lower reaches on the eastern side of the suburb and generally undeveloped on the western side. The steep upper reaches of Green Space and Magnetic Island National Park are also undeveloped. The suburb of Horseshoe Bay has a significant portion of developable land in flatter areas.

Figure 3.3.1 A to D shows the subcatchment breakup, with **A** showing the overall catchment and **B, C, and D** having been enlarged to show the urbanised areas. **Table 3.3.1** shows catchment parameters. Catchment parameters were determined through analysing the available GIS layers and site inspection.



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flow Path

Subcatchments

Discharge Points

Reporting Locations

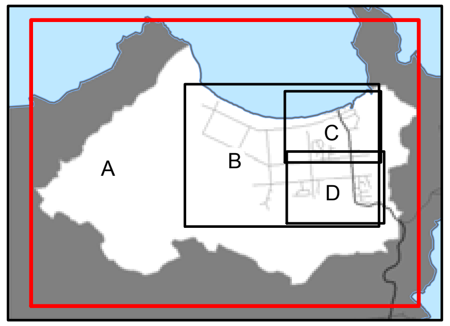
Catchments

Beeran East

Beeran West

Endeavour

Gorge



720 360 0

Meters

SCALE: 1:20,000 @ A3

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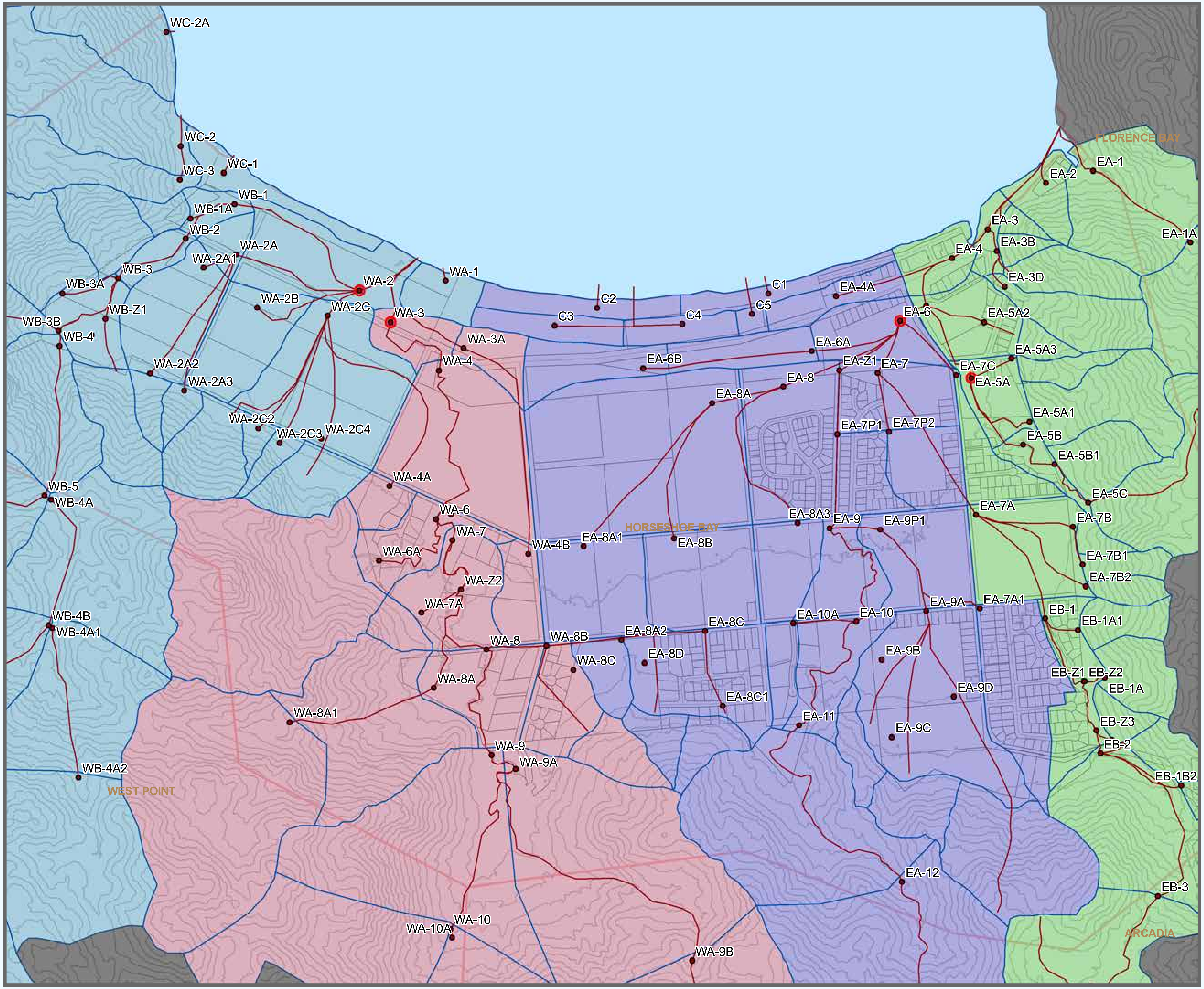
Figure 3.3.1:
Catchment



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STUDY AREA

LEGEND

Flow Path

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Beeran East

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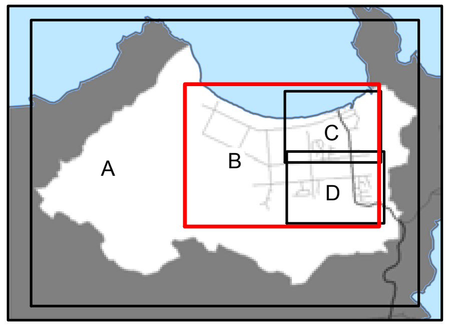

360 180 0

Meters

SCALE: 1:10,000 @ A3

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Figure 3.3.1: Catchment

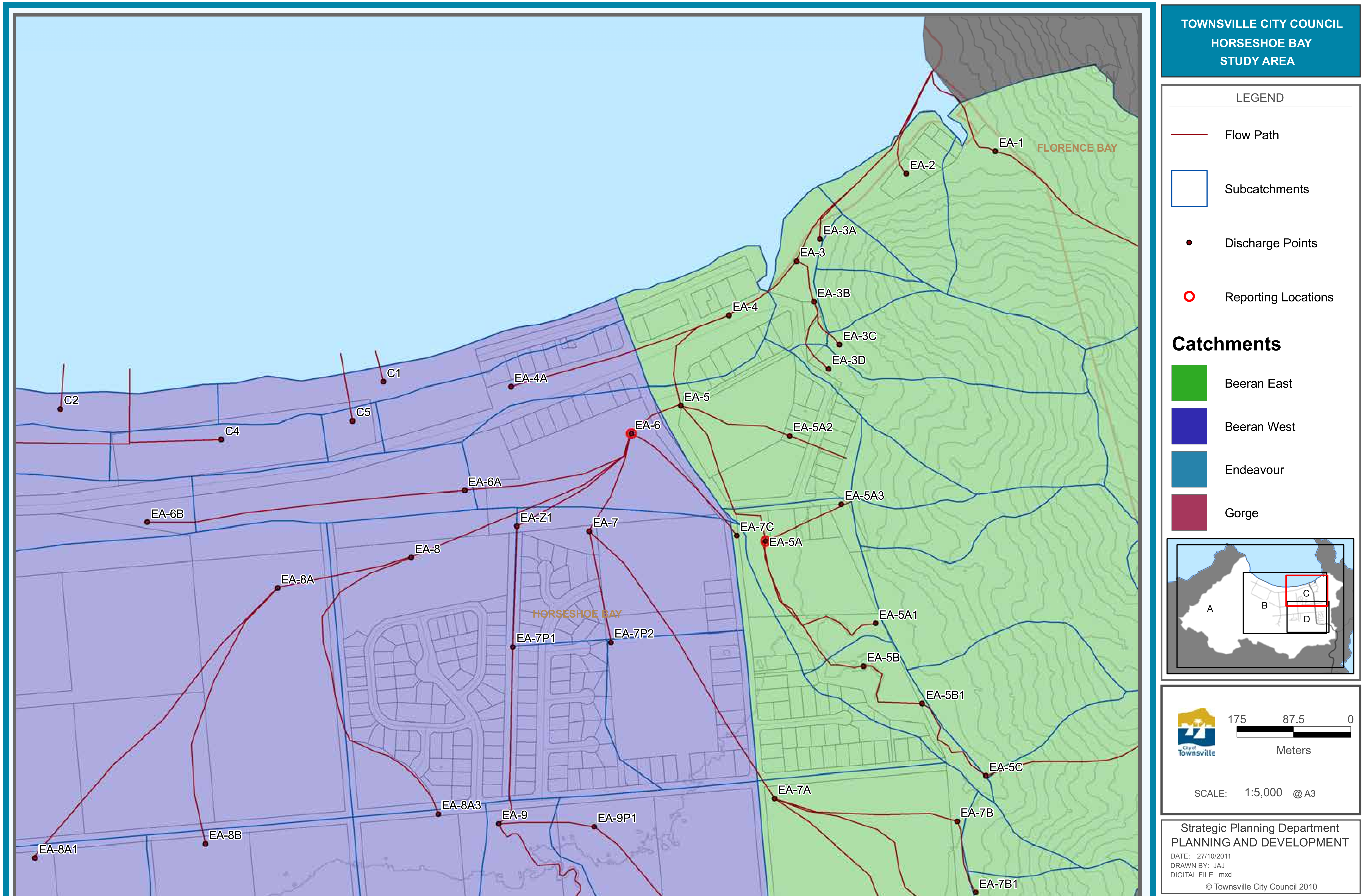
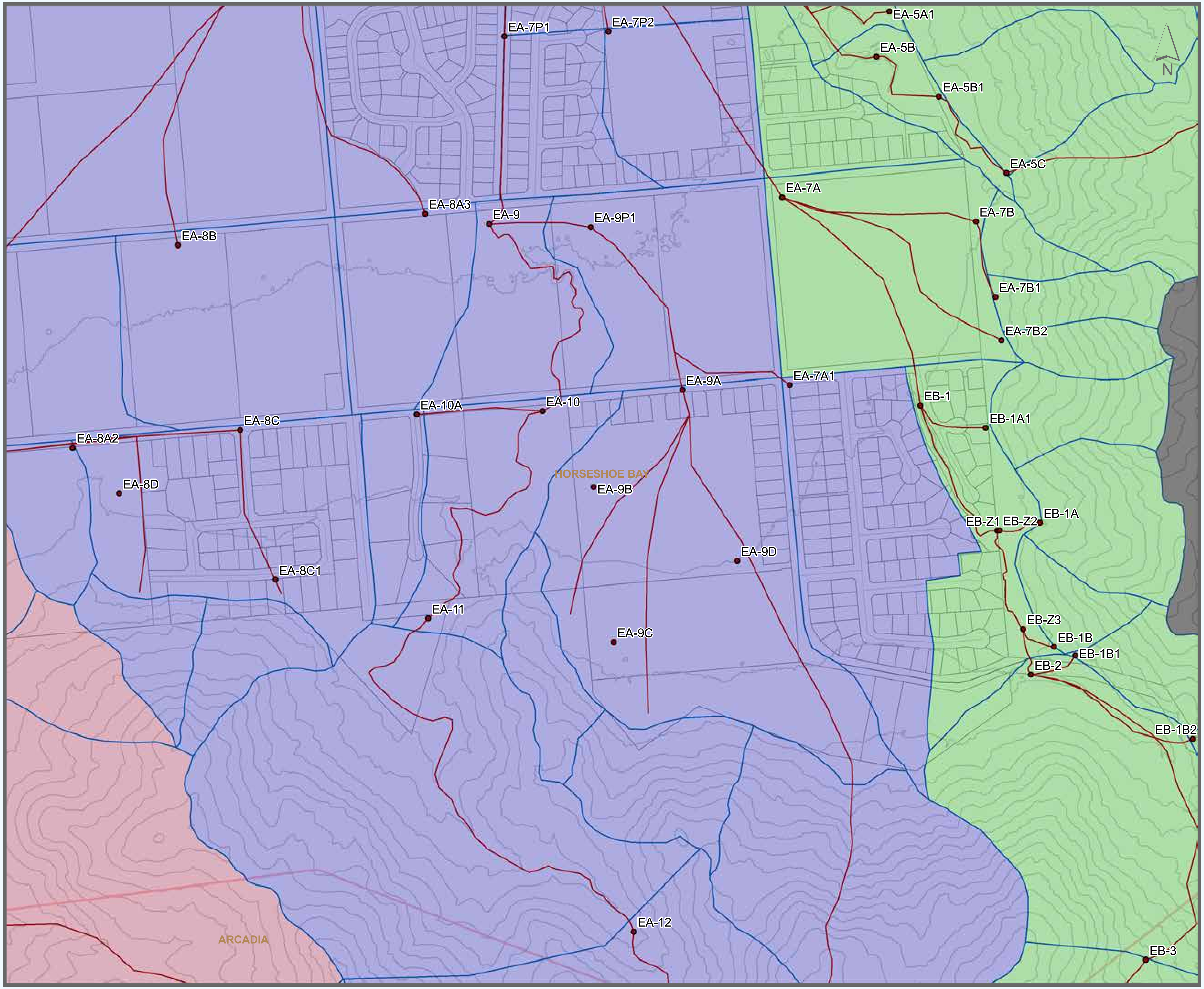


Figure 3.3.1: Catchment



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flow Path

Subcatchments

Discharge Points

Reporting Locations

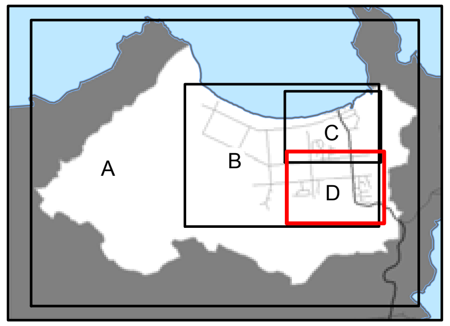
Catchments

Beeran East

Beeran West

Endeavour

Gorge



175 87.5 0

Meters

SCALE: 1:5,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 27/10/2011
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Figure 3.3.1:
Catchment

Table 3.3.1: Attributes of Horseshoe Bay

Sub-Catchment	Area [ha]	Slope	Fraction Impervious	Pervious Surface Retardance	Impervious Surface Retardance	Link Length [m]	Link Slope
C1	3.2	0.06	0.01	0.05	0.02	49.5	0.03
C2	3.6	0.08	0	0.05	0.02	68.7	0.02
C3	3.0	0.14	0	0.05	0.02	342.6	0.01
C4	2.5	0.12	0	0.05	0.02	254.7	0.01
C5	0.7	0.15	0	0.05	0.02	105.8	0.01
EA-1	13.1	0.15	0	0.08	0.02	172.0	0.01
EA-10	6.2	0.13	0.3	0.06	0.02	437.7	0.01
EA-10A	2.4	0.03	0.3	0.06	0.02	182.9	0.02
EA-11	23.3	0.15	0	0.08	0.02	467.0	0.02
EA-12	24.9	0.15	0	0.08	0.02	754.9	0.06
EA-1A	15.5	0.15	0	0.08	0.02	356.0	0.15
EA-2	3.1	0.15	0.02	0.08	0.02	172.3	0.02
EA-3	1.7	0.07	0.05	0.06	0.02	363.2	0.00
EA-3A	0.8	0.15	0	0.08	0.02	321.8	0.01
EA-3B	1.0	0.15	0	0.08	0.02	74.3	0.02
EA-3C	4.2	0.15	0	0.08	0.02	80.0	0.02
EA-3D	5.5	0.15	0	0.08	0.02	123.8	0.02
EA-4	3.5	0.05	0.4	0.06	0.02	133.8	0.00
EA-4A	3.4	0.10	0.05	0.05	0.02	353.3	0.00
EA-5	5.5	0.06	0.1	0.07	0.02	187.2	0.01
EA-5A	3.9	0.09	0.05	0.06	0.02	267.7	0.02
EA-5A1	8.1	0.15	0	0.08	0.02	278.6	0.01
EA-5A2	1.3	0.15	0	0.08	0.02	268.6	0.05
EA-5A3	1.9	0.15	0	0.08	0.02	149.8	0.07
EA-5B	2.1	0.15	0.01	0.08	0.02	270.6	0.01
EA-5B1	4.4	0.15	0	0.08	0.02	143.8	0.01
EA-5C	15.3	0.15	0	0.08	0.02	166.3	0.04
EA-6	5.6	0.04	0.03	0.07	0.02	85.7	0.01
EA-6A	3.9	0.08	0	0.07	0.02	290.8	0.00
EA-6B	4.9	0.05	0	0.07	0.02	490.7	0.00
EA-7	6.7	0.03	0.45	0.06	0.02	163.8	-0.01
EA-7A	9.2	0.04	0.02	0.06	0.02	501.6	0.02
EA-7A1	9.9	0.05	0.6	0.06	0.02	408.8	0.02
EA-7B	1.1	0.15	0	0.08	0.02	285.4	0.02
EA-7B1	1.8	0.15	0	0.08	0.02	114.2	0.04
EA-7B2	1.5	0.15	0	0.08	0.02	407.0	0.03
EA-7C	4.0	0.04	0.45	0.06	0.02	226.9	0.03
EA-7P1	3.8	0.04	0.45	0.06	0.02	185.4	0.00
EA-7P2	4.9	0.03	0.45	0.06	0.02	173.8	0.02
EA-8	12.0	0.03	0.45	0.06	0.02	398.7	0.00
EA-8A	28.2	0.02	0.03	0.06	0.02	209.9	0.00
EA-8A1	8.9	0.04	0.01	0.06	0.02	562.5	0.01
EA-8A2	2.8	0.10	0.6	0.06	0.02	145.2	0.01
EA-8A3	4.8	0.03	0.1	0.06	0.02	549.2	0.01
EA-8B	9.2	0.03	0.01	0.06	0.02	432.8	0.01
EA-8C	10.6	0.05	0.6	0.06	0.02	315.0	0.01
EA-8C1	2.5	0.15	0	0.08	0.02	248.3	0.04
EA-8D	2.2	0.15	0.1	0.08	0.02	390.8	0.04
EA-9	5.1	0.05	0.4	0.06	0.02	279.9	0.02
EA-9A	17.9	0.06	0.25	0.06	0.02	282.7	0.01
EA-9B	2.4	0.15	0	0.08	0.02	380.6	0.04
EA-9C	4.0	0.15	0	0.08	0.02	478.1	0.05
EA-9D	12.5	0.15	0	0.08	0.02	601.2	0.06
EA-9P1	8.0	0.03	0.1	0.06	0.02	147.1	0.01
EB-1	6.1	0.09	0.6	0.06	0.02	379.5	0.02

Table 3.3.1: Attributes of Horseshoe Bay							
Sub-Catchment	Area [ha]	Slope	Fraction Impervious	Pervious Surface Retardance	Impervious Surface Retardance	Link Length [m]	Link Slope
EB-1	6.1	0.09	0.6	0.06	0.02	379.5	0.02
EB-1A	4.1	0.15	0	0.08	0.02	62.5	0.12
EB-1A1	2.8	0.15	0	0.08	0.02	107.7	0.03
EB-1B	1.5	0.15	0	0.08	0.02	55.3	0.12
EB-1B1	2.6	0.15	0	0.08	0.02	73.3	0.11
EB-1B2	1.4	0.15	0	0.08	0.02	263.5	0.11
EB-2	14.9	0.15	0	0.08	0.02	232.6	0.03
EB-3	13.9	0.15	0	0.08	0.02	584.6	0.14
WA-1	2.9	0.09	0	0.05	0.02	38.7	0.01
WA-10	18.3	0.15	0	0.08	0.02	607.3	0.04
WA-10A	17.0	0.15	0	0.08	0.02	25.7	0.21
WA-2	9.9	0.06	0	0.05	0.02	193.0	0.00
WA-2A	1.8	0.03	0	0.06	0.02	383.5	0.01
WA-2A1	8.1	0.04	0.01	0.08	0.02	101.8	0.01
WA-2A2	1.6	0.15	0	0.08	0.02	424.8	0.02
WA-2A3	1.4	0.15	0	0.08	0.02	424.2	0.03
WA-2B	7.0	0.05	0.1	0.06	0.02	336.5	0.00
WA-2C	14.8	0.03	0.01	0.07	0.02	122.7	0.02
WA-2C1	5.5	0.15	0	0.08	0.02	453.2	0.02
WA-2C2	1.0	0.15	0	0.08	0.02	386.0	0.02
WA-2C3	1.3	0.15	0	0.08	0.02	393.5	0.02
WA-2C4	4.6	0.15	0	0.08	0.02	479.6	0.02
WA-3	3.2	0.08	0	0.07	0.02	224.0	0.00
WA-3A	2.8	0.04	0	0.07	0.02	411.9	0.01
WA-4	15.8	0.03	0.01	0.06	0.02	299.1	0.01
WA-4A	2.3	0.04	0.01	0.06	0.02	707.1	0.01
WA-4B	3.5	0.02	0.01	0.06	0.02	685.5	0.01
WA-5	0.9	0.06	0	0.06	0.02	555.3	0.01
WA-6	4.4	0.08	0	0.08	0.02	574.0	0.00
WA-6A	27.9	0.15	0	0.08	0.02	377.9	0.01
WA-7	7.7	0.07	0	0.08	0.02	112.6	0.00
WA-7A	1.8	0.15	0	0.08	0.02	133.2	0.04
WA-8	7.3	0.08	0.05	0.08	0.02	556.2	0.01
WA-8A	16.8	0.15	0	0.08	0.02	595.9	0.01
WA-8A1	32.4	0.15	0	0.08	0.02	438.1	0.22
WA-8B	5.2	0.05	0.6	0.06	0.02	178.2	0.00
WA-8C	3.3	0.15	0	0.08	0.02	306.4	0.04
WA-9	25.2	0.15	0	0.08	0.02	382.8	0.00
WA-9A	33.1	0.15	0	0.08	0.02	98.1	0.02
WA-9B	32.1	0.15	0	0.08	0.02	1009.8	0.10
WB-1	1.8	0.11	0.01	0.06	0.02	476.0	0.00
WB-10	19.6	0.15	0	0.08	0.02	532.7	0.16
WB-11	20.7	0.15	0	0.08	0.02	987.5	0.13
WB-1A	1.2	0.15	0	0.08	0.02	138.7	0.01
WB-2	1.8	0.09	0	0.08	0.02	191.1	0.01
WB-2A	4.8	0.15	0	0.08	0.02	200.4	0.00
WB-3	4.6	0.07	0	0.08	0.02	43.5	0.01
WB-3A	17.3	0.15	0	0.08	0.02	181.1	0.01
WB-3B	15.6	0.15	0	0.08	0.02	261.2	0.00
WB-3B1	22.0	0.15	0	0.08	0.02	518.1	0.24
WB-3C	5.2	0.15	0	0.08	0.02	156.0	0.05

Table 3.3.1: Attributes of Horseshoe Bay							
Sub-Catchment	Area [ha]	Slope	Fraction Impervious	Pervious Surface Retardance	Impervious Surface Retardance	Link Length [m]	Link Slope
WB-3C	5.2	0.15	0	0.08	0.02	156.0	0.05
WB-4	11.2	0.15	0	0.08	0.02	302.6	0.00
WB-4A	19.5	0.15	0	0.08	0.02	23.0	-0.12
WB-4A1	14.8	0.15	0	0.08	0.02	13.9	0.00
WB-4A2	23.6	0.15	0	0.08	0.02	442.9	0.24
WB-4B	37.9	0.15	0	0.08	0.02	403.1	0.03
WB-4C	27.5	0.15	0	0.08	0.02	867.0	0.16
WB-4C1	20.2	0.15	0	0.08	0.02	752.2	0.09
WB-4D	38.8	0.15	0	0.08	0.02	664.5	0.06
WB-5	26.6	0.15	0	0.08	0.02	444.2	0.19
WB-6	12.0	0.15	0	0.08	0.02	553.8	0.04
WB-6A	22.3	0.15	0	0.08	0.02	455.0	0.17
WB-7	11.6	0.15	0	0.08	0.02	13.7	0.05
WB-8	9.7	0.15	0	0.08	0.02	483.5	0.15
WB-8A	13.9	0.15	0	0.08	0.02	497.9	0.14
WB-8B	22.1	0.15	0	0.08	0.02	531.2	0.14
WB-9	12.2	0.15	0	0.08	0.02	16.2	0.16
WC-1	3.7	0.08	0.01	0.05	0.02	60.4	0.09
WC-2	18.2	0.15	0	0.08	0.02	89.8	0.01
WC-2A	13.4	0.15	0	0.08	0.02	23.3	0.04
WC-3	11.1	0.15	0	0.08	0.02	100.8	0.02
EA-Z1						233.2	0.00
EB-Z1						240.1	0.01
EB-Z2						3.0	0.16
EB-Z3						163.5	0.02
WA-Z2						243.5	0.01
WB-Z1						124.2	0.01

Note- Sub-Catchments EA-Z1 to WB-Z1 are dummy nodes created for modelling purposes only.

Rainfall Loss

Rainfall loss parameters in XP-RAFTS were determined while verifying the XP-RAFTS model to the Rational Method. Pervious subcatchments were all assigned relatively high losses because of the non cohesive nature of the soil. Lower areas of the catchment were assigned an Initial Loss (IL) of 20mm and a Continuing Loss (CL) of 4mm/h. Upper areas of the catchment with dense vegetation and broken rock geology were assigned and IL of 40mm and a CL of 4mm/h. These values are higher than average values for Queensland given in ARR (1998), but are within the acceptable limits.

Higher losses have been assigned to the mountainous reaches to account for the high level of fractured rock and gravel type surfaces. The Horseshoe Bay Drainage Management Plan, section 5.7 contains the following except which lead to the adopting of high loss values:

> Early hydrogeological investigations undertaken by Wyatt (1959) and Stephenson (1962) determined that while the fractures in the volcanics and granites may contain some groundwater reserves, the main supplies would occur in the coastal alluvial areas backing the bays including Horseshoe Bay.
>
> Heidecker (1979 and 1981) proposed that although the granite on the Island is not porous, it is dissected by interconnected fracture systems which collect and transmit water. He believed that a complex fracture system up Gustav Creek near 483350E 7882552N could supply up to 360000 litres/day from granitic rocks.
>
> Although not directly related to the Horseshoe Bay catchment, Heidecker's observation is important since it indicates the extent to which the fracture systems in grantic rock can act as baseload feeders to the aquifers. Analysis of recent air photographs may indicate a set of interceding fracture systems close to 4862E 78862N which may provide a baseflow to some of the stream aquifer systems at the eastern end of Horseshoe Bay.

The TFHAS (undertaken in 2005) assigned higher loss value to the sandy areas of the catchment, and a constant value for all other areas. The HBFS assigned a constant loss value for subcatchments located in the lower reaches. The Horseshoe Bay XP-RAFTS model was verified to the rational method to give confidence in the rainfall loss values chosen. Choosing lower loss value in the lower reaches is a conservative approach as it reduces the risk of underestimating flood levels.

For Impervious subcatchments, IL of 1mm and a CL of 0mm were chosen in accordance with ARR (1998).

Channel Routing

For the Horseshoe Bay model, XP-RAFTS routes flow using the Channel Routing method. The channel cross section dimensions, length, and slope are specified and XP-RAFTS calculates reach lag time and attenuation based on these parameters. The channel cross sections were modelled in XP RAFTS as one of a few standard reach types. The standard reach types were *narrow channel*, *wide channel*, *small channel*, and *plain*. Each of these routes was modelled with a typical cross section for the respective type. The link length, and slope parameters for the links downstream of each subcatchment, can be found in **Table 3.3.1**.

3.4 Verification / Calibration

Because there are no stream gauges in the Horseshoe Bay area, the XP-RAFTS model was verified to the Rational Method at several points about the Study Area. Surface Retardance and Rainfall Losses, were the main parameters altered for verification.

The Rational Method estimation of peak flows was performed according to the Queensland Urban Drainage Manual – second edition 2008. Time of Concentrations for the Rational Method were calculated using the Bransby-Williams' equation.

Table 3.4.1 shows the Rational Method results compared to the XP-RAFTS results.

Table 3.4.1: A comparison of Rational Method and XP-RAFTS

	XP-RAFTS Peak Flow Rate: 50 year ARI (m^3/s)	XP-RAFTS Peak Flow Rate: 2 year ARI (m^3/s)	Rational Method Peak Flow Rate: 50 year ARI (m^3/s)	Rational Method Peak Flow Rate: 2 year ARI (m^3/s)
WB-1	96.0	22.8	93.3	31.6
EA-6	70.4	17.4	63.1	21.2
EB-1	14.9	3.3	13.9	4.7
EA-9P1	20.0	5.7	18.8	6.3
EA-10	15.6	3.7	16.7	5.7
EA-9A	14.1	4.1	14.7	5.0
EA-5A	11.7	2.6	12.2	4.1
WA-6	70.0	16.1	59.3	20.7

Refer to **Appendix B** for the full set of Rational Method calculations.

3.5 Probable Maximum Flood and 500 year ARI events

The rainfall intensity is required as an input into XP-RAFTS to model the PMF. This was calculated according to the GSDM detailed by Bureau of Meteorology. The GSDM requires that the PMF storm is applied with rainfall intensities that vary with concentric ellipses. **Table 3.5.1** shows the rainfall intensities for the PMF as calculated according to the GSDM. The 500 year storm event also requires intensity input into XP-RAFTS, also found in **Table 3.5.1**. These values were extrapolated from IFD data. This method was verified for the 1 hour event using an interpolation between 1 in 100 AEP and the PMP according to Australian Rainfall and Runoff (1998).

Table 3.5.1: Probable Maximum Precipitation Calculations

Duration [h]	1	1.5	3	4.5
Rainfall Depth [mm]	480	588	817	977
Ellipse A intensity [mm/hr]	463	399	282	226
Ellipse A initial mean rainfall depth [mm]	493	636	901	1082
Ellipse B intensity [mm/hr]	426	361	251	200
Ellipse B initial mean rainfall depth [mm]	462	590	825	987
Ellipse C intensity [mm/hr]	401	347	214	169
Ellipse C initial mean rainfall depth [mm]	460	588	817	977
500y [mm/hr]	165	129	83	64

3.6 Design Storm Flows

The verified XP-RAFTS model produced flows for each subcatchment that were used as sources for the Hydraulic Model. **Table 3.6.1** shows a summary of the maximum catchment flows at key locations around Horseshoe Bay. See **Figure 3.3.1 B** for reporting locations.

