3.0 Hydraulic Assessment

3.1 Overview

MIKE FLOOD was used as the platform to construct a dynamically linked hydraulic model for the Lower Bohle/Stony Creek area to assess flooding for the base case. The Lower Bohle/Stony Creek model extent is shown in Figure 3-1 along with those for previous overlapping studies undertaken as part of the C*itywide Flood Constraints Project.*

3.2 MIKE FLOOD Hydraulic Model

MIKE FLOOD is a numerical hydraulic model developed by the Danish Hydraulic Institute (DHI). The model dynamically couples the one-dimensional MIKE URBAN pipe hydraulics and one-dimensional MIKE 11 elements (culverts, bridges and open channels) with the two-dimensional overland flow model MIKE 21. Outputs from MIKE FLOOD include GIS compatible maps of flood extents, water depth, water level, flow and velocities.

3.2.1 MIKE 11

MIKE 11 is a software package used for one-dimensional simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies. The model is typically used to assess one-dimensional flows through structures such as bridges and culverts. It also enables simulation of complex river systems where one-dimensional flow predominates.

3.2.2 MIKE 21

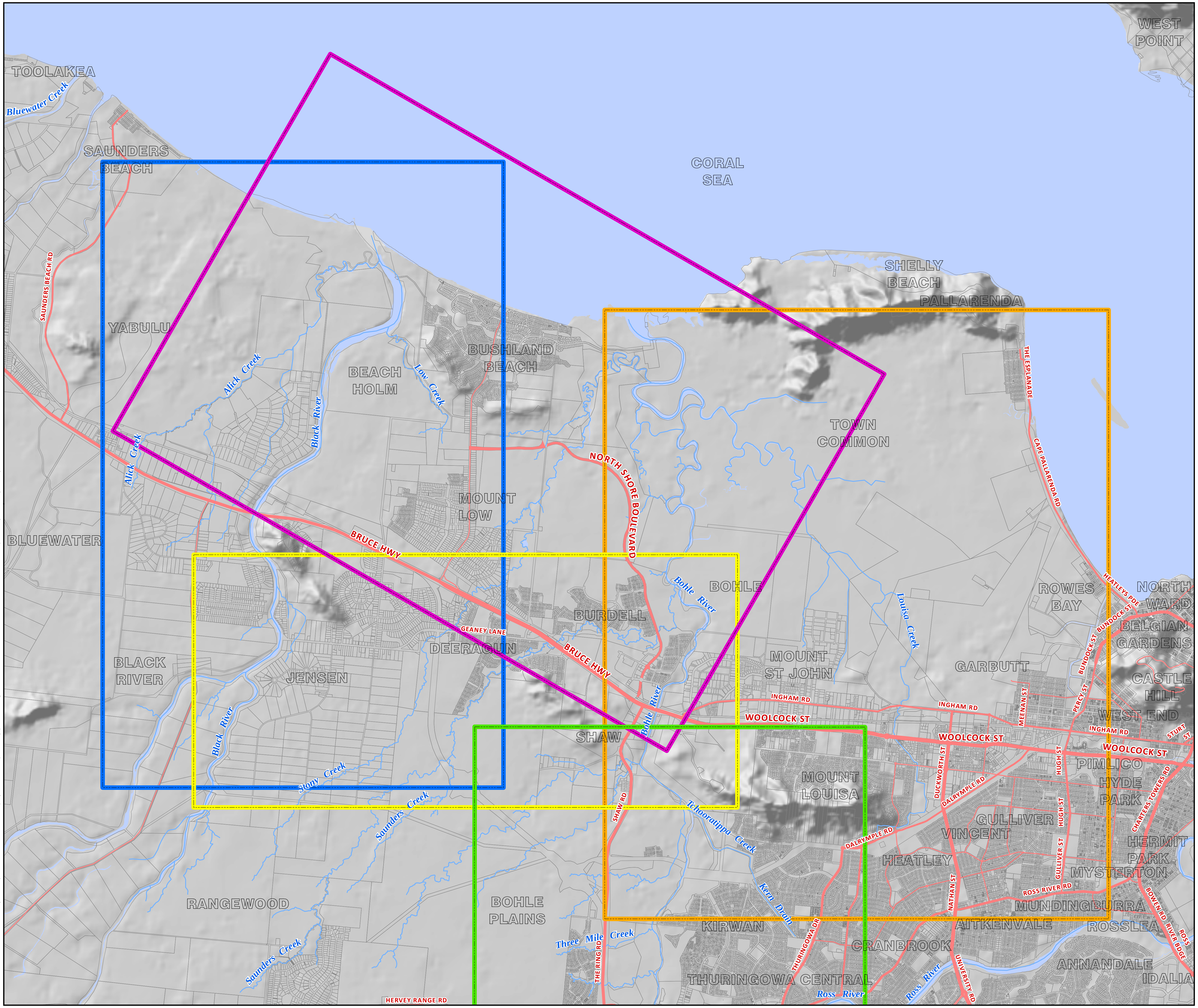
MIKE 21 is a software package used for two-dimensional simulation of flow distribution based on water and ground levels at each time step of a model run. The two-dimensional model provides a more accurate determination of the extent, magnitude and direction of the flood flows than MIKE 11, without the need to pre-determine the flow path.

