TOWNSVILLE CITY COUNCIL
NORTH WARD
CATCHMENT

LEGEND

- Calibration Points

200 100 0

Meters

SCALE: 1:6,000 @ A3

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PLANNING AND DEVELOPMENT

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Fig 2.3.1
Historical Flood Levels

2.4 Historical Rainfall

North Ward currently has a Rainfall Alert gauge on Howitt Street, and there is also a Rainfall Alert gauge situated on Castle Hill. Both of these were installed recently in 2008 and do not have a long period of record. To assist with calibration, gauges from outside the catchment with a longer period of record were also used. Data from the Townsville Aero and Mysterton gauges was obtained to help calibrate the hydrological & hydraulic models. **Figure 2.4.1** shows the location of the rainfall alert gauges.

2.5 Design Rainfall

Design storms are specified from IFD input data. The IFD input parameters for Townsville, were taken from Australian Rainfall and Runoff, 1987, Volume 2. **Table 2.5.1** shows the IFD input data.

Table 2.5.1: IFD Input Data for Townsville

Parameter	Value
Latitude [° E]	19.2667
Longitude [° S]	146. 8167
1 hour, 2 year intensity [mm/h]	53.7
12 hour, 2 year intensity [mm/h]	11.71
72 hour, 2 year intensity [mm/h]	3.85
1 hour, 50 year intensity [mm/h]	110.5
12 hour, 50 year intensity [mm/h]	24.5
72 hour, 50 year intensity [mm/h]	9.34
Average Regional Skewness, G	0.06
Geographical Factor, F2	3.93
Geographical Factor, F50	17.1

2.6 GIS Layers

A number of standard base GIS layers were used to create this model including;

- Urban 2009 Aerial Photograph;
- Stormwater Infrastructure;
- Cadastral layer for determining roughness, pervious and impervious areas; and
- Roads for helping determine subcatchment break up.

As well as these standard base GIS layers, a number of layers were created as a result of the study:

- Surveyed Stormwater Infrastructure Invert Levels
- Subcatchment Discharge Locations
- 1D Extent
- North Ward Subcatchment Breakup
- North Ward Major Catchments

Figure 2.6.1 A1 to B2 show some of the GIS layers used.

TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT

LEGEND

- Alert Gauges

N

Townsville Airport

North Ward

Castle Hill

Mysterton

TOWN COMMON
ROWES BAY
NORTH WARD
CASTLE HILL
MOUNT ST JOHN
GARBUTT
WEST END
CURRAJONG
RAILWAY ESTATE
VINCENT
PIMLICO
GULLIVER
HEATLEY
MYSTERTON
HERMIT PARK
STUART
AITKENVALE
MUNDINGBURRA
OONOONBA
ROSSLEA
IDALIA
CLUDEN

ESPLANADE
ROAD
ROSE STREET
WARBURTON STREET
COOK STREET
EYRE STREET
MITCHELL STREET
THE STRAND
ROPER STREET
BALMORAL DRIVE
BURKE STREET
ALEXANDRA STREET
STANLEY STREET
GREGORY STREET
CARTER STREET
SIR LESLIE THIESS DRIVE
VICTORIA STREET
HALE STREET
WILLS STREET
WALKER STREET
STURT STREET
FLINDERS STREET
HANRAN STREET
DEAN STREET
DENHAM STREET
PALMER STREET
ROSS STREET
ARCHER STREET
HUBERT STREET
MOREHEAD STREET
DAVIDSON STREET
PERKINS STREET
TULLY STREET
BELL STREET
MOREY STREET
EIGHTH AVENUE
SIXTH AVENUE
BOUNDARY STREET
SEVENTH STREET
SAMPHIRE DRIVE
EIGHTH STREET
ANZAC LANE
BARNICLE STREET
BROOKS STREET
CAMERON STREET
ROAD
FREDERICK STREET
ABBOTT STREET
CARMODY STREET
NORRIS STREET
SHERRIFF STREET
HODEL STREET
LINDSAY STREET
BALLS LANE
FLETCHER STREET
JONES STREET
MORRIS STREET
WILSON STREET
BRODIE STREET
CHARTERS TOWERS ROAD
MARKS STREET
WINDSOR STREET
QUEENS ROAD
SOONING STREET
FIRST AVENUE
FLOWERS STREET
RAILWAY AVENUE
NINTH AVENUE
TENTH AVENUE
ELEVENTH AVENUE
PARK LANE
SUSSEX STREET
FAIRLEY STREET
KINGS ROAD
FRENCH STREET
GROSVENOR STREET
CAVENDISH STREET
PARK STREET
CHEYNE STREET
DIPROSE STREET
BURTON STREET
TOWNSEND STREET
DESAILLY STREET
CORE STREET
LEEDS STREET
TYRRELL STREET
FULHAM ROAD
DESCHAMP STREET
BOURKE STREET
HEALY STREET
WELLINGTON STREET
BUNA AVENUE
CAMP STREET
GARDEN STREET
SWALES STREET
ROSS RIVER ROAD
TULIP STREET
ROGERS STREET
MADDEN STREET
ANNE STREET
BAINBRIDGE STREET
CHARLES STREET
POINCIANA STREET
LABURNUM STREET
PASKIN STREET
WILLIS STREET
TYLER STREET
MILL DRIVE
NARANGI STREET
WILKIE STREET
TANLON STREET
NATHAN STREET
CAMBRIDGE STREET
MCLEAN STREET
KENT STREET
TIPPETT STREET
BEGG STREET
HALSTEAD STREET
SARGEANT STREET
TREGASKIS STREET
PALMERSTON STREET
GOODWIN STREET
HAMMETT STREET
COOPER STREET
CORCORAN STREET
HOWLETT STREET
BAYSWATER ROAD
ALBANY ROAD
DILLANE STREET
VIRGIL STREET
YEATMAN STREET
WOOLCOCK STREET
SHAW STREET
LIVINGSTONE STREET
INGHAM ROAD
MARTINEZ AVENUE
KEANE STREET
PUNARI STREET
DALRYMPLE ROAD
LILLIPILLI STREET
ILLUKA STREET
MOONEY STREET
DUCKWORTH STREET
GREG JABS COURT
DAVIES STREET
CALDWELL STREET
LEYLAND STREET
PILKINGTON STREET
HAMILL STREET
BLAKEY STREET
FRANCIS STREET
GARRICK STREET
MARY STREET
HENRY STREET
EDWARDS STREET
TOWNSVILLE STREET
ESTATE STREET
LEIGH STREET
HUGH STREET
PERCY STREET
BUNDOCK STREET
GREEN STREET
WILLIAM STREET
STAGPOLE STREET
HAROLD STREET
CROWDER STREET
MEENAN STREET
PEEL STREET
DOUGLAS STREET
SUNDERLAND STREET
LOCKHEED STREET
HALIFAX STREET
LANCASTER STREET
DEARNESS STREET
VISCOUNT DRIVE
OLD COMMON ROAD
LYNAM STREET
HOOPER STREET
PARRY STREET
POTTS STREET
SLOANE STREET
HEATLEYS PARADE
BALM STREET

860 430 0
Meters

SCALE: 1:25,000 @ A3

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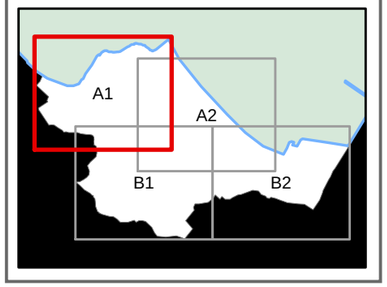
Figure 2.4.1
Historical Rainfall

TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT

LEGEND

- Subcatchment Discharge Locations
- 1D Extent
- North Ward
- North Ward Major Subcatchments
- Stormwater Network <900mm
- Stormwater Network >900mm



City of Townsville

150 75 0

Meters

SCALE: 1:5,000 @ A3

Strategic Planning Department
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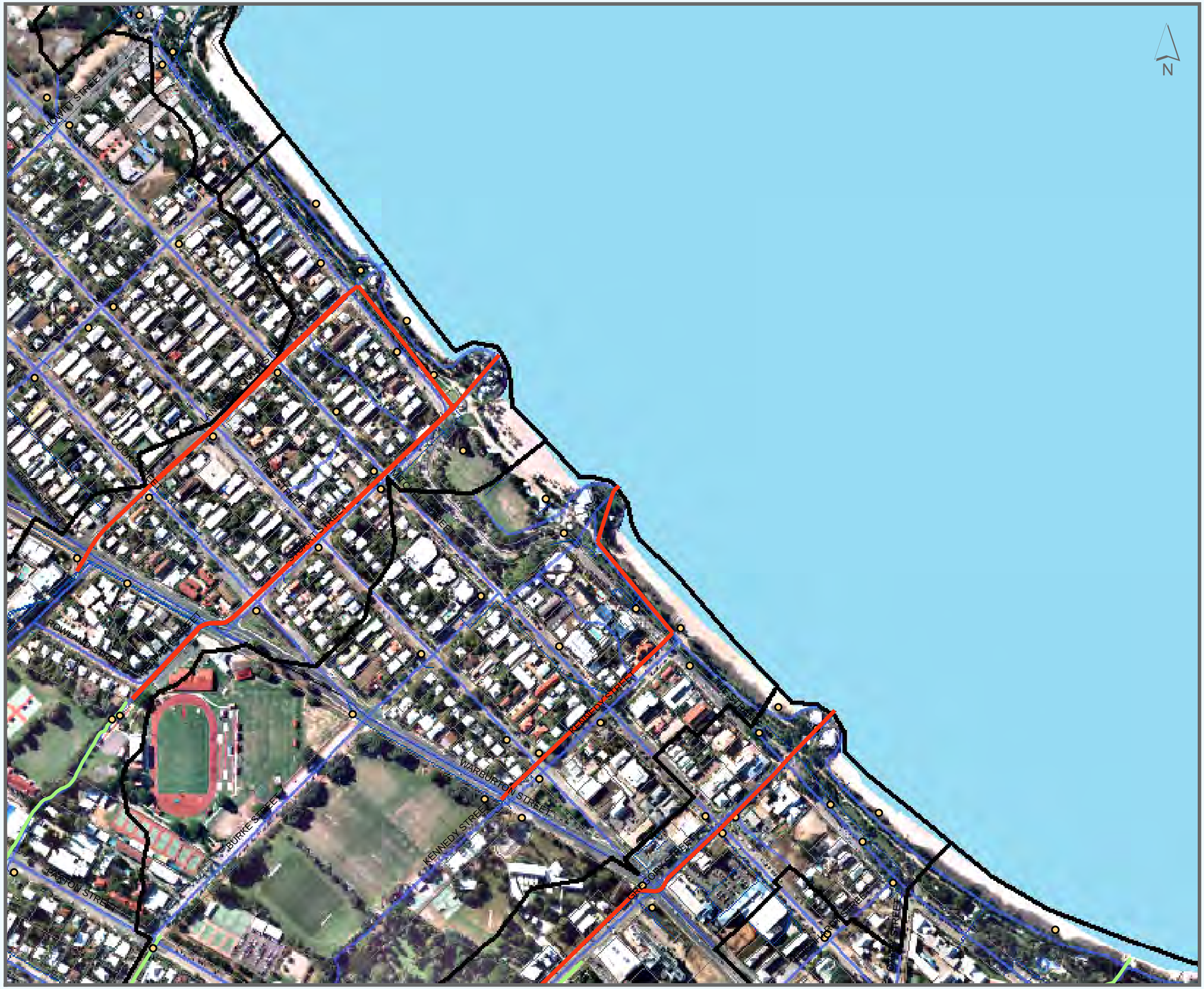
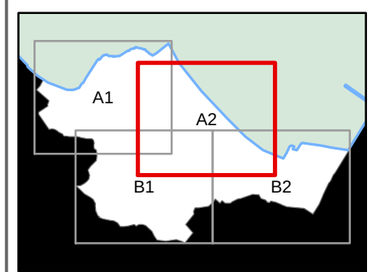
Figure 2.6.1
GIS Layers

TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT



LEGEND

- Subcatchment Discharge Locations
- 1D Extent
- North Ward
- North Ward Major Subcatchments
- Stormwater Network <900mm
- Stormwater Network >900mm



City of Townsville

150 75 0
Meters

SCALE: 1:5,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

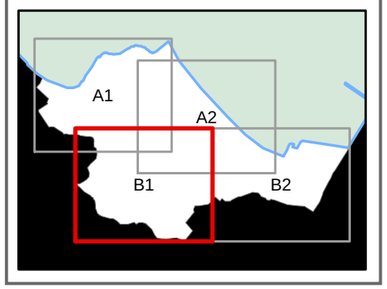
DATE: 14/03/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure 2.6.1
GIS Layers

TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT

LEGEND

- Subcatchment Discharge Locations
- 1D Extent
- North Ward
- North Ward Major Subcatchments
- Stormwater Network <900mm
- Stormwater Network >900mm



150 75 0

Meters

SCALE: 1:5,000 @ A3

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DIGITAL FILE: mxd

Figure 2.6.1
GIS Layers

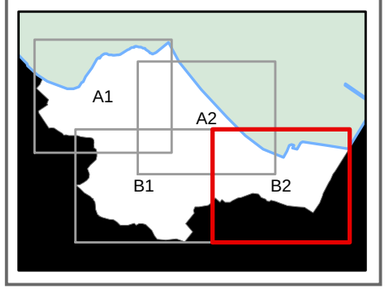
TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT

N

MITCHELL STREET
EYRE STREET
OWEN STREET
CARTER STREET
MACKNADE STREET
CLEVELAND TERRACE
HERBERT STREET
WILLMETT STREET
HAMILTON STREET
DENHAM STREET
MELTON TERRACE
FLINDERS STREET
DENHAM LANE
TOMLINS STREET
ANTHONY STREET
DIBBS STREET
PALMER STREET
MCILWRAITH STREET
ARCHER STREET
LANEWAY
GEORGE ROBERTS BRIDGE
STANLEY STREET
OGDEN STREET
WILLS STREET
STOKES STREET
THE STRAND
KING STREET
ROSS STREET
SIR LESLIE THIESS DRIVE
ENTERTAINMENT DRIVE

LEGEND

- Subcatchment Discharge Locations
- 1D Extent
- North Ward
- North Ward Major Subcatchments
- Stormwater Network <900mm
- Stormwater Network >900mm



City of Townsville

150 75 0
Meters

SCALE: 1:5,000 @ A3

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Figure 2.6.1
GIS Layers

2.7 Previous Reports

To update the topography from base case 2008 to base case 2009, the *Mitchell Street Drainage Report October 2008* was used. It contains the latest invert levels in the Mitchell Street area. This report also contains historical data that was used in calibration.

The Townsville Flood Hazard Assessment Study was used to verify results of the North Ward Flood Study.

A Landslip Hazard Study on Castle Hill has been undertaken. This report should be read in conjunction with that study.

3.0 Hydrological Assessment

3.1 Overview

The North Ward catchment was divided up into 9, standalone catchments representing the 9 outlets of the study area. 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 171 sub-catchments were used for the North Ward model. XP-RAFTS was used to create a hydrologic model of the study area. The model was verified to the rational method, then jointly calibrated with the hydraulic model to historical flood level data. The calibrated model 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 AR&R 1987 data.