Table 3.6.1: Max Catchment Flow [m^3/s]

	WA-2	WA-3	EA-6	EA-5A
2y	20.8	13.8	16.5	2.0
5y	42.5	28.1	32.8	4.5
10y	56.0	39.4	42.5	6.3
20y	77.6	56.2	55.2	8.9
50y	107	74.6	70.3	11.7
100y	131	92.3	86.7	14.5
500y	193	138	130	21.7
PMF	635	407	373	54.3

4.0 Hydraulic Assessment

4.1 Overview

The Horseshoe Bay Study Area was modelled using the hydraulic modelling software, MIKE FLOOD. The majority of the topography was represented using MIKE 21, but stormwater, narrow open channels, steeper open channels, and structures were modelled in MIKE 11. Inflow hydrographs applied at source points and boundaries came from the XP-RAFTS hydrologic model.

As there was no historical flood level data available, the model was unable to be calibrated, however the flows were verified with results from the TFHAS, HEC-RAS models, and hand calculations where applicable. A sensitivity analysis was also undertaken on roughness value within the hydraulic model. For comparison with previous flood models, see **Section 5.2**.

4.2 MIKE FLOOD

MIKE FLOOD is a hydraulic modelling software package that dynamically links DHI's 1D (MIKE 11 and MIKE URBAN) and 2D (MIKE 21) models. It allows the user to simultaneously run models with different areas being represented by the most appropriate model. MIKE FLOOD links models by transferring water levels and flows at specified points known as couples. Each model type can be directly coupled to the other.

MIKE 11

MIKE 11 is a software package used for the simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies.

It is a dynamic, one-dimensional modelling tool used for the detailed design, management and operation of both simple and complex river and channel systems.

MIKE 21

MIKE 21 is a software package containing a comprehensive modelling system for 2D free-surface flows. MIKE 21 is applicable to the simulation of hydraulic and related phenomena in lakes, estuaries, bays, coastal areas and seas where stratification can be neglected.

MIKE URBAN

MIKE URBAN is a GIS-based urban modeling system for water distribution systems, wastewater collection systems, and stormwater.

4.3 Model Setup

The geometry of the Horseshoe Bay model was set up such that the pipe network was represented by MIKE URBAN, the steep channels and the narrow channels were represented by MIKE 11, and the flatter flood plain areas were represented by MIKE 21. All three models were run together through MIKE FLOOD, to represent the hydraulics of the whole study area. **Figure 4.3.1** shows the model set-up for Horseshoe Bay.

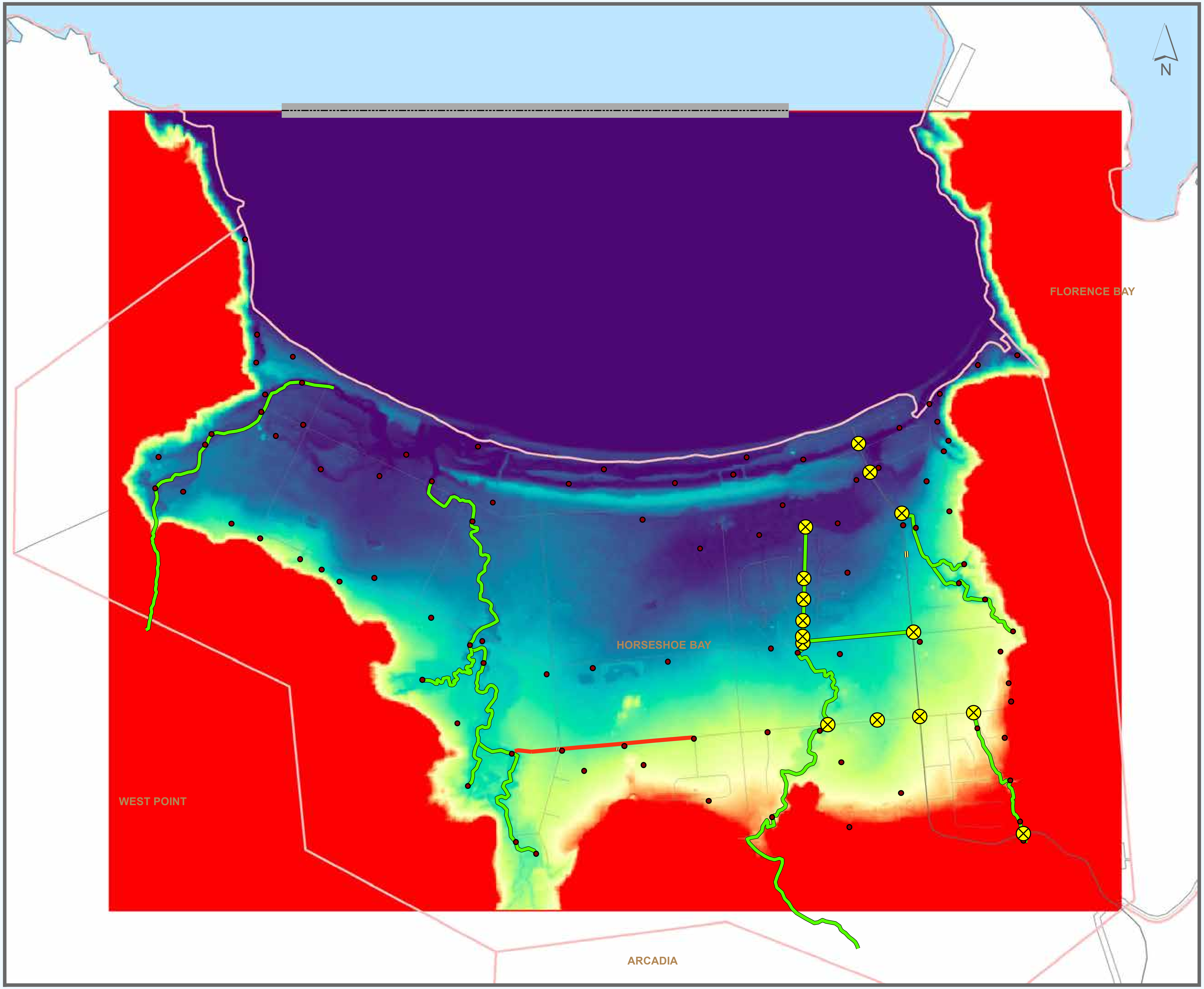


Figure 4.3.1: Model Setup

MIKE 11

MIKE 11 was setup to represent channels. The flow paths and centrelines of the channels were determined from contour data and site inspection. Cross sections were extracted from LiDAR data at regular intervals, and at hydraulic controls. Couples between MIKE 11 and MIKE 21 were setup to represent structure inlets and outlets, and flow between channels and the flood plain. All culvert structures, regardless of size, were represented in MIKE 11 to incorporate key hydraulic controls.

Refer to **Figure 2.2.2** for culvert locations.

MIKE 21

MIKE 21 was setup to represent flood plain areas. Most data in the model is entered via a grid format. The topographic data was built from LiDAR data from 2009. Initial conditions were set to a constant sea level of 1.17m AHD for Horseshoe Bay based on MHWS. Roughness was determined by aerial photography, and site inspection. **Table 4.3.1** and **Figure 4.3.2** show the various Roughness values used in the model. A sensitivity analysis was undertaken on these roughness values. See **Section 4.5** for details.

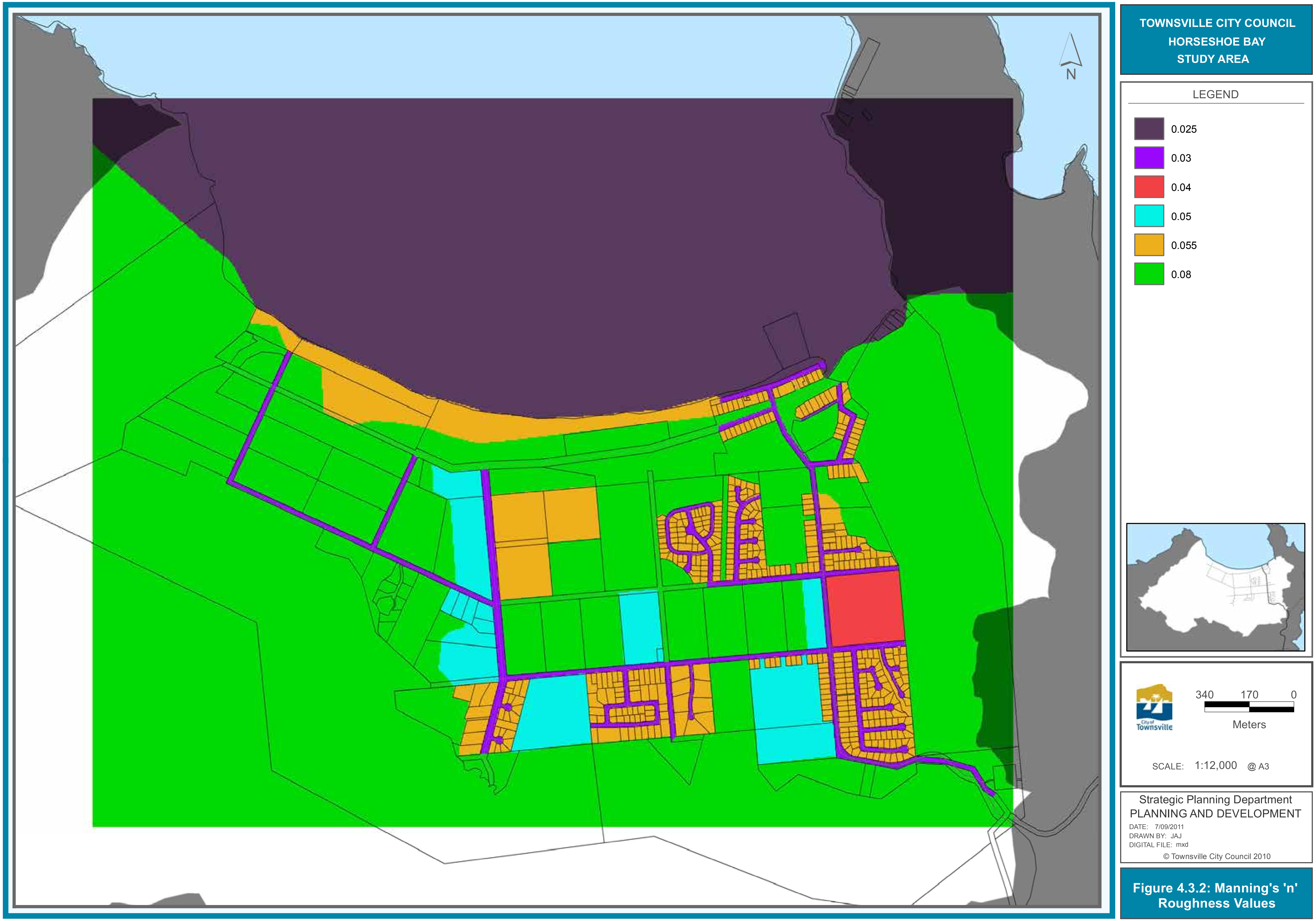
Table 4.3.1: Hydraulic model roughness values

Land Use	Roughness Value (Manning's 'n')
Road	0.03
Residential (Low)	0.05
Residential (Medium)	0.055
Bush / Residential (High)	0.08
Open grassland	0.04
Ocean	0.025

MIKE URBAN

MIKE URBAN was setup to represent the underground pipe network of Horseshoe Bay. Pipe dimensions and invert levels were obtained from TCC geospatial data. No headwall inlets to underground pipe networks exist within Horseshoe bay and couples between MIKE 21 and MIKE URBAN were setup to represent inlets pits only. The couple between MIKE 11 and MIKE URBAN was setup to represent the downstream outlet for transferring underground flow to channel flow.

Only pipes of diameter 900mm or greater were modelled in MIKE URBAN. It was identified that underground stormwater network pipes less than 900mm in diameter generally have an insignificant effect on flood levels based on a slope equal to or flatter than 0.5%.



**TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA**

Strategic Planning Department
PLANNING AND DEVELOPMENT
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Figure 4.3.2: Manning's 'n' Roughness Values

4.4 Structure Verification

To verify the accuracy of various structures modelled in MIKE FLOOD, the hydraulics of these structures were verified using HEC-RAS. A HEC-RAS model was created for each structure, and the corresponding upstream and downstream channels. Maximum flows from the 50 year, 1 hour event were applied to the model and results were compared to MIKE FLOOD results. **Table 4.4.1** contains the results of each HEC-RAS verification. A description of each structure is available below.

Horseshoe Bay Road at Henry Lawson Street
A 900mm diameter culvert provides a flow path under Horseshoe Bay Road just south of Henry Lawson Street.

Horseshoe Bay Road at the Lagoon
Five 750mm diameter culverts provide a flow path under Horseshoe Bay Road at the outlet of the lagoon.

40 Gifford St
A 450mm diameter culverts provides a flow path under Gifford Street at number 40.

52 Gifford St
Three 1050mm diameter culverts provide a flow path under Gifford Street at number 52.

Table 4.4.1: HEC-RAS verification

Culvert	Time of peak	Flow m^3/s	MIKE level [m AHD]		HEC-RAS level [m AHD]	
			Upstream	Downstream	Upstream	Downstream
Henry Lawson	3:41:00	0.6	2.7	2.6	2.7	2.6
Lagoon	4:35:00	5.0	2.9	2.6	2.9	2.6
52 Gifford St	1:00:00	25.0	14.8	13.4	14.8	13.4
40 Gifford St	0:40:00	13.2	14.0	13.0	14.1	13.0

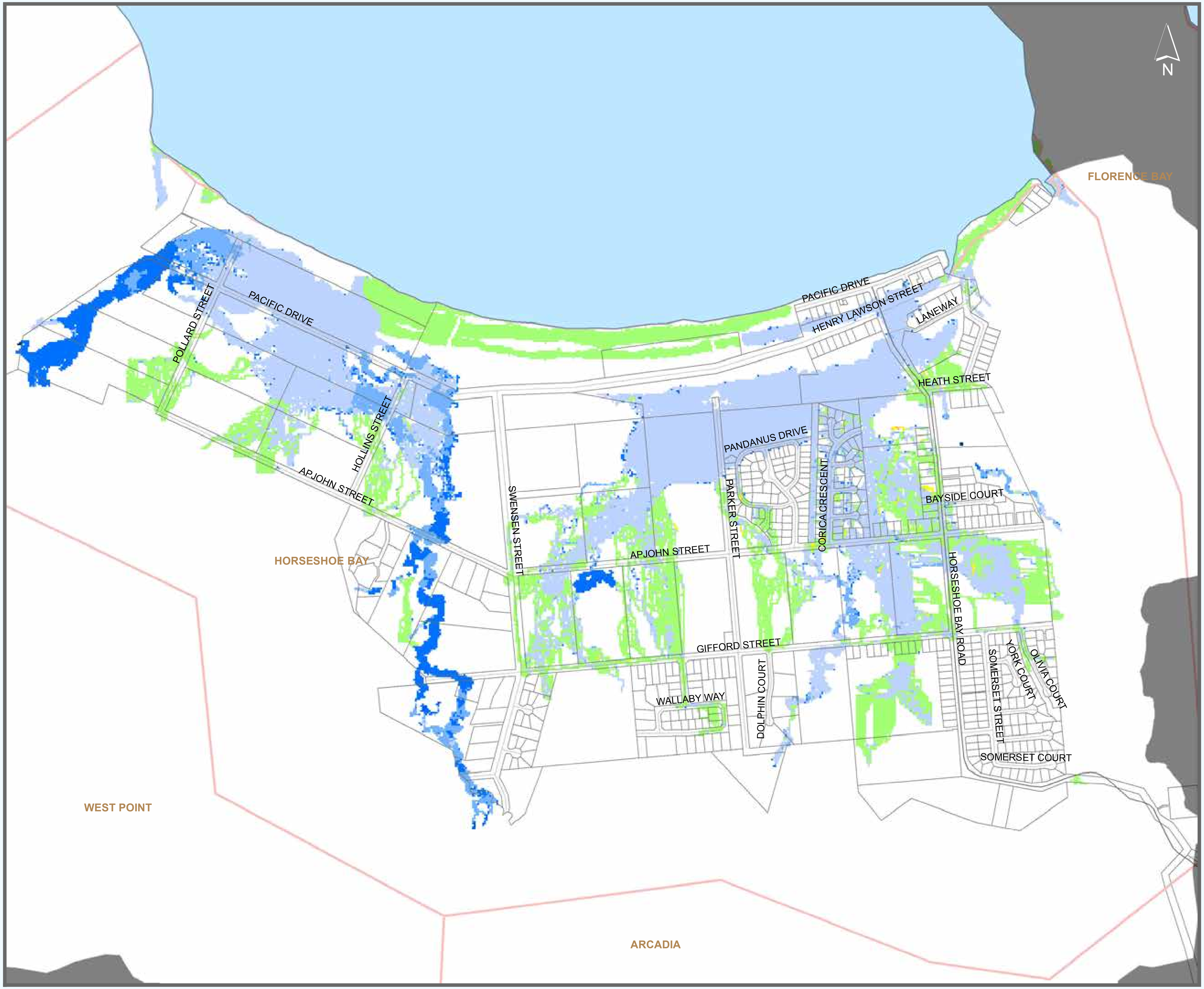
The culvert at the intersection of Horseshoe Bay Road and Apjohn Street was verified using a maximum capacity hand calculations. **Table 4.4.2** shows the results.

Table 4.4.2 - Capacity verification of culvert at intersection of Horseshoe Bay Rd and Apjohn St

	Flow [m^3/s]	Upstream Water Level [m]	Downstream Water Level [m]
Hand Calculation	1.72	11.67	10.96
Model Results	1.73	11.7	11.22

4.5 Sensitivity Analysis

For the Horseshoe Bay model, the adopted roughness values are those shown in **Table 4.3.1**. To assess the sensitivity of the hydraulic model with respect to roughness, a sensitivity analysis was undertaking. This assessed the model with a 20% increase and a 20% decrease in roughness values throughout the model. For both scenarios, there were no significant changes in water levels throughout the urban areas. Along Endeavour Creek and Gorge Creek, water levels varied by over 100mm between scenarios and flooding extents of the Creeks varied slightly along the reaches. **Figure 4.5.1** and **4.5.2** show the flood level difference maps associated with the Sensitivity Analysis.



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Difference to Base Case

- < -1 m
- -1 - -0.5 m
- -0.5 - -0.3 m
- -0.3 - -0.1 m
- -0.1 - -0.05 m
- -0.05 - -0.01 m
- -0.01 - 0.01 m
- 0.01 - 0.05 m
- 0.05 - 0.1 m
- 0.1 - 0.3 m
- 0.3 - 0.5 m
- 0.5 - 1 m
- > 3 m

City of Townsville

340 170 0
Meters

SCALE: 1:10,000 @ A3

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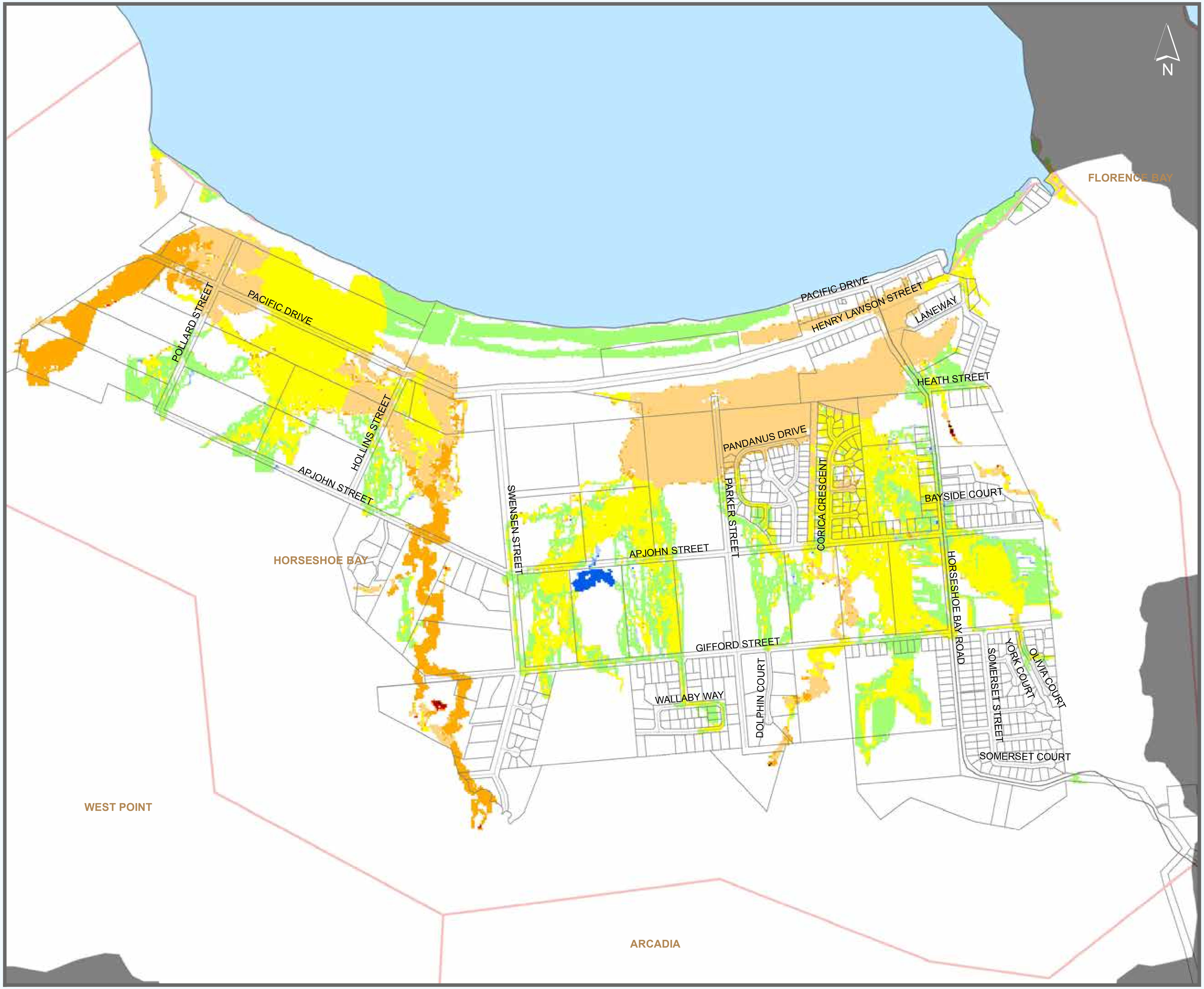
Figure 4.5.1:
-20% Roughness Difference

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA



LEGEND

Difference to Base Case

- < -1 mm
- -1 - -0.5 mm
- -0.5 - -0.3 mm
- -0.3 - -0.1 mm
- -0.1 - -0.05 mm
- -0.05 - -0.01 mm
- -0.01 - 0.01 mm
- 0.01 - 0.05 mm
- 0.05 - 0.1 mm
- 0.1 - 0.3 mm
- 0.3 - 0.5 mm
- 0.5 - 1 mm
- > 3 mm

350 175 0
Meters

SCALE: 1:10,000 @ A3

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Figure 4.5.2:
+20% Roughness Difference

4.6 Verification

Various methods of verification were used to obtain a level of confidence in the model results. The flow paths that formed in the results of the hydraulic model were verified to evidence of flow paths found at site visits. Sediment and debris deposits are examples of the kinds evidence use to verify flow paths. **Figure 4.6.0** shows the locations and the photographs of some of the evidence found at site visits.

Townsville Flood Hazard Assessment (TFHAS)
The Townsville Flood Hazard Assessment Study was undertaken in 2005 by Maunsell on behalf of Council. The study aimed to quantify flood inundation, determine the flood hazards and the vulnerability of community and infrastructure, and identify possible risk mitigation measures and strategies to allow proper and effective management of the identified risks. The main differences between the Townsville Flood Hazard Assessment model and the Horseshoe Bay Flood model are listed below.

- TFHAS was set up as a 1D model only, where the HBFS was set up as a coupled 2D/1D model using the most appropriate model type where required.
- The HBFS hydraulically modelled a range of storm durations from 30 minutes to 24 hours. The TFHAS only hydraulically modelled the 1.5 hour storm within Horseshoe Bay.
- The Horseshoe Bay Flood Model includes all stormwater infrastructure within the scope of the study up to August 2011, whereas the TFHAS has not considered infrastructure installed since 2005.
- The Horseshoe Bay Drainage Management Plan (2007) has provided information leading to more accurate rainfall loss values being adopted in the HBFS. This change has lead on to the HBFS generally having smaller flow volumes then the TFHAS. See **Section 3.3** for details on losses and **Table 4.6.2** below for details on flows.
- The HBFS XP-RAFTS model limited catchment slopes to a maximum of 15% because of potential errors. The TFHAS did not limit catchment slopes.
- Development has occurred in Horseshoe Bay in the time between the completion of the TFHAS and the commencement HBFS. These developments have had topographical changed associated with them which have been represented in the HBFS but not the TFHAS. The following areas (see **Figure 1.2.2** for reference to locations) have had topographic changes due to construction which have affected flow paths:
    - The Sandals Development
    - Properties on Gifford Street between Dolphin Court and Horseshoe Bay Road
    - Heath Street
    - The Laneway off Dent Street
    - Between Apjohn Street and Bayside Court
    - Gifford Street east of Horseshoe Bay Road
- In the THFAS, the Mike 11 branch representing the flow path between the Sandals Development and the Corica Crescent Development has been manipulated to stop water from escaping to other areas.

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY STUDY AREA

LEGEND

● Photo Locations

110 55 0

Meters

SCALE: 1:4,000 @ A3

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DIGITAL FILE: mxd

Figure 4.6.0: Site Visit Photographs

Results of the Horseshoe Bay Flood Model were compared to the Townsville Flood Hazard Assessment Model. **Table 4.6.1** shows the levels produced from each model at various points around the catchment. **Figure A0** in **Appendix A** shows the locations of the points used for comparison.

Table 4.6.1: a comparison of the HBFS to the TFHAS

Point	TFHAS 50y Water Level [m]	HBFS Model 50y Water Level [m]	Difference [m]
1	-	3.4	-
2	-	3.5	-
3	5.0	4.7	-0.3
4	3.4	3.6	0.1
5	3.5	3.8	0.3
6	4.3	3.6	-0.8
7	4.8	4.5	-0.2
8	7.1	6.9	-0.1
9	7.9	7.8	-0.1
10	8.5	8.7	0.2
11	12.2	12.1	-0.2
12	19.2	18.1	-1.0
13	13.7	14.0	0.3
14	14.6	14.5	0.0
15	7.2	7.1	-0.1
16	-	7.2	-
17	-	12.3	-
18	7.5	7.5	0.0
19	2.7	3.2	0.5
20	3.5	4.2	0.7

- implies that that the point in question was not inundated

For most of the points listed in **Table 4.6.1**, the HBFS levels are within 30mm of the TFHAS levels. Comparison points with differences greater than 30mm are explained below.

- Point 6 – A difference of 0.8m can be explained by the limitations of a 1D model representing a flood plain. Because there is no network branch in the immediate vicinity of point 6, the results must be interpolated from nearby branches, which is not always accurate.
- Point 12 – A difference of 1m can be explained by the recently installed culverts under Gifford Street and the associated topography changed and redirection of flows.
- Points 19 and 20 – Differences of 0.5m and 0.7m respectively, can be explained by a change at the outlet of Endeavour Creek since the completion of the TFHAS. Since 2005, the mouth of the river has meandered East by approximately 120m thereby increasing its length. The invert of the sand bank at the outlet has also been raised by 300-400mm.