3.2.3 MIKE URBAN

MIKE URBAN is a software package used for one-dimensional simulation of sanitary or storm drain sewers as well as water distribution systems that couples with MIKE 11 and MIKE 21. This software package can be used to analyse a range of parameters including water quality, rainfall runoff and infiltration.

TOWNSVILLE CITY COUNCIL
LOWER BOHLE/STONY CREEK
FLOOD STUDY
Location and Extents of Model Extents

Figure 3-1



Legend

- Lower Bohle Model Extent
- Deeragun Model Extent
- Black River Model Extent
- Louisa Creek Model Extent
- Middle Bohle Model Extent
- Highways
- Main Roads
- Watercourse

0 1,000 2,000 4,000
Metres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

Data sources:
Roads © 2012 (StreetPro)
Localities © 2012 (Queensland Govt)

AECOM
www.aecom.com

User: mathieu-burrym | Date Saved: 19/05/2014 | FileName: J:\MMPL\60249277\4. Tech Work Area\4.99 GIS\02-Rework\mxd\Report_20140514_FINAL\Fig3-1_ModelExtents.mxd

3.3 Model Development

The Lower Bohle/Stony Creek hydraulic model was developed using information extracted from previously developed hydraulic models, as-built or design plans of new developments, details of road culverts and information from existing XP-RAFTS hydrologic models. The Black River, Louisa Creek, Middle Bohle and Deeragun models overlap as shown in Figure 3-1 and provided relevant information for the construction of the Lower Bohle model.

3.3.1 Model Geometry

A 10 m by 10 m Cartesian grid was developed to represent the topography of the land within the model extent. The grid was based on the 2009 and 2012 LiDAR topography supplied by TCC using the most recent data where possible and consists of nearly 1.1 million cells that represent the average elevation over each cell area. The grid has been rotated 30 degrees so that the southern boundary is parallel to Bruce Highway/North Coast Railway.

Embankment levels of Bruce Highway, North Coast Railway, Mount Low Parkway, Geaney Lane, Shaw Road, Bowden Road, Percheron Place, Arabian Place, Holstein Place, Andalusian Place, Clydesdale Place, and North Shore Boulevard were incorporated into the MIKE 21 grid as they act as major flood control mechanisms within the study area. Hydrographic survey data supplied by TCC for Black River, Stony Creek and the Bohle River was also incorporated into the grid.

Hydraulic structures within the study area were represented using either the 1D MIKE 11 model or MIKE URBAN elements that were dynamically coupled into the 2D MIKE 21 grid. All major bridges and culverts within the model were represented in the MIKE 11 model. Details of these structures are provided below in Table 3-1 and Table 3-2 and illustrated in Figure 3-2. All underground stormwater infrastructure within the model extent is generally represented using the MIKE URBAN model. Note that only structures with a cross-sectional area equivalent or in excess of that of a 900 mm diameter pipe were included in the MIKE URBAN and Mike 11 networks.

Table 3-1 Details of Culverts Modelled using MIKE 11

Culvert Reference	Configuration	Invert level