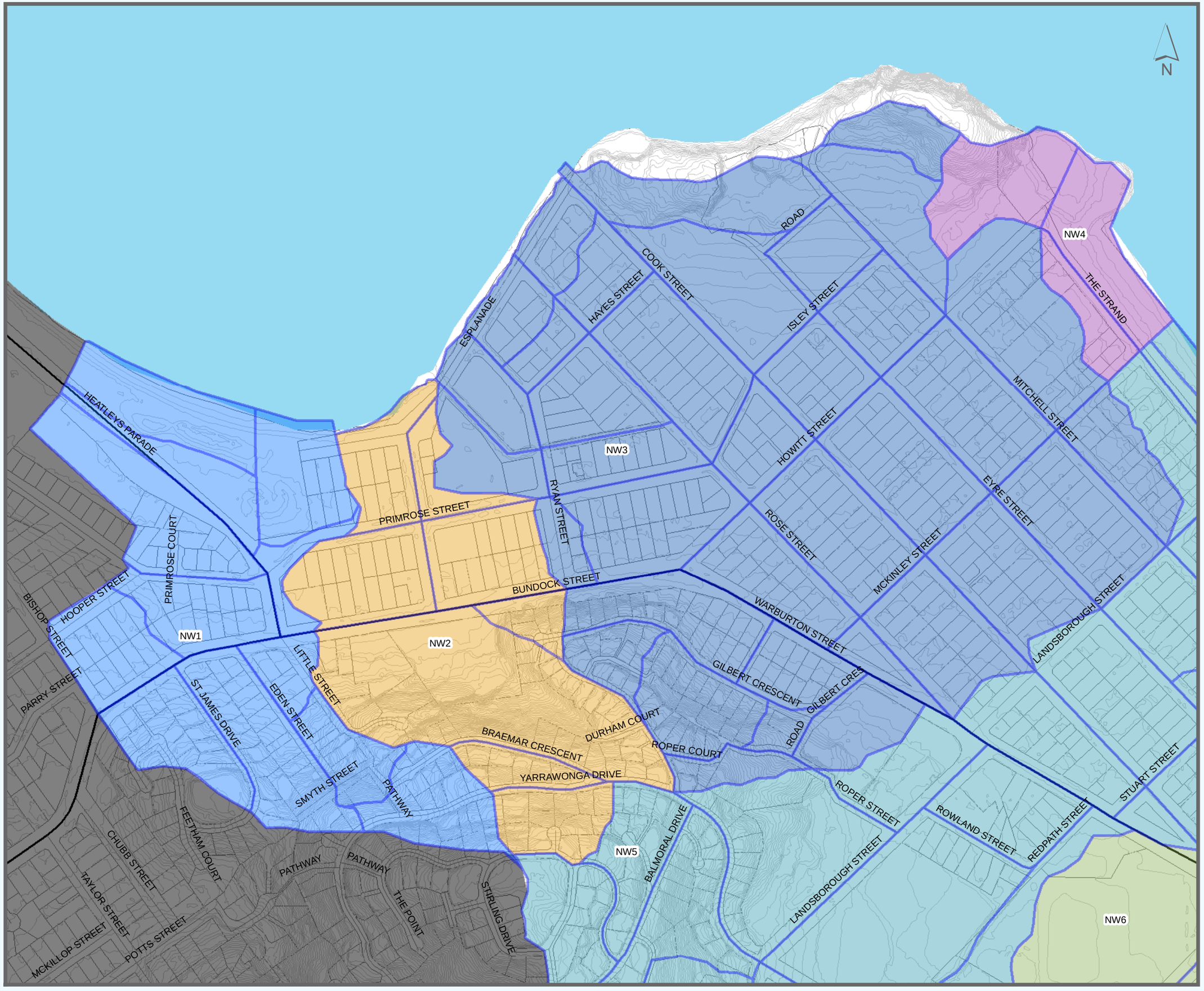
3.3 Catchment

The North Ward catchments include the north eastern slopes of Castle Hill. It covers areas of the suburbs North Ward, Castle Hill, and Belgian Gardens with a total area of 414 Ha.

The North Ward catchment is generally developed in the lower reaches and undeveloped from Stanley Street West up to the headwaters on top of Castle Hill. Because of the steep grade of the undeveloped land, and the majority of Castle Hill being designated Green Space, significant further development in the study area is very unlikely.

Figure 3.3.1 A1 to B2 shows the subcatchment breakup, and **Table 3.3.1** shows catchment parameters. Catchment parameters were determined through analysing the available GIS layers and site inspection.

TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT



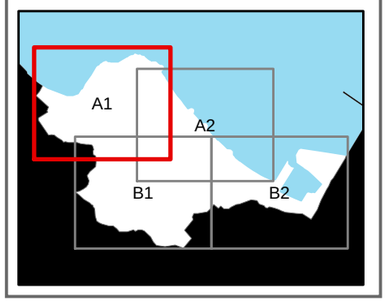
LEGEND

North Ward Sub-catchments

Major Sub-catchments

Subcatchment Group

- NW1
- NW2
- NW3
- NW4
- NW5
- NW6
- NW7
- NW8
- NW9



City of Townsville

0.1 0.05 0

Kilometers

SCALE: 1:5,000 @ A3

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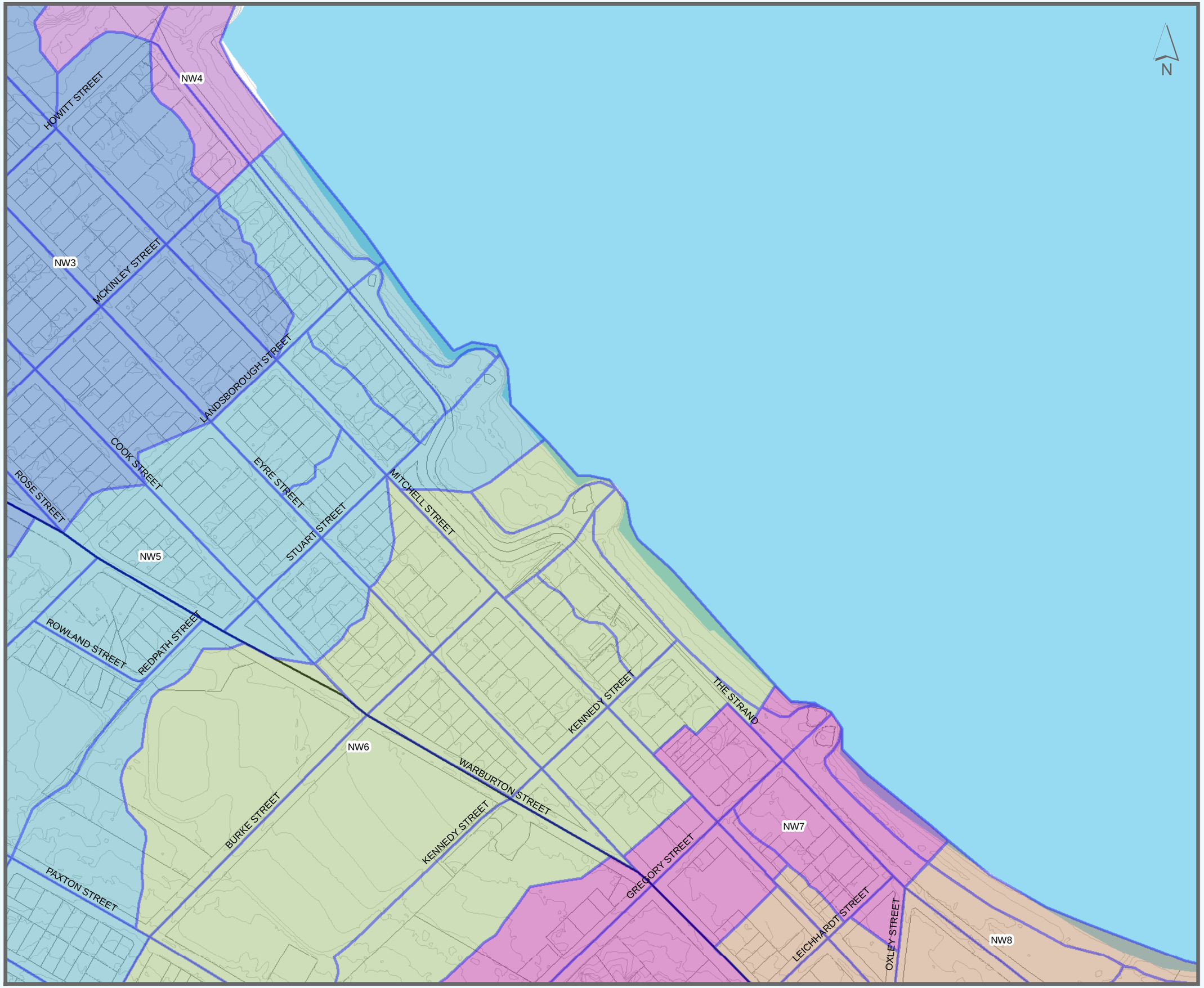
Fig 3.3.1: Catchment



TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT

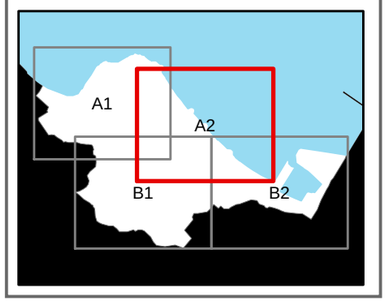
LEGEND

North Ward Sub-catchments

Major Sub-catchments

Subcatchment Group

- NW1
- NW2
- NW3
- NW4
- NW5
- NW6
- NW7
- NW8
- NW9



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Kilometers

SCALE: 1:5,000 @ A3

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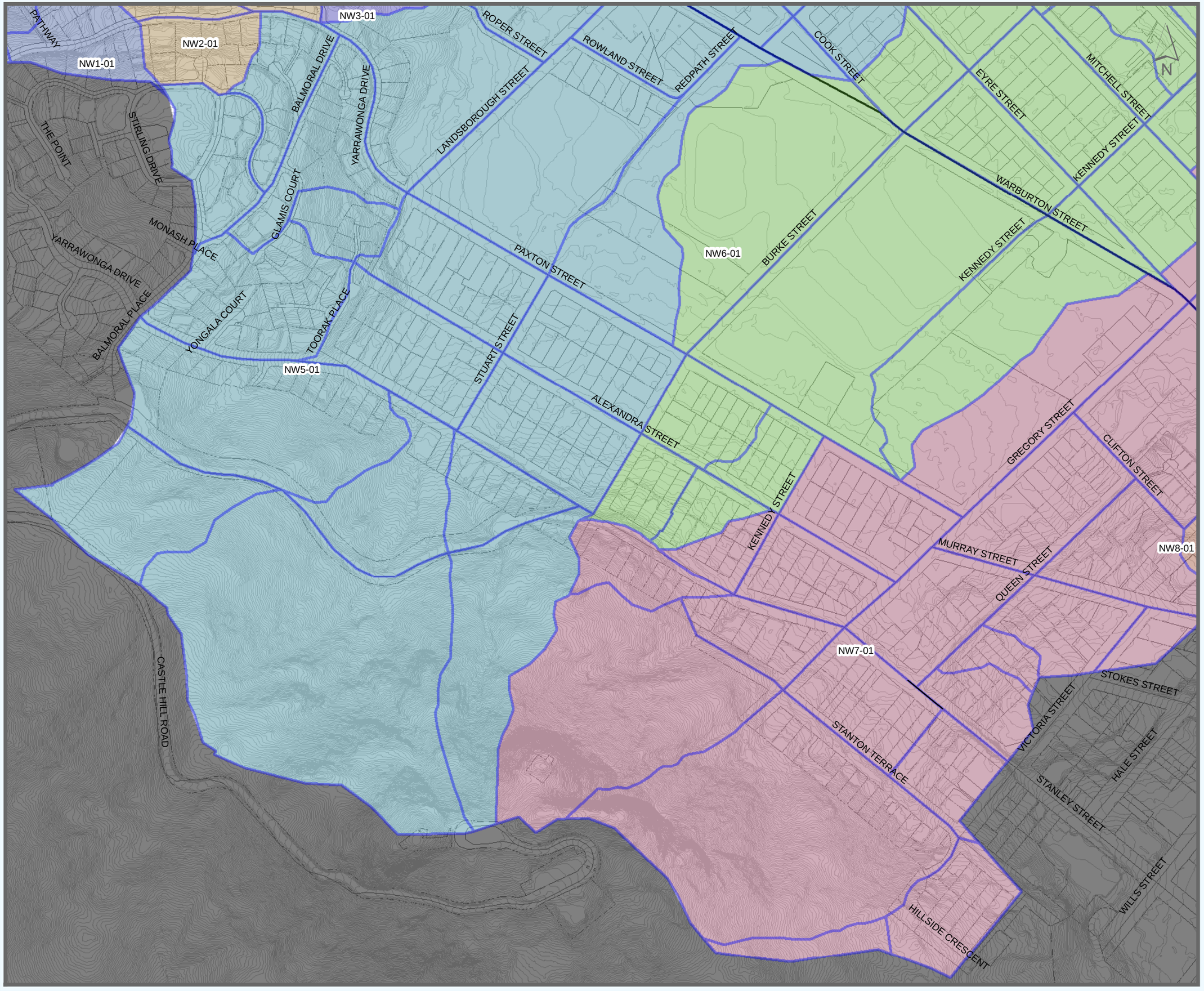
Fig 3.3.1: Catchment

TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT



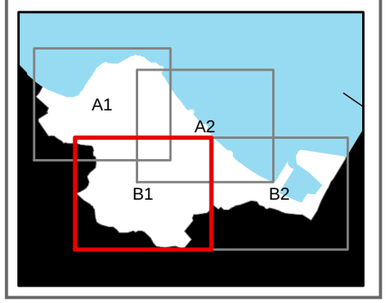
LEGEND

North Ward Sub-catchments

Major Sub-catchments

Subcatchment Group

- NW1
- NW2
- NW3
- NW4
- NW5
- NW6
- NW7
- NW8
- NW9



0.1 0.05 0

Kilometers

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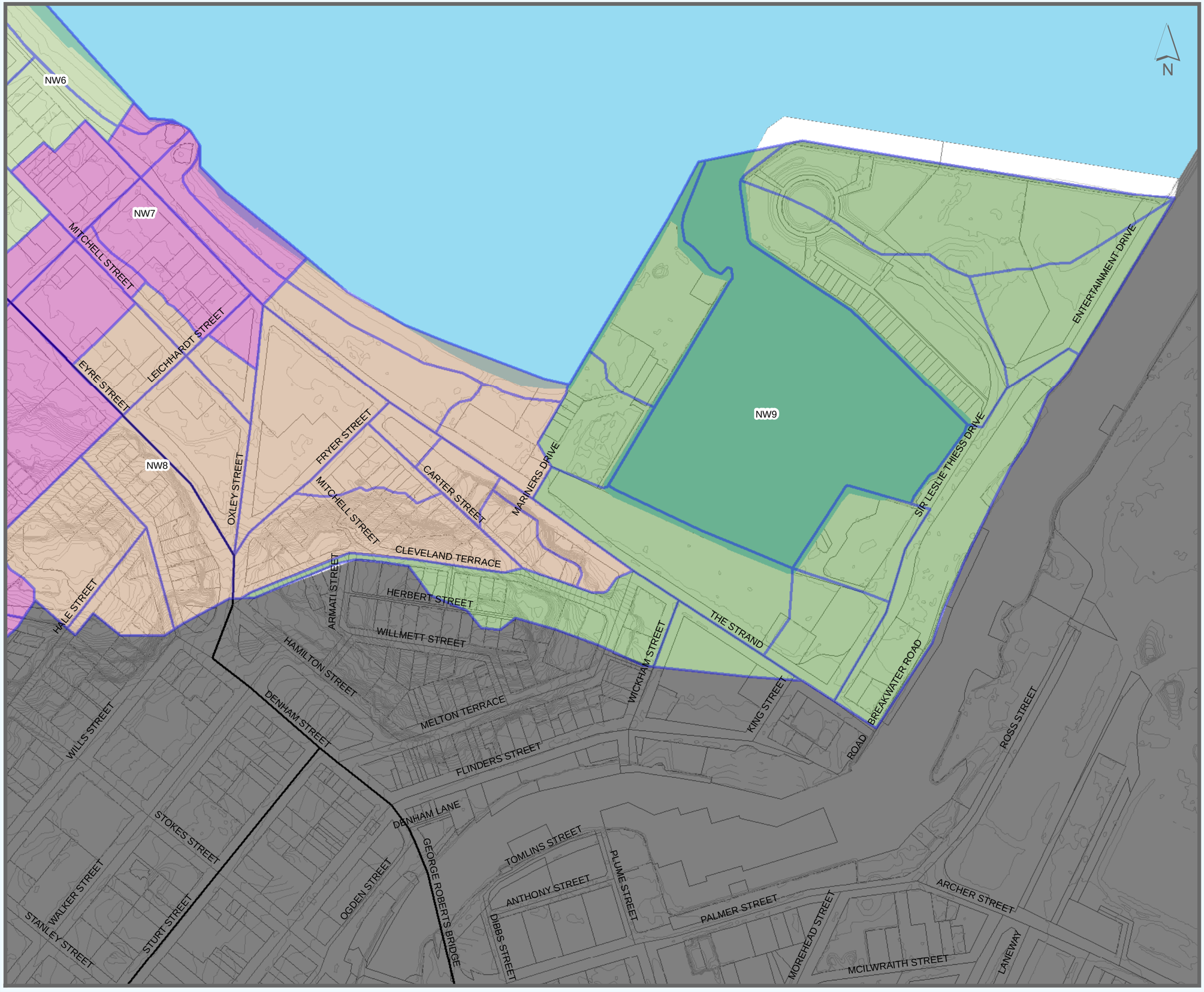
Fig 3.3.1: Catchment

TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT



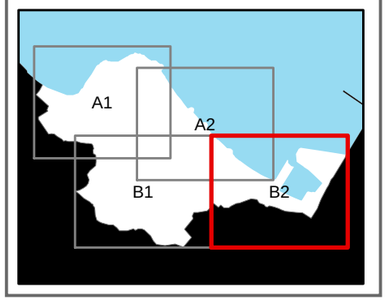
LEGEND

North Ward Sub-catchments

Major Sub-catchments

Subcatchment Group

- NW1
- NW2
- NW3
- NW4
- NW5
- NW6
- NW7
- NW8
- NW9



0.1 0.05 0

Kilometers

SCALE: 1:5,000 @ A3

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DATE: 14/03/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Fig 3.3.1: Catchment

Table 3.3.1: Attributes of North Ward							
Sub-Catchment	Area [ha]	Slope	Fraction Impervious	Pervious Surface Retardance	Impervious Surface Retardance	Downstream Link Length [m]	Link Slope
NW9-03	5.03	0.020	0.95	0.068	0.02	64	0.003
NW1-07.01	3.01	0.181	0.45	0.068	0.015	65	0.025
NW2-05	7.76	0.204	0.50	0.068	0.015	130	0.009
NW4-3	2.44	0.077	0.35	0.05	0.02	-	-
NW3-09.02.03	2.17	0.290	0.55	0.07	0.02	112	0.013
NW6-11	10.50	0.020	0.25	0.058	0.01	69	0.002
NW7-11.03	11.26	0.536	0.08	0.068	0.015	110	0.05
NW8-03	2.05	0.004	0.35	0.065	0.015	16	0.033
NW1-07	0.89	0.060	0.45	0.068	0.015	140	0.0135
NW1-07.02	2.12	0.164	0.55	0.068	0.015	0	0.009
NW1-07.00.01	1.31	0.164	0.35	0.068	0.015	122	0.0787
NW1-07.00.02	2.15	0.287	0.45	0.07	0.015	102	0.15
NW1-01	2.34	0.059	0.05	0.068	0.02	-	-
NW1-03	1.46	0.010	0.30	0.068	0.02	20	0.002
NW1-05	3.30	0.006	0.95	0.05	0.02	30	0.002
NW1-02	2.17	0.013	0.05	0.06	0.02	91	0.002
NW1-04	0.71	0.007	0.60	0.06	0.02	110	0.005
NW1-06.01	1.99	0.029	0.60	0.068	0.015	225	0.017
NW1-06	2.05	0.026	0.70	0.068	0.015	45	0.002
NW2-01	1.72	0.003	0.55	0.068	0.015	-	-
NW2-02	0.89	0.005	0.85	0.068	0.015	53	0.002
NW2-03	2.27	0.025	0.75	0.068	0.015	138	0.002
NW2-04	2.50	0.007	0.70	0.068	0.015	23	0.002
NW2-05.01	0.72	0.208	0.35	0.068	0.015	173	0.014
NW2-05.02	0.94	0.243	0.60	0.068	0.015	206	0.278
NW2-05.03	1.57	0.352	0.40	0.068	0.015	350	0.195
NW3-04	1.43	0.012	0.55	0.07	0.02	82	0.002
NW3-01	1.36	0.002	0.30	0.068	0.015	147	0.002
NW3-02	1.14	0.037	0.30	0.07	0.02	-	-
NW3-03	1.11	0.061	0.35	0.07	0.02	120	0.005
NW3-02.02	1.17	0.016	0.60	0.07	0.02	145	0.003
NW3-02.01	0.69	0.010	0.50	0.07	0.02	82	0.002
NW3-05	1.91	0.010	0.55	0.07	0.02	0	0
NW3-06	1.51	0.008	0.50	0.07	0.015	0	0
NW3-04.01	0.72	0.033	0.85	0.07	0.02	0	0
NW3-09	2.93	0.019	0.55	0.07	0.02	90	0.002
NW3-07	3.10	0.003	0.53	0.07	0.02	0	0
NW3-07.01	3.17	0.035	0.10	0.07	0.02	140	0.002
NW3-08	1.35	0.001	0.65	0.055	0.02	90	0.002
NW3-12	1.71	0.006	0.50	0.07	0.02	20	0.002
NW3-14.01	2.33	0.040	0.20	0.07	0.02	132	0.012
NW3-07.01.02	1.43	0.040	0.05	0.05	0.02	190	0.036
NW3-14	1.71	0.027	0.55	0.07	0.02	134	0.002
NW3-16.01	1.74	0.076	0.65	0.07	0.02	228	0.008
NW3-16	3.83	0.019	0.55	0.07	0.02	130	0.005
NW3-15	3.02	0.016	0.50	0.07	0.02	133	0.003
NW3-15.01	3.02	0.005	0.65	0.075	0.02	227	0.006
Note: some subcatchments do not have link data as they discharge straight into the ocean							

Table 3.3.1: Attributes of North Ward							
Sub-Catchment	Area [ha]	Slope	Fraction Impervious	Pervious Surface Retardance	Impervious Surface Retardance	Downstream Link Length [m]	Link Slope
NW3-15.01	3.02	0.005	0.65	0.075	0.02	227	0.006
NW3-13.01	2.75	0.014	0.75	0.07	0.02	295	0.007
NW3-13	3.02	0.009	0.70	0.07	0.02	20	0.002
NW3-11.01	2.66	0.019	0.75	0.05	0.02	229	0.012
NW3-11	3.03	0.015	0.60	0.07	0.02	132	0.002
NW3-09.02	1.40	0.043	0.55	0.07	0.02	156	0.008
NW3-09.01	2.48	0.076	0.55	0.07	0.02	217	0.018
NW3-10	2.32	0.028	0.55	0.07	0.02	82	0.002
NW3-10.01	0.68	0.030	0.15	0.07	0.02	231	0.017
NW3-09.02.01	1.55	0.108	0.90	0.07	0.02	160	0.008
NW3-09.02.04	0.81	0.201	0.35	0.07	0.02	159	0.121
NW3-09.02.02	0.48	0.282	0.15	0.07	0.02	83	0.036
NW3-09.02.05	1.07	0.164	0.80	0.07	0.02	138	0.055
NW3-07.01.01	2.80	0.176	0.30	0.07	0.02	132	0.014
NW3-14.01.01	1.14	0.279	0.10	0.07	0.02	287	0.038
NW5-01.01	0.92	0.112	0.00	0.06	0.02	-	-
NW5-04	1.86	0.049	0.70	0.068	0.013	223	0.003
NW5-02	0.91	0.002	0.10	0.068	0.013	75	0.002
NW5-05	1.74	0.040	0.70	0.055	0.013	107	0.004
NW5-03	2.14	0.047	0.20	0.068	0.013	-	-
NW5-06	1.43	0.048	0.55	0.068	0.013	80	0.002
NW5-08	1.04	0.009	0.70	0.068	0.013	34	0.002
NW5-07	1.98	0.009	0.60	0.055	0.013	146	0.003
NW5-09	0.90	0.019	0.45	0.068	0.013	51	0.002
NW5-11	1.61	0.023	0.55	0.068	0.013	186	0.011
NW5-10	3.30	0.011	0.70	0.068	0.013	126	0.002
NW5-13	0.50	0.008	0.50	0.068	0.013	53	0.023
NW5-12	2.68	0.011	0.65	0.068	0.013	129	0.016
NW5-15	2.25	0.024	0.65	0.075	0.013	60	0.002
NW5-14	1.99	0.046	0.95	0.068	0.013	133	0.067
NW5-16	3.87	0.017	0.60	0.068	0.013	77	0.003
NW5-17	6.37	0.034	0.20	0.068	0.013	132	0.012
NW5-14.01	4.48	0.166	0.20	0.068	0.013	176	0.025
NW5-19	3.04	0.024	0.60	0.068	0.013	322	0.017
NW5-21	3.08	0.110	0.50	0.068	0.013	115	0.042
NW5-14.03	1.91	0.000	0.70	0.05	0.013	282	0.124
NW5-14.04	2.24	0.000	0.45	0.068	0.013	250	0.1
NW5-20	3.21	0.094	0.45	0.04	0.013	164	0.017
NW5-20.02	3.94	0.000	0.60	0.068	0.013	0	0
NW5-18	3.02	0.095	0.50	0.068	0.013	322	0.017
NW5-20.03	6.64	0.000	0.15	0.068	0.013	134	0.031
NW5-14.02	2.81	0.000	0.50	0.068	0.013	273	0.046
NW6-03	2.00	0.008	0.25	0.05	0.013	-	-
NW6-06.01	2.13	0.017	0.70	0.05	0.01	15	0.002
NW6-02	2.12	0.117	0.01	0.05	0.013	-	-
NW6-01	1.69	0.047	0.70	0.068	0.013	-	-
NW6-06	3.02	0.050	0.70	0.058	0.015	206	0.002
NW6-07	2.32	0.008	0.80	0.058	0.01	20	0.002
NW6-09.01	1.44	0.064	0.55	0.058	0.01	231	0.002
Note: some subcatchments do not have link data as they discharge straight into the ocean							

Table 3.3.1: Attributes of North Ward							
Sub-Catchment	Area [ha]	Slope	Fraction Impervious	Pervious Surface Retardance	Impervious Surface Retardance	Downstream Link Length [m]	Link Slope
NW6-09.01	1.44	0.064	0.55	0.058	0.01	231	0.002
NW6-09	2.21	0.018	0.60	0.058	0.01	135	0.002
NW6-08	0.63	0.006	0.75	0.058	0.01	135	0.003
NW6-11.01	7.75	0.017	0.45	0.058	0.01	232	0.009
NW6-10	5.35	0.021	0.25	0.058	0.01	60	0.002
NW6-12	1.26	0.047	0.60	0.058	0.01	446	0.025
NW6-13	1.80	0.055	0.55	0.06	0.01	446	0.02
NW7-07.04	1.59	0.324	0.18	0.068	0.02	141	0.121
NW6-14	1.26	0.197	0.45	0.058	0.015	136	0.041
NW6-15	0.94	0.128	0.50	0.04	0.015	130	0.045
NW6-04	1.64	0.024	0.75	0.058	0.01	187	0.002
NW6-05	1.38	0.039	0.80	0.058	0.01	125	0.013
NW6-03.01	1.23	0.100	0.10	0.025	0.025	-	-
NW7-01.02	0.15	0.107	0.00	0.058	0.01	-	-
NW7-03.01	0.45	0.021	0.45	0.068	0.02	149	0.002
NW7-07.01	2.79	0.028	0.68	0.068	0.015	456	0.016
NW7-07.02	2.00	0.073	0.65	0.068	0.02	133	0.044
NW7-10	2.69	0.074	0.60	0.068	0.025	277	0.025
NW7-10.02	0.72	0.029	0.80	0.068	0.015	171	0.115
NW7-10.01	1.96	0.119	0.60	0.068	0.015	143	0.082
NW7-10.04	1.33	0.133	0.65	0.068	0.015	203	0.042
NW7-11.01	1.56	0.134	0.70	0.068	0.015	80	0.075
NW7-11	2.40	0.111	0.65	0.068	0.015	0	0
NW7-11.02	1.69	0.122	0.62	0.068	0.015	99	0.097
NW7-11.03.01	2.18	0.203	0.65	0.068	0.015	117	0.15
NW7-11.02.01	8.47	0.614	0.00	0.068	0.015	132	0.121
NW7-02	1.62	0.013	0.88	0.068	0.015	113	0.002
NW7-01.03	0.87	0.106	0.00	0.068	0.015	-	-
NW7-01.01	1.23	0.040	0.48	0.058	0.01	-	-
NW7-03	2.30	0.034	0.55	0.068	0.02	73	0.002
NW7-05	0.73	0.012	0.02	0.068	0.015	31	0.002
NW7-06	1.64	0.025	0.90	0.068	0.015	29	0.002
NW7-07	4.89	0.019	0.20	0.068	0.015	133	0.008
NW7-08	5.44	0.119	0.70	0.068	0.015	133	0.008
NW7-09	3.20	0.061	0.60	0.068	0.015	232	0.01
NW7-09.01	2.61	0.134	0.45	0.068	0.015	130	0.126
NW8-07.04	0.40	0.060	0.65	0.068	0.015	117	0.005
NW7-11.03.02	0.81	0.304	0.01	0.068	0.015	171	0.15
NW8-07.01.03	2.76	0.212	0.70	0.06	0.015	85	0.185
NW8-07.01.02	1.17	0.167	0.75	0.068	0.015	142	0.095
NW8-07.01.01	2.84	0.175	0.60	0.068	0.015	255	0.022
NW8-07.01	2.43	0.061	0.60	0.068	0.015	184	0.003
NW8-07.02	0.61	0.016	0.60	0.068	0.015	28	0.043
NW8-01	1.60	0.108	0.00	0.068	0.015	-	-
NW8-02	1.63	0.014	0.55	0.065	0.015	84	0.002
NW8-04	0.74	0.225	0.60	0.068	0.015	37	0.016
Note: some subcatchments do not have link data as they discharge straight into the ocean							