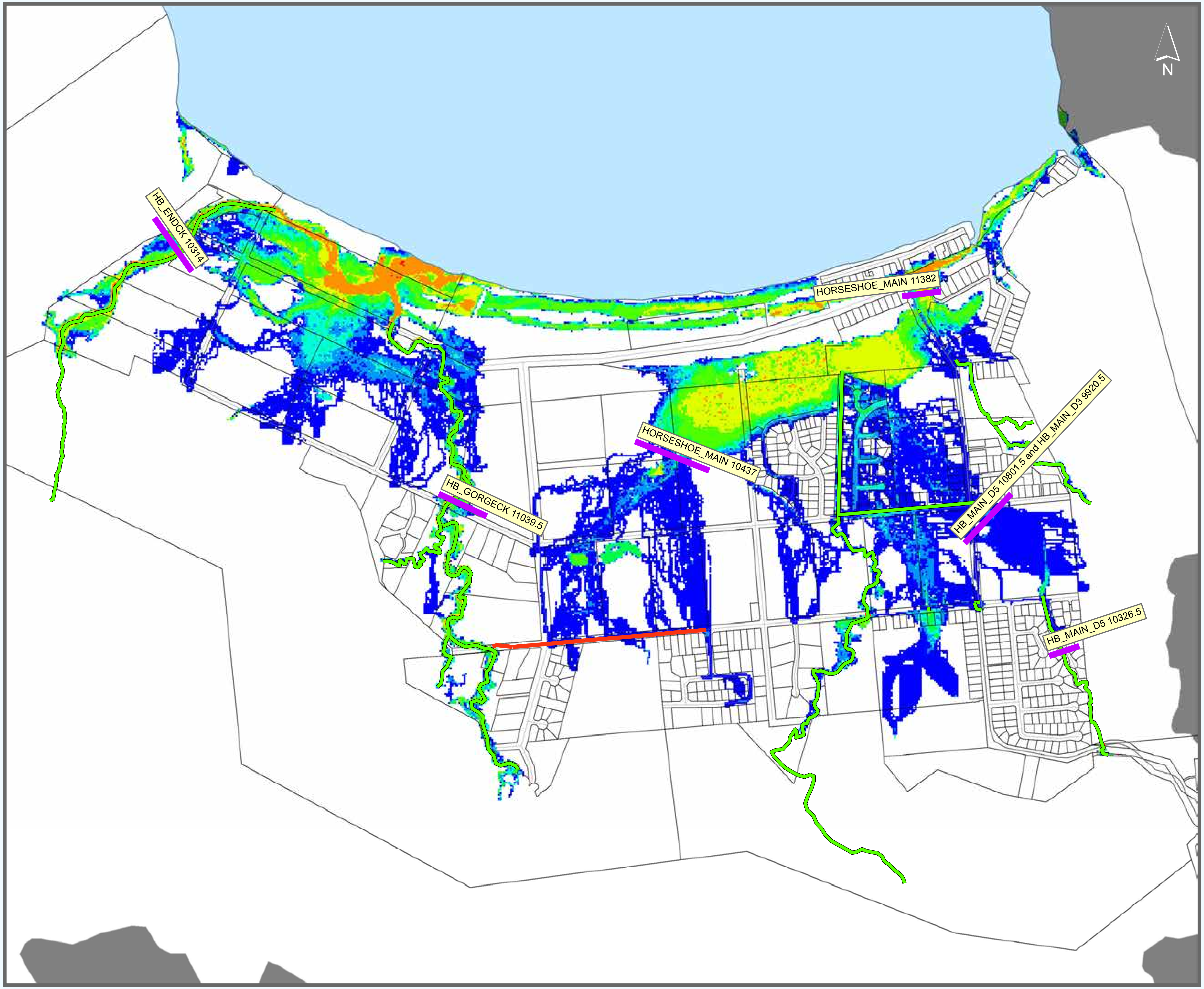
A comparison of maximum flows results was also undertaken at key locations. These locations are presented in **Figure 4.6.1** along with the maximum flow rates in **Table 4.6.2**. The HBFS has generally smaller flows than the TFHAS, except at the outlet of the park on the corner of Horseshoe Bay Road and Apjohn Street, and at the outlet of the lagoon. Since the completion of the TFHAS, box culverts have been installed at the intersection of Jaydn Court and Gifford Street. These works have helped to redirect flows into the park, where previously they had run down Gifford Street. This is the reason that the HBFS shows a larger maximum flow than the TFHAS at the outlet of the park (HB_MAIN_D5 10801.5 and HB_MAIN_D3 9920.5 in **Table 4.6.2**). A comparison between 2004 and 2009 aerial survey shows that the Lagoon has accumulated up to 1.2m of sediment since the TFHAS was completed. This has led to a smaller capacity for water storage, which is the reason that the HBFS is significantly larger than the TFHAS at the outlet of the lagoon (HORSESHOE_MAIN 11382 in **Table 4.6.2**).

Table 4.6.2: A comparison between TFHAS and HBFS of maximum flows

TFHAS Branch and Chainage	TFHAS Flow [m^3/s]	HBFS Flow [m^3/s]	Difference [%]
HORSESHOE_MAIN 10437	12.1	10.3	17
HB_MAIN_D5 10801.5 and HB_MAIN_D3 9920.5	13.1	14.6	10
HB_MAIN_D5 10326.5	13	11.1	17
HB_GORGECK 11039.5	58.5	53.6	9
HB_ENDCK 10314	106.9	94.2	13
HORSESHOE_MAIN 11382	12.4	36.6	66

In the THFAS, the Mike 11 branch representing the flow path beside the Sandals Development has been manipulated to stop water from escaping to other areas. Also, the structure at Apjohn Street was not constructed when the TFHAS was undertaken. All these factors help contribute to water level differences in the HBFS.

Figure 4.6.2 shows the inundation maps of the TFHAS and the HBFS.



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

HB_FlowCalcs

50y Flood Envelope

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

280 140 0
Meters

SCALE: 1:10,000 @ A3

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Figure 4.6.1: Flow Comparison Locations

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HORSESHOE BAY
STUDY AREA

LEGEND

HBFS

TFHAS

City of Townsville

275 137.5 0

Meters

SCALE: 1:10,000 @ A3

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Figure 4.6.2: 50y TFHAS and HBFS extent map

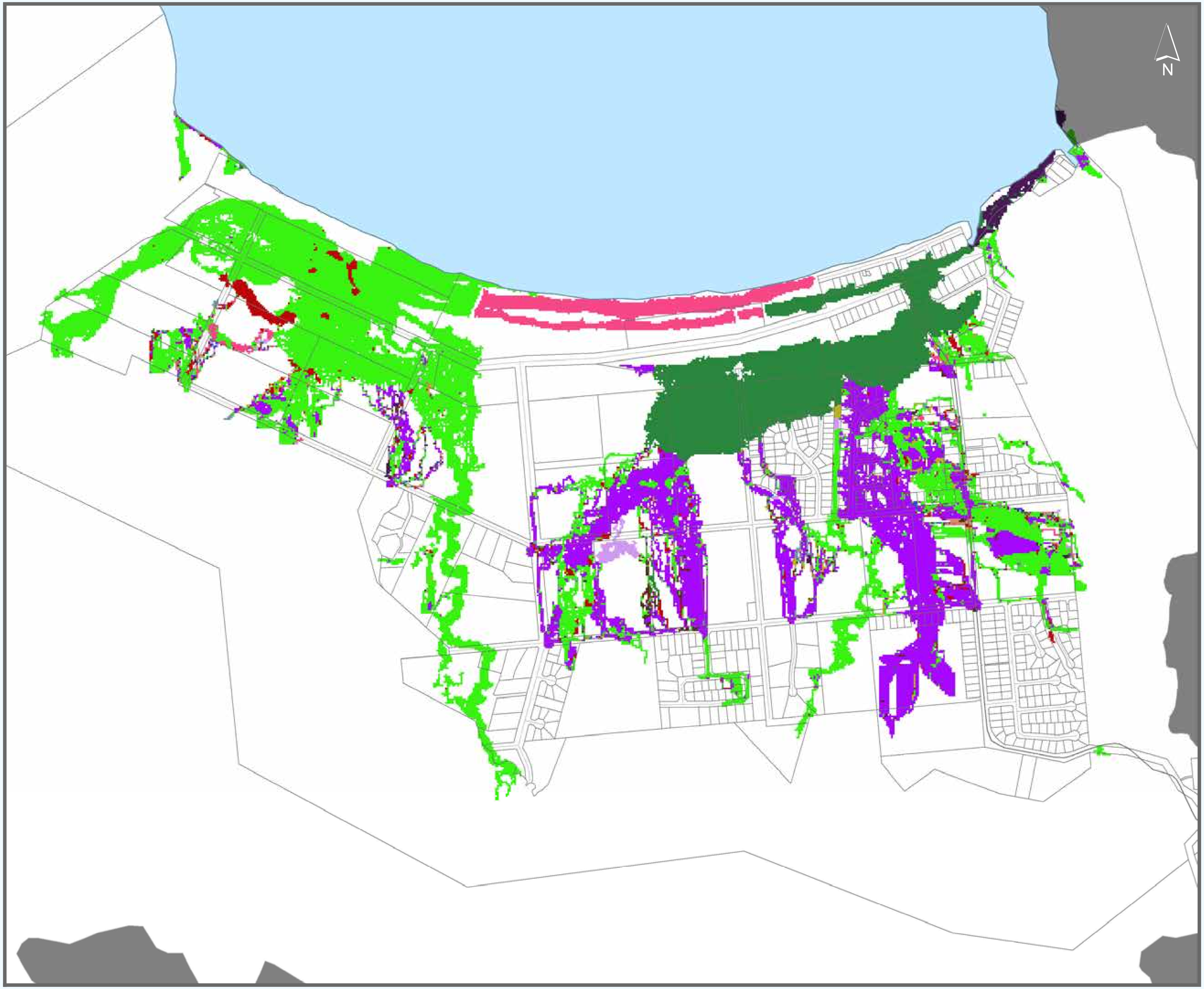
4.7 Design Flood Assessment

Design Flood model results were obtained from a base line model which was set up using 2009 LiDAR, latest stormwater infrastructure including the 2011 installation of the culvert at 40 Gifford St, and 2009 areal photograph showing an up to date level of urbanisation. A range of storm durations and Average Recurrence Intervals were assessed. The ARIs modelled were 2 year, 5 year, 10 year, 20 year, 50 year, 100 year, 500 year, and PMF. The storm durations modelled were 30 minutes, 45 minutes, 1 hour, 1.5 hours, 2 hours, 3 hours, 4.5 hours, 6 hours, 9 hours, 12 hours, 18 hours, and 24 hours.

The duration that yields the greatest water level at a particular point in the catchment is the critical duration, and changes depending on the location within the catchment. **Figures 4.7.1** to **4.7.2** show the critical durations at within the Study Area.

Because Horseshoe Bay has number of different critical durations at different points throughout the catchment, Flood Envelopes have been created for each ARI. **Figures 4.7.1** to **4.7.2** show that for the majority of areas, the critical duration is either 1, 1.5, 3, or 4.5 hours. This was also demonstrated in the results table, **Table A1** in **Appendix A**, which shows the flood level for each duration at various points around the catchment. **Figure A0** shows the location of the points in the results table. From this analysis, only those 4 critical duration scenarios were run through the model. At each point in the catchment, for a given ARI, the Flood Envelope displays the highest water level from either the 1, 1.5, 3, or 4.5 hour storm events. Flood Envelope maps are contained within **Appendix A**.

Hazard Maps have been created based on a flood hazard assessment and an assessment on the impact of climate change on flooding has also been completed.



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Critical Duration [hr]

0.5
0.75
1
1.5
2
3
4.5
6
9
12
18
24

290 145 0
Meters

SCALE: 1:10,000 @ A3

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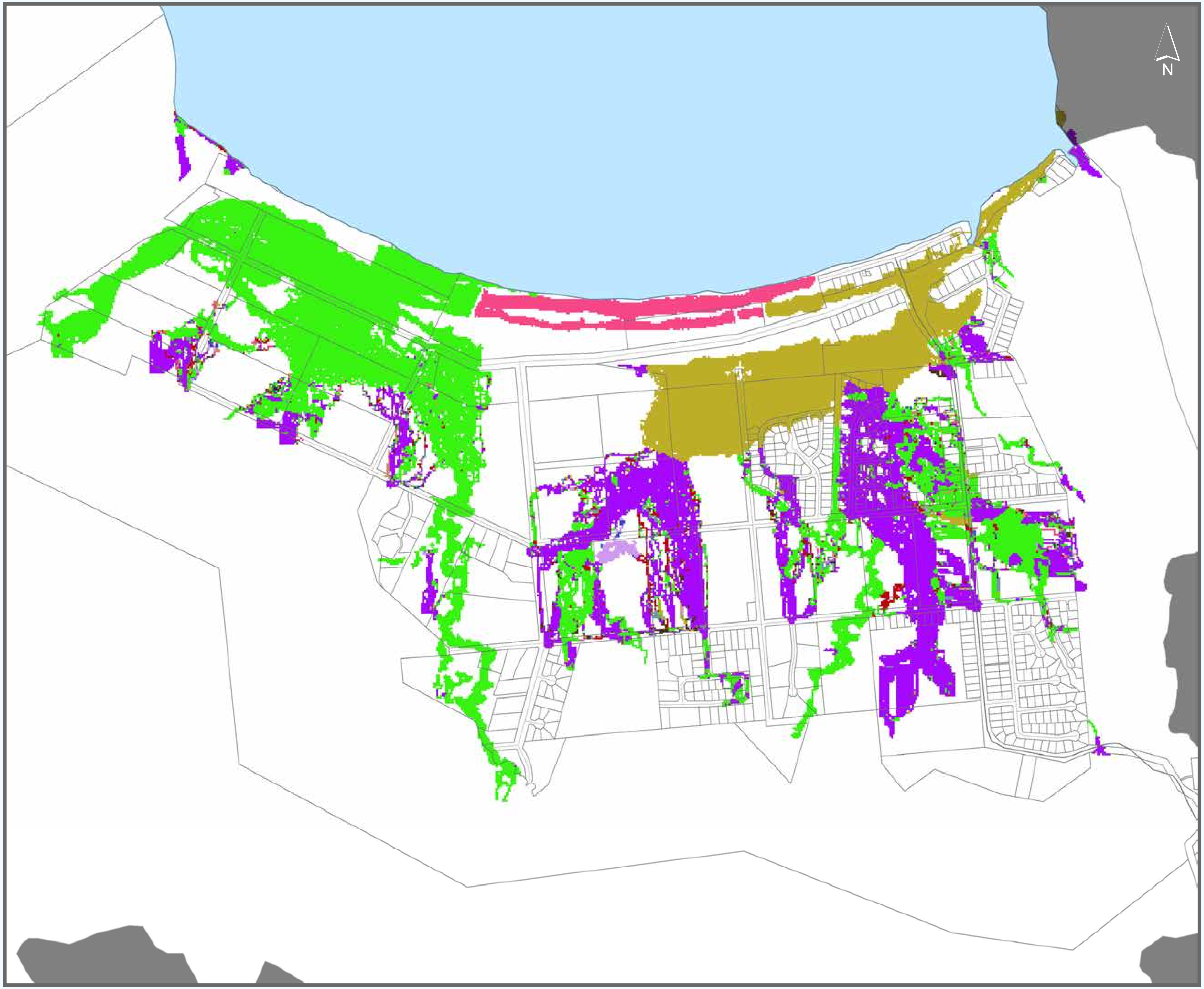
Figure 4.7.1: 50y Critical Duration

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA



LEGEND

Critical Duration [hr]

- 0.5
- 0.75
- 1
- 1.5
- 2
- 3
- 4.5
- 6
- 9
- 12
- 18
- 24

City of Townsville

290 145 0
Meters

SCALE: 1:10,000 @ A3

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Figure 4.7.2: 100y Critical Duration

5.0 Base-line Flooding Assessment

5.1 Overland Results

Base-line surface flow results generated from the model are shown as flood envelopes in **Appendix A**. **Table 5.1.1** summarises the flooding for each ARI. Where numbers of inundated residential properties are provided, they are on the basis of 200 mm water depth across the lot, which does not mean floor levels are exceeded (though in some cases floor levels may be exceeded if they are less than 200 mm above the ground). Roads are also determined to be closed when water depths reach 200mm over the road. To undertake a comparison to floor levels would require survey of all floor levels within the study area.

Table A1 shows the maximum water surface levels for the 50 year ARI at points identified in **Figure A0** (refer to **Appendix A**). Flows have been determined at several locations about the catchment. These flows were used in comparing the HBFS and the TFHAS and can be found in **Section 4.6**.

Table 5.1.1 – Overland Results

Event	**Description**
2 year ARI	• Slight floodplain inundation in the lower reaches of Endeavour and Gorge Creeks. • Sheet flow downstream of Gifford Street between Parker and Swensen Streets. • Sheet flow through the park on the corner of Horseshoe Bay Road and Apjohn Streets. • Apjohn Street closed at the Corica Crescent Development and west of Swensen Street. • Inundation of 3 residential properties on Gifford Street to around 800mm water depth. • Inundation of 5 residential properties downstream of Apjohn Street. • Velocities up to 2.5m/s in Beeran Creek East upstream of Gifford Street. • Velocities over 1.5m/s along Corica Crescent
5 year ARI	• Increased floodplain inundation in the lower reaches of Endeavour and Gorge Creeks. • Inundation of 3 residential properties on Gifford Street to around 800mm water depth. • Inundation of 7 residential properties downstream of Apjohn Street. • Velocities up to 3m/s in Beeran Creek East upstream of Gifford Street. • Velocities over 2m/s along Corica Crescent. • Velocities over 1.5m/s on Apjohn Street. • Velocities to around 1m/s in the channel between the Sandals and the Corica Crescent Developments.
10 year ARI	• Apjohn Street closed at the Corica Crescent Development, west of Swensen Street, and at the intersection with Horseshoe Bay Road. • Inundation of 3 residential properties on Gifford Street to

	around 900mm water depth. • Inundation of 14 residential properties downstream of Apjohn Street. • Velocities to around 1.5m/s in the channel between the Sandals and the Corica Crescent Developments. • Velocities more than 1.5m/s over Horseshoe Bay Road at Apjohn Street.
20 year ARI	• Floodplain inundation in the lower reaches of Endeavour and Gorge Creeks causing rural properties in the area to be effected but structures such as houses appear to be unaffected. • Gifford Street closed west of Horseshoe Bay Road. • Horseshoe Bay Road closed at the outlet of the Lagoon. • Inundation of 3 residential properties on Gifford Street to around 900mm water depth. • Inundation of 21 residential properties downstream of Apjohn Street. • Inundation of 1 rural property on the western end of Pacific Drive. • Velocities over 2m/s on Apjohn Street. • Velocities to around 1m/s through properties on the western side of Horseshoe Bay Road and North of Apjohn Street. • Velocities around 2m/s over Horseshoe Bay Road at Apjohn Street. • Velocities more than 1.5m/s over Heath Street • Velocities more than 1m/s over Horseshoe Bay Road at the Lagoon outlet.
50 year ARI	• Gifford Street closed west of the intersection with Horseshoe Bay Road. • Inundation of 3 residential properties on Gifford Street to around 900mm water depth. • Inundation of 30 residential properties downstream of Apjohn Street. • Velocities up to 4m/s in Beeran Creek East upstream of Gifford Street. • Velocities around 2m/s over Horseshoe Bay Road at Apjohn Street.
100 year ARI	• Gifford Street closed at the intersection with Horseshoe Bay Road. • Inundation of 3 residential properties on Gifford Street to around 900mm water depth. • Inundation of 43 residential properties downstream of Apjohn Street. • Inundation of 3 properties on Pacific Drive.
500 year ARI	• Gifford Street closed at Pirie Street. • Pandanus Drive closed. • Inundation of 3 residential properties on Gifford Street to around 1m water depth. • Inundation of 66 residential properties downstream of Apjohn Street. • Inundation of 3 rural property on the western end of Pacific Drive.

	• Velocities over 2m/s over Horseshoe Bay Road at Apjohn Street. • Velocities more than 2m/s over Heath Street • Velocities over 2.5m/s along Corica Crescent. • Velocities to around 1.5m/s in the channel between the Sandals and the Corica Crescent Developments.
PMF	• Swensen Street closed. • 8 rural properties fully inundated in the lower reaches of Endeavour and Gorge Creeks. • Inundation of 3 residential properties on Gifford Street to around 1.2m water depth. • Inundation of 119 residential properties downstream of Apjohn Street, including every property within the Corica Crescent Development. • Inundation of 19 properties on the eastern side of Pacific Drive. • Velocities over 2.5m/s over Horseshoe Bay Road at Apjohn Street. • Velocities up to 1.5m/s through properties on the western side of Horseshoe Bay Road and North of Apjohn Street. • Velocities more than 2.5m/s over Heath Street • Velocities more than 1.5m/s over Horseshoe Bay Road at the Lagoon outlet. • Velocities over 3m/s along Corica Crescent. • Velocities to around 2m/s in the channel between the Sandals and the Corica Crescent Developments.

*Note: At the time this study was undertaken, council did not have the information required to determine whether dwellings were inundated along with the inundated properties.

5.2 MIKE URBAN Results

Table 5.2.1 shows discharge results from each pipe in the underground pipe network. **Table 5.2.2** shows the surcharge of water from the underground network to overland flow at each stormwater inlet. For each ARI, the maximum discharge for any storm duration has been reported. For reference to **Tables 5.2.1 and 5.2.2**, **Figure 5.2.1** has been included to show the underground network model setup and the locations of the nodes.

The pipe network along Gifford Street was shown to have pipe-full flow in the 5 year ARI with some surcharge of pipe flows. This suggests that there is capacity within the Gifford Street Pipes for the 2 year ARI which is the design criteria. The pipe network along Gifford Street has a smaller pipe branch servicing Swensen Street upstream of Gifford Street and the connecting streets. It also has another smaller pipe branch servicing the Wallaby Way Development. Any rainfall that fell within these developed areas was assumed to be taken directly into the Gifford Street pipe network. Detailed drainage modelling is required to confirm the pipe capacity within these smaller branches.

Table 5.2.1: MIKE URBAN maximum pipe discharges [m^3/s]								
Pipe ID	**From node**	**To node**	**Size (mm)**	**2y**	**5y**	**10y**	**20y**	**50y**
1	0446D9U	0446D8U	900	1.6	1.9	2.1	2.3	2.6
2	0446D8U	0446D7U	900	1.6	1.7	1.8	1.9	2.1
3	0446D7U	0446D6U	900	1.6	1.7	1.8	1.9	2.0
4	0446D6U	0446D5U	900	1.6	1.7	1.8	1.9	1.9
5	0446D5U	0446D05U	1500	1.6	1.7	1.7	1.9	1.9
6	0446D05U	0446D4U	1500	1.5	1.7	1.7	1.9	1.9
7	0446D4U	0446D04U	1500	1.5	1.6	1.7	1.9	1.9
8	0446D04U	0446D3U	1500	1.8	2.0	2.1	2.2	2.3
9	0446D3U	0446D2U	1500	1.8	2.0	2.1	2.2	2.3
10	0446D2U	Outlet	1500	1.8	2.0	2.1	2.2	2.3

	Table 5.2.1: MIKE URBAN maximum node surcharge [m^3/s]				
Nodes	**2y**	**5y**	**10y**	**20y**	**50y**
0446D8U	0.0	0.2	0.3	0.4	0.5
0446D7U	0.0	0.0	0.0	0.0	0.2
0446D04U	0.0	0.0	0.0	0.0	0.0

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

- Modelled Inlet Pits
- MIKE URBAN Manholes
- MIKE URBAN Outlets
- MIKE URBAN Links

40 20 0
Meters

SCALE: 1:1,868 @ A3

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Figure 5.2.1: Mike Urban setup

5.3 Road Closures

A number of sections of road within Horseshoe Bay were analysed for closure due to flooding. Roads were considered non trafficable when the water depth exceeded 200mm. **Table 5.3.1** shows the level of immunity of some of the more important roads around Horseshoe Bay. **Figure 5.3.1** show the locations of the points of closure.

Table 5.3.1: Times of road closure [h:mm]

Point number	Road	Immunity
1	Horseshoe Bay Road at Lagoon outlet	2y
2	Heath Street at Horseshoe Bay Road	50y
3	Culvert at Apjohn Street Channel	50y
4	Apjohn Street at number 53	less than 2y
5	Horseshoe Bay Road just south of the intersection with Apjohn Street	5y
6	Apjohn Street just east of the intersection with Horseshoe Bay Road	2y
7	Gifford Street at numer 38	10y
8	Gifford Street at numer 52	50y
9	Horseshoe Bay Road at the crossing with Beeran Creek East Upstream.	100y
10	Apjohn Street at the crossing with Gorge Creek	less than 2y

Apjohn Street at the crossing with Gorge Creek (point number 10 in **Table 5.3.1** and **Figure 5.3.1**) is on the only evacuation route for the low lying area to the west and is the only access to the Sewerage Treatment Plan. An upgrade of Apjohn Street at this crossing would likely be required if residential development occurs on Hollins Street, Pollard Street, and Pacific Drive and Apjohn Street west of the crossing.

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HORSESHOE BAY
STUDY AREA

LEGEND

Road Closure Points, Flood Immunity

Road Centre Line

240 120 0
Meters

SCALE: 1:7,500 @ A3

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DIGITAL FILE: mxd

Figure 5.3.1:
Road Closure Points

5.4 Flood Plain Hazard

The safety of people and potential for damage to property is dependent on both the depth of inundation and the velocity of the flood waters. Floodwaters that flow deep and swift are obviously more hazardous than those flows that are shallow and slow.

The degree of hazard varies across the floodplain in response to:

- flood severity;
- floodwater depth and velocity;
- rate of rise of floodwater;
- duration of flooding;
- evacuation capacity;
- population at risk;
- land-use;
- flood awareness; and
- warning time.

To assist with floodplain management it is necessary to determine the hazard and ensure land uses are suitably aligned. *Floodplain Management in Australia: Best practices and principles (CSIRO, 2000)* identifies four degrees of hazard:

- **Low –** no significant evacuation problems; children and elderly could wade to safety with little difficulty; maximum flood depths and velocities along evacuation routes are low; evacuation distances are short; evacuation is possible by sedan-type motor vehicle; There is ample time for flood forecasting, flood warning and evacuation; evacuation routes remain trafficable for at least twice as long as the time required for evacuation.

- **Medium** – Fit adults can wade to safety, but children and the elderly may difficulty; evacuation routes are longer; maximum flood depths and velocities are greater; evacuation by sedan type motor vehicle is possible in the early stages of flooding, after which 4WD vehicles or trucks are required; evacuation routes remain trafficable for at least 1.5 times as long as the necessary evacuation time.

- **High** – fit adults have difficulty wading to safety; wading evacuation routes are longer again; maximum flood depths and velocities are greater (up 1.0 m and 1.5 m/s respectively); motor vehicle evacuation is possible only by 4WD vehicles or trucks in the early stages of flooding; boats and helicopters may be required; evacuation routes remain trafficable only up to the minimum evacuation time.

- **Extreme –** boats or helicopters are required for evacuation; wading is not an option because of the rate of rise and/or the depth and velocity of the floodwaters; maximum flood depths and velocities are over 1.0 m and 1.5 m/s respectively.

Prior to detailed assessment of floodplain hazard based on all the factors influencing hazard, preliminary assessment is often undertaken based on flood depth and velocity. **Figure 5.4.1** provides the basis for defining hazard as a function of depth and velocity as provided in *Floodplain Management in Australia: Best practices and principles (CSIRO, 2000)*.

Flood Hazard Maps have been generated for the Horseshoe Bay study area based on 100 Year, 500 Year, and PMF model results. These Flood Hazard Maps are shown in **Figure 5.4.2 to Figure 5.4.4**. The Flood Hazard Map is a preliminary assessment, only considering water depth and velocity. Because the critical storm duration for Horseshoe Bay is generally in the order of 1 to 4.5 hours, warning time for evacuation is low which could lead to higher hazards than those shown on the Flood Hazard Maps.

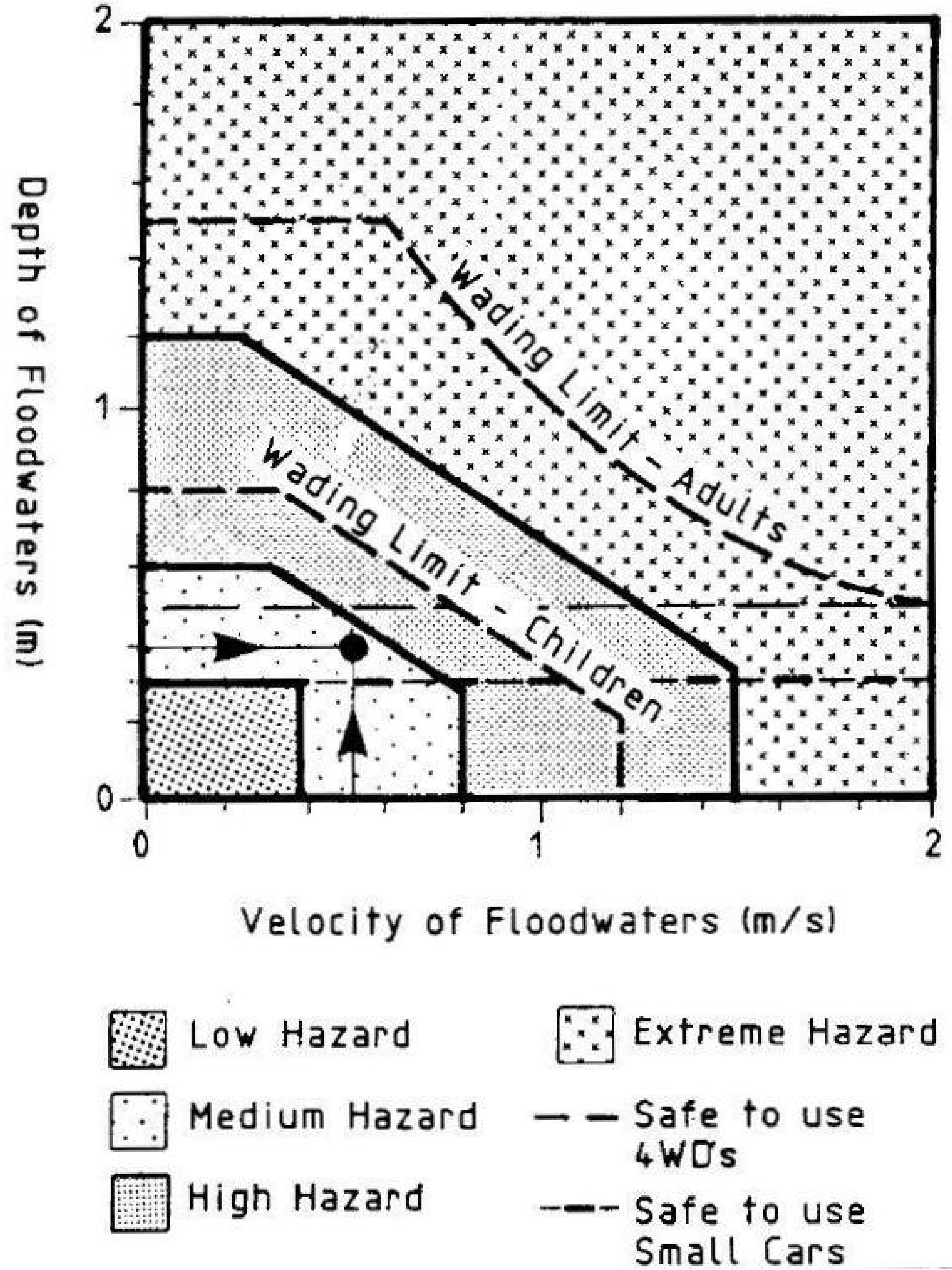


Figure 5.4.1: Hazard Classification of Flood Waters

As **Figures 5.4.2 to 5.4.4** show, there are some areas where the higher levels of hazard affect residence. These areas, and the resulting effects, are detailed below for only 100 year, 500 year, and PMF events.

The Corica Crescent Development

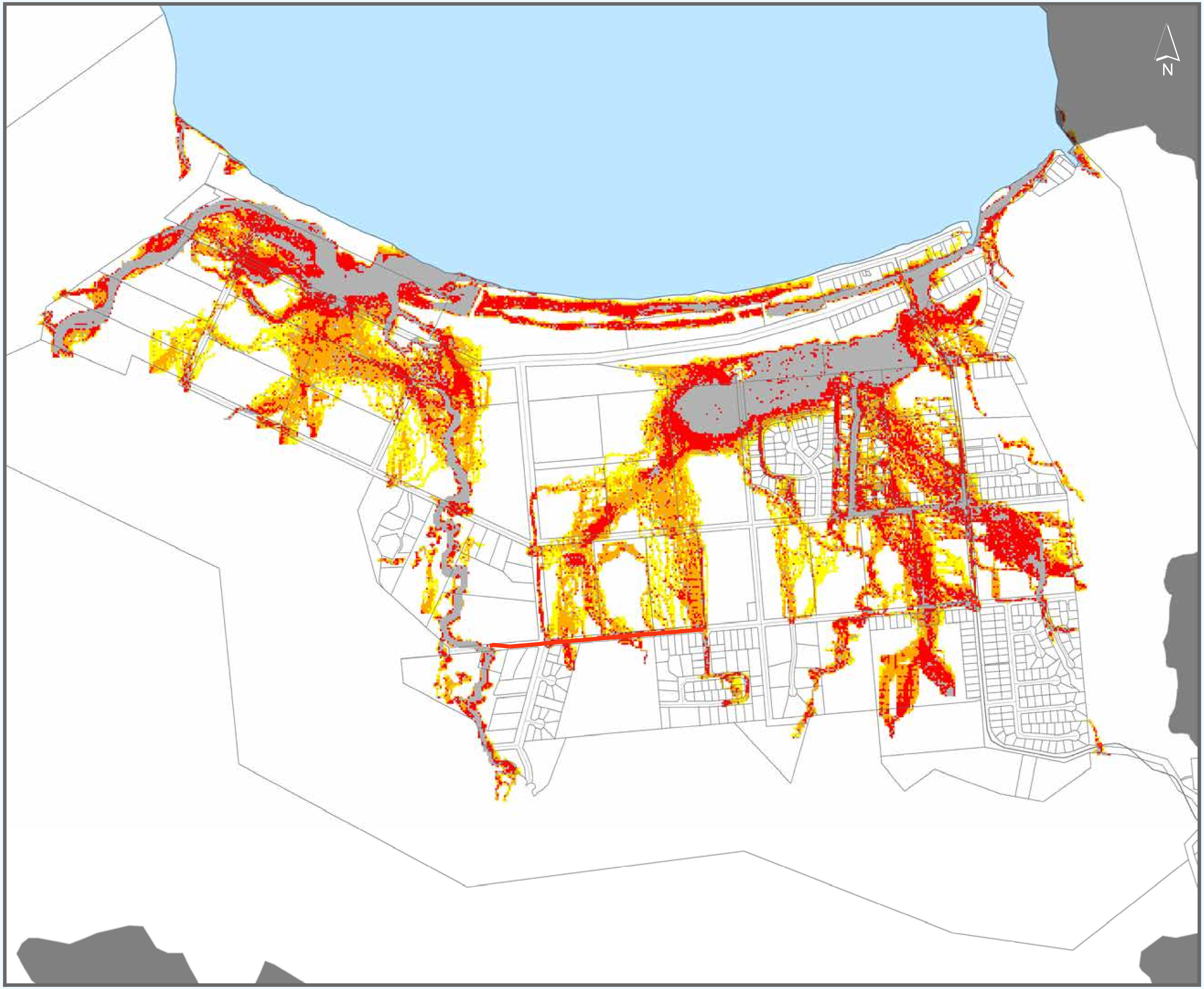
- Corrica Crescent is an extreme hazard in the 100 year, 500 year, and PMF storms.
- In the 100 year storm, there is a mixture of medium and high hazard areas throughout properties in the Corrica Development
- In the PMF, all properties in the Corrica Development have areas of extreme hazard.

The intersection of Apjohn Street and Horseshoe Bay Road

- The intersection of Apjohn Street is an area of extreme hazard for 100 year to PMF events.
- Horseshoe Bay Road has an extreme level of hazard along 380m of the road across the intersection for the PMF, and 290m for the Q100.
- Apjohn Street has an extreme level of hazard along 520m of road for the PMF and 360m for the Q100.
- Apjohn Street has an extreme level of hazard from Horseshoe Bay Road to Corica Crescent for Q100 events and above.

The Sandals Development

- Pandanus Drive, Tiramula Court, and Sandals Boulevard have areas of medium and high hazard for the 100 year event and areas of extreme hazard from the PMF.



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Hazard Level

- No Hazard
- Low Hazard
- Medium Hazard
- High Hazard
- Extreme Hazard

City of Townsville

280 140 0
Meters

SCALE: 1:10,000 @ A3

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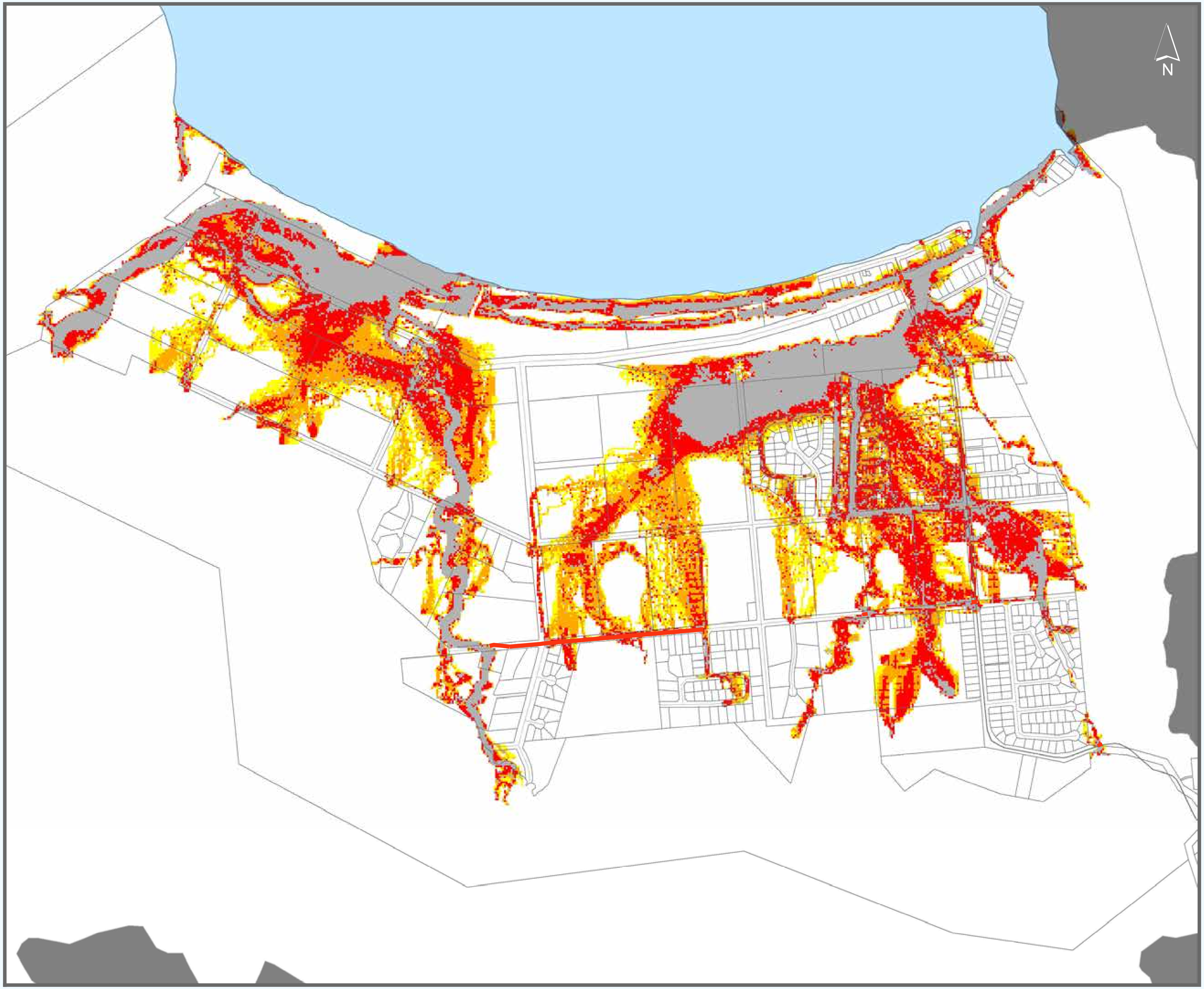
Figure 5.4.2:
100 Hazard Map



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Hazard Level

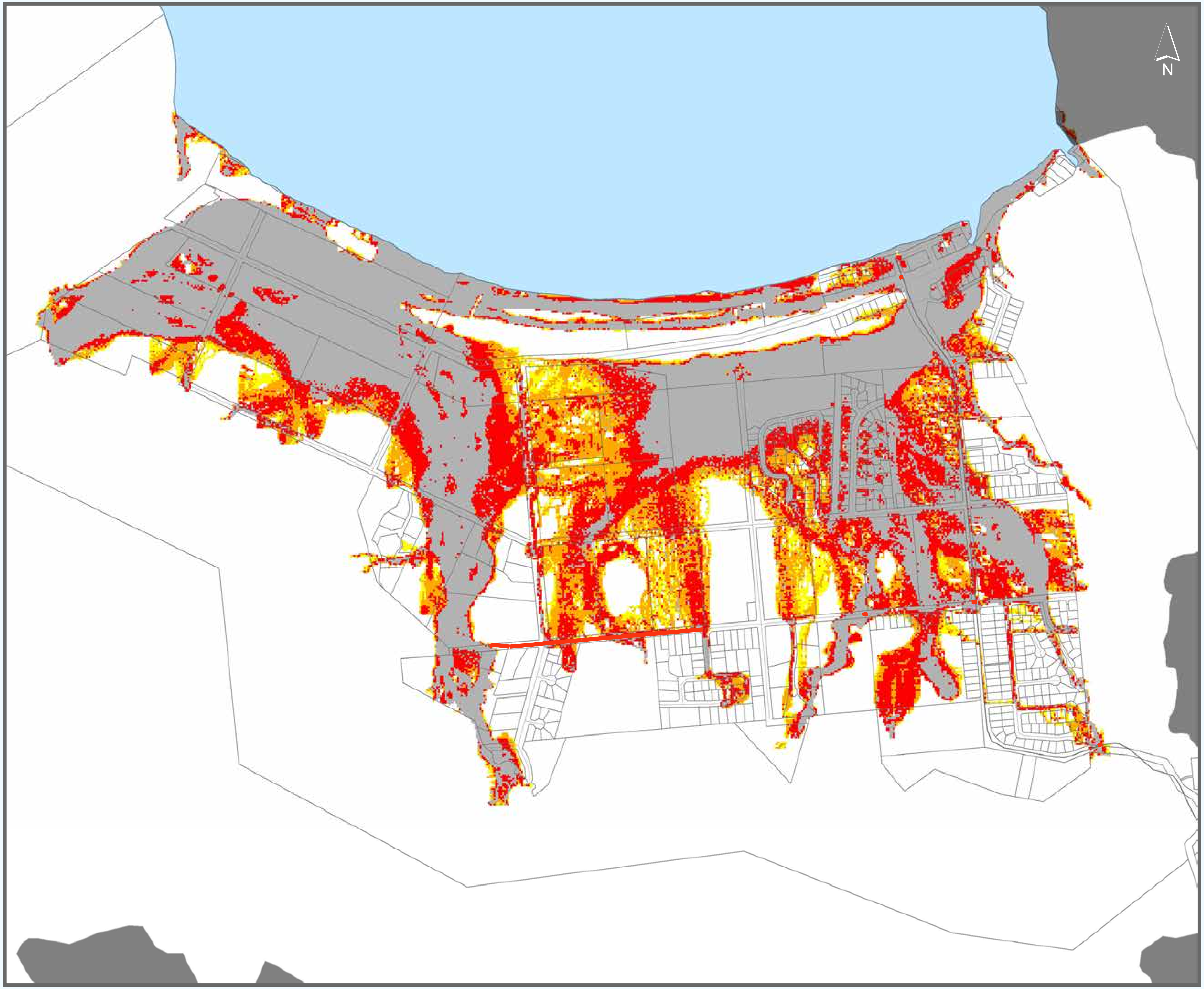
- No Hazard
- Low Hazard
- Medium Hazard
- High Hazard
- Extreme Hazard

280 140 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT
DATE: 25/10/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

**Figure 5.4.3:
500y Hazard Map**



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Hazard Level

- No Hazard
- Low Hazard
- Medium Hazard
- High Hazard
- Extreme Hazard

280 140 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT
DATE: 25/10/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

**Figure 5.4.4:
PMF Hazard Map**

5.5 Problem Flooding Areas

Several problem Flooding areas exist in Horseshoe Bay with flooding to properties in the study area. The sections below give details to the problems.

As there are a lot of existing flooding problems within Horseshoe Bay and so many constraints already exist in the area, all development applications should be assessed on their impact on council's ability to complete potential mitigation works within Horseshoe Bay. It is recommended that mitigation options be assessed under an overall scheme for the study area. It is also recommended that mitigation measures do not hinder the recharge of the underground aquifer system, and take into consideration the geomorphic processes within the catchment.

Gifford Street

A small area upstream of Gifford Street at number 40 is a trap low point for flood water. 3 houses are regularly inundated for long periods of time. **Chapter 5.7** explores this issue and a recent culvert upgrade in this location.

Apjohn Street

Apjohn Street is another area prone to flooding problems. Water crosses Apjohn Street between the Sandals Development and Horseshoe Bay Road. Most of the water that crosses Apjohn Street comes from Beeran Creek West, but some also comes from Beeran Creek East upstream of Gifford Street via the park (see **Figure 1.2.2** for reference). This water floods many properties within the Corica Crescent Development and on Apjohn Street, and closes the road to traffic (see **Table 5.1.1** for details).

Corica Crescent Development

Much of the water crossing Apjohn Street, as mentioned above, ends up in the Corica Crescent Development. All the properties within the Corica Crescent Development are at least partially inundated in the 50 year ARI event and many are fully inundated at more frequent events. See **Table 5.1.1** for details.

The Lagoon

The Lagoon is another area that is a problem for flooding in Horseshoe Bay. The culvert that drains the lagoon through Horseshoe Bay Road cannot cope with a 5 year ARI storm and water overtops the road. Almost 20 residential properties are unable to evacuate when Horseshoe Bay Road is closed at the Lagoon outlet. The Lagoon is also an environmentally sensitive area and many species of wild life rely on it for year-round supply of fresh water.

A potential problem also exists with the recharge of the aquifer which maintains the Lagoon's fresh water. Any development should stay clear of aquifer recharge zone (see **Figure 5.8.1**) and not divert major drainage paths away from the Lagoon.

Beeran Creek East upstream of Gifford Street

The Beeran Creek East channel upstream of Gifford Street that runs behind properties on the eastern side of Horseshoe Bay Road has problems with erosion. The banks of the channel are eroding towards existing properties. Rock gabion structures have been installed to protect the properties but the issue still exists. The sediment that is washed out of this area of Beeran Creek East is causing problem in downstream areas as detailed below. **Figure 5.5.1** shows an example of the source of the sediment problems.

Figure 5.5.1: Beeran Creek East upstream of Gifford Street showing an exposed pipe due to extensive washout within the channel.

Figures 5.5.2 and 5.5.3 show the sediment being deposited in the culvert on Gifford Street and in the park just downstream. The sediment is also being deposited along Apjohn Street as **Figures 5.5.4 and 5.5.5** show.

Figure 5.5.2: Sediment in the culvert under Gifford Street where Beeran Creek East discharges into the park.

Figure 5.5.3: Sediment in the park just downstream of the culvert under Gifford Street, viewed from Gifford Street.

Figure 5.5.4: Sediment beside Apjohn Street in the park viewed from Horseshoe Bay Road.

Figure 5.5.5: Sediment on Apjohn Street viewed from number 39 Apjohn Street.

As flows continue downstream, sediment is then deposited in the channel between the Sandals Development and the Corica Crescent Development, and finally in the Lagoon. This sediment is detrimental to the heath of the ecosystem of the lagoon which is an important environmental feature of Horseshoe Bay as outlined in the HBDMP. Removal of sediment from roads, properties, and the Lagoon is also quite costly.

5.6 Emergency Management Consideration

Because the critical storm duration for Horseshoe Bay is 1 to 1.5 hours for most locations, the flood warning time is too short to effectively implement pre-emptive emergency management measures. Council may be able to get some idea of an imminent flood from severe weather warnings of heavy rainfall issued by BoM.

In the event that Horseshoe Bay residence need to evacuate prior to or during an event, it is likely that most will need to leave Horseshoe Bay. The recreation centre in the park on the corner of Horseshoe Bay Road and Apjohn Street is the only Major Evacuation Centre in Horseshoe Bay however it is a post-impact evacuation centre and is not proposed to be used during flood events. At 500 year ARI storm events flood waters extend to the recreation centre. If flood levels overtop floor levels, this may render the recreation centre unusable as a post-impact evacuation centre. A survey of club house floor levels is required to determine the immunity of the structure.

The Horseshoe Bay Sewerage Treatment Plant is located on the corner of Apjohn Street and Pollard Street. While the treatment facility is immune to the Probable Maximum Flood, access to the facility is limited by the Apjohn Street crossing of Gorge Creek which closes for less than 2 year ARI storm events.

As well as mitigation works to solve property flooding issues, evacuation routes will need to be considered in a mitigation scheme. It is recommended that the results of this flood study be used to update council's Disaster Management mapping layers and Evacuation Plan.

Based on Registration as at October 2011, there were 15 properties in Horseshoe Bay then known to Council where there are elderly people that may require assistance to evacuate. The numbers of residence affected by frequent road closures are given below:

- Apjohn Street at the crossing of Gorge Creek closes at under a 2 year ARI storm event. 1 senior resident is affected by this closure.
- The Corica Crescent Development and Apjohn Street west of Horseshoe Bay Road are particularly flood prone and Apjohn Street closes at less than a 2 year ARI storm event. 3 senior residents are affected by this closure;
- The intersection of Horseshoe Bay Road and Apjohn Street closes at less than a 10 year ARI storm event. 4 senior residents are affected by this closure.
- Gifford Street closes west of Horseshoe Bay Road at less than a 10 year ARI storm event. 2 senior residents are affected by this closure.

For more information on road closures, see **Section 5.3**.

5.7 Gifford Street Culvert

In mid 2011, the culvert adjacent to number 40 Gifford Street was upgraded. In the prior wet season, the road and the existing 450mm diameter pipe were damaged. The road was repaired and the structure was upgraded to two 1200mm x 600mm box culverts. The area upstream of the road is a trap low point where ponded water affects the properties of numbers 38, 40, and 42.

To test the efficiency of the new culvert, a pre-2009 scenario model was run with results showing that in the 50 Year ARI, water depths got to over a metre and took an excessive period to drain. The culvert under Gifford Street at number 40 is the only way to drain the area. The recently constructed culvert upgrade was modelled in the base case scenario representing conditions in 2011.

The model results show an improvement in localised flooding due to the installation of the culvert. The benefits were demonstrated for durations of 1 hour and 4.5 hours for the 50 year ARI storm event, and the 1 hour duration for the 2 year ARI storm event. A summary of the benefits for the events investigated is given below:

- 50 year, 1 hour storm shows maximum water depths reductions of 70mm.
- 50 year, 1 hour storm shows a reduced time of inundation of 2 hours.
- 50 year, 4.5 hour storm shows a reduced time of inundation of 3 hours.
- 2 year, 1 hour storm showing maximum water depth reductions of over 400mm.
- 2 year, 1 hour storm shows a reduced time of inundation of 2 hours and 30 minutes; from 3 hours down to 30 minutes.

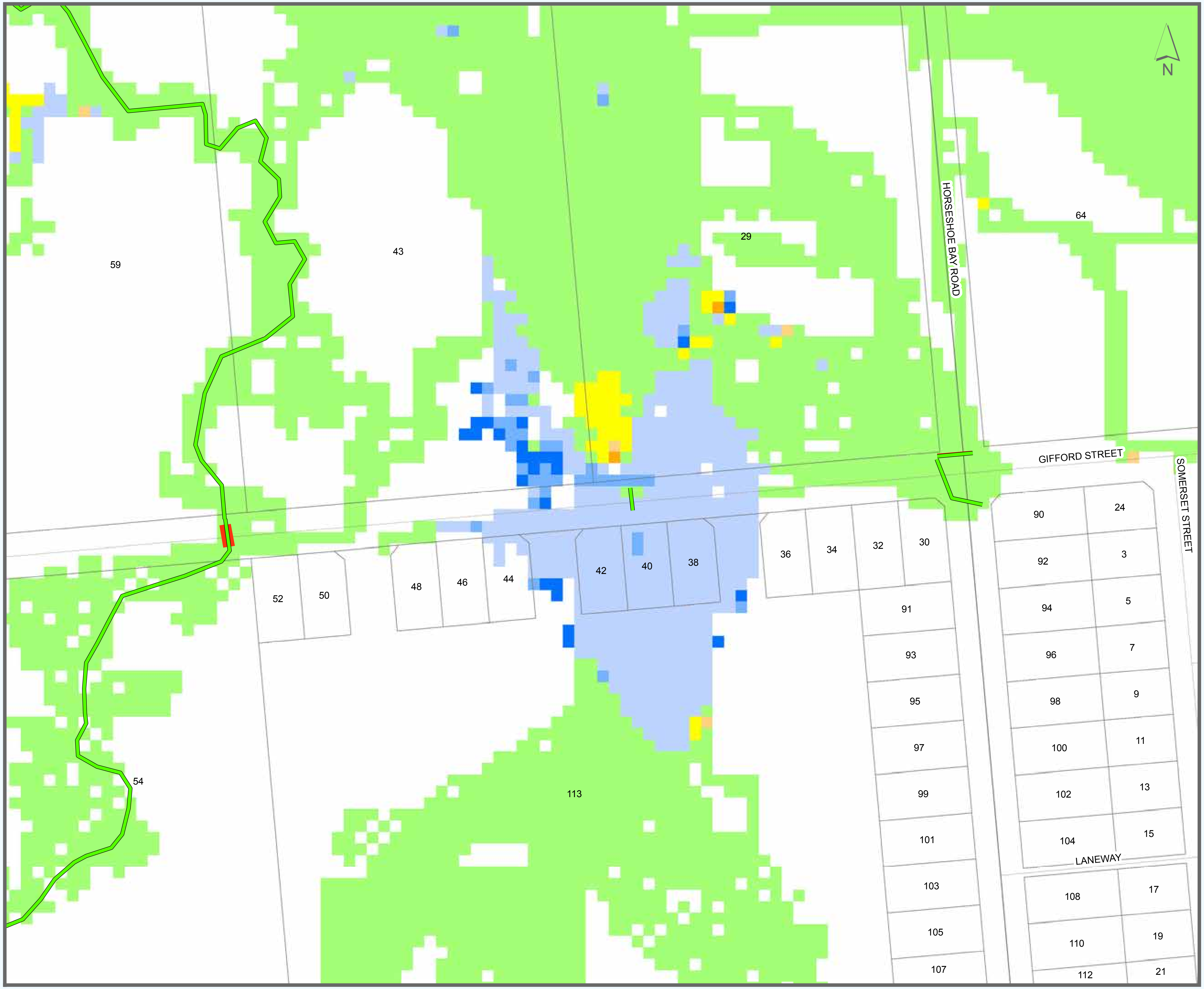
Figure 5.7.1 shows the difference in flood levels as a result of the works for the 50 year ARI, 1 hour duration storm which was critical for most of the surrounding area. This map shows that the construction has decreased flood levels upstream of the works by generally up to 50mm. Immediately downstream of the works, flood levels increased up to 50mm in the immediate vicinity of the culvert.

Figure 5.7.2 shows the difference in flood levels as a result of the works for the 2 year ARI, 1 hour duration storm. For the 2 year storm, the average reduction of levels upstream of Gifford Street is almost 300mm.

Figure 5.7.3 shows a water depth time series plot for before and after the culvert construction at a point just upstream of the culvert for the 2 year ARI. A water depth of 200mm was chosen as a point of comparison as this provides a high level of confidence in the model results. This plot demonstrates that the time of inundation has been reduced from approximately 3 hours, to approximately 30 minutes.

Chapter 5.8 explores the options required for further flood mitigation of this area.

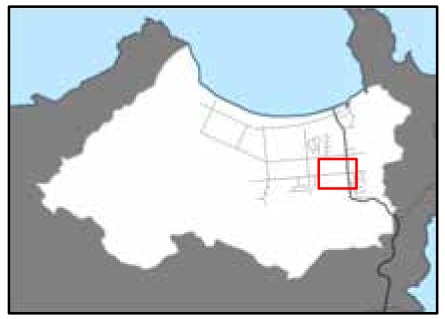
TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA



LEGEND

Water Level Difference [m]

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- > 3



City of Townsville

40 20 0
Meters

SCALE: 1:1,500 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

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DIGITAL FILE: mxd

Figure 5.7.1: Impact of the culvert at No. 40 Gifford Street on the 50 year storm

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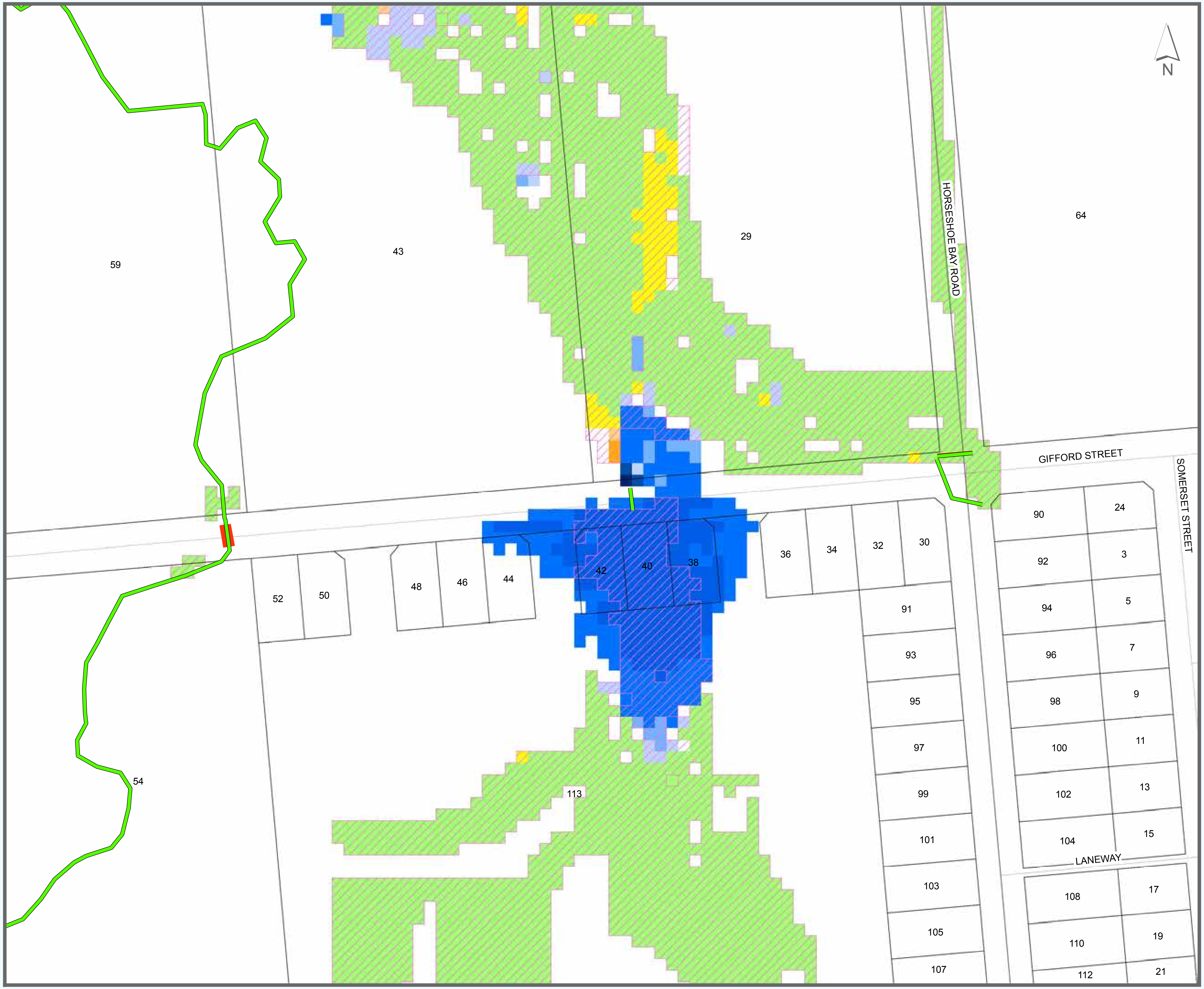
HORSESHOE BAY
STUDY AREA

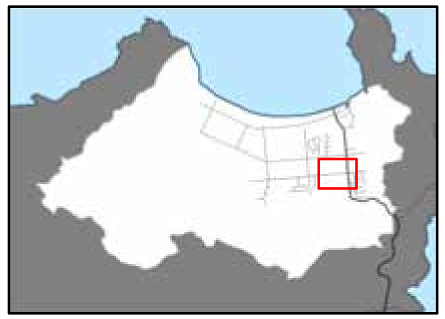


LEGEND

Water Level Difference [m]

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- > 3

New Culvert Flooding Extent



City of Townsville

40 20 0

Meters

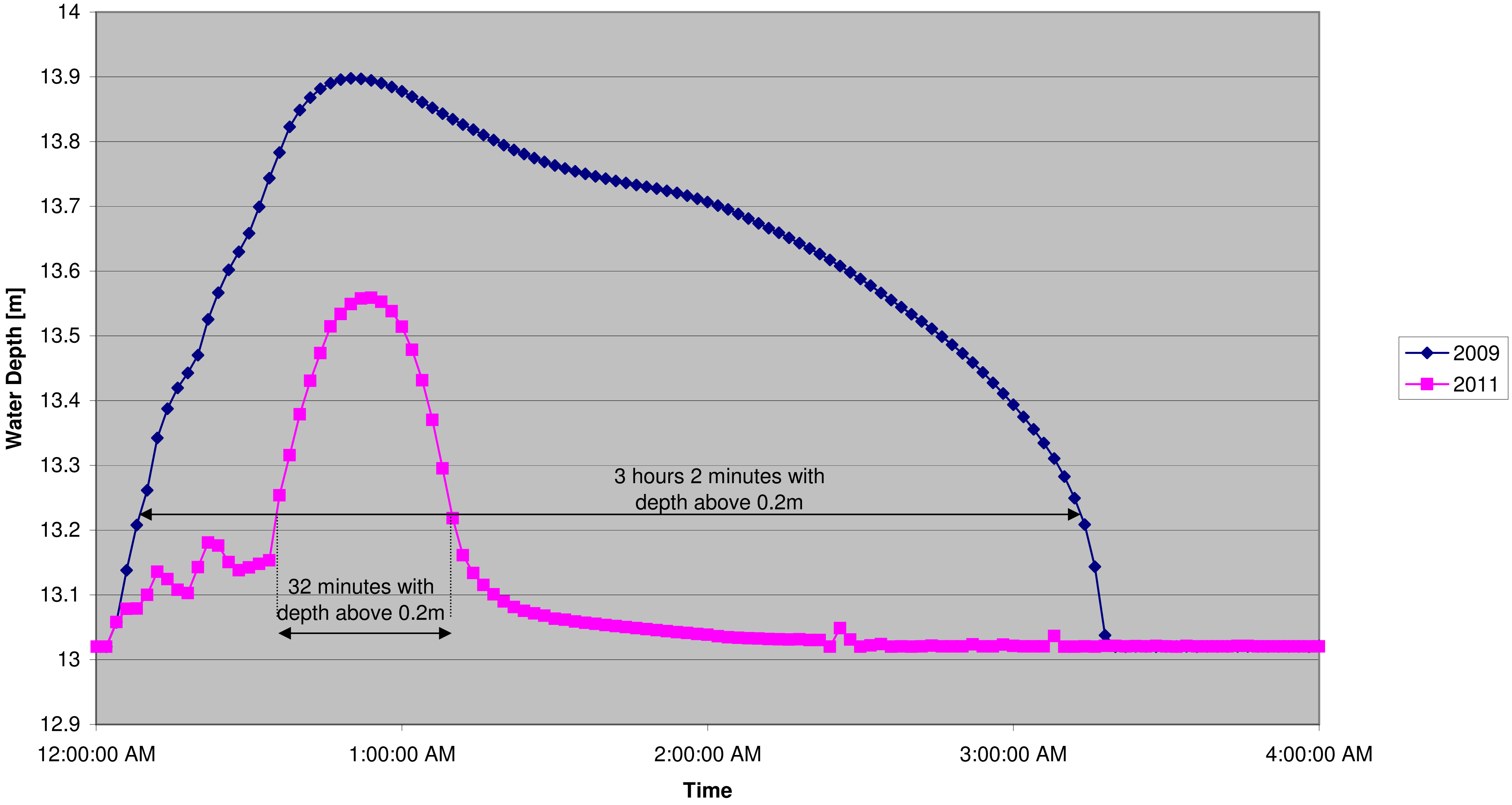
SCALE: 1:1,500 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 23/10/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure 5.7.2: Impact of the culvert at No. 40 Gifford Street on the 2 year storm

Figure 5.7.3: Time Series at No. 40 Gifford Street, 2 year 1 hour event



5.8 Potential Mitigation Constraints

The following constraints limit the ability to provided any potential mitigations options.