Table 3.3.1: Attributes of North Ward							
Sub-Catchment	Area [ha]	Slope	Fraction Impervious	Pervious Surface Retardance	Impervious Surface Retardance	Downstream Link Length [m]	Link Slope
NW8-04	0.74	0.225	0.60	0.068	0.015	37	0.016
NW8-05	0.47	0.014	0.65	0.068	0.015	33	0.018
NW8-06	1.08	0.030	0.70	0.068	0.02	61	0.002
NW8-07	3.49	0.031	0.70	0.068	0.015	121	0.002
NW8-04.01	0.87	0.114	0.60	0.06	0.015	103	0.002
NW8-04.02	0.82	0.135	0.70	0.02	0.015	77	0.15
NW8-06.01	3.52	0.346	0.40	0.068	0.015	38.5	0.032
NW9-01	14.10	0.000	1.00	0.068	0.015	-	-
NW9-02	6.46	0.019	0.90	0.068	0.015	-	-
NW9-04	2.91	0.005	0.98	0.068	0.015	50	0.003
NW9-05	4.52	0.017	0.90	0.068	0.02	-	-
NW9-06	1.87	0.012	0.95	0.068	0.02	74	0.003
NW9-07	3.84	0.011	0.10	0.068	0.02	20	0.003
NW9-08	1.89	0.012	0.75	0.068	0.02	130	0.009
NW9-09	1.08	0.011	0.99	0.068	0.015	70	0.02
NW9-10	3.15	0.165	0.80	0.068	0.02	65	0.018
NW4-1	2.26	0.096	0.10	0.07	0.02	-	-
NW4-2	1.03	0.050	0.80	0.07	0.02	70	0.051
NW5-01	0.68	0.002	0.05	0.05	0.015	42	0.119
NW5-02.01	0.67	0.110	0.01	0.025	0.025	-	-
NW5-20.01	1.17	0.000	0.35	0.05	0.013	228	0.062
NW7-01	0.48	0.040	0.30	0.058	0.01	-	-
NW7-04	0.32	0.060	0.85	0.03	0.015	202	0.012
NW8-07.03	1.32	0.025	0.75	0.068	0.02	129	0.012
NW7-10.03	0.69	0.133	0.50	0.068	0.015	98	0.097
NW9-03.01	2.90	0.020	0.85	0.068	0.015	-	-
NW9-04.01	1.77	0.005	0.95	0.068	0.015	90	0.003
NW7-07.03	0.91	0.128	0.50	0.068	0.015	200	0.016
NW5-24	3.70	0.000	0.00	0.05	0.013	238	0.191
NW5-22	1.75	0.000	0.10	0.07	0.013	128	0.095
NW5-23	5.11	0.000	0.00	0.068	0.013	176	0.191
Note: some subcatchments do not have link data as they discharge straight into the ocean							

Rainfall Loss

Rainfall loss parameters in XP-RAFTS were determined while verifying the XP-RAFTS model to the Rational Method. A range of values for the pervious areas were tested to get the most accurate results, from 20 – 30 mm initial loss, and from 1 – 3 mm continuing loss. For design storms, the following loss parameters were adopted: for pervious areas, an initial rainfall loss of 25mm and a continuing loss 2.5mm/hr; and for impervious areas, an initial rainfall loss of 1mm and no continuing rainfall loss. These values are typical according to AR&R, Book 2. (1987).

Channel Routing

For the North Ward model, XP-RAFTS calculates flows using the Channel Routing method. The channel cross section dimensions, length, and slope are specified and XP-RAFTS calculates routing time based on these parameters. The channels cross sections were modelled in XP RAFTS as one of a few standard routes. The standard routes were roads, constructed open channels, natural channels in steeper reaches, and natural channels in lower reaches. Each of these routes were 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 North Ward area, the XP-RAFTS model was verified to the Rational Method for each major sub-catchment. Surface Retardance and Rainfall Losses, were the main parameters used 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 based on standard inlet times, and flow travel times. The Stream Velocity method was also used for natural channels. **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)
N1	10.4	3.8	12.3	4.4
N2	7.8	3.4	8.8	3.1
N3	24.6	9.9	21.3	7.5
N5	37.5	11.6	37.9	13.4
N6	16.7	6.7	20.9	7.4
N7	27.4	9.0	26.1	9.3
N8	14.0	5.4	13.8	4.9

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

The XP-RAFTS model was also jointly calibrated with the hydraulic model to historical water level data. Refer to **Chapter 4.6** for the details of this calibration.

3.5 Probable Maximum Flood

The rainfall intensity is required as an input into XP-RAFTS to model the Probable Maximum Flood. This was calculated according to the General Short Duration Method (GSDM). 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.

Table 3.5.1: Probable Maximum Precipitation Calculations				
Duration [h]	1	1.5	2	3
Ellipse A [mm/hr]	463	562	350	282
Ellipse B [mm/hr]	438	597	333	266

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 for each major subcatchment group.

Table 3.6.1: Max Catchment Flow [m^3/s]									
	NW1	**NW2**	**NW3**	**NW4**	**NW5**	**NW6**	**NW7**	**NW8**	**NW9**
2y	3.9	3.5	9.9	0.9	11.7	6.8	9.0	5.4	17.4
5y	5.8	4.7	14.4	1.6	20.0	9.9	14.9	8.0	23.2
10y	8.7	6.2	21.1	2.4	34.1	15.7	26.4	11.3	26.5
20y	8.8	6.6	20.0	2.5	31.0	14.3	23.4	11.8	31.1
50y	10.5	7.7	24.6	3.0	37.8	17.2	27.4	14.0	34.8
100y	12.3	9.1	28.5	3.6	44.5	20.1	32.2	16.3	39.3
500y	15.6	11.4	36.3	4.6	57.6	25.5	42.1	20.1	48.0
PMF	33.3	24.1	95.6	9.5	153.0	70.1	114.1	44.3	81.3

4.0 Hydraulic Assessment

4.1 Overview

The North Ward Study Area was modelled using the hydraulic modelling software, MIKE FLOOD. The majority of the topography was represented in MIKE 21, but stormwater pipes were modelled in MIKE URBAN, and 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.

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. All model types can be directly coupled to the others.

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 North Ward 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 type areas were represented by MIKE 21. The three models were run together through MIKE FLOOD, which represented the whole study area. The tail water conditions for all models were set to the MHWS level of 1.254m in the base case scenario. Model setup differs for Climate Change analysis, see Chapter 6 for details. **Figure 4.3.1** shows the entire model set-up for North Ward.

TOWNSVILLE CITY COUNCIL

NORTH WARD

CATCHMENT

N

Boundary

LEGEND

1D Branch

Pipe Network

Source Points

Structures

2D Bathymetry

High : 70

Low : -3

0 125 250 375

Meters

SCALE: 1:12,000 @A3

Strategic Planning Department

PLANNING AND DEVELOPMENT

DATE: 17/02/2011

DRAWN BY: JAJ

DIGITAL FILE: mxd

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.

MIKE 21
MIKE 21 was setup to represent flood plain areas. Most data in the model is entered via a grid format, with each grid representing a 5m by 5m area of the catchment. The topographic data was built from LiDAR data and the Mitchell Street Drainage Report October 2008. Initial conditions were set to a constant sea level of 1.254m AHD based on MHWS. Roughness was determined by aerial photography, site inspection, and calibration to historical data. Table 4.3.1 shows the various Roughness values used in the model.

Table 4.3.1: Hydraulic model roughness values

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

MIKE URBAN

MIKE URBAN was setup to represent the underground pipe network of North Ward. Pipe dimensions and invert levels were obtained from TCC geospatial data, and from survey completed by Brazier/Motti. Couples between MIKE 21 and MIKE URBAN were setup to represent inlets pits and outlets in lower reaches where appropriate. Couples between MIKE 11 and MIKE URBAN were setup to represent headwalls for channel flow to underground flow and vice versa.

As a basis for the model, only pipes of diameter 900mm or greater were modelled in MIKE URBAN. It was identified that pipes 900mm and larger, would start to influence surface flood levels. Some pipes smaller than 900mm in diameter were included in the MIKE URBAN model to incorporate key hydraulic controls. These areas were;

- Landsborough Street; and
- Gregory Street at Paxton Street.

4.4 Ryan Street Culvert

To verify its accuracy, the structure at Ryan Street was modelled using a separate program. A HEC-RAS model was created of the structure and the channels upstream and downstream. Maximum flows from the 100 year, 1.5 hour event were applied to the model and results were compared to MIKE FLOOD results. **Table 4.4.1** contains the results of the HEC-RAS verification.

Table 4.4.1: HEC-RAS verification for a flow of 17.062 m^3/s		
	MIKE level [m AHD]	**HEC-RAS level [m AHD]**
Downstream	2.65	2.63
Upstream	2.98	2.96

4.5 Calibration

To ensure that the hydraulic model is accurate, a joint calibration between the hydrologic & hydraulic models was undertaken. Historical event rainfall data was applied to the XP-RAFTS model and the resulting catchment runoffs were applied to the MIKE FLOOD model. The results were compared with surveyed flood levels at the time of the event. The only data available for the calibration of North Ward was from two historical events.

January 1998

The rainfall from the January 1998 event had an approximate average recurrence interval of 500 years. This was determined in **Figure 4.5.1** by plotting the recorded intensity versus duration data against those of standard ARI return periods as given by ARR. The January 1998 event lasted from the 9/01/1998 to the 13/01/1998, with the majority of rain falling within 18 hours over the night of the 10th of January. A number of rain gauges had data from the event, the closest of which came from the Airport.

Only four historical water levels were available from the January 1998 event. **Table 4.5.1** shows a comparison of model results and surveyed data. To calibrate the model to historical data hydraulic model roughness values were altered, with the values in **Table 4.5.1** determined from the calibration.

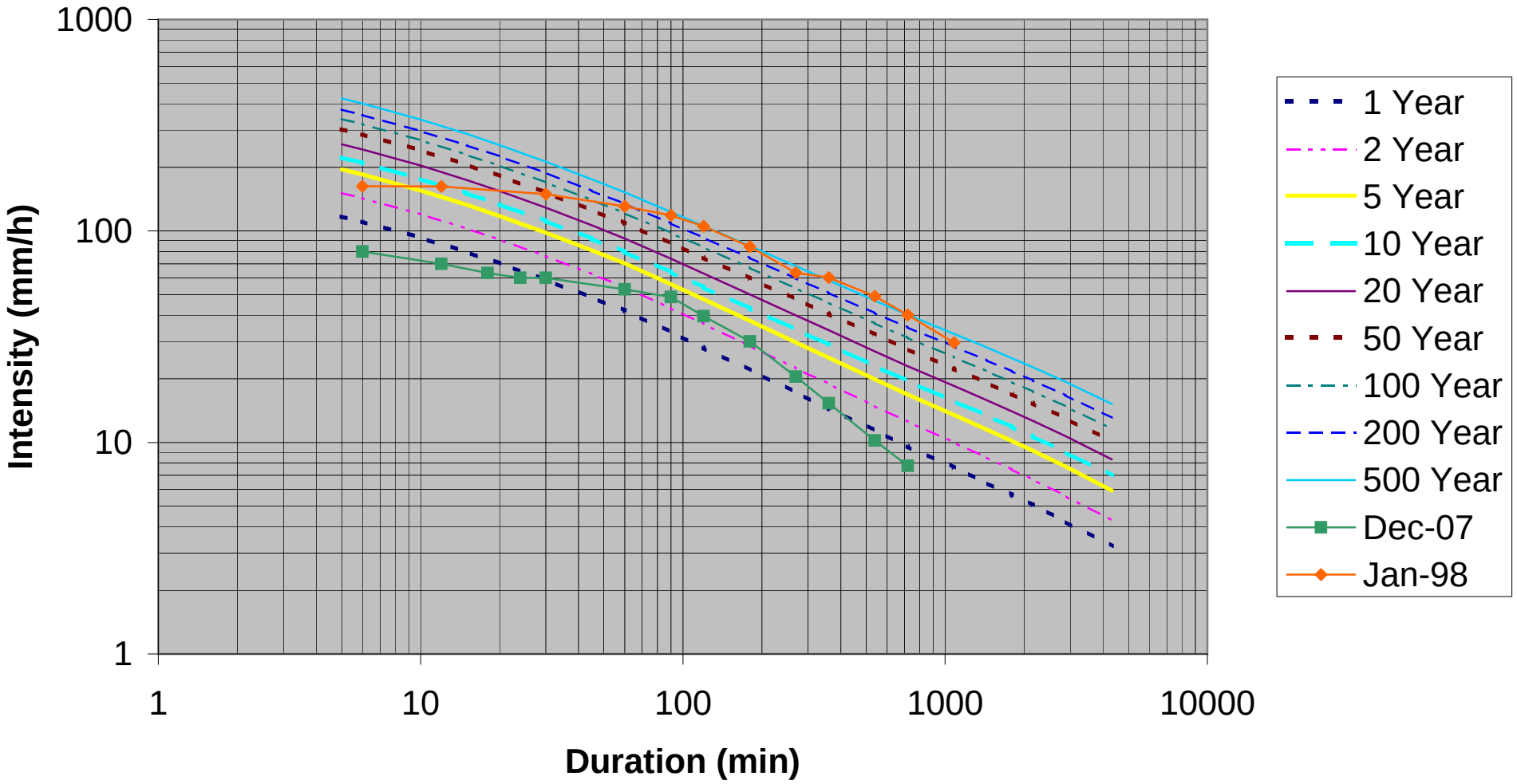
Table 4.5.1: Historical Flood Levels			
Jan-98			
Street	**M21 Model Results**	**Surveyed Results**	**Difference [mm]**
56 Alexandra St	19.69	19.75	-60
300 Stanley St	31.76	31.89	-130
13 Gregory St	14.36	14.38	-20
12 Redpath St	10.87	10.8	70

December 2007

The December 2007 event was a small event compared to the January 1998 event. It only caused localised flooding in some areas. The rainfall in North Ward has been determined to have an average recurrence interval between 2 and 5 years as shown by **Figure 4.5.1**. A number of rain gauges had data from the event, the closest of which came from the Airport.

The flood extent of the December 2007 event and anecdotal reports suggest that the rainfall in North Ward may have been more intense than that recorded by the Airport Rainfall gauge. To better simulate actual conditions, the Mysterton Alert gauge data was applied to the XP-RAFTS model.

Figure 4.5.1: Historial Event ARIs



The December 2007 levels used for calibration came from the Mitchell Street Drainage Report October 2008 and are localised to that area. To successfully calibrate to this event, previously existing topography had to be used in the model run. This was obtained through LiDAR data which is dated to before the Mitchell Street mitigation works.

As the rain event on the 27th of December 2007 was preceded by a less intense, but longer duration rainfall event 24 hours earlier, the 10mm initial loss and 1mm/hr continuing loss were used in the XP-RAFTS model. **Table 4.5.2** shows the comparison of model results and surveyed data.