Aquifer

Figure 5.8.1 is an extract from the Horseshoe Bay Drainage Management Plan (HBDMP) that shows the groundwater recharge / emergent zones within Horseshoe Bay. As the HBDMP highlights the importance of the aquifer on the ecosystem of Horseshoe Bay, flood mitigation works must not divert flow away from recharge zones. It may be that flood mitigation solutions that assist aquifer recharge, like detention basins, may be desirable. These details are beyond the scope of this study, and more investigation is required

Gifford Street

Any flood mitigation works completed for Gifford Street would likely impact on flood levels downstream at Apjohn Street and the Corica Crescent Development. The hydraulic model should be used to evaluate any future mitigation options, including all areas both upstream and downstream of the works.

Apjohn Street

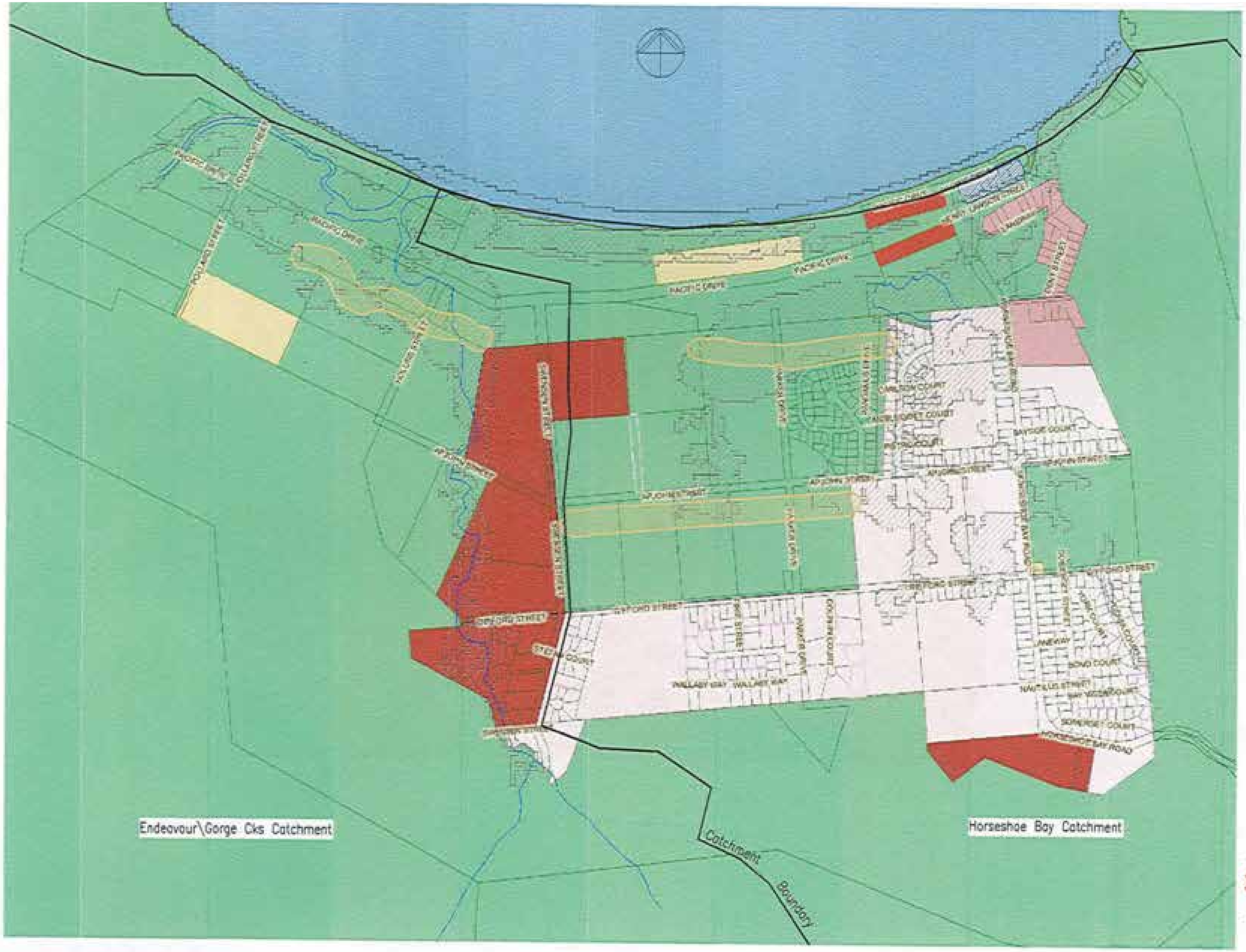
Any mitigation works completed for Apjohn Street could have the potential to negatively impact downstream areas. As Apjohn Street is affected by sediment from Beeran Creek East, council would need to undertake a detailed geomorphic assessment to gain a proper understanding of the issues and ensure sediment issues are addressed as part of any flood mitigation concept. The hydraulic model should be used to evaluate any future mitigation options, including all areas upstream and downstream of the works.

Corica Crescent Development

As the flood problems within the Corica Crescent Development are from the same flows that cause the problems on Apjohn Street, the mitigation options identified for Apjohn Street could also address the flooding issues within the Corica Crescent Development.

Beeran Creek East upstream of Gifford Street.

Access and space to the area is limited as the channel is in close proximity to the properties. To gain a better understanding of the issues in Beeran Creek East upstream of Gifford Street, council would need to undertake a detailed geomorphic assessment. Hydraulic modelling of the each proposed option would be required to determine the most appropriate solution. The model would need to include the whole Beeran Creek catchment as so many areas are affected by flood waters from Beeran Creek East upstream of Gifford Street.



LEGEND

- Traditional Residential
- Neighborhood Residential
- Rural Residential
- Community and Government
- Mixed Residential
- Neighborhood Centre
- Green Space / Coastline
- Recharge and Emergent Zones
- Q50 Inundation

FLANAGAN CONSULTING GROUP

Horseshoe Bay Drainage Management Plan

EXISTING LAND USES AND CONTRAINTS OVERLAY

Q50 & EMERGENT ZONES

5157-SK12 | NTS | A3 Full Size

22nd April 2008

6.0 Climate Change

An evaluation of the potential impact of climate change on flooding has been undertaken. The sea-level rise specified within the *Queensland Coastal Plan* of 0.8m to allow for conditions in 2100 was adopted. This value was adopted from advice from *the IPCC Fourth Assessment Report: Climate Change* (2007). The *Climate Change Risks to Australia's Coast – A First Pass National Assessment* Report, completed by the Department of Climate Change and Energy Efficiency, also outlines projected sea level rise values taking into account more recent studies. It gives a high end scenario prediction of a 1.1m sea-level rise by 2100 which it states is justified for decision-making.

Predictions on changes to ARI storm intensities have been made based only on the analysis of 24 and 72 hour storm durations. At this point there is no conclusive assessment to indicate that these values are relevant for shorter duration storms like those critical in Horseshoe Bay. It is on this basis that only a sea level rise has been modelled in the evaluation for climate change for the present study.

To assess the potential impact of sea-level rise on Horseshoe Bay flooding, the tailwater level of the flood model was updated to include both the 0.8 and the 1.1m sea level rise values. The impacts of climate change on ARIs 2, 50 and 100 years have been evaluated for a 0.8m sea-level rise and on ARIs 50 and 100 for a 1.1m sea-level rise. **Appendix C** contains maps showing the difference between the base case scenario and the climate change scenario for each ARI.

The analysis shows that a sea level rise due to climate change, has a greater effect at more frequent durations, and that it is the lower reaches that are most affected. The areas that exhibit water level changes due to climate change are the Lagoon, the outlet of Endeavour and Gorge Creeks, and the swale behind the primary sand dune. 2 properties on Henry Lawson Street, 11 properties on Pacific Drive, 5 properties within the Corica Crescent Development, and 11 properties with the Sandals Development are affected by increased flood levels due to sea-level rise.

7.0 Conclusion

The *Horseshoe Bay Flood Study – Baseline Flooding Assessment* is part of the City Wide Flood Constraints project being completed by Townsville City Council. This report details the model setup and the conclusions on existing conditions.

The hydrologic XP-RAFTS model and the hydraulic MIKE FLOOD model were set up using various data sources available to council. The models were verified to the rational method, the TFHAS and various other hand calculations. The verified models were run to simulate the 2 year, 5 year, 10 year, 20 year, 50 year, 100 year, 500 year ARI floods, and the PMF. For each ARI, the storm durations modelled were 30 minutes, 45 minutes, 1 hour, 2 hours, 3 hours, 4.5 hours, 6 hours, 9 hours, 12 hours, 18 hours, and 24 hours.

The results of the model were used to generate flood maps of water depth, flood level, and flow velocities. Along with the overland flow results, underground pipe network results were reported. Details of the main existing problem areas were also identified to be;

- the trap low point just upstream of Gifford Street at number 40;
- Apjohn Street between Horseshoe Bay Road and the Sandals Development;
- the Corica Crescent Development;
- Beeran Creek East upstream of Gifford Street; and
- the lagoon at the outlet at Horseshoe Bay Road.

Horseshoe Bay also has sediment problems at various locations about the study area which all seem to arise from Beeran Creek East upstream of Gifford Street.

Potential mitigation options were also given for the areas mentioned above, but it is recommended that the mitigation be assessed under an overall scheme for the study area. It is also recommended that mitigation measures do not hinder the recharge of the underground aquifer system, and should take into consideration the Geomorphic processes within the catchment. All development applications should be assessed on their impact on council's ability to complete potential mitigation works within Horseshoe Bay.

An analysis of road closures was undertaken identifying points along Apjohn Street and Horseshoe Bay Road as having an immunity equal to or less than a 2 year ARI storm. Apjohn Street west of Horseshoe Bay Road is the only existing evacuation route for the Corica and Sandals Developments and evacuation from these developments is quite difficult in any flood equal to or greater than the 2 year ARI. Apjohn Street at the crossing of Gorge Creek is part of the evacuation route for the low lying area to the west and has a flood immunity less than 2 years. An upgrade of Apjohn Street at this crossing would likely be required if residential development occurs on Hollins Street, Pollard Street, and Pacific Drive and Apjohn Street west of the crossing.

As detailed in the Emergency Management Considerations chapter, the Sewage Treatment Plant on the corner of Apjohn Street and Pollard Street is immune to the Probable Maximum Flood, but inaccessible in less than 2 year ARI storm events. The recreation centre in the park on the corner of Horseshoe Bay Road and Apjohn Street is the only Major Evacuation Centre in Horseshoe Bay however it is a post-impact evacuation centre and is not proposed to be used during flood events. It is likely that only storm events greater than 500 year ARI will cause damages to the centre potentially prevent its use as a post impact evacuation centre.

A flood plain hazard analysis of the catchment was undertaken for the 100 Year, 500 Year, and PMF ARIs. This analysis classified each area of the catchment with a hazard ranging from none to extreme. The particularly hazardous areas are:

- Apjohn Street including the intersection of Apjohn Street and Horseshoe Bay Road.
- The Corica Crescent Development.
- The Sandals Development.

The recent construction works at number 40 Gifford Street have been analysed using the hydraulic model. A summary of the benefits for the events investigated is given below:

- 50 year, 1 hour storm shows maximum water depths reductions of 70mm.
- 50 year, 1 hour storm shows a reduced time of inundation of 2 hours.
- 50 year, 4.5 hour storm shows a reduced time of inundation of 3 hours.
- 2 year, 1 hour storm showing maximum water depth reductions of over 400mm.
- 2 year, 1 hour storm shows a reduced time of inundation of 2 hours and 30 minutes; from 3 hours down to 30 minutes.

The analysis of the effects of a sea level rise due to climate change was completed on the study area. A sea level rise was shown to have a greatest effect on more frequent events in low lying areas. 2 properties on Henry Lawson Street, 11 properties on Pacific Drive, 5 properties within the Corica Crescent Development, and 11 properties with the Sandals Development are affected by increased flood levels due to sea-level rise.

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Appendix A

Flood Maps

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Model Result Points

1D Branch

Pipe Network

City of Townsville

280 140 0

Meters

SCALE: 1:10,000 @ A3

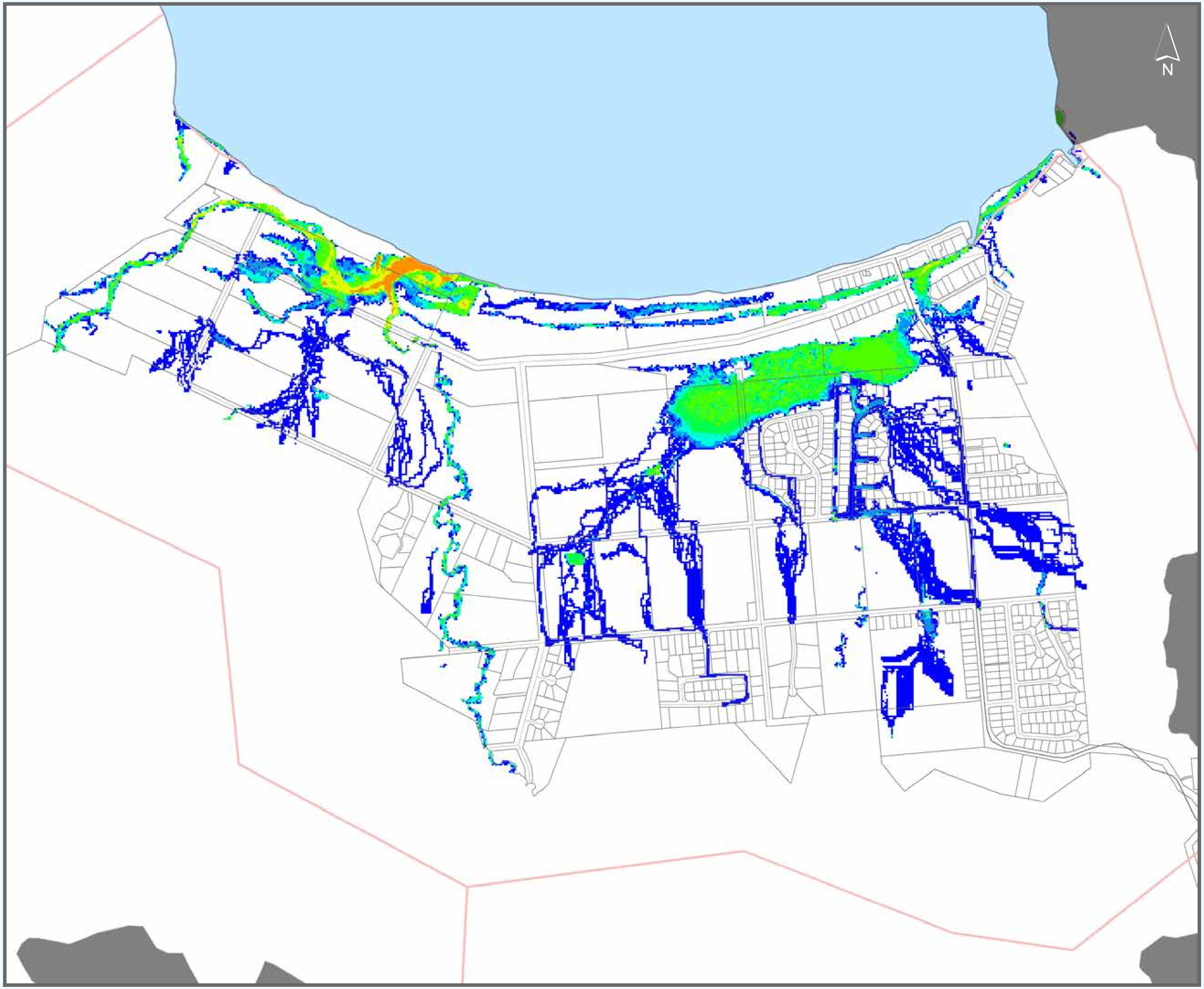
Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 19/09/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure A0: Results Points

Table A1: Maximum water levels and critical durations for base case 2011, 50 year ARI																
Duration			Water Level [m]													
Points	X	Y	0.5	0.75	1	1.5	2	3	4.5	6	9	12	18	24	Max	Critical Duration
1	520	324	-	-	-	3.19	3.29	3.38	3.39	3.39	3.36	3.33	3.33	3.35	3.39	4.50
2	528	304	-	3.13	3.26	3.36	3.42	3.47	3.47	3.47	3.45	3.43	3.43	3.44	3.47	4.50
3	547	278	4.66	4.67	4.69	4.69	4.68	4.67	4.66	4.66	4.66	4.65	4.63	4.67	4.69	1.50
4	482	265	2.92	3.17	3.33	3.46	3.52	3.55	3.56	3.55	3.54	3.54	3.52	3.53	3.56	4.50
5	492	257	3.73	3.76	3.78	3.78	3.77	3.76	3.75	3.75	3.75	3.73	3.72	3.74	3.78	1.00
6	453	242	-	-	3.33	3.46	3.52	3.55	3.56	3.55	3.54	3.54	3.52	3.53	3.56	4.50
7	482	225	4.32	4.41	4.51	4.55	4.54	4.50	4.44	4.41	4.43	4.41	4.39	4.50	4.55	1.50
8	491	203	6.89	6.92	6.94	6.94	6.93	6.91	6.89	6.89	6.89	6.88	6.85	6.87	6.94	1.00
9	480	185	7.71	7.74	7.79	7.80	7.80	7.78	7.75	7.74	7.75	7.74	7.73	7.79	7.80	1.50
10	507	188	8.68	8.71	8.74	8.73	8.72	8.70	8.68	8.68	8.67	8.66	8.64	8.65	8.74	1.00
11	558	193	12.02	12.07	12.08	12.08	12.07	12.07	12.05	12.05	12.04	12.03	12.00	12.03	12.08	1.00
12	599	143	18.01	18.08	18.12	18.12	18.10	18.09	18.05	18.06	18.06	18.01	17.98	18.04	18.12	1.50
13	533	131	13.99	14.01	14.02	14.02	14.01	14.00	13.99	13.98	13.97	13.97	13.95	13.96	14.02	1.00
14	498	128	13.78	14.27	14.49	14.51	14.50	14.47	14.35	14.25	14.36	14.17	14.06	14.47	14.51	1.50
15	390	176	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.08	7.07	7.09	7.09	1.00
16	336	172	7.19	7.22	7.24	7.24	7.23	7.22	7.20	7.20	7.19	7.18	7.15	7.17	7.24	1.00
17	321	114	12.28	12.27	12.29	12.28	12.27	12.26	12.27	12.27	12.26	12.27	12.25	12.25	12.29	1.00
18	255	194	7.05	7.35	7.49	7.53	7.49	7.45	7.36	7.34	7.38	7.21	7.14	7.40	7.53	1.50
19	179	288	2.73	2.92	3.08	3.17	3.17	3.14	3.04	2.97	3.00	2.98	2.92	3.14	3.17	1.50
20	107	348	3.64	4.00	4.18	4.22	4.20	4.15	4.03	3.99	4.04	3.89	3.79	4.14	4.22	1.50

- implies that the point was not inundated



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flooding Depth [m]

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

300 150 0
Meters

SCALE: 1:10,000 @ A3

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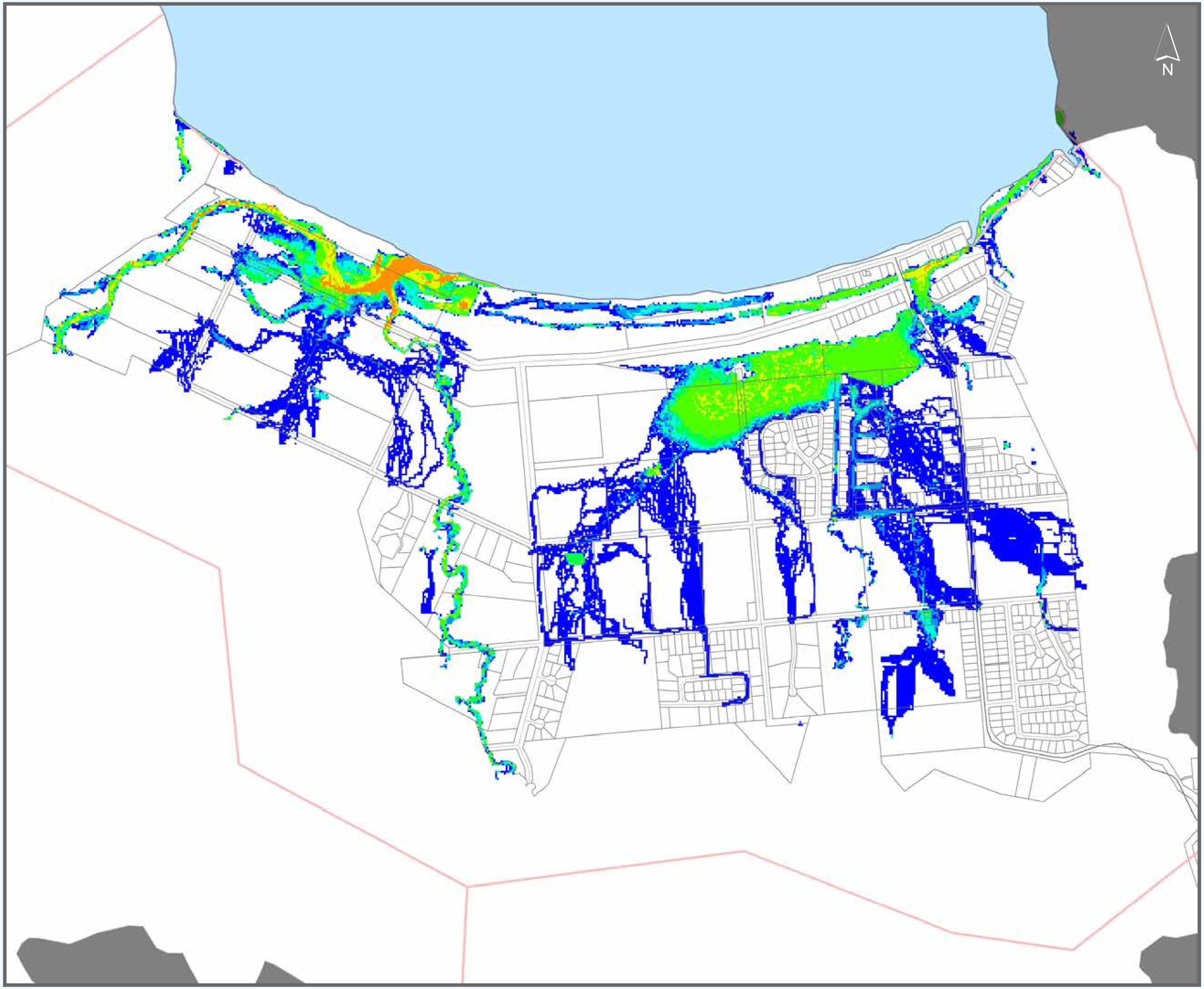
**Figure A1:
2y Flood Envelope**



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flooding Depth [m]

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

300 150 0
Meters

SCALE: 1:10,000 @ A3

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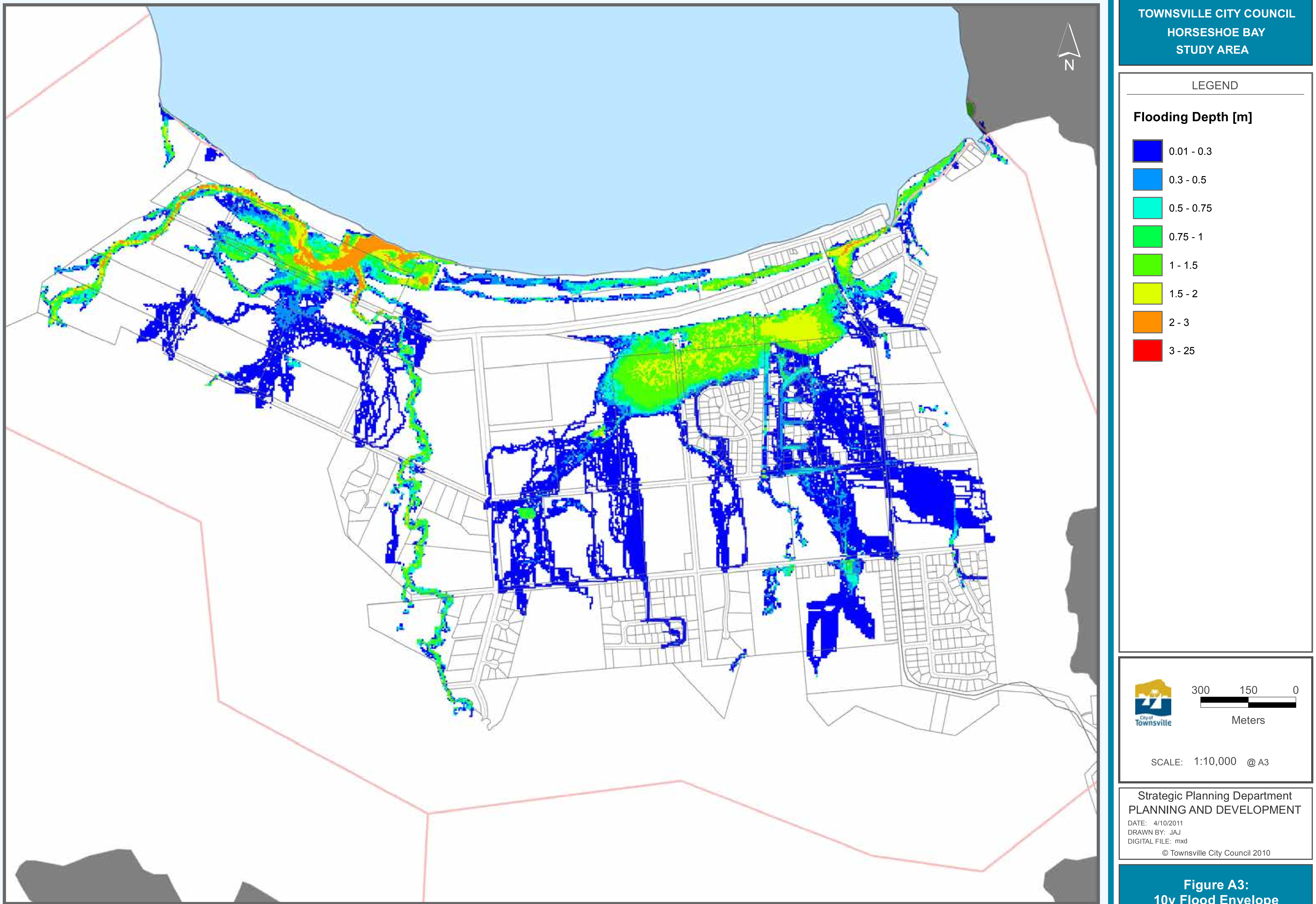
Figure A2:
5y Flood Envelope

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA



SCALE: 1:10,000 @ A3

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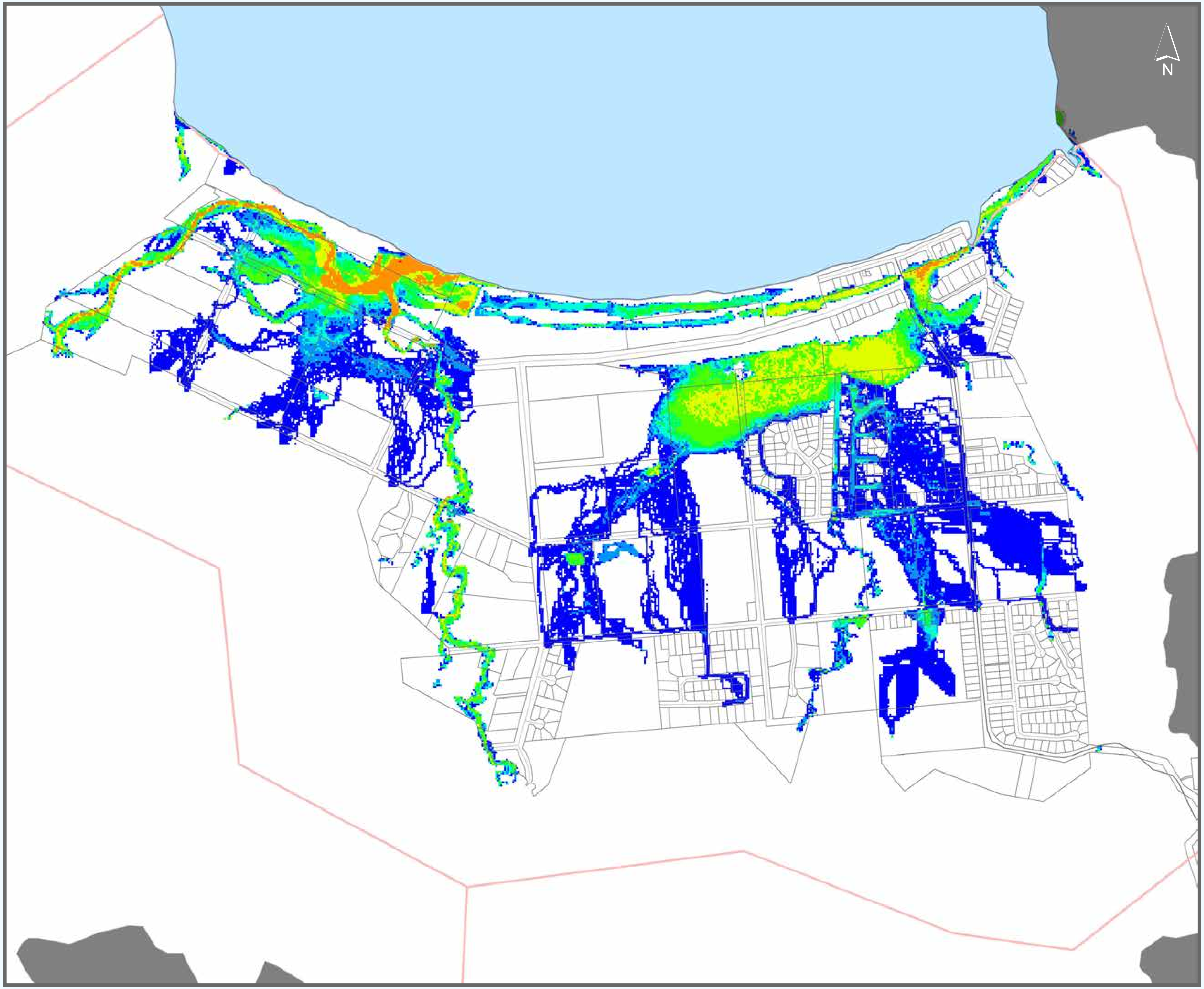
Figure A3:
10y Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

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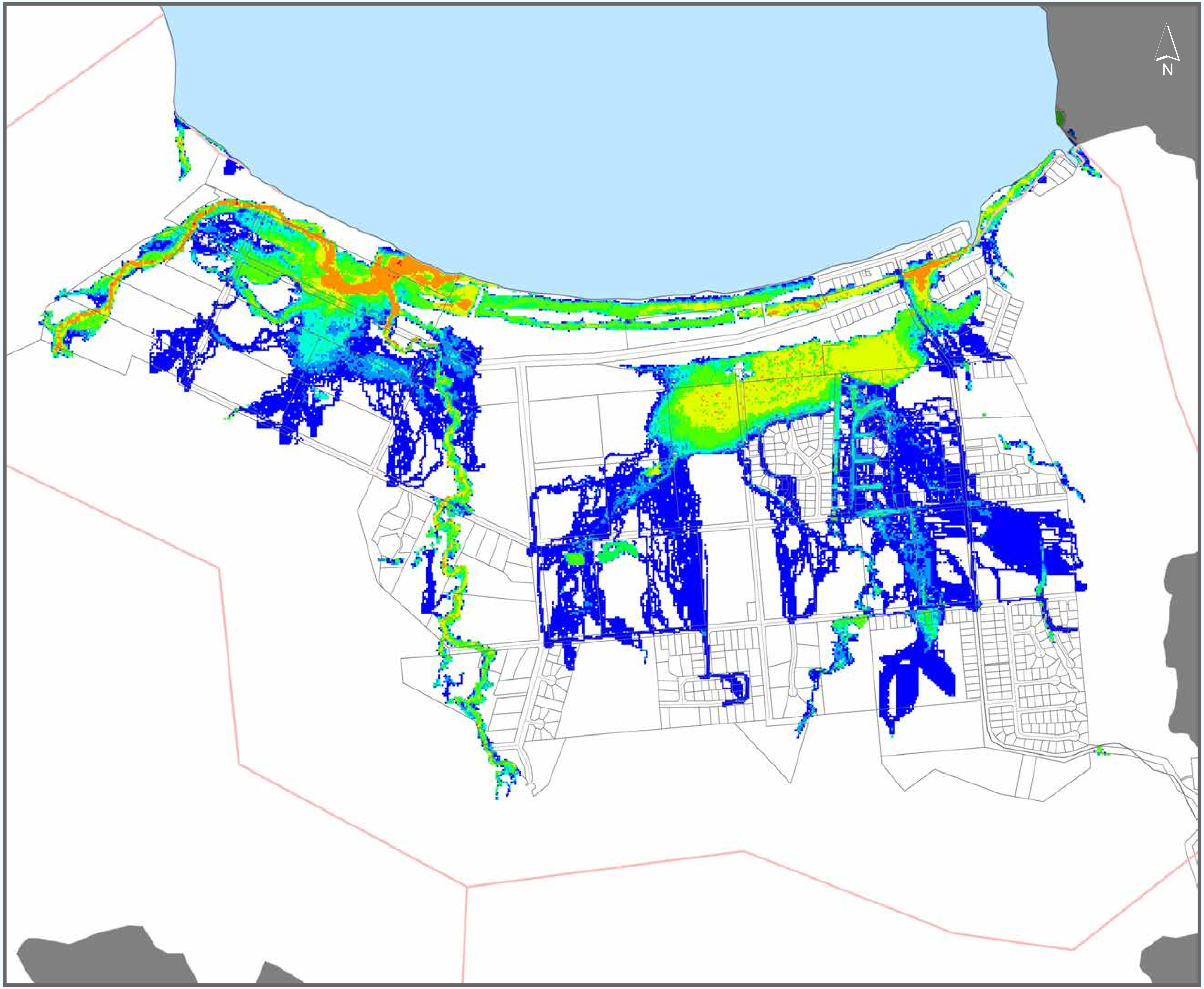
**Figure A4:
20y Flood Envelope**



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flooding Depth [m]

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

City of Townsville

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

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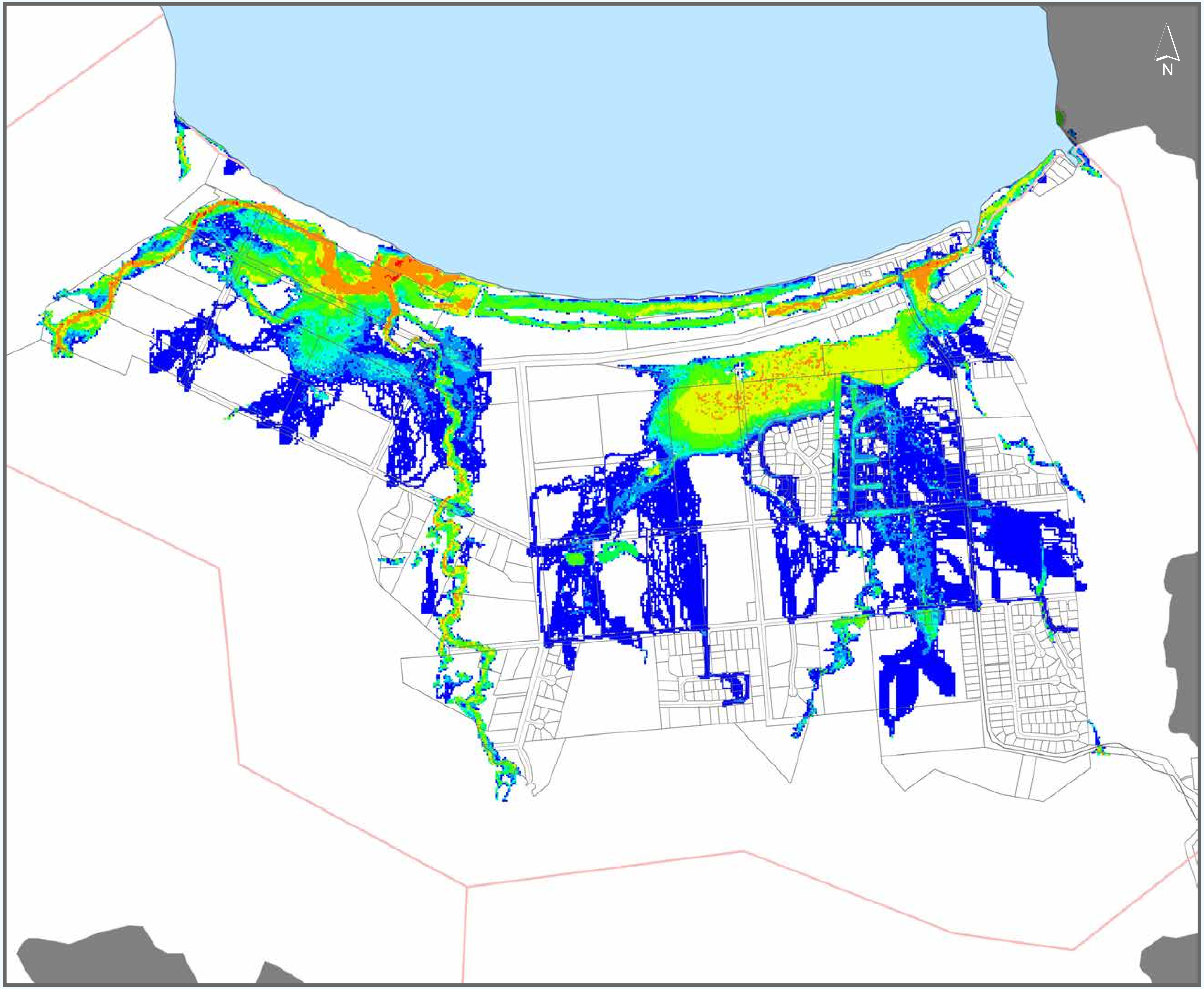
Figure A5:
50y Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flooding Depth [m]

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
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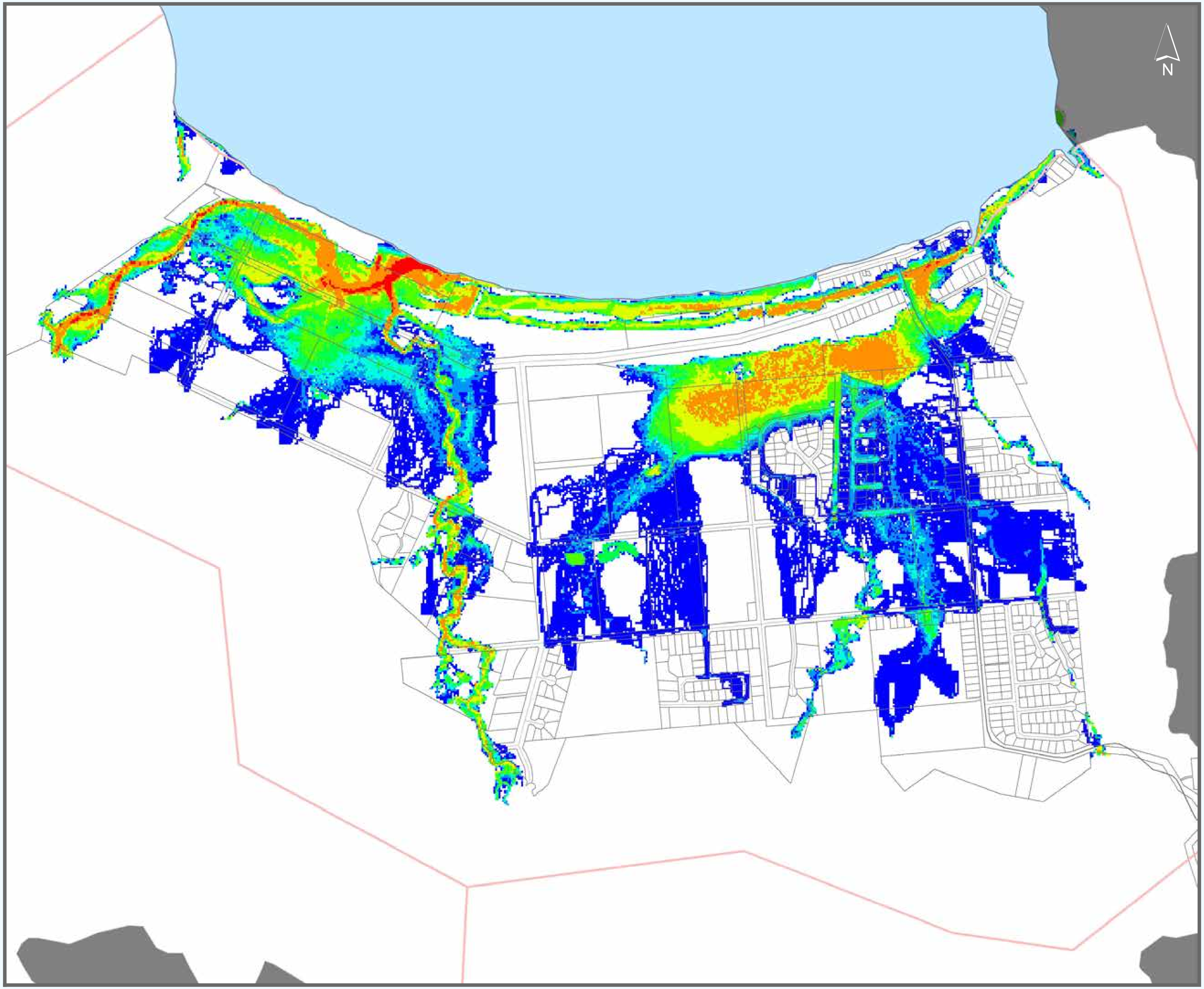
DIGITAL FILE: mxd

Figure A6:
100y Flood Envelope

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA



LEGEND

Flooding Depth [m]

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

300 150 0

Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 4/10/2011
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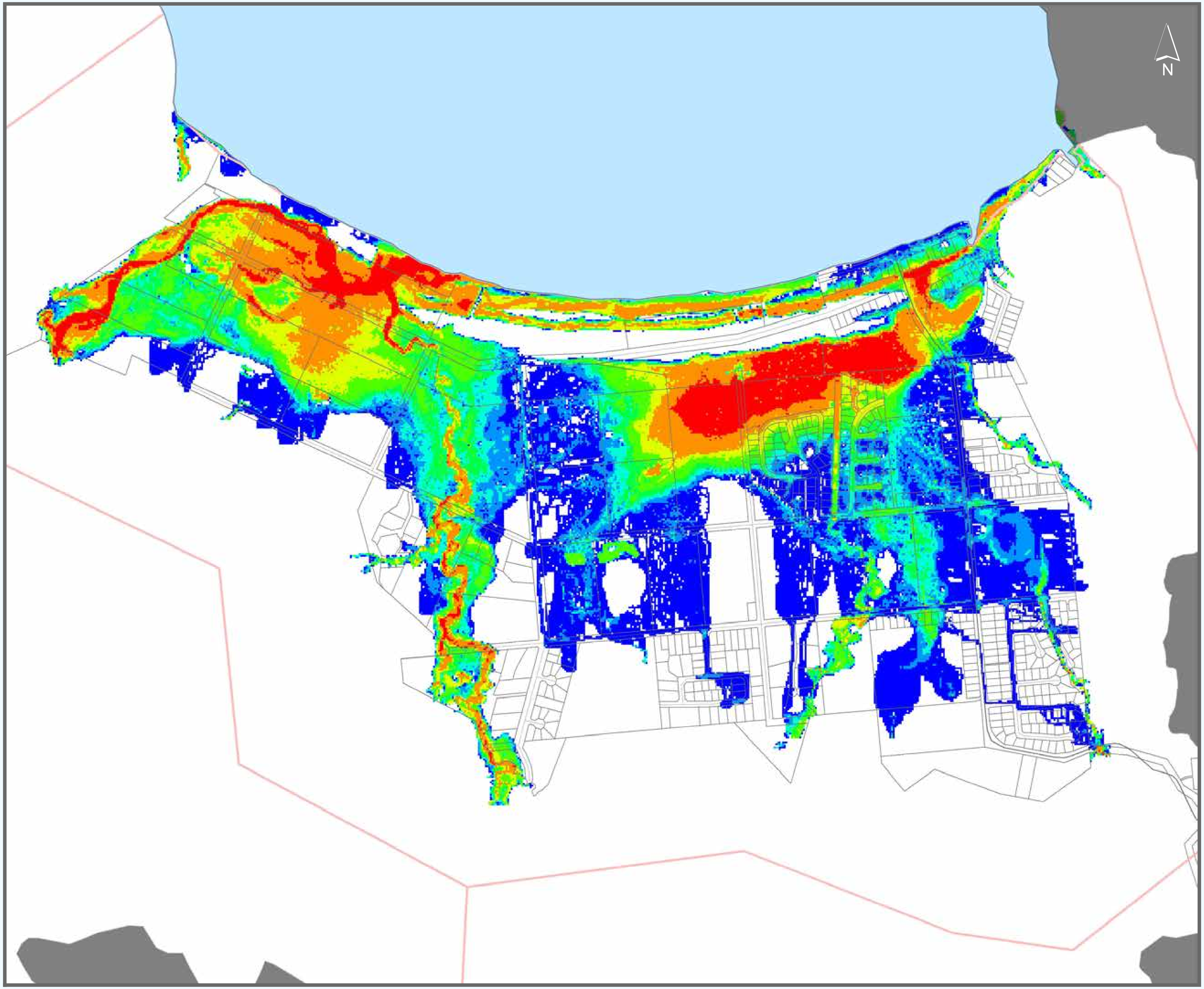
DIGITAL FILE: mxd

Figure A7:
500y Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flooding Depth [m]

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

300 150 0
Meters

SCALE: 1:10,000 @ A3

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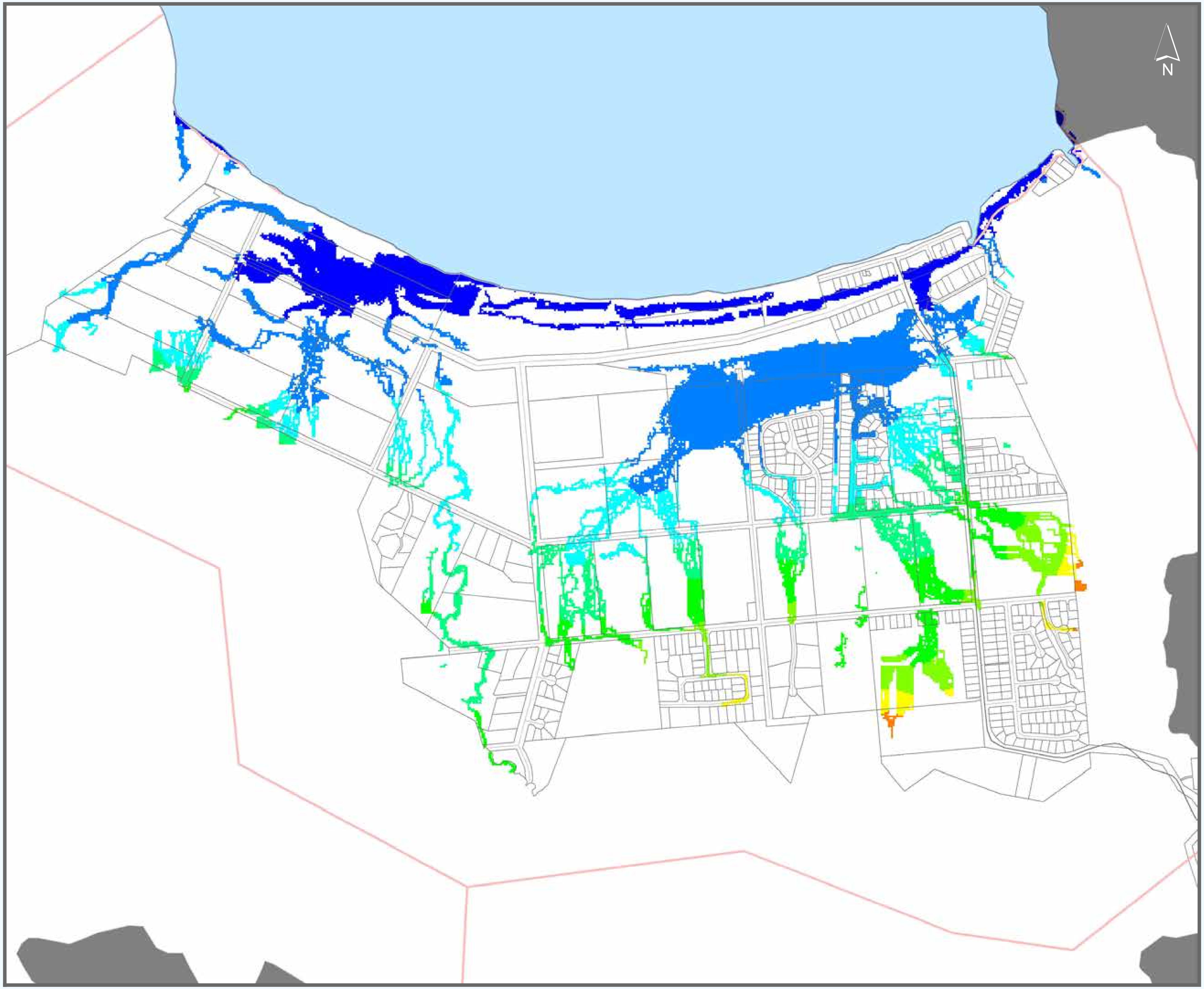
DIGITAL FILE: mxd

**Figure A8:
PMF Flood Envelope**



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Surface Elevation [m AHD]

1.254 - 2.5
2.5 - 4.5
4.5 - 7.5
7.5 - 11
11 - 15
15 - 19
19 - 23
23 - 28.5
28.5 - 38

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT
DATE: 4/10/2011
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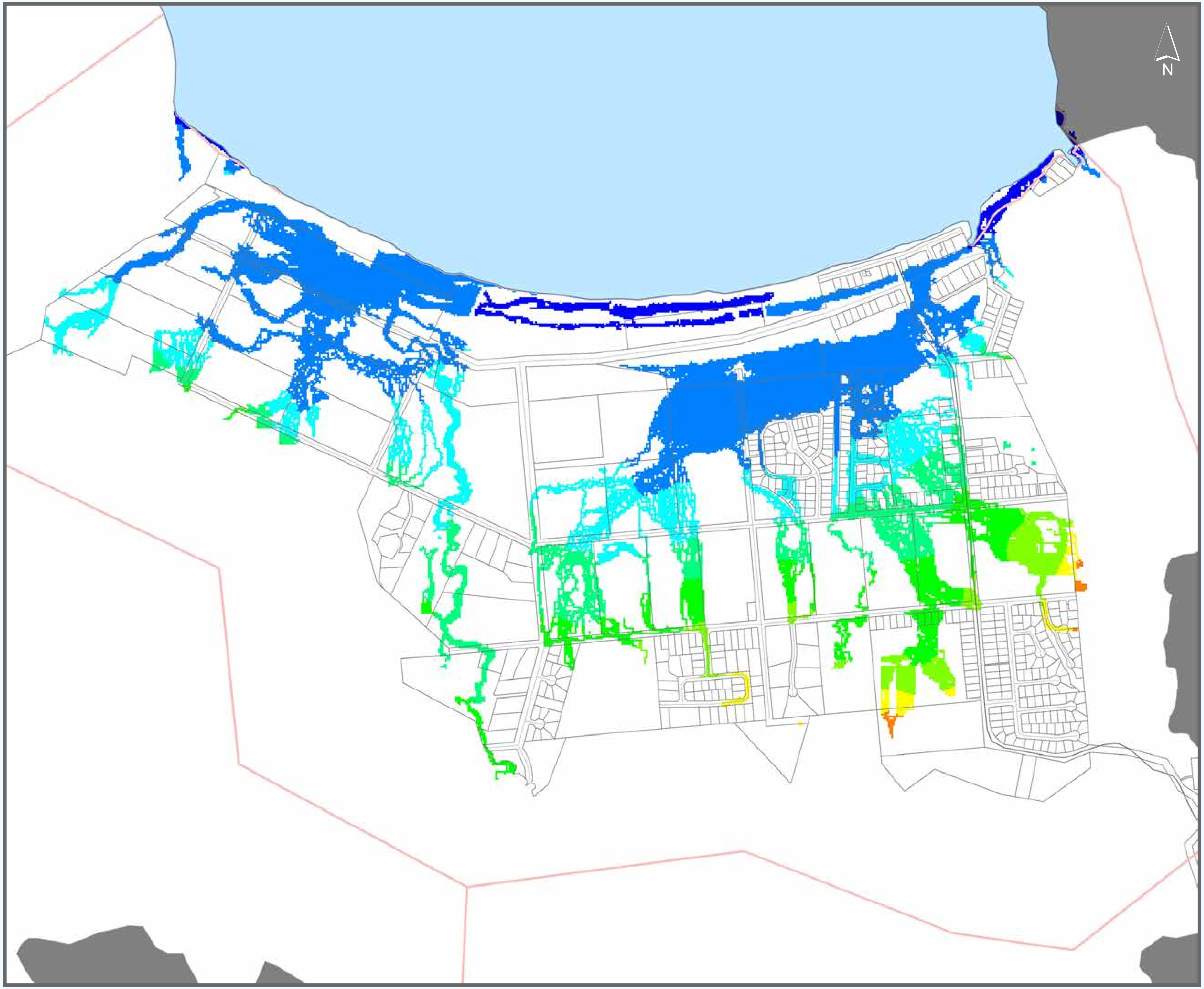
DIGITAL FILE: mxd

Figure A9:
2y Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Surface Elevation [m AHD]

- 1.254 - 2.5
- 2.5 - 4.5
- 4.5 - 7.5
- 7.5 - 11
- 11 - 15
- 15 - 19
- 19 - 23
- 23 - 28.5
- 28.5 - 38

City of Townsville

300 150 0

Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 4/10/2011
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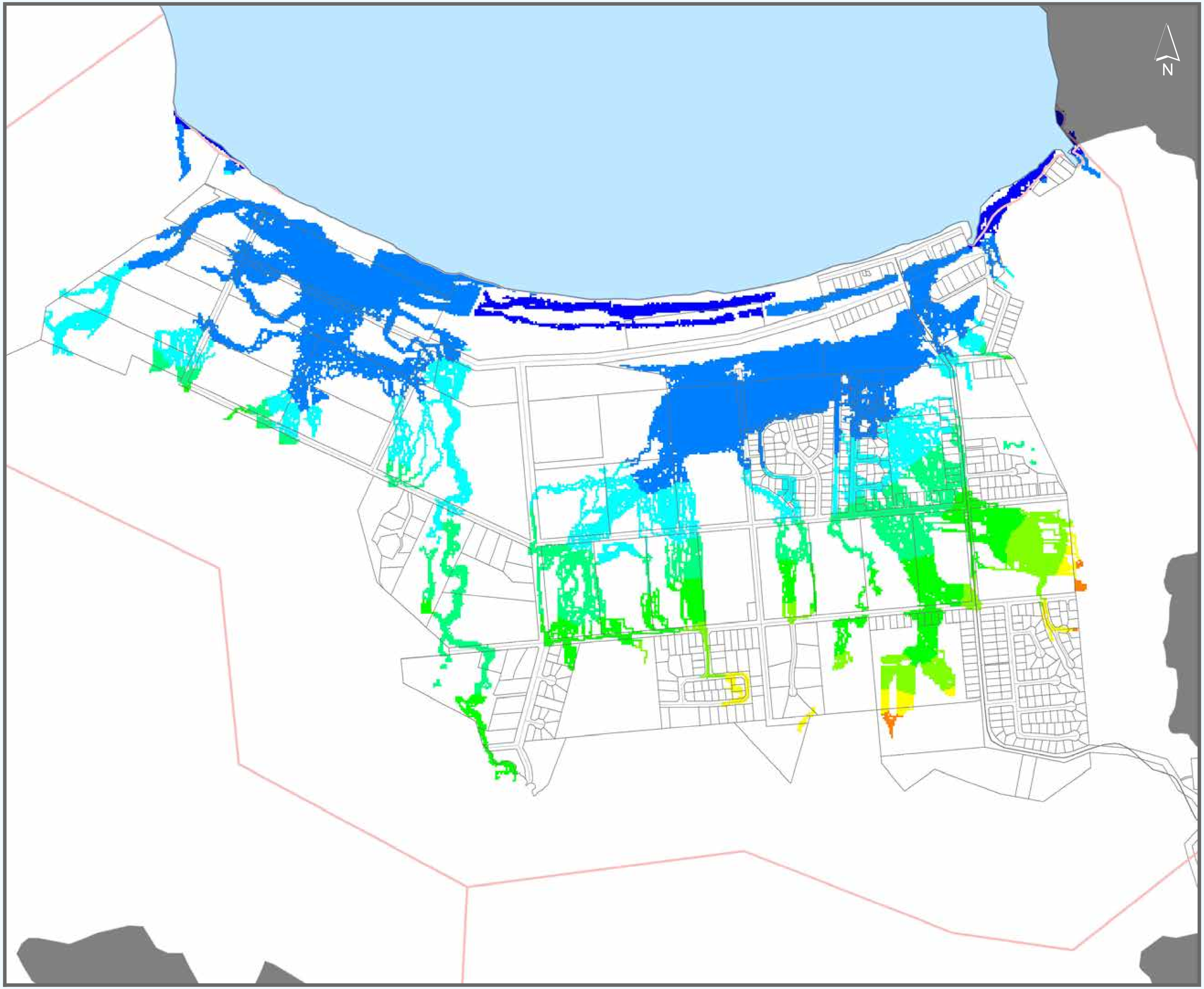
DIGITAL FILE: mxd