Table 4.5.2: Historical Flood Levels			
Dec-07			
Street	**M21 Model Results**	**Surveyed Results**	**Difference [mm]**
76 Mitchell St	6.73	6.8	-70
88 Mitchell St	6.73	6.8	-70

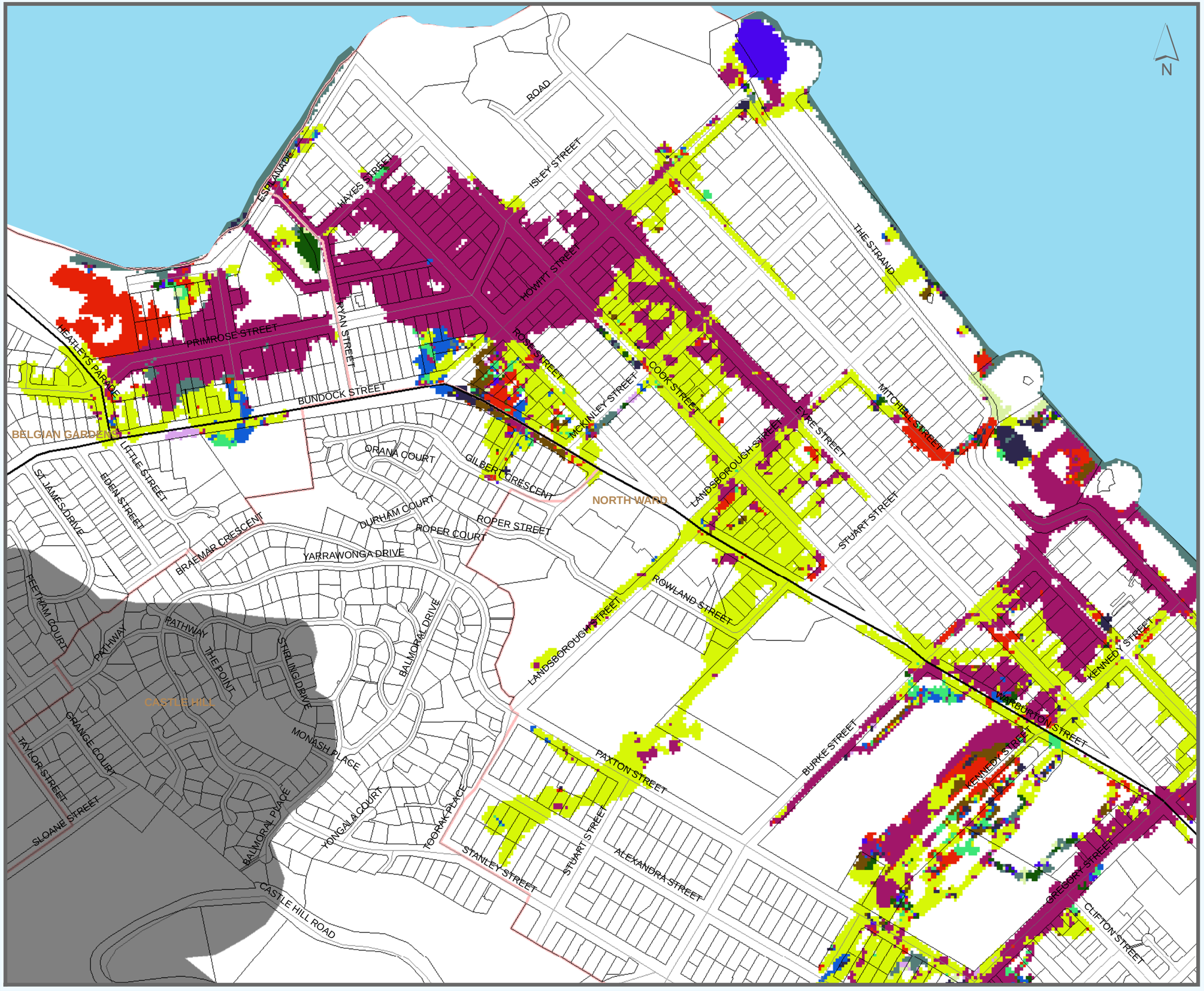
4.6 Design Flood Assessment

Design Flood model runs were set up according to 2009 conditions. A separate run was setup for each duration and each Average Recurrence Interval. 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, 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 (known as the critical duration), changes depending on the location within the catchment. **Figures 4.6.1** to **4.6.4** show the critical duration at each point in the catchment.

Because North Ward has number of different critical durations at different points throughout the catchment, Flood Envelopes have been created for each ARI. At each point in the catchment, for a given ARI, the Flood Envelope displays the water level from critical duration storm for that point. 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

NORTH WARD CATCHMENT

LEGEND

Duration Source

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

200 100 0

Meters

SCALE: 1:6,000 @ A3

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DATE: 15/03/2011
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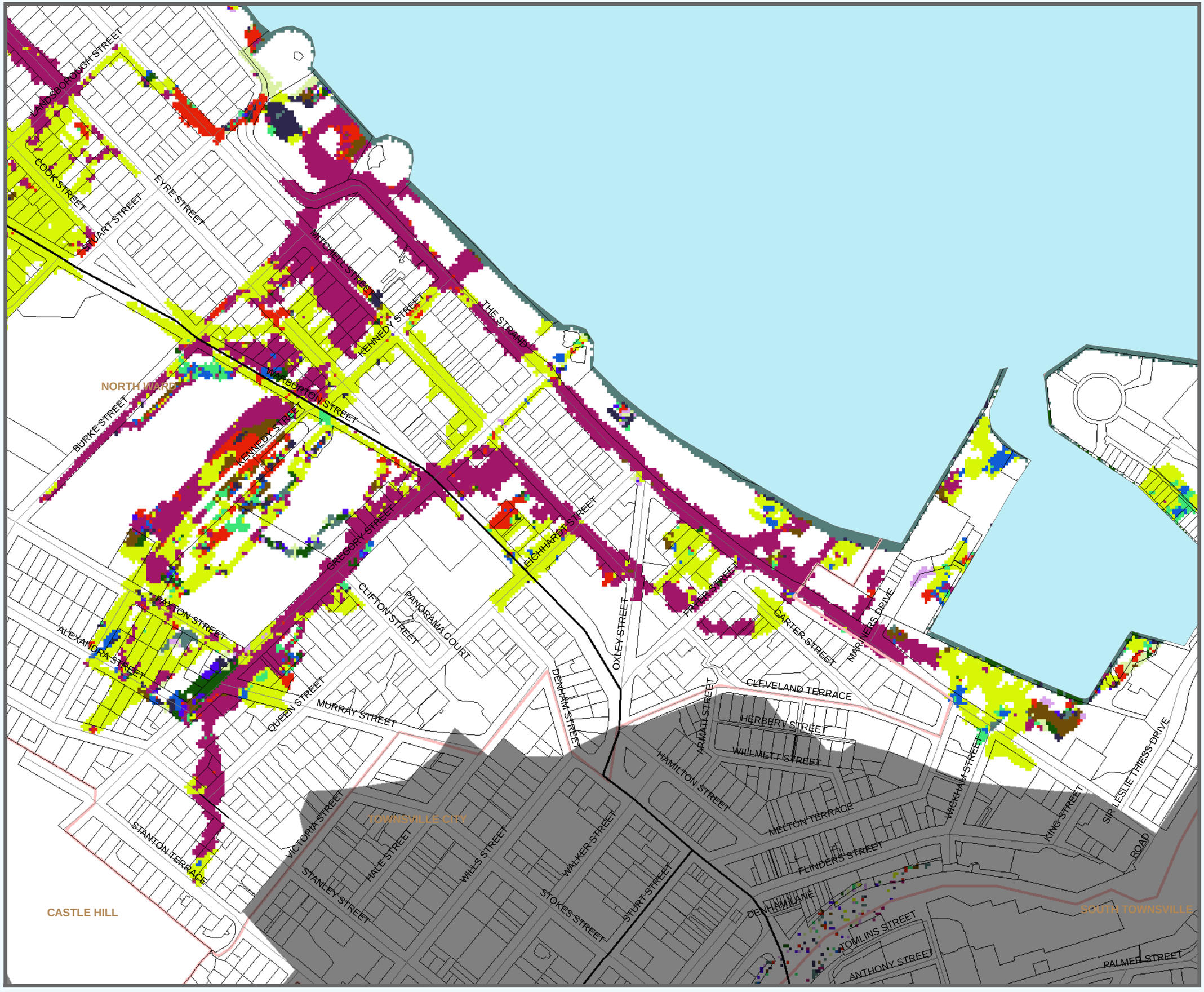
DIGITAL FILE: mxd

Figure 4.6.1: 50y Critical Duration Areas 1 of 2



TOWNSVILLE CITY COUNCIL

NORTH WARD CATCHMENT

LEGEND

Duration Source

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

210 105 0

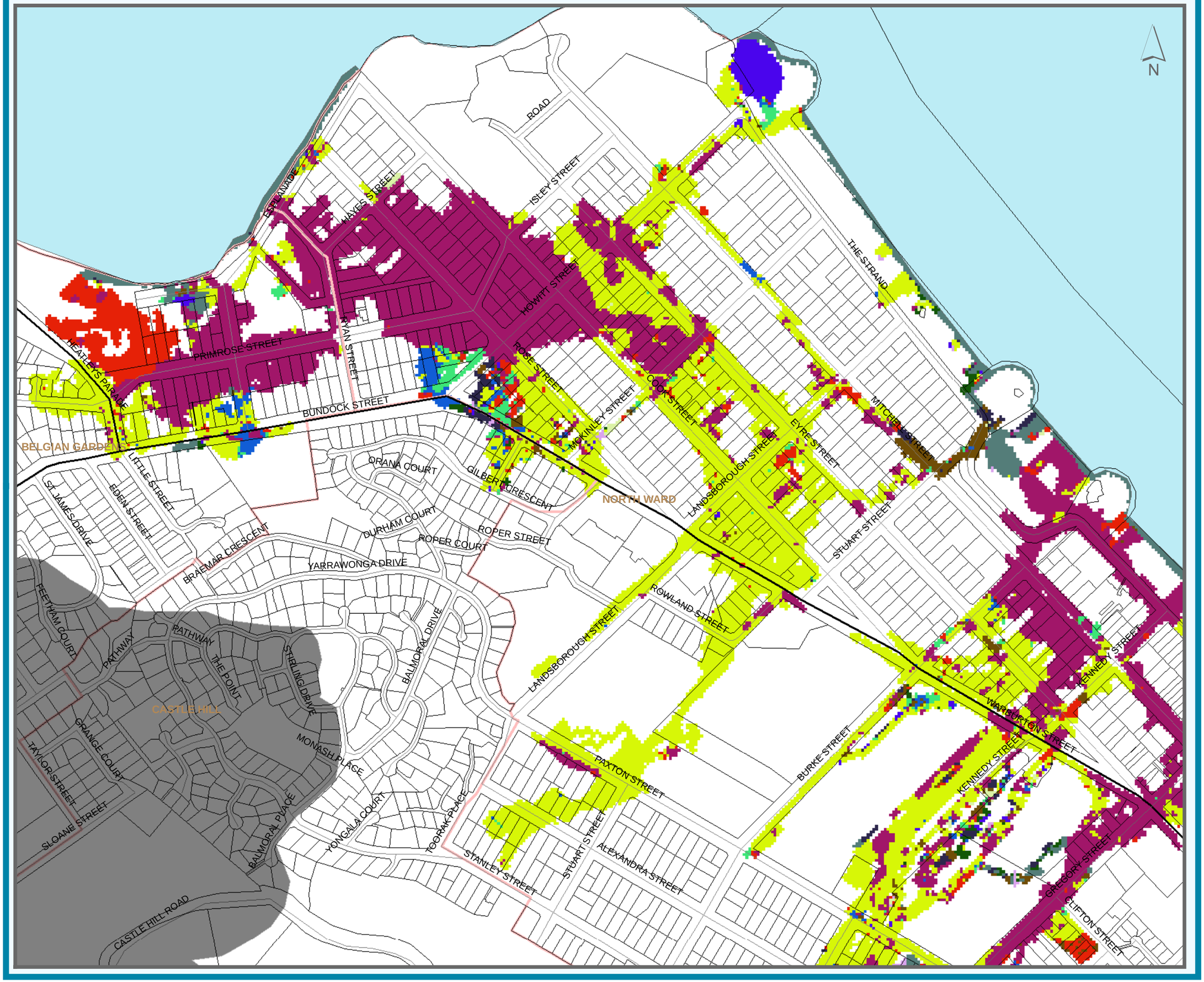
Meters

SCALE: 1:6,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 07/02/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure 4.6.2: 50y Critical Duration Areas 2 of 2



TOWNSVILLE CITY COUNCIL

NORTH WARD CATCHMENT

LEGEND

Duration Source

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

210 105 0

Meters

SCALE: 1:6,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 15/03/2011
DRAWN BY: JDJ
DIGITAL FILE: mxd

Figure 4.6.1: 100y Critical Duration Areas 1 of 2

TOWNSVILLE CITY COUNCIL

NORTH WARD CATCHMENT

LEGEND

Duration Source

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

220 110 0

Meters

SCALE: 1:6,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 15/03/2011
DRAWN BY: JDJ
DIGITAL FILE: mxd

Figure 4.6.2: 100y Critical Duration Areas 2 of 2

5.0 Base-line Flooding Assessment

The base-line model results have confirmed all problematic areas known to council. **Table 5.0.1** shows a summary of the number of properties inundated for each ARI for the base case. Properties were considered flooded if a significant portion of the land was inundated with more than 200mm of water.

Table 5.0.1: Number of Inundated Properties	
ARI	**Number of Properties**
2	27
5	38
10	50
20	73
50	106
100	144
500	200
PMF	439

5.1 Major Flow Paths

The Major flow paths for North Ward can be summarised through the major subcatchment groups. **Figure 3.3.1 A1 to B2** show these catchments and the groups of subcatchments they are comprised of.

NW1

Flows in subcatchment group NW1 start at the headwaters just upstream of Yarrawonga Drive. They continue along Little and Eden Streets, before converging on Little Street via Bundock Street. The flow then spreads out at the intersection of Little Street, Heatleys Parade, and Primrose Street which is a trap low point. The flows finally discharge to Cleveland Bay through Soroptimist Park as surface flow. A 900mm diameter pipe runs from the intersection of Bundock Street and Little Street to discharge at the outlet.

NW2

The headwaters of NW2 also start just upstream of Yarrawonga Drive. Flows continue through the property of 34 Bundock Street, before spreading out and inundating blocks adjacent to Primrose and Marshall Streets. The main flow path for surface water is along Marshall Street to the Esplanade before discharging to Cleveland Bay. 600mm diameter pipes service this subcatchment group but these weren't modelled due to the scope of the study.

NW3

NW3 is one of the larger catchments in North Ward. It has headwaters at both Jezanine Barracks in the North, and at Roper Court in the South. Flows from the South continue down Styx Street and Gilbert Crescent before diverging at Warburton Street and heading towards Howitt Street. Sheet flow exists from the Jezanine Barracks down until flooding occurs at Cook and Isley Streets. Flows through the catchment

also start at the intersections of Landsborough and Eyre Streets, and Landsborough and Cook Streets. They travel down Cook and Eyre Streets until the reach Hotwitt Street. From this point, all flows not conveyed by the 900mm diameter pipe to Ryan Street Drain, flow towards the drain via overland flow. The Ryan Steet Drain discharges to Cleveland Bay.

NW4

NW4 is small sub-catchment group located at The Rock Pool on The Strand. It has a total area of almost 6 hectares. Only 1 property is fully encompassed within NW4, and isn't affected by any storm event modelled in this study.

NW5

NW5 is the largest subcatchment group within North Ward. The headwaters for the catchment start at the top of Castle Hill, where flows concentrate to a natural channel that flows into a pipe network at the top of Stuart Street. When flows overtop the channel embankments, they travel down Stanely Street and through properties and an open drain between Stuart Street and Toorak Place. Flows cross Alexandra Street and properties between Landsborough and Stuart Streets before crossing Paxton Street by a large culvert, and overland flow in larger events. Downstream of Paxton Street, flows converge into an open drain that runs through Townsville Grammar School.

The open drain ends at Redpath Street where flows either enter 1200mm box culverts, or at higher ARIs, overtop the drain. The overland flow inundates Redpath Street and diverges at Warburton Street. Properties between Stuart Street and Landsborough Street are inundated before the flows and cross over into NW3. Significant storm water infrastructure also services Landsborough Street and The Strand, where it connects with the Stuart Street culverts before discharging in Cleveland Bay.

NW6

The headwaters to this catchment start the intersection of Burke and Stanley Streets. From Paxton Street, flows travel as sheet flow through Queens Park and also travels down kerb and channel along Burke Street. Once flows reach Warburton Street they converge into more confined overland flow and some are taken into culverts that service Kennedy Street. Overland flow inundates properties on Mitchell Street in between Burke Street and Kennedy Street which is a trap low point and the subject of recent mitigation works. Flows exit the trap low point through Strand Park and discharge to Cleveland Bay through several points along The Strand.