Figure A10:
5y Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Surface Elevation [m AHD]

- 1.254 - 2.5
- 2.5 - 4.5
- 4.5 - 7.5
- 7.5 - 11
- 11 - 15
- 15 - 19
- 19 - 23
- 23 - 28.5
- 28.5 - 38

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 4/10/2011
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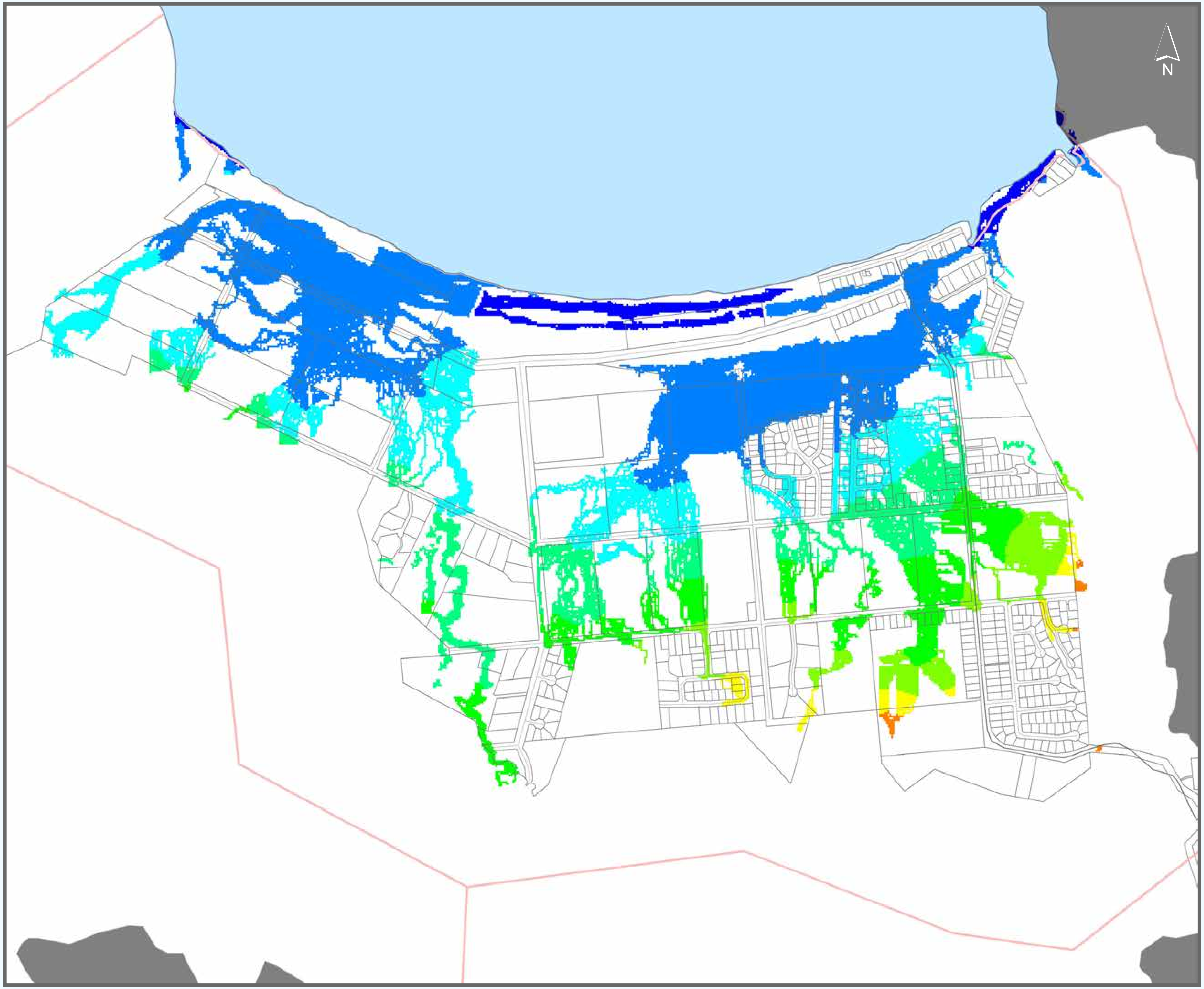
DIGITAL FILE: mxd

**Figure A11:
10y Flood Envelope**



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Surface Elevation [m AHD]

- 1.254 - 2.5
- 2.5 - 4.5
- 4.5 - 7.5
- 7.5 - 11
- 11 - 15
- 15 - 19
- 19 - 23
- 23 - 28.5
- 28.5 - 38

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
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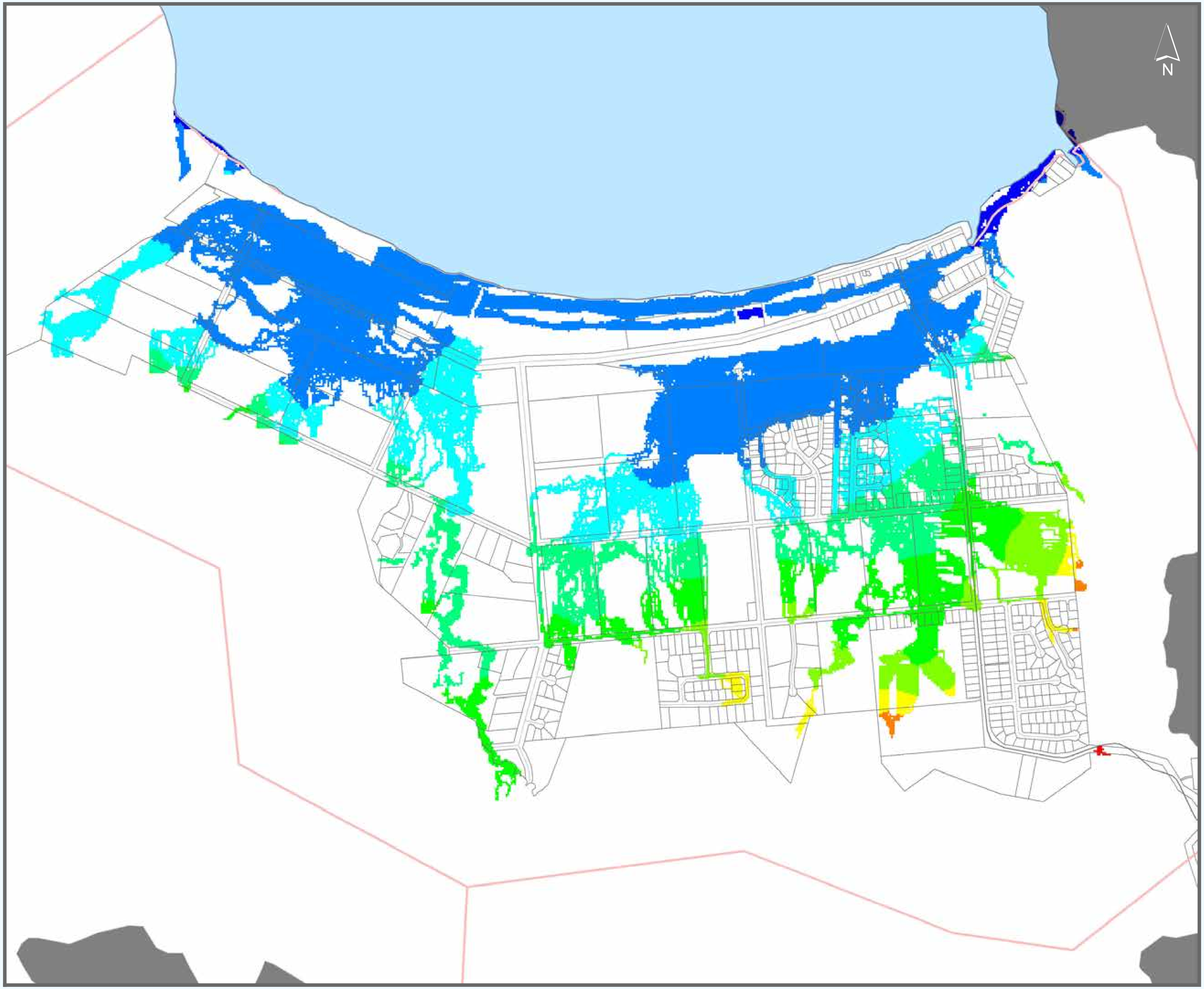
DIGITAL FILE: mxd

Figure A12:
20y Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Surface Elevation [m AHD]

- 1.254 - 2.5
- 2.5 - 4.5
- 4.5 - 7.5
- 7.5 - 11
- 11 - 15
- 15 - 19
- 19 - 23
- 23 - 28.5
- 28.5 - 38

300 150 0
Meters

SCALE: 1:10,000 @ A3

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PLANNING AND DEVELOPMENT

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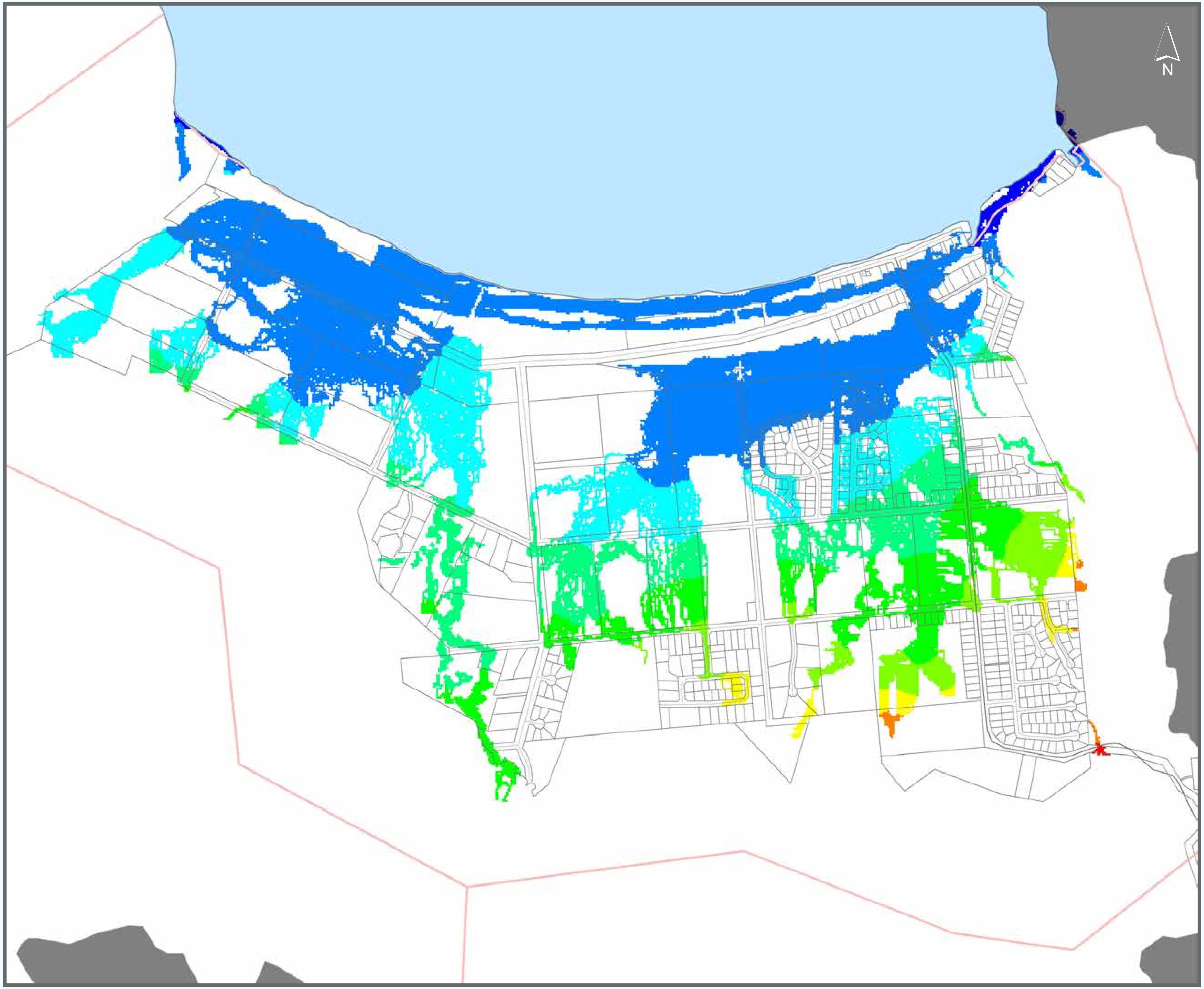
Figure A13:
50y Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Surface Elevation [m AHD]

- 1.254 - 2.5
- 2.5 - 4.5
- 4.5 - 7.5
- 7.5 - 11
- 11 - 15
- 15 - 19
- 19 - 23
- 23 - 28.5
- 28.5 - 38

300 150 0
Meters

SCALE: 1:10,000 @ A3

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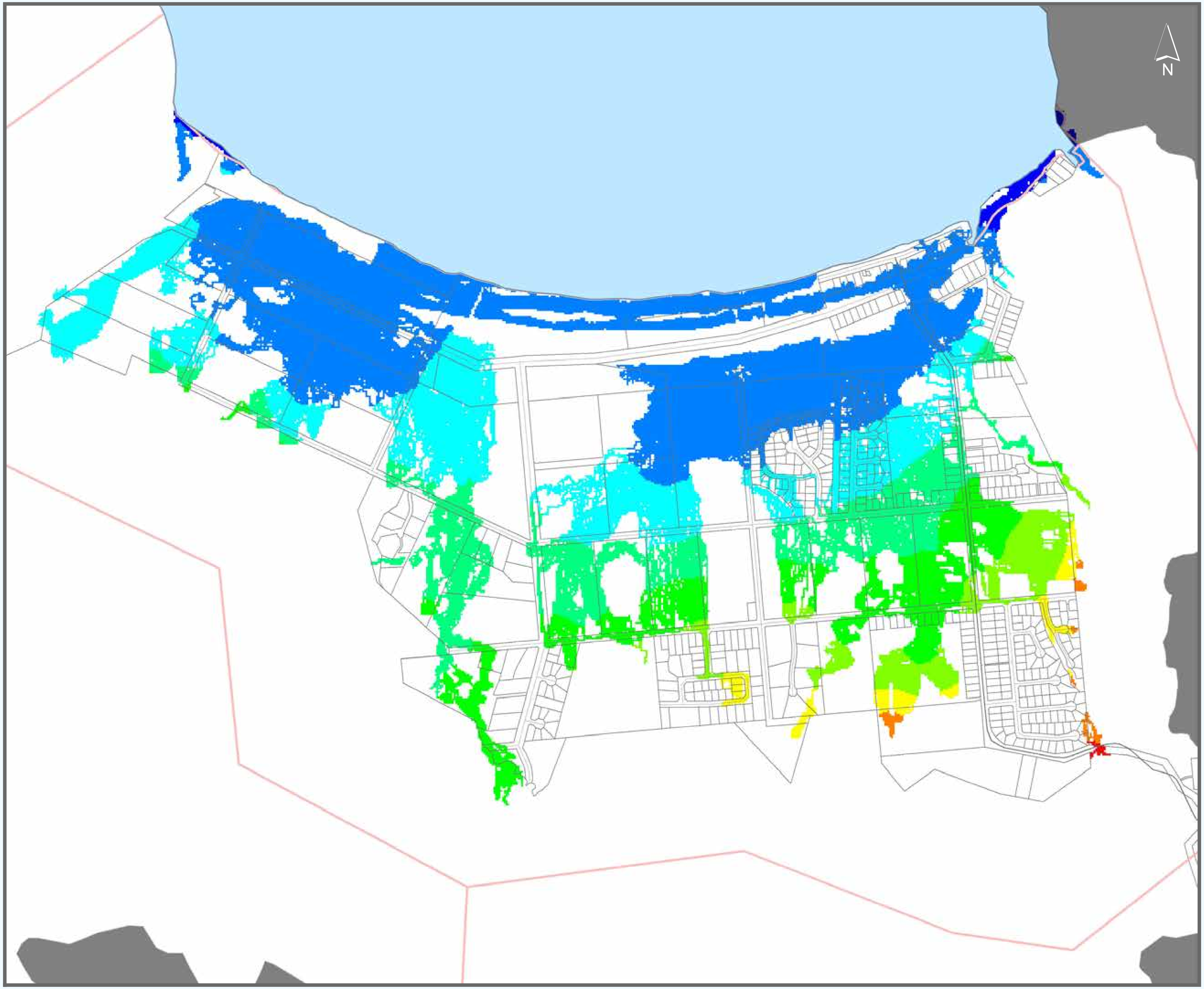
DIGITAL FILE: mxd

Figure A14:
100y Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Surface Elevation [m AHD]

- 1.254 - 2.5
- 2.5 - 4.5
- 4.5 - 7.5
- 7.5 - 11
- 11 - 15
- 15 - 19
- 19 - 23
- 23 - 28.5
- 28.5 - 38

300 150 0
Meters

SCALE: 1:10,000 @ A3

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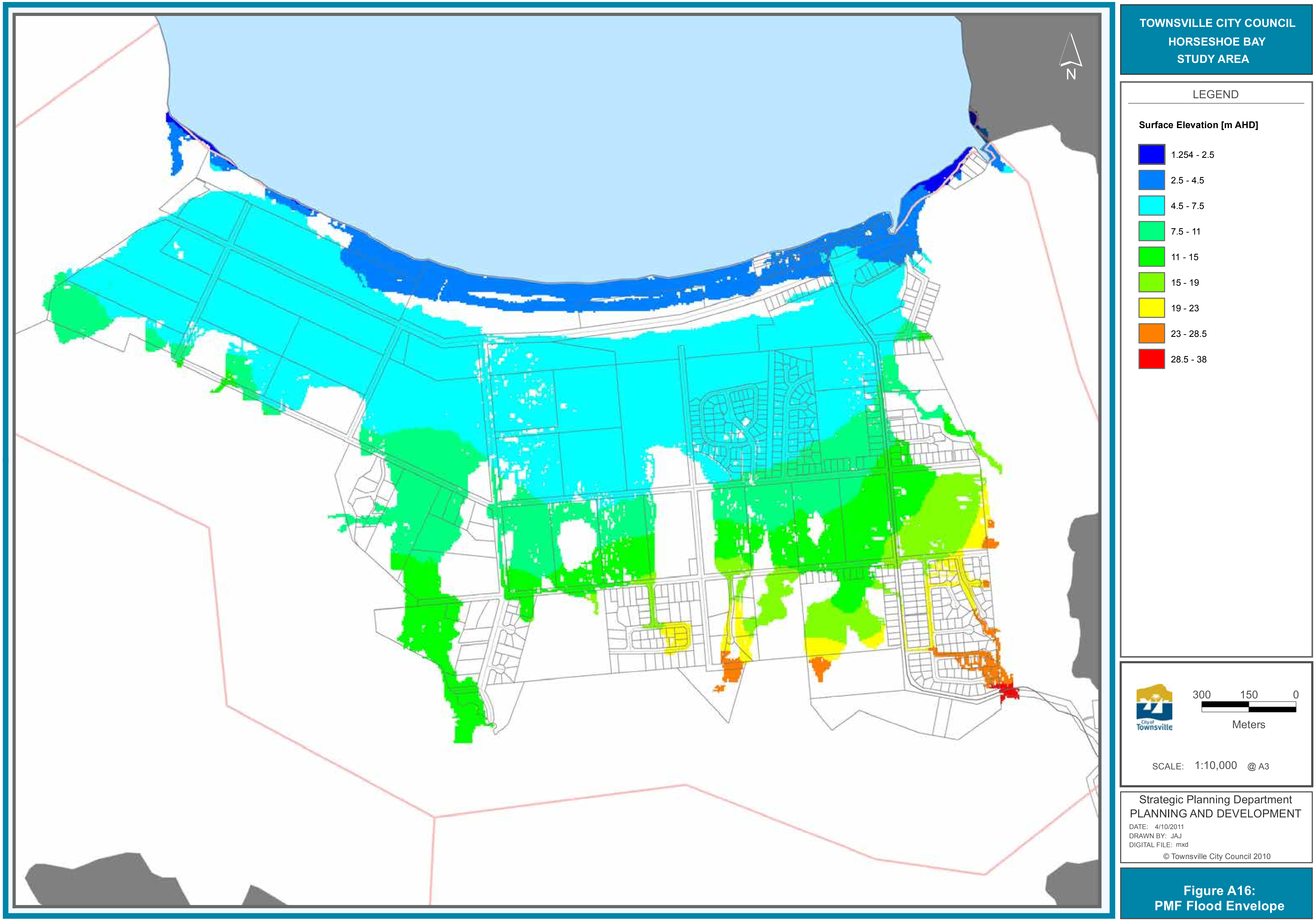
DIGITAL FILE: mxd

Figure A15:
500y Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

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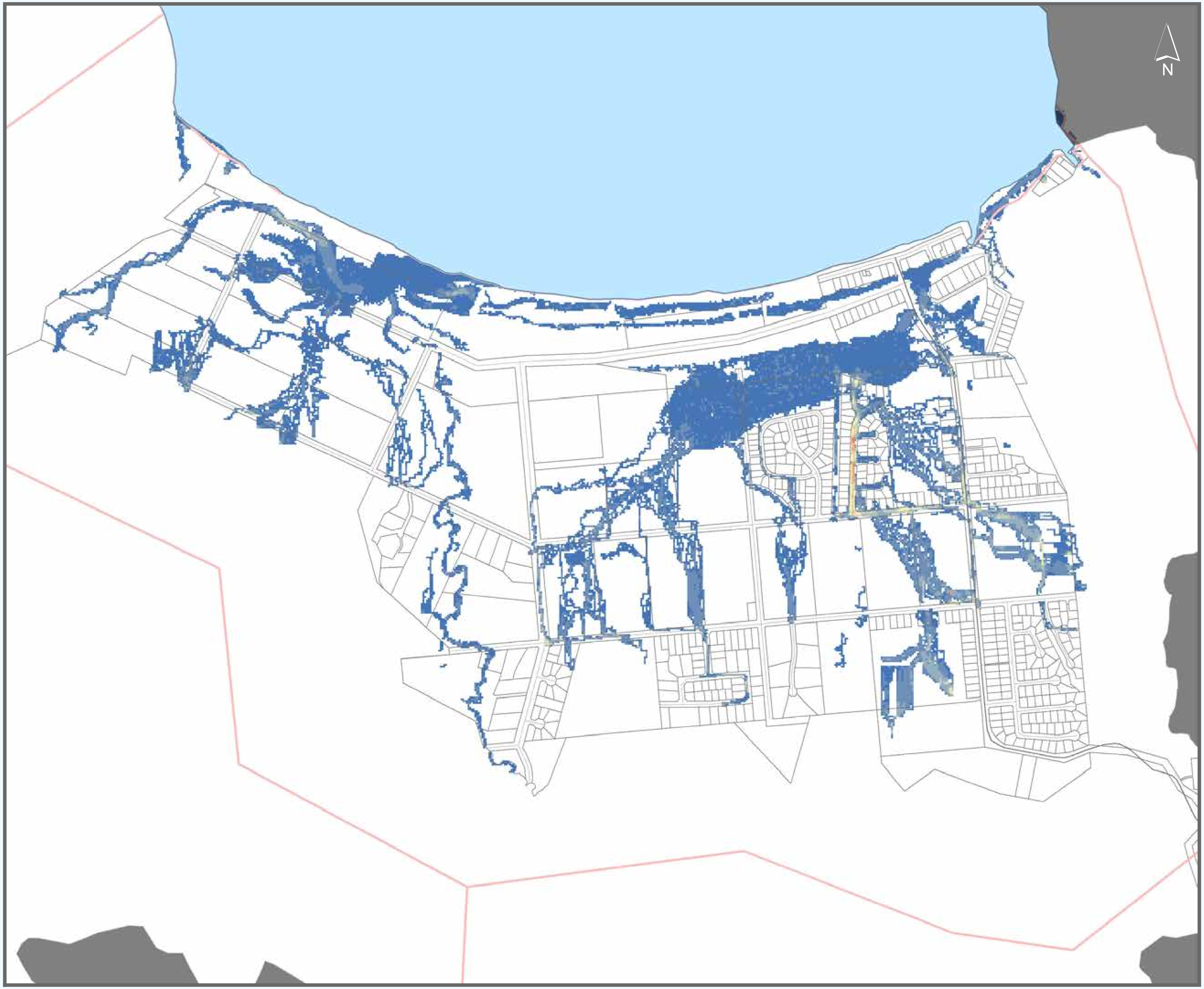
PLANNING AND DEVELOPMENT
DATE: 4/10/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure A16:
PMF Flood Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flow Velocity [m/s]

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 3
- 3 - 6

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT
DATE: 4/10/2011
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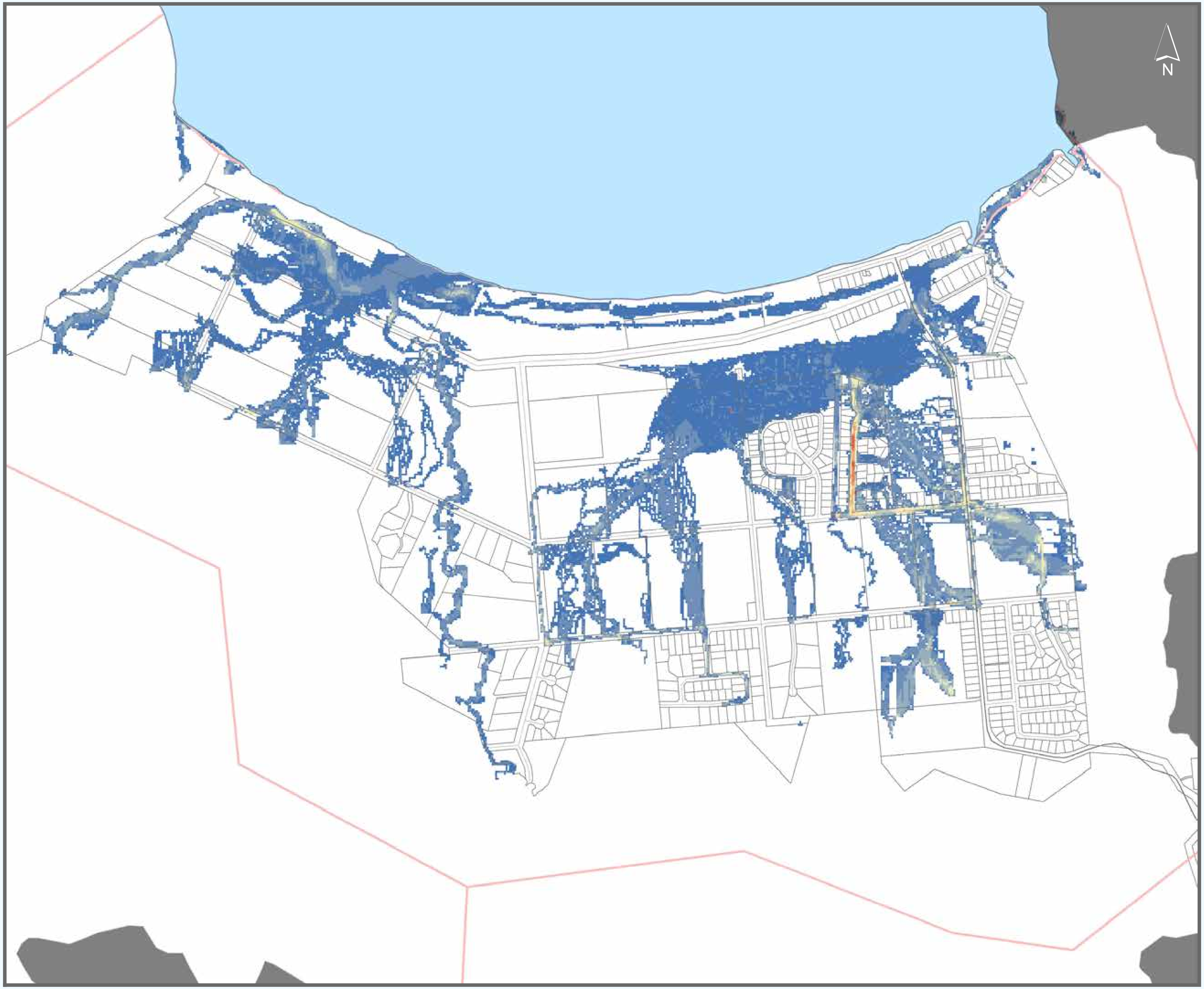
DIGITAL FILE: mxd

Figure A17:
2y Velocity Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flow Velocity [m/s]

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 3
- 3 - 6

City of Townsville

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT
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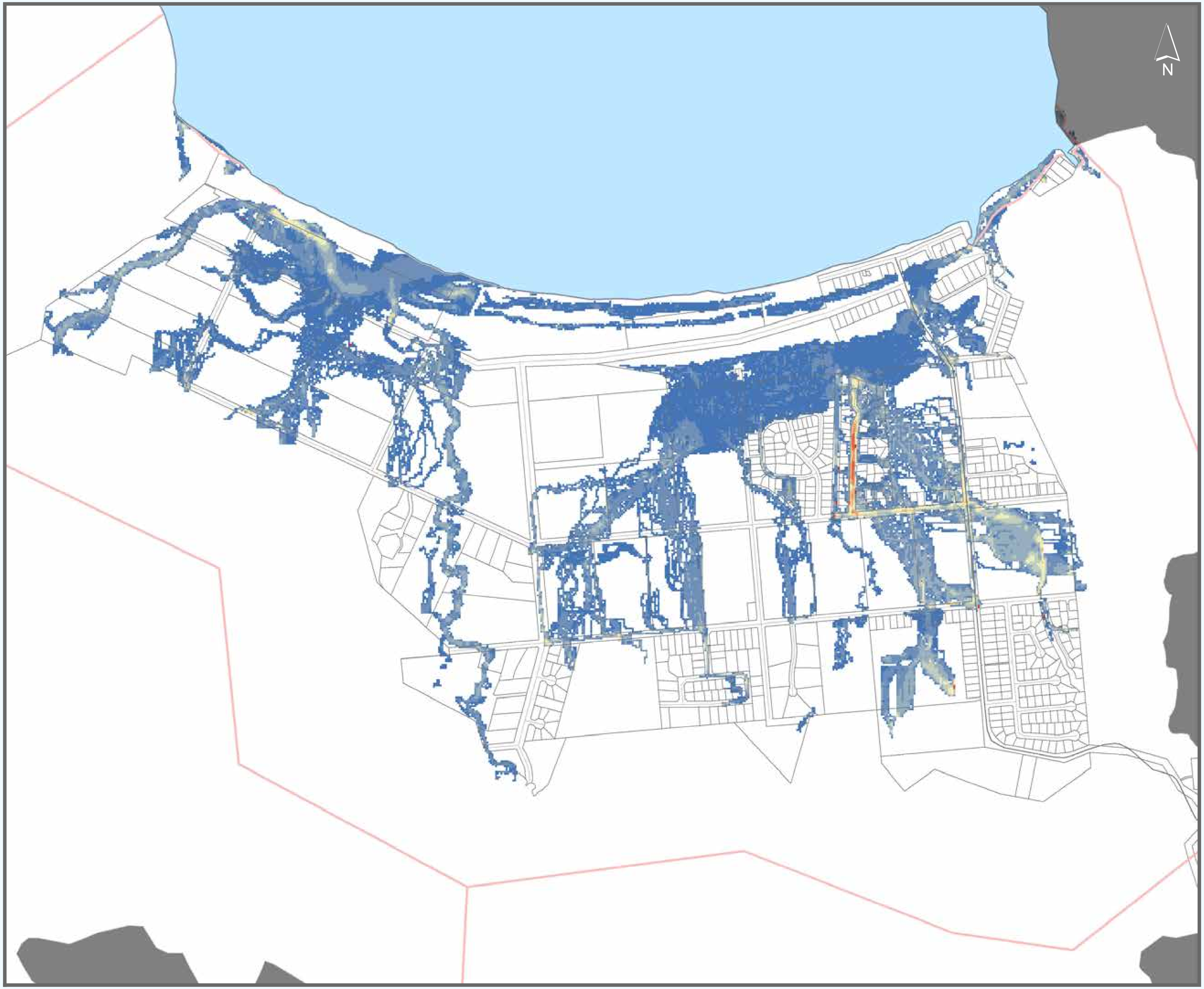
DIGITAL FILE: mxd

Figure A18:
5y Velocity Envelope

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA



LEGEND

Flow Velocity [m/s]

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 3
- 3 <

City of Townsville

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
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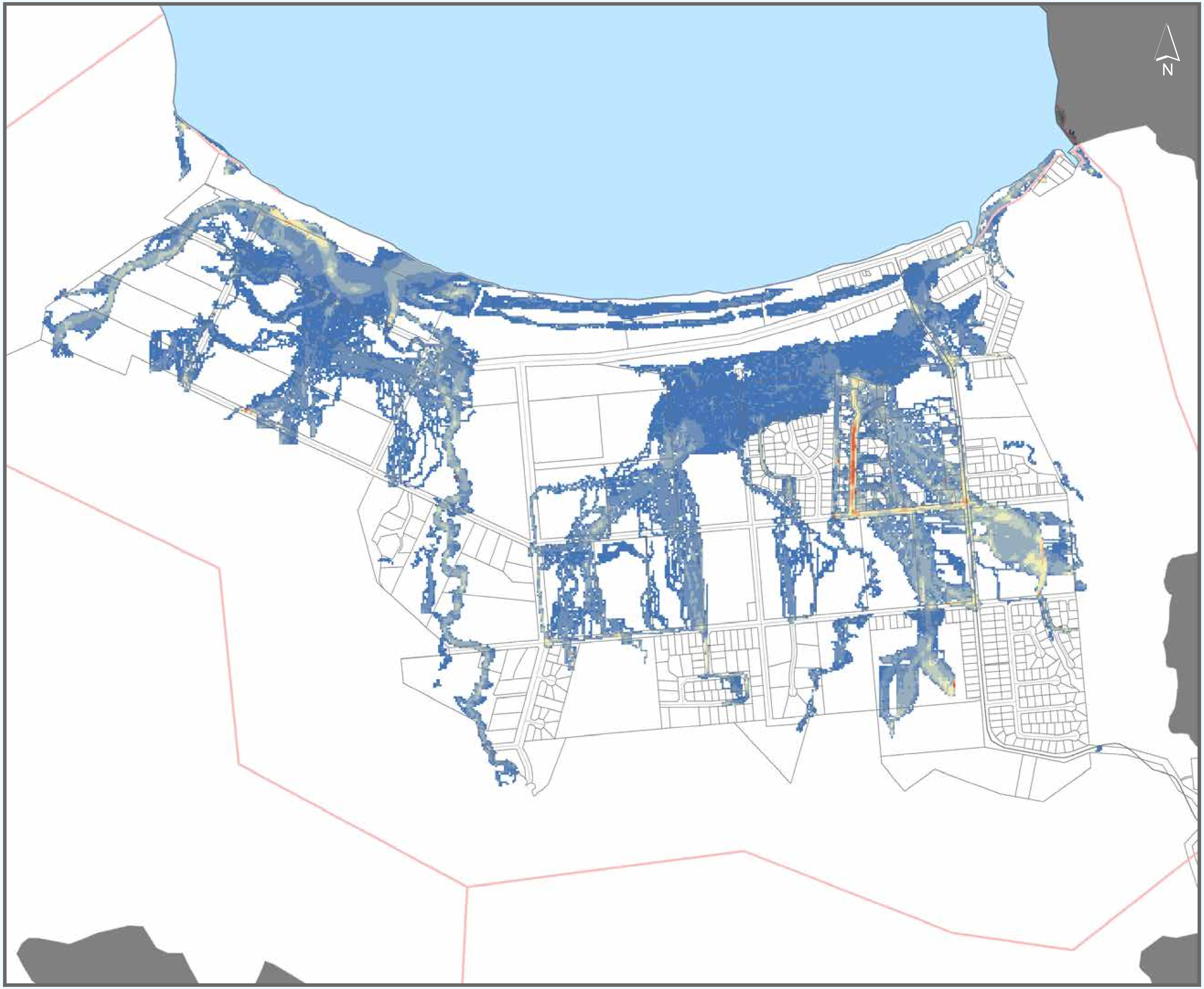
DIGITAL FILE: mxd

**Figure A19:
10y Velocity Envelope**



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flow Velocity [m/s]

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 3
- 3 <

300 150 0
Meters

SCALE: 1:10,000 @ A3

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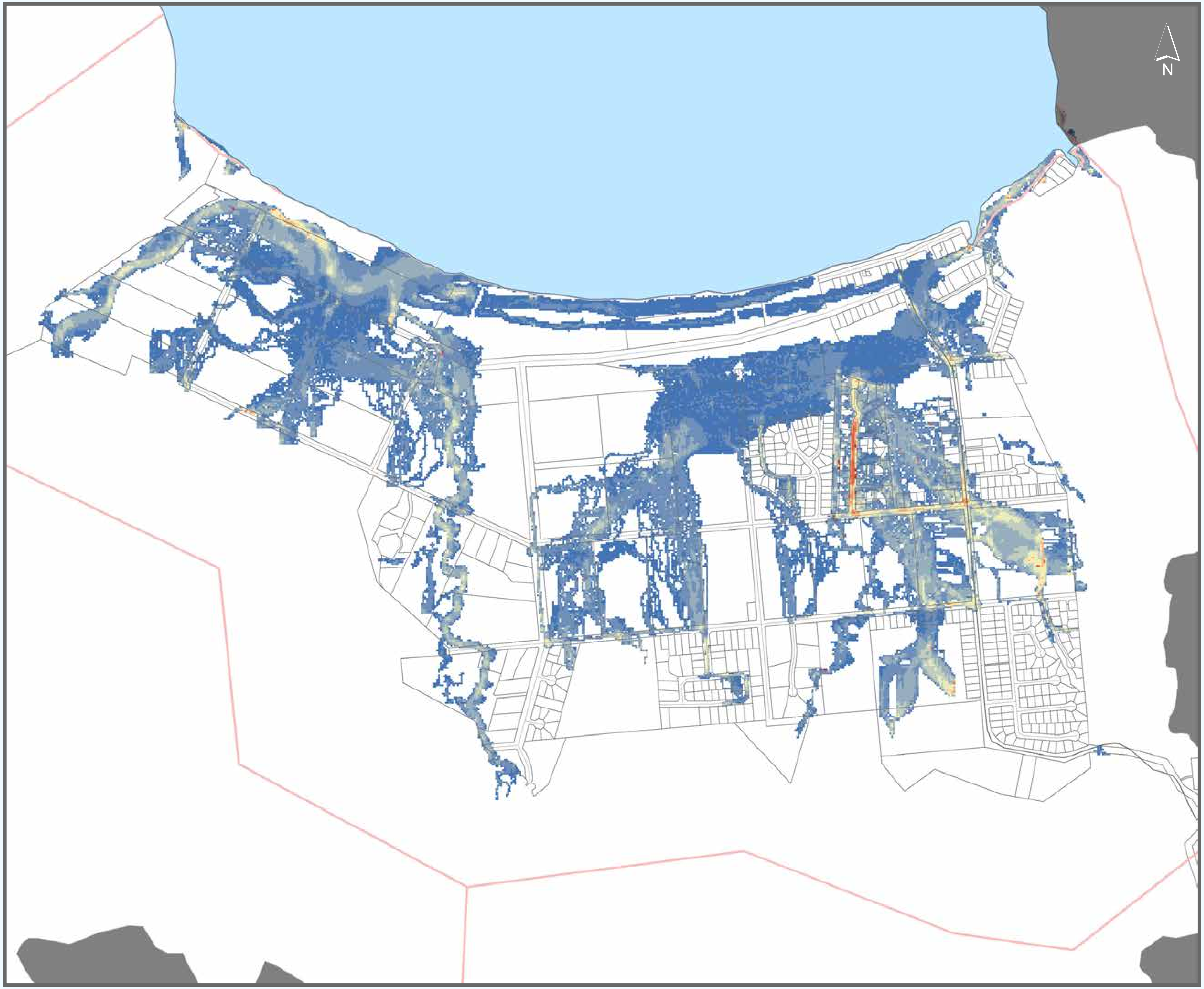
**Figure A20:
20y Velocity Envelope**



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flow Velocity [m/s]

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 3
- 3 <

City of Townsville

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
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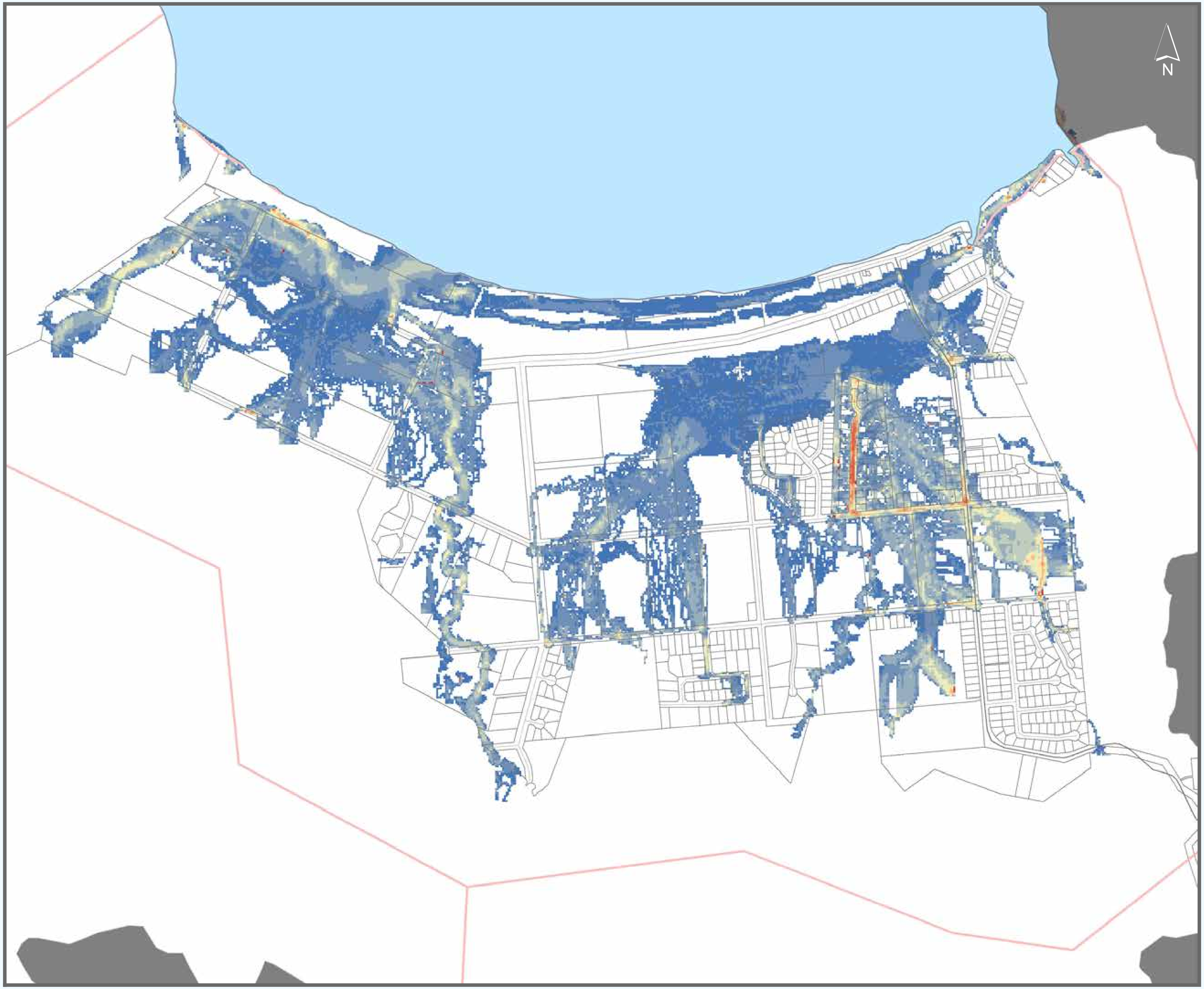
Figure A21:
50y Velocity Envelope



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flow Velocity [m/s]

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 3
- 3 <

City of Townsville

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
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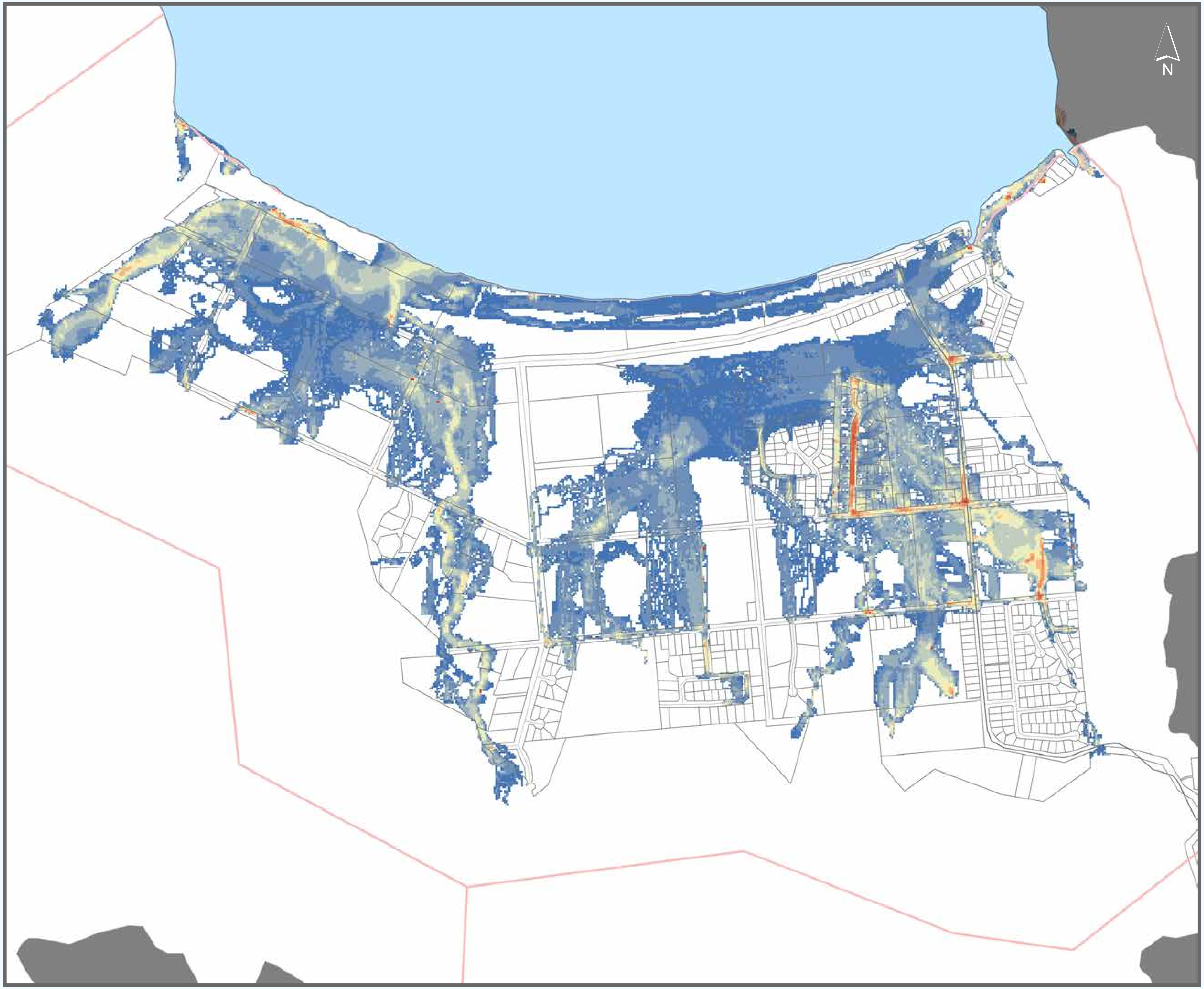
DIGITAL FILE: mxd

Figure A22:
100y Velocity Envelope

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA



LEGEND

Flow Velocity [m/s]

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 3
- 3 <

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
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DATE: 4/10/2011
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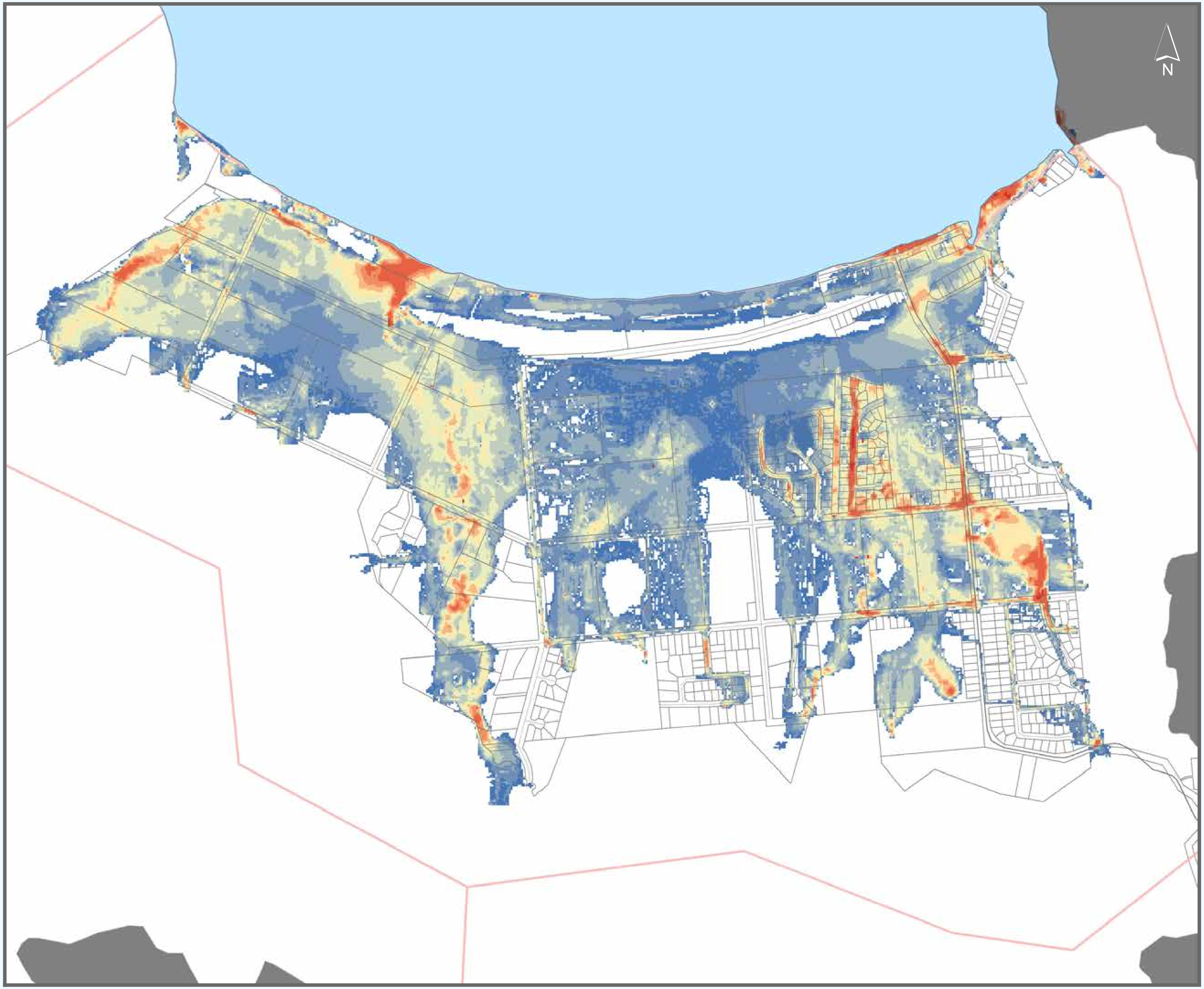
DIGITAL FILE: mxd

**Figure A23:
500y Velocity Envelope**



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Flow Velocity [m/s]

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 3
- 3 <

City of Townsville

300 150 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT
DATE: 4/10/2011
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DIGITAL FILE: mxd

**Figure A24:
PMF Velocity Envelope**

Appendix B

Rational Method Calculations

Table B1: Rational Method Calculations

Catchment	WB-1	EA-6	EB-1	EA-9P1	EA-10	EA-9A	EA-5A	WA-6
XP-RAFTS								
Max event 50y	90m	90m	90m	60m	60&90m	60&90m	90m	90m
Flow 50y (cms)	96.0	70.4	14.9	20.0	15.6	14.1	11.7	70.0
Max event 2y	12h	24h	12h	90m	12h	90m	12h	12h
Flow 2y (cms)	22.8	17.4	3.3	5.7	3.7	4.1	2.6	16.132
Area (Hectares)	439.00	275.00	47.30	54.80	57.00	36.80	35.70	255.00
Area (km2)	4.39	2.75	0.47	0.55	0.57	0.37	0.36	2.55
unit area flow 50y (cms/km2)	21.9	25.6	31.5	36.5	27.4	38.3	32.8	27.5
unit area flow 2y (cms/km2)	5.2	6.3	6.9	10.4	6.5	11.1	7.2	6.3
Rational Method								
Time of Concentration (min)	81.1	78	44	32	45	23	32	68
Average Rainfall Intensity 50y (mm/h)	95	97	131	153	131	178	153	104
Average Rainfall Intensity 2y (mm/h)	43.5	44	60.5	70	60	82	70	49
Area (ha)	439.00	275.00	47.30	54.80	57.00	36.8	35.7	255.00
Fraction Impervious	0	0.13	0.08	0.2	0.05	0.12	0	0
Intensity 1h10y (mm/h)	80	80	80	80	80	80	80	80
C10	0.7	0.74	0.7	0.7	0.7	0.7	0.7	0.7
Frequency Factor for 50y	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Coefficient of Discharge for 50y	0.805	0.851	0.805	0.805	0.805	0.805	0.805	0.805
Frequency Factor for 2y	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Coefficient of Discharge for 2y	0.595	0.629	0.595	0.595	0.595	0.595	0.595	0.595
Conversion factor	0.00278	0.00278	0.00278	0.00278	0.00278	0.00278	0.0028	0.00278
Peak Flow Rate for 50y (m3/s)	93.3	63.1	13.9	18.8	16.7	14.7	12.2	59.3
Peak Flow Rate for 2y (m3/s)	31.6	21.2	4.7	6.3	5.7	5.0	4.1	20.7

Appendix C

Climate Change Difference Maps

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Water Level Difference [m]

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- > 3

City of Townsville

290 145 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 17/10/2011
DRAWN BY: JAJ
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Figure C1: Climate Change Water Level Difference for 2 year ARI

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Water Level Difference [m]

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- > 3

290 145 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
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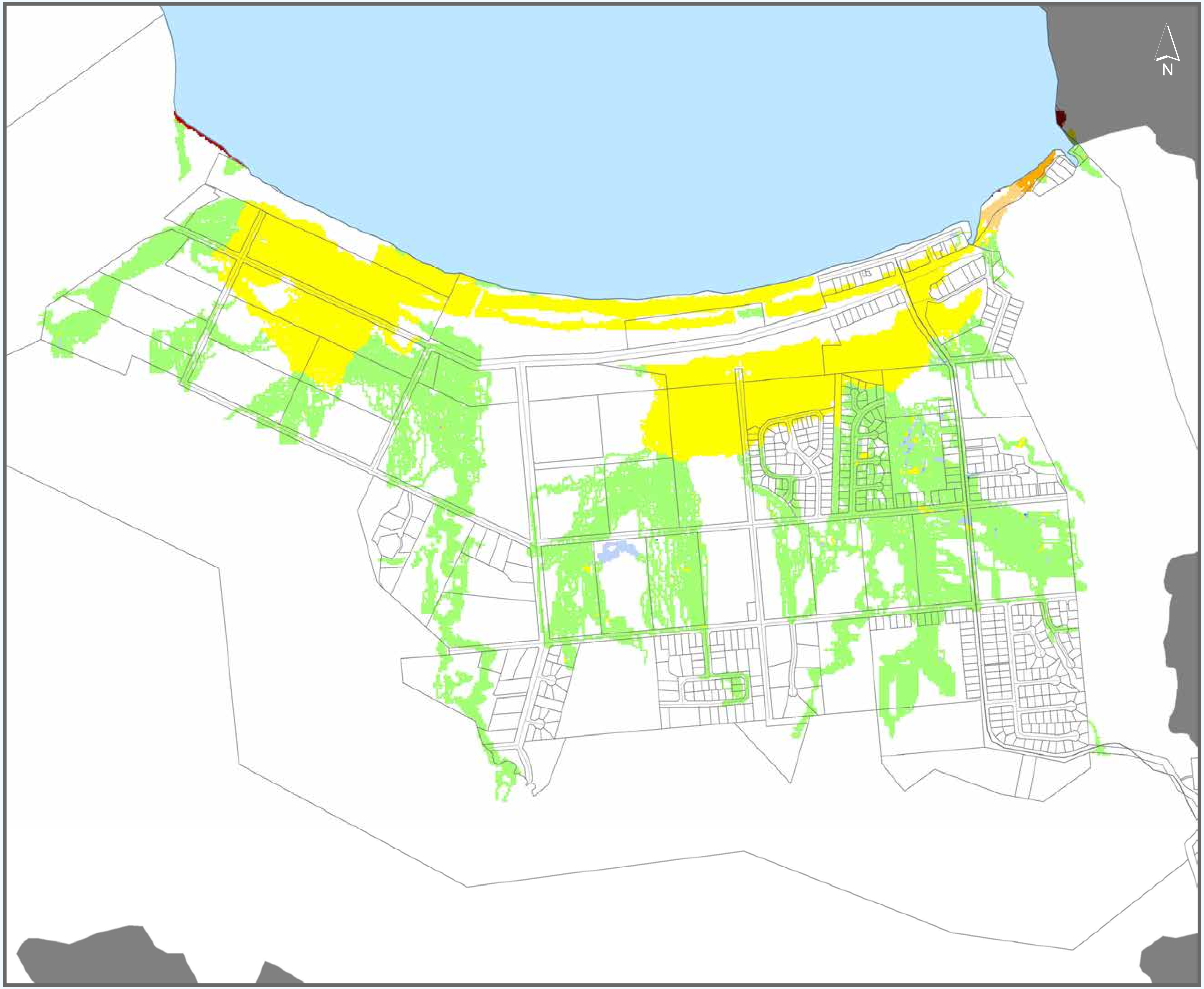
Figure C2: Climate Change Water Level Difference for 50 year ARI



TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Water Level Difference [m]

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- > 3

290 145 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
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Figure C3: Climate Change Water Level Difference for 100 year ARI

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Water Level Difference [m]

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- > 3

City of Townsville

290 145 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT
DATE: 17/10/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure C4: DCC Water Level Difference for 50 year ARI

TOWNSVILLE CITY COUNCIL
HORSESHOE BAY
STUDY AREA

LEGEND

Water Level Difference [m]

< -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
> 3

290 145 0
Meters

SCALE: 1:10,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 17/10/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure C5: DCC Water Level Difference for 100 year ARI