NW7

The NW7 catchment is another large catchment with its headwaters at the top of Castle Hill. Flow concentrates to a natural channel at Stanton Terrace with overland flow at Stanley Street through properties adjacent to Kennedy Street. The natural channel at Stanley Street flows through properties until it reaches the intersection of Murray and Gregory Streets, where some enters the underground pipe network and the rest flows along Gregory Street kerb and channel. Once the flows converging at Stanley Street reach Paxton Street, they are directed towards Gregory Street, except in higher ARIs where water flows over into Queens Gardens in NW7. Flows along Paxton Street either enter into the underground pipe network or continue to Gregory Street. The majority of overland flow along Gregory Street is diverged at Warburton Street and eventually on to Mitchell Street. These flows end up in either NW6 or NW8.

NW8

The headwaters of NW8 are at Denham Street. These flows continue onto Leichhardt Street by kerb and channel and onto Mitchell Street where they meet up with over flows from NW7. Flow then pass under Oxley Street through a culvert and briefly pass through a natural channel before entering into the underground pipe network beneath St Patrick's College, which discharges to Cleveland Bay just East of Fryer Street. Overland flow also occurs on the blocks adjacent to Fryer Street and then discharges over The Strand.

NW9

NW9 is mostly made up of the areas immediately surrounding the Breakwater Marina. It is mostly comprised of local flows into the Marina. Some water does run down Cleveland Terrace and into the Marina by overland flow through Anzac Memorial Park.

5.2 Comparison to Townsville Flood Hazard Assessment Study

Results of the North Ward Flood Study model were compared to the Townsville Flood Hazard Assessment model. **Table 5.2.1** 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. At most points, the NWFS shows a higher level than the TFHAS. The flood extents from the NWFS are also greater than the TFHAS. The causes of these differences can be attributed to the fact that the TFHAS was set up as a much broader and coarser model than the NWFS, and the NWFS has examined a range of storm durations to get peak flood levels.

There were several points throughout the catchment where the flood levels of the NWFS were lower than those given by the TFHAS study. These areas were in trap low points where the main flow path from the area was via the underground pipe network. Because the underground pipe network wasn't modelled in the TFHAS, flood levels in these areas were over represented. Flood levels were also lower in the NWFS at Mitchell Street due to the recent mitigation works.

Table 5.2.1: A comparison of water levels in the new model to those of the Townsville Flood Hazard Assessment Study								
Point	**TFHAS 50y Water Level [m]**	**NWFS Model 50y Water Level [m]**	**Difference [m]**		**Point**	**TFHAS 50y Water Level [m]**	**NWFS Model 50y Water Level [m]**	**Difference [m]**
1	2.97	3.19	0.22		33	-	7.28	-
2	2.94	3.16	0.22		34	-	5.15	-
3	2.94	3.17	0.23		35	5.96	6.04	0.08
4	3.04	3.23	0.19		36	4.22	4.39	0.17
5	3.1	3.34	0.24		37	4.29	4.39	0.1
6	4.4	4.64	0.24		38	-	4.01	-
7	-	5.22	-		39	2.86	2.9	0.04
8	2.76	2.8	0.04		40	1.77	2.52	0.75
9	2.9	2.94	0.04		41	1.82	2.89	1.07
10	2.82	2.84	0.02		42	-	2.97	-
11	2.77	2.94	0.17		43	-	3.08	-
12	-	3.94	-		44	-	6.4	-
13	6.49	6.85	0.36		45	3.92	4.27	0.35
14	6.05	6.19	0.14		46	-	6.81	-
15	9.64	10	0.36		47	-	5.17	-
16	6.75	6.79	0.04		48	-	12.94	-
17	10.4	10.81	0.41		49	8.09	8.09	0
18	-	17.17	-		50	9.18	9.34	0.16
19	-	19.27	-		51	9.78	10.09	0.31
20	5.75	5.77	0.02		52	11.66	12.03	0.37
21	6.77	6.32	-0.45		53	-	12.74	-
22	5.36	5.46	0.1		54	-	14.53	-
23	6.91	6.99	0.08		55	-	15.09	-
24	-	9.15	-		56	-	11.38	-
25	-	7.78	-		57	-	10.31	-
26	-	17.97	-		58	6.86	6.92	0.06
27	-	23.36	-		59	5.17	5.33	0.16
28	-	16.48	-		60	-	5.26	-
29	-	30.29	-		61	-	4.89	-
30	-	17.45	-		62	6.29	6.24	-0.05
31	10.36	10.37	0.01		63	-	9.98	-
32	8.32	8.42	0.1		64	5.93	5.65	-0.28
33	-	7.28	-		65	3.96	3.7	-0.26

- implies that that the point in question was not inundated in the TFHAS

5.3 Overland Results

Surface flow results generated from the model are shown as flood envelopes in **Appendix A**. **Table 5.3.1** summarises the results. Unless otherwise stated, water levels below 0.2m are ignored in the summary. **Table A1** shows a comparison of the surface levels for each ARI at points identified in **Figure A0**. **Figure A0** and **Table A1** are located in **Appendix A**.

Table 5.3.1: 2 year ARI Overland Flow Results					
	Roads	**Properties**	**Velocities**	**Depths**	**Other**
NW1	Heatleys Parade, and Primrose St are partially inundated with depths up to 0.4.	No properies inundated.	Velocities less than 1m/s.	Depths up to 0.4m in Soroptimist Park and on the roads.	Trap low point at the intersection of Heatleys Parade, Primrose St, and Little St.
NW2	Primrose St inundated from Heatleys Pde to Ryan St. Marshall St inundated over 150m crossing Primrose St.	6 properties on Primrose St, mostly on the southern side, and 2 other properties in NW2.	Velocities less than 1m/s.	Depths less than 0.6m on roads, less than 0.4m for most properties.	Trap low point at Primrose St.
NW3	Howitt, Cook, and Isley Streets are inundated across the width of the roads.	3 properties are inundated in the area.	Velocities less than 1m/s.	Depths in kerb and channel up to 0.6m on Cook St and 0.4m on Isley St.	Large trap low point in areas surrounding inundated roads.
NW5	The Warburton St outbound land is partially inundated with levels around 0.3m.	3 properties are inundated upstream of Paxton St.	Velocities less than 1m/s on Alexandra St; up to 1.8m/s over Paxton St; and less than 1m/s through the Stuart Street open drain.	Depths within the natural channel upstream of Paxton St vary from around 1m to less than 0.2m. Depths in the Stuart St channel vary from 1m to less than 0.2m.	
NW6	The intersection of Mitchell St and Burke St is partially inundated with levels less than 0.4m. Eyre St and the outbound lane of Warburton St are both inundated with levels less than 0.3m. The Strand is inundated to less than 0.5m.	4 properties are inundated around the Mitchell Street area.	Velocities less than 1m/s along Warburton St.	Depths less than 0.4m for properties in the Mitchell St area. Depths less than 0.5 in Strand Park.	
NW7	Gregory St is inundated with depths around 0.2m around kerb and channel. The Strand is inundated with depths less than 0.6m.	No properies inundated.	Velocities through the natural channel upstream of Murray St less than 1m/s. Velocities over Stanley St up to 1.5m/s and 1.2m/s along Gregory St kerb and channel.	Depths less than 0.5m in the natural channel upstream of Murray St. Depths less than 0.3m on Mitchell St kerb and channel.	
NW8	The Strand is partially inundated in the inbound lane with depths around up to 0.3m. Mitchell St is inundated with depths less than 0.8m at the Oxley St end.	1 property on Fryer St is inundated up to 0.4m.	Velocities on Leichhardt St up to 1.5m/s		
NW9	No roads fully inundated with depths over 0.2m.	No properies inundated.	All velocities below 1m/s	Depths in Anzac Memorial Park less than 0.4m.	

Table 5.3.1: 5 year ARI Overland Flow Results					
	Roads	**Properties**	**Velocities**	**Depths**	**Other**
NW1	Heatleys Parade, and Primrose St are inundated across the intersection with depths varying from 0.5 to less than 0.2m.	1 property is inundated on on Heatleys Parade just north of Primrose St	Velocities less than 1m/s.	Depths up to 0.5m in Soroptimist Park and on the roads.	Trap low point at the intersection of Heatleys Parade, Primrose St, and Little St.
NW2	Primrose St inundated from Heatleys Pde to Ryan St. Marshall St inundated over 150m crossing Primrose St.	6 properties on Primrose St, mostly on the southern side, and 2 other properties in NW2.	Velocities less than 1m/s.	Depths less than 0.6m on roads, less than 0.5m for most properties.	Trap low point at Primrose St.
NW3	Howitt, Cook, Eyre, Rose, Primrose, and Isley Streets are inundated across the width of the roads.	10 properties are inundated on the flooded roads.	Velocities reach over 1m/s on Eyre and Rose Streets and 0.8m on Styx Streets.	Depths up to 0.75m on Cook St and 0.5m on Isley St.	Large trap low point in areas surrounding inundated roads.
NW5	The Warburton St outbound land is partially inundated with levels up to 0.5m.	4 properties are inundated upstream of Paxton St. 1 properties are inundated on Redpath St.	Velocities reach; 1.4m/s on Alexandra St; 2.5m/s over Paxton St; less than 1m/s through the Stuart Street open drain; less than 1m/s through properties on Redpath Street.	Depths within the natural channel upstream of Paxton St vary from around 1.2m to 0.2m. Depths in the Stuart St channel vary from 1m to 0.3m. Property on Redpath St are inundated with levels up to 0.4m.	
NW6	The intersection of Mitchell St and Burke St is inundated with levels less than 0.4m. Eyre St and the outbound lane of Warburton St are both inundated with levels less than 0.3m. The Strand is inundated to around 0.5m.	5 properties are inundated around the Mitchell Street area.	Velocities reach around 1m/s along Warburton St.	Depths less than 0.5m for properties in the Mitchell St area. Depths up to 0.5 in Strand Park.	
NW7	Gregory St is inundated with depths around 0.3m around kerb and channel and below 0.2m over the road crown. The Strand is inundated with depths around 0.6m.	2 properties are inundated around the natural channel upstream of Murray St.	Velocities through the natural channel upstream of Murray St reach over 1m/s. Velocities over Stanley St up to 1.8m/s and 1.3m/s along Gregory St kerb and channel.	Depths up to 0.7m in the natural channel upstream of Murray St, but usually stayed below 0.5m. Depths around 0.3m on Mitchell St kerb and channel.	
NW8	The Strand is inundated in the inbound lane with depths up to 0.4m. Mitchell St is inundated with depths up to 0.8m at the Oxley St end.	1 property on Fryer St is inundated up to 0.4m.	Velocities on Leichhardt St up to 1.6m/s		
NW9	No roads fully inundated with depths over 0.2m.	No properies inundated.	All velocities below 1m/s	Depths in Anzac Memorial Park less than 0.4m.	

Table 5.3.1: 10 year ARI Overland Flow Results					
	Roads	**Properties**	**Velocities**	**Depths**	**Other**
NW1	Heatleys Parade, and Primrose St on both directions are inundated across the width of the road with depths varying from 0.5 to less than 0.2m.	1 property is inundated on on Heatleys Parade just north of Primrose St	Velocities less than 1m/s.	Depths up to 0.5m in Soroptimist Park and on the roads.	Trap low point at the intersection of Heatleys Parade, Primrose St, and Little St.
NW2	Primrose St inundated from Heatleys Pde to Ryan St. Marshall St inundated over 160m crossing Primrose St.	6 properties on Primrose St, mostly on the southern side, and 2 other properties in NW2.	Velocities less than 1m/s.	Depths less than 0.6m on roads, less than 0.5m for most properties.	Trap low point at Primrose St.
NW3	Howitt, Cook, Eyre, Rose, Primrose, and Isley Streets are inundated across the width of the roads.	17 properties are inundated on the flooded roads.	Velocities reach over 1m/s on Eyre, Rose, and Styx Streets.	Depths in kerb and channel up to 0.75m on Cook St and 0.5m on Isley St.	Large trap low point in areas surrounding inundated roads.
NW5	The Warburton St outbound land is inundated with level between 0.2 and 0.5m.	5 properties are inundated upstream of Paxton St. 3 properties are inundated around Warburton St.	Velocities reach; 1.8m/s on Alexandra St; more than 2.5m/s over Paxton St; less than 1m/s through the Stuart Street open drain; less than 1m/s through properties on Redpath Street.	Depths within the natural channel upstream of Paxton St vary from around 1.2m to 0.2m. Depths in the Stuart St channel vary from 1m to 0.3m. Properties on Redpath St are inundated with levels up to 0.4m.	
NW6	The intersection of Mitchell St and Burke St is inundated with levels less than 0.4m. Eyre St and the outbound lane of Warburton St are both inundated with levels less than 0.3m. The Strand is inundated to around 0.5m.	5 properties are inundated around the Mitchell Street area.	Velocities reach around 1m/s along Warburton St and on The Strand at Strand Park.	Depths up to 0.5m for properties in the Mitchell St area. Depths up to 0.5 in Strand Park.	
NW7	Gregory St is inundated with depths up to 0.4m around kerb and channel and below 0.2m over the road crown. The Strand is inundated with depths up to 0.7m.	4 properties are inundated around the natural channel upstream of Murray St.	Velocities through the natural channel upstream of Murray St reach over 1m/s. Velocities over Stanley St and along Gregory St kerb and channel exceed 2m/s.	Depths up to 1m in the natural channel upstream of Murray St, but usually stayed below 0.5m. Depths to 0.3m in Gregory St kerb and channel. Depths around 0.3m on Mitchell St kerb and channel.	
NW8	The Strand is inundated in the inbound lane with depths up to 0.4m. Mitchell St is inundated with depths up to 0.8m at the Oxley St end.	1 property on Fryer St is inundated up to 0.4m.	Velocities on Leichhardt St up to 1.7m/s		
NW9	No roads fully inundated with depths over 0.2m.	No properies inundated.	All velocities below 1m/s	Depths in Anzac Memorial Park up to 0.4m.	

Table 5.3.1: 20 year ARI Overland Flow Results					
	Roads	**Properties**	**Velocities**	**Depths**	**Other**
NW1	Heatleys Parade, and Primrose St on both directions are inundated across the width of the road.	3 properties on Primrose St; 2 beside Soroptimist Park, and 1 on Heatleys Parade just north of Primrose St	Velocities less than 1m/s.	Depths up to 0.7m in Soroptimist Park, and up to 0.6m on roads.	Trap low point at the intersection of Heatleys Parade, Primrose St, and Little St.
NW2	Primrose St inundated from Heatleys Pde to Ryan St. Marshall St inundated over 160m crossing Primrose St.	9 properties on Primrose St, mostly on the southern side, and 2 other properties in NW2.	Velocities less than 1m/s.	Depths up to 0.6m on roads.	Trap low point at Primrose St.
NW3	Howitt, Cook, Eyre, Rose, Primrose, and Isley Streets are inundated across the width of the roads.	31 properties are inundated on the flooded roads.	Velocities reach over 1m/s on Cook, Eyre, Rose, Howitt and Styx Streets.	Depths in kerb and channel up to 0.75m on Cook St and 0.6m on Isley St.	Large trap low point in areas surrounding inundated roads.
NW5	Warburton St is inundated with water over the entire width with depths up to 0.4m. Rowland St is inundated with levels around 0.2m. Alexandra St and Paxton St is inundated with water under 0.2m depth.	7 properties are inundated upstream of Paxton St. 6 properties are inundated around Warburton St.	Velocities reach; 1.8m/s on Alexandra St; more than 2.5m/s over Paxton St; 1m/s through the Stuart street open drain; around 1-1.5m/s through properties on Redpath Street; and over 1-1.5m/s through kerb and channel on Redpath St, Cook St, and Landsborough St.	Depths within the natural channel upstream of Paxton St vary from 1.3m to 0.2m. Depths in the Stuart St channel are generally around 1m but go as low as 0.4m. Properties on Redpath St are inundated with levels less than 0.6m.	
NW6	The intersection of Mitchell St and Burke St is inundated with levels greater than 0.4m. Eyre St and the outbound lane of Warburton St are both inundated with levels around 0.3m. The Strand is inundated to around 0.6m.	6 properties are inundated around the Mitchell Street area.	Velocities reach around 1m/s along Warburton St and on The Strand at Strand Park.	Depths up to 0.5m for properties in the Mitchell St area. Depths up to 0.5 in Strand Park.	
NW7	Gregory St is inundated with depths up to 0.5m around kerb and channel and below 0.2m over the road crown. The Strand is inundated up to 0.7m.	4 properties are inundated around the natural channel upstream of Murray St. 1 properties are inundated on Gregory St towards Warburton St.	Velocities through the natural channel upstream of Murray St reach over 1m/s. Velocities over Stanley St and along Gregory St kerb and channel exceed 2m/s.	Depths up to 1m in the natural channel upstream of Murray St, but usually stayed below 0.5m. Depths up to 0.4m in Gregory St kerb and channel. Depths around 0.3m on Mitchell St kerb and channel.	
NW8	The Strand is inundated in the inbound lane with depths up to 0.5m. Carter St is inundated across the width up to 0.5m. Mitchell St is inundated with depths up to 0.8m at the Oxley St end.	1 property on Fryer St is inundated up to 0.4m.	Velocities on Leichhardt St up to 1.8m/s		
NW9	No roads fully inundated with depths over 0.2m.	No properies inundated.	All velocities below 1m/s	Depths in Anzac Memorial Park up to 0.4m.	

Table 5.3.1: 50 year ARI Overland Flow Results					
	Roads	**Properties**	**Velocities**	**Depths**	**Other**
NW1	Heatleys Parade, and Primrose St on both directions are inundated across the width of the road.	4 properties on Primrose St; 2 beside Soroptimist Park, and 2 on Heatleys Parade just north of Primrose St	Velocities less than 1m/s.	Depths up to 1.5m in Soroptimist Park, and up to 0.7m on roads.	Trap low point at the intersection of Heatleys Parade, Primrose St, and Little St.
NW2	Primrose St inundated from Heatleys Pde to Ryan St. Marshall St inundated over 170m crossing Primrose St.	11 properties on Primrose St, mostly on the southern side, and 5 other properties in NW2.	Velocities less than 1m/s.	Depths up to 0.6m on roads.	Trap low point at Primrose St.
NW3	Howitt, Cook, Eyre, Rose, Primrose, and Isley Streets are inundated across the width of the roads.	49 properties are inundated on the flooded roads.	Velocities reach over 1m/s on Cook, Eyre, Rose, Howitt and Styx Streets.	Depths in kerb and channel up to 0.75m on Cook St and 0.6m on Isley St.	Large trap low point in areas surrounding inundated roads.
NW5	Rowland St and Warburton St are both inundated with water over the entire width. Alexandra street is inundated with a narrow corridor of water deeper than 200mm.	8 properties are inundated upstream of Paxton St. 10 properties are inundated around Warburton St.	Velocities reach; almost 1.7m/s on Alexandra St; more than 2.5m/s over Paxton St; 1m/s through the stuart street open drain; around 1m/s through properties on Redpath Street; and 1m/s through kerb and channel on Redpath St, Cook St, and Landsborough St.	Depths within the natural channel upstream of Paxton St vary from 1.5m to 0.2m. Depths in the Stuart St channel are generally around 1m but go as low as 0.4m. Properties on Redpath St are inundated with levels grater than 0.6m.	
NW6	The intersection of Mitchell St and Burke St is inundated with levels greater than 0.4m. Eyre St and the outbound lane of Warburton St are both inundated with levels around 0.3m. The Strand is inundated to around 0.6m.	9 properties are inundated around the Mitchell Street area.	Velocities reach around 1m/s along Warburton St and on The Strand at Strand Park.	Depths up to 0.5m for properties in the Mitchell St area. Depths over 0.5 in Strand Park.	
NW7	Gregory St is inundated with depths up to 0.5m around kerb and channel and below 0.2m over the road crown. The Strand is inundated up to 0.7m.	4 properties are inundated around the natural channel upstream of Murray St. 2 properties are inundated on Gregory St towards Warburton St.	Velocities through the natural channel upstream of Murray St reach over 1m/s. Velocities over Stanley St and along Gregory St kerb and channel exceed 2m/s.	Depths up to 1m in the natural channel upstream of Murray St, but usually stayed below 0.5m. Depths up to 0.4m in Gregory St kerb and channel. Depths around 0.4m on Mitchell St kerb and channel.	
NW8	The Strand is inundated in the inbound lane with depths up to 0.6m. Carter St is inundated across the width up to 0.75m. Mitchell St is inundated with depths up to 0.8m at the Oxley St end.	1 property on Fryer St is inundated up to 0.4m.	Velocities on Leichhardt St up to 2m/s		
NW9	No roads fully inundated with depths over 0.2m.	No properies inundated.	All velocities below 1m/s	Depths in Anzac Memorial Park up to 0.4m.	

Table 5.3.1: 100 year ARI Overland Flow Results					
	Roads	**Properties**	**Velocities**	**Depths**	**Other**
NW1	Heatleys Parade and Primrose St on both directions are inundated across the width of the road.	4 properties on Primrose St; 2 beside Soroptimist Park, and 2 on Heatleys Parade just north of Primrose St.	Velocities less than 1m/s.	Depths up to 1.5m in Soroptimist Park, and up to 0.7m on roads.	Trap low point at the intersection of Heatleys Parade, Primrose St, and Little St.
NW2	Primrose St inundated from Heatleys Pde to Ryan St. Marshall St inundated over 170m crossing Primrose St.	12 properties on Primrose St, mostly on the southern side, and 6 other properties in NW2.	Velocities up to 1m/s.	Depths up to 0.7m on roads.	Trap low point at Primrose St.
NW3	Howitt, Cook, Eyre, Rose, Primrose, and Isley Streets are inundated across the width of the roads.	66 properties are inundated on the flooded roads.	Velocities up to 1.5m/s on Cook, Eyre, and Styx Streets. Velocities over 1m/s on Rose and Howitt Streets.	Depths in kerb and channel up to 0.85m on Cook St and 0.7m on Isley St and Rose St.	Large trap low point in areas surrounding inundated roads.
NW5	Rowland St, Alexandra St, and Warburton St are both inundated with water over the entire width.	8 properties are inundated upstream of Paxton St. 12 properties are inundated around Warburton St.	Velocities reach; almost 1.8m/s on Alexandra St; more than 2.8m/s over Paxton St; 1m/s through the Stuart street open drain; as high as 1.5m/s through properties on Redpath Street; and 1-1.4m/s through kerb and channel on Redpath St, Cook St, and Landsborough St.	Depths within the natural channel upstream of Paxton St vary from 1.5m to 0.2m. Depths in the Stuart St channel are generally around 1m. Houses on Redpath St are inundated with levels grater than 0.7m. Properties just downstream of Warburton St are inundated with levels up to 0.35m.	
NW6	The intersection of Mitchell St and Burke St is inundated with levels greater than 0.6m. Eyre St and the outbound lane of Warburton St are both inundated with levels up to 0.4m. The Strand is inundated to around 0.6m.	10 properties are inundated around the Mitchell Street area.	Velocities reach around 1.2m/s along Warburton St and on The Strand at Strand Park.	Depths up to 0.6m for properties in the Mitchell St area, depths to 0.5 in Strand Park.	
NW7	Gregory St is inundated with depths up to 0.5m around kerb and channel and around 0.2m over the road crown. The Strand is inundated up to 0.7m.	4 properties are inundated around the natural channel upstream of Murray St. 1 property on Gregory St near Murray St, and 2 properties on Gregory St towards Warburton St.	Velocities through the natural channel upstream of Murray St reach over 1.2m/s. Velocities over Stanley St are around 2m/s and over 2.5m/s along Gregory St kerb and channel.	Depths up to 1m in the natural channel upstream of Murray St, but usually stayed below 0.5m. Depths up to 0.4m in Gregory St kerb and channel. Depths around 0.4m on Mitchell St kerb and channel.	
NW8	The Strand is inundated in the inbound lane with depths up to 0.6m. Carter St is inundated across the width up to 0.8m. Mitchell St is inundated with depths up to 0.9m at the Oxley St end.	1 property on Fryer St is inundated up to 0.4m.	Velocities on Leichhardt St up to 2m/s		
NW9	No roads fully inundated with depths over 0.2m.	No properies inundated.	All velocities below 1m/s	Depths in Anzac Memorial Park up to 0.4m.	

5.4 MIKE URBAN Results

Table 5.4.1 shows results for the underground pipe network at each node. For each ARI, the maximum water level for any storm duration has been reported. For reference to **Table 5.4.1**, **Figure 5.4.1** has been included to show the underground network model setup.

Table 5.4.2 below shows an estimate of the ARI at which each separate pipe network reaches its capacity. For each individual pipe network, detailed drainage modelling would be required to confirm the network capacity.

Table 5.4.2: Pipe Network Capacities

Pipe network	Approximate ARI at full capacity
Little Street	2
Ryan Street	2
Landsborough Street	5
Stuart Street	5
Gregory Street	20
Carter Street	10-20

Table 5.4.2 does not include data for the pipe network under Kennedy Street. This pipe network includes a number of smaller pipes that were not modelled. These pipes convey flows from significant overland flow paths into the pipe network. As the inlets to the system are not accurately modelled, the flows in the pipe network are under represented. To determine accurate capacities of the pipe networks within the Kennedy Street area, drainage modelling would need to be undertaken.

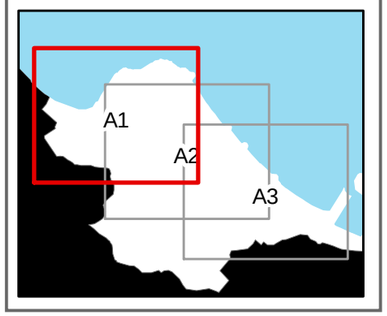
	Table 5.4.1: MIKE URBAN node results, max water level [m]							
Nodes	**2y**	**5y**	**10y**	**20y**	**50y**	**100y**	**500y1h**	**PMF1h**
0119A32U	4.52	4.67	5.57	5.06	5.50	5.75	5.96	6.40
0119A31U	4.12	4.42	5.58	5.03	5.51	5.76	5.96	6.37
0119A28U	4.12	4.43	5.56	5.03	5.50	5.74	5.94	6.36
0119A27U	3.64	3.85	4.89	4.56	4.85	5.00	5.15	5.85
0119A26U	2.96	3.22	4.64	4.34	4.63	4.75	4.89	5.74
0119A25U	2.92	3.19	4.63	4.33	4.62	4.74	4.88	5.73
0119A24U	2.84	3.14	4.61	4.32	4.60	4.72	4.86	5.72
0119A23U	2.76	3.09	4.56	4.28	4.56	4.68	4.82	5.69
0119A21U	2.74	3.07	4.46	4.21	4.48	4.60	4.75	5.67
0119A20U	2.75	3.07	4.38	4.15	4.40	4.53	4.71	5.67
0119A16U	2.55	2.84	4.19	3.94	4.18	4.30	4.43	5.22
0119A14U	2.51	2.81	3.96	3.73	3.96	4.07	4.19	4.95
0119A13U	2.49	2.78	3.77	3.57	3.76	3.86	3.97	4.68
0119A11U	2.48	2.76	3.59	3.41	3.58	3.66	3.75	4.42
0119A10U	2.46	2.74	3.41	3.27	3.40	3.47	3.55	4.17
0119A9U	2.41	2.66	3.17	3.06	3.16	3.21	3.25	3.70
0119A6U	2.12	2.39	2.80	2.71	2.79	2.83	2.86	3.19
0119A3U	2.10	2.35	2.57	2.53	2.57	2.59	2.59	2.72
0119A1D	1.29	1.48	1.65	1.62	1.64	1.66	1.81	1.87
0153K1D	1.41	1.55	1.77	1.74	1.84	1.95	2.07	2.29
0153K2U	1.56	1.75	2.04	1.99	2.12	2.26	2.50	3.08
0153K3U	1.87	2.09	2.42	2.37	2.52	2.71	3.13	4.44
0153K4U	2.03	2.25	2.60	2.55	2.75	3.03	3.72	5.69
0153K5U	2.32	2.56	2.96	2.90	3.10	3.47	4.37	6.98
0153K6U	2.32	2.56	2.97	2.91	3.13	3.55	4.54	7.37
0153A3U	2.36	2.60	3.00	2.94	3.15	3.57	4.62	7.62
0153A4U	3.84	4.06	4.41	4.40	4.60	4.74	6.04	13.44
0153A5U	4.65	4.78	4.96	4.86	4.93	5.08	6.63	16.74
0153A6U	5.52	5.72	6.03	5.90	6.05	6.27	7.19	19.92
0153A7U	5.56	5.75	6.07	5.94	6.08	6.31	7.33	21.16
0153A8U	5.64	5.81	6.13	6.01	6.14	6.37	7.45	22.31
0153A9U	6.11	6.20	6.41	6.32	6.39	6.46	7.57	23.67
0153A11U	6.53	6.72	7.02	6.90	6.95	7.09	7.79	26.41
0126A01D	1.84	2.07	2.36	2.25	2.33	2.41	2.55	2.79
0126A02U	2.21	2.54	2.90	2.78	2.87	2.98	3.22	4.27
0126A3U	3.10	3.42	3.86	3.70	3.82	3.93	4.15	5.34
0126A04U	4.33	4.61	5.08	4.94	5.10	5.25	5.58	7.61
0126A6U	4.64	4.95	5.43	5.27	5.42	5.56	5.95	8.70
0126A8U	5.58	5.93	6.46	6.27	6.42	6.58	6.88	10.10
0126A9U	5.64	6.06	6.58	6.36	6.52	6.68	7.04	10.39
0126A11U	5.81	6.33	6.87	6.65	6.81	6.98	7.35	10.89
0126A14U	5.88	6.40	6.93	6.71	6.87	7.05	7.45	10.96
0126A16U	7.92	8.23	8.55	8.44	8.53	8.61	8.73	11.36
0126A17U	8.14	8.42	8.90	8.72	8.87	9.01	9.22	11.56
0126A18U	9.67	10.07	10.17	10.15	10.16	10.16	10.14	11.70
0126AP1U	14.02	14.24	14.48	14.36	14.47	14.49	14.65	16.37
0126A19U	10.51	10.85	10.94	10.89	10.93	10.97	11.02	11.82
0126AP2U	14.73	15.64	16.74	16.19	16.73	16.85	17.05	17.54
0126A20U	11.24	11.58	11.71	11.68	11.71	11.74	11.80	12.29
0126A21U	11.54	12.34	12.50	12.46	12.49	12.53	12.60	12.96
0126A22U	12.79	13.46	13.63	13.59	13.63	13.66	13.73	14.06
0126A23U	12.90	14.02	14.17	14.13	14.16	14.20	14.27	14.58
0126A24U	13.51	14.55	14.75	14.70	14.75	14.78	14.86	15.19
0126A25U	14.43	15.56	15.95	15.86	15.95	16.01	16.13	16.56
0126A26U	14.49	15.73	16.15	16.06	16.16	16.22	16.34	16.80
0143A13U	3.00	3.10	3.31	3.21	3.30	3.36	3.54	10.40
0143A12U	2.96	3.06	3.28	3.17	3.26	3.32	3.45	9.58
0143A11U	2.95	3.05	3.27	3.17	3.25	3.32	3.45	9.37
0143A10U	2.93	3.02	3.25	3.14	3.23	3.30	3.43	8.79

Nodes	2y	5y	10y	20y	50y	100y	500y1h	PMF1h
0143A9U	2.92	3.01	3.25	3.14	3.22	3.29	3.43	8.67
0143A8U	2.89	2.99	3.24	3.12	3.21	3.29	3.42	8.52
0143A7U	2.84	2.95	3.20	3.09	3.18	3.25	3.39	7.62
0143A6U	2.82	2.94	3.20	3.08	3.17	3.25	3.38	7.47
0143A4U	2.82	2.93	3.20	3.07	3.17	3.24	3.38	7.04
0143A3U	2.80	2.92	3.19	3.06	3.16	3.24	3.37	6.61
0143A1Da	2.80	2.91	3.19	3.06	3.16	3.24	3.37	9.68
0170AD1U	4.43	5.21	5.78	6.01	7.00	8.25	11.38	41.51
0170A6U	4.08	4.42	4.92	5.07	5.28	5.66	6.87	20.35
0170A5U	3.81	4.14	4.48	4.61	4.77	5.06	5.78	13.34
0170A4U	3.66	3.80	4.13	4.30	4.42	4.64	5.02	10.66
0170A3U	2.58	3.28	3.74	4.02	4.21	4.42	4.82	9.58
0170AC1U	3.66	3.80	4.12	4.31	4.42	4.64	5.03	10.66
0170AM1U	2.16	2.82	3.25	3.24	3.36	3.47	3.69	6.90
0170AC2U	3.66	3.81	4.22	4.32	4.42	4.62	5.01	10.65
0170A2U	2.01	2.53	3.06	2.96	3.06	3.15	3.39	5.97
0170A04U	1.78	2.19	2.92	2.71	2.86	2.98	3.11	4.83
0170A03U	1.59	1.90	2.87	2.62	2.79	2.89	3.02	4.21
0170A02U	1.35	1.68	2.75	2.50	2.68	2.77	2.88	3.35
0170AB1U	1.59	1.90	2.87	2.62	2.79	2.90	3.02	4.26
0170A002U	1.18	1.40	2.24	2.00	2.18	2.25	2.34	2.69
0170A1D	0.81	0.93	1.04	1.04	1.04	1.04	1.04	1.04
0163A26U	21.46	21.81	22.48	22.52	22.82	23.82	26.58	65.05
0163A25U	20.57	20.76	20.94	20.95	21.01	21.45	22.39	44.78
0163A24U	17.79	18.00	18.20	18.21	18.26	19.34	19.78	33.12
0163A23U	14.38	14.55	14.69	14.72	14.78	15.77	16.18	21.74
0163A22U	13.81	13.98	14.24	14.28	14.32	14.87	15.34	17.95
0163AR1U	12.16	12.42	12.70	12.88	13.55	13.88	14.16	17.41
0163A21U	13.40	13.55	13.73	13.92	14.17	14.66	15.15	17.18
0163A19U	9.86	10.55	10.79	11.19	11.51	11.76	12.09	14.45
0163A021U	11.17	11.38	11.69	12.36	12.82	13.15	13.50	15.47
0163A18U	9.70	10.23	10.45	10.78	11.04	11.25	11.58	14.05
0163A17U	9.40	9.75	10.03	10.26	10.45	10.56	10.74	13.21
0163A16U	9.19	9.37	9.67	9.87	10.06	10.18	10.35	12.66
0163A15U	8.97	9.00	9.26	9.47	9.70	9.82	9.99	12.27
0163A14U	7.47	7.85	8.33	8.51	8.83	9.02	9.36	11.69
0163A13U	6.65	6.84	7.52	7.59	7.85	7.95	8.21	10.24
0163A11U	5.96	6.34	7.20	7.24	7.50	7.64	7.94	9.94
0163A12U	6.35	6.65	7.14	7.18	7.44	7.59	7.91	9.95
0163A10U	5.67	6.16	7.09	7.14	7.41	7.57	7.90	9.94
0163A9U	5.58	6.08	6.90	6.90	7.12	7.26	7.56	9.28
0163A08U	5.45	5.99	6.81	6.78	7.00	7.15	7.45	9.10
0163A7U	5.28	5.84	6.67	6.62	6.83	6.99	7.30	8.87
0163A6U	5.27	5.83	6.66	6.61	6.82	6.98	7.28	8.85
0163A5U	5.16	5.73	6.53	6.45	6.68	6.85	7.18	8.72
0163A4U	5.09	5.67	6.39	6.28	6.47	6.63	6.97	8.28
0163A3U	5.12	5.67	6.39	6.28	6.47	6.64	6.97	8.28
0163A2U	4.89	5.23	5.87	5.73	5.91	6.08	6.38	7.37
0163A1U	4.80	5.07	5.64	5.50	5.66	5.82	6.09	6.98
0163A01U	4.03	4.25	4.97	4.84	4.97	5.11	5.34	6.14
0163F1U	3.57	4.05	4.36	4.27	4.36	4.37	4.41	4.70
0163F2U	3.67	4.24	4.58	4.47	4.58	4.59	4.62	5.41
0163F1D	2.01	2.25	2.49	2.36	2.45	2.64	2.68	2.70
0163F3U	3.77	4.41	4.78	4.67	4.77	4.79	4.83	6.21
0163F04U	5.69	5.77	6.06	5.91	6.07	6.12	6.27	7.88
0163F4U	7.44	7.89	8.22	8.06	8.23	8.28	8.55	10.08
0163F05U	9.16	9.51	9.88	9.77	9.92	10.00	10.18	11.18
0163F5U	9.36	9.90	10.27	10.16	10.31	10.39	10.57	11.50
0163F6U	10.80	11.40	11.97	11.86	12.02	12.14	12.32	13.10

TOWNSVILLE CITY COUNCIL
NORTH WARD
CATCHMENT

LEGEND

- MIKE URBAN Outlets
- MIKE URBAN Manholes
- MIKE URBAN Links



100 50 0
Meters

SCALE: 1:3,000 @ A3

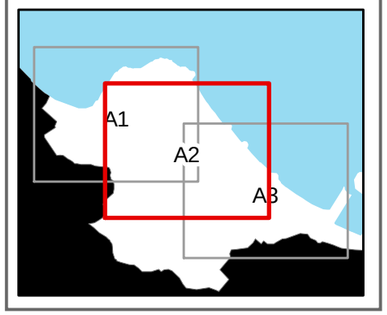
Strategic Planning Department
PLANNING AND DEVELOPMENT
DATE: 17/02/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure 5.4.1:
Mike Urban setup

TOWNSVILLE CITY COUNCIL
NORTH WARD
CATCHMENT

LEGEND

- MIKE URBAN Outlets
- MIKE URBAN Manholes
- MIKE URBAN Links



130 65 0

Meters

SCALE: 1:4,000 @ A3

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DATE: 17/02/2011
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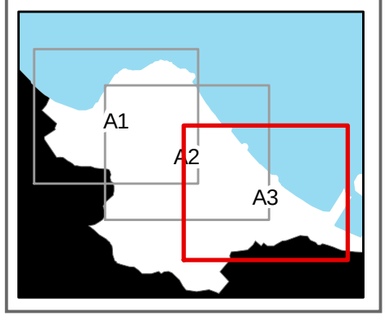
DIGITAL FILE: mxd

Figure 5.4.1:
Mike Urban setup

TOWNSVILLE CITY COUNCIL
NORTH WARD
CATCHMENT

LEGEND

- MIKE URBAN Outlets
- MIKE URBAN Manholes
- MIKE URBAN Links



130 65 0

Meters

SCALE: 1:4,000 @ A3

Strategic Planning Department
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DATE: 17/02/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure 5.4.1:
Mike Urban setup

5.5 Road Closures

A number of sections of road within North Ward were analysed for closure. Roads were considered non trafficable when the water depth exceeded 200mm. **Table 5.5.1** shows the times of closure for each ARI of some of the Main and Secondary roads around North Ward. Heatleys Parade and Howitt Street are both closed at more frequently and for long periods of time than the other roads that were analysed. The Howitt Street closure is not a major concern as there are alternative routes. But Heatleys Parade is the only access point to Rowes Bay and Pallarenda making evacuation of those areas a potential problem. **Figure 5.5.1** show the locations of the points of closure.

Table 5.5.1: Times of road closure [h:mm]

Point number	Road	ARI [years]							
		2	5	10	20	50	100	500	PMF
1	Heatleys Parade	0:00	0:00	0:00	0:50	1:15	2:27	2:25	3:32
2	Bundock Street Inbound	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:12
3	Bundock Street Outbound	0:00	0:00	0:00	0:05	0:05	0:05	0:05	2:02
4	Howitt Street	0:00	0:52	1:12	1:37	2:42	2:57	2:42	4:22
5	Warburton St @ Landsborough St	0:00	0:00	0:00	0:00	0:00	0:00	0:05	0:25
6	Warburton St @ Kennedy St	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:27
7	Gregory Street	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:17
8	Stanley Street	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:40

TOWNSVILLE CITY COUNCIL
NORTH WARD CATCHMENT

LEGEND

- Road Closures Points

Road Centre Line

- Main Road
- Secondary Road

280 140 0

Meters

SCALE: 1:8,000 @ A3

Strategic Planning Department
PLANNING AND DEVELOPMENT

DATE: 15/03/2011
DRAWN BY: JAJ
DIGITAL FILE: mxd

Figure 5.5.1:
Road Closure Points

5.6 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 areas where flows 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 5.6.1** 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 has been generated for the North Ward study area based on 100 Year, 500 Year, and PMF model results. These Flood Hazard Maps are shown in **Figure 5.6.2 to Figure 5.6.4**. The Flood Hazard Map is a preliminary assessment, only considering water depth and velocity. Because the critical storm duration for North Ward is generally in the order of 1 to 1.5 hours, warning time for evacuation is low which could lead to higher hazards than those shown on the Flood Hazard Maps.

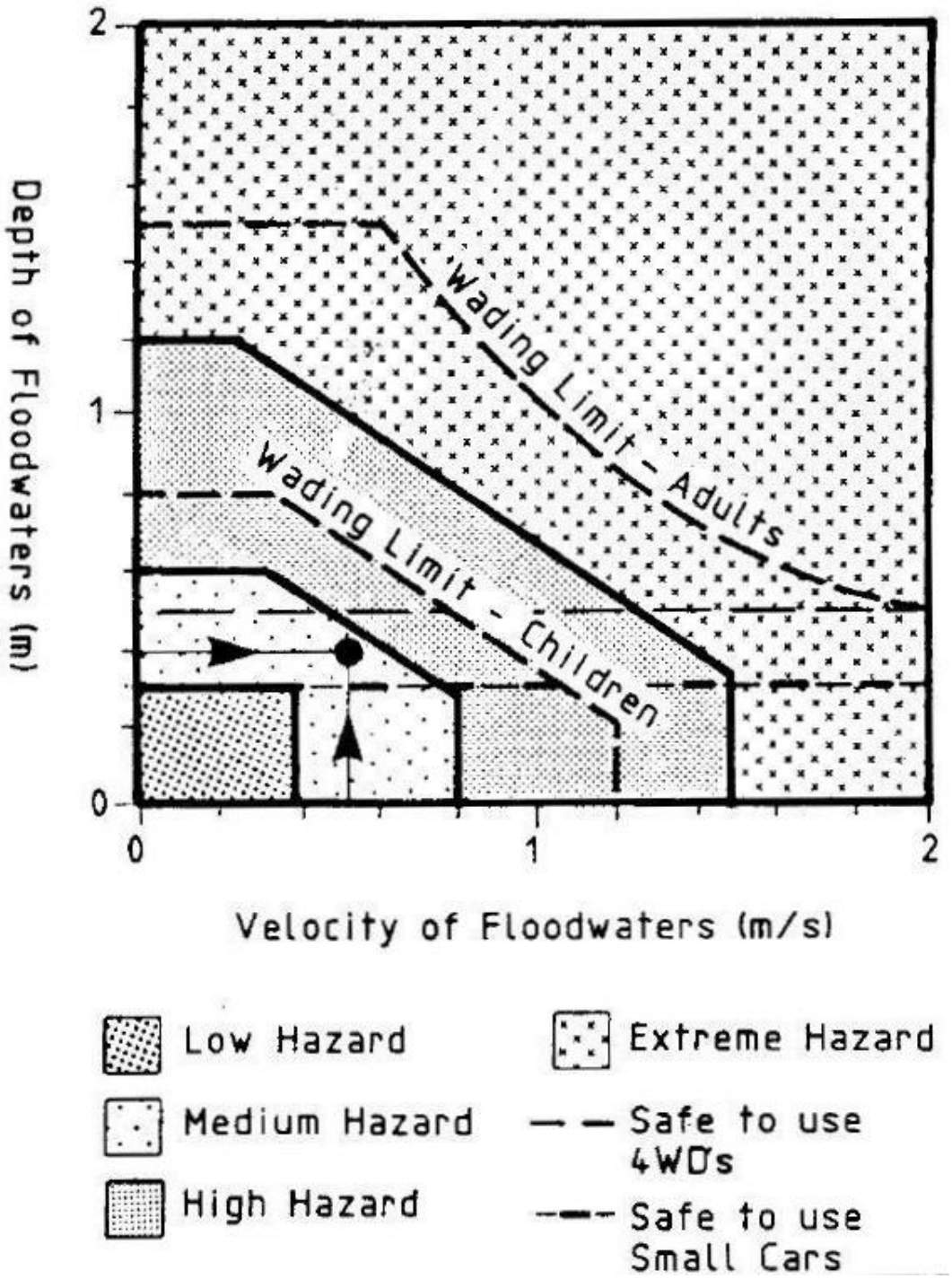


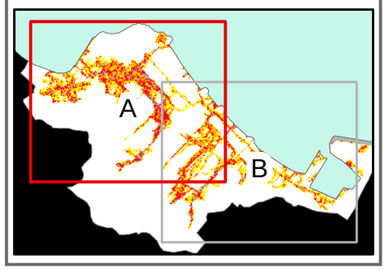
Figure 5.6.1: Hazard Classification of Flood Waters

TOWNSVILLE CITY COUNCIL
NORTH WARD
CATCHMENT

LEGEND

Flood Hazard

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



0 60 120 180
Meters

SCALE: 1:6,000 @ A3

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Figure 5.6.1:
Flood Hazard Map - 100y

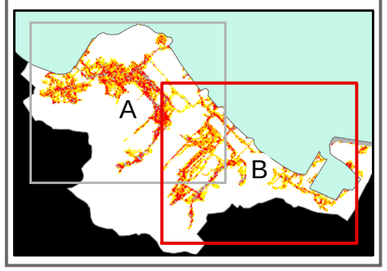
TOWNSVILLE CITY COUNCIL
NORTH WARD
CATCHMENT

N

LEGEND

Flood Hazard

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



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Meters

SCALE: 1:6,000 @ A3

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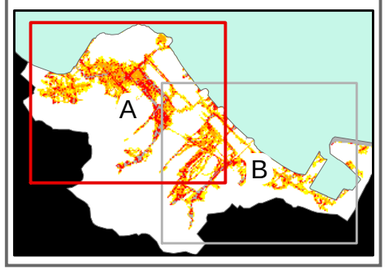
Figure 5.6.1:
Flood Hazard Map - 100y

TOWNSVILLE CITY COUNCIL
NORTH WARD
CATCHMENT

LEGEND

Flood Hazard

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



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Meters

SCALE: 1:6,000 @ A3

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Figure 5.6.2:
Flood Hazard Map - 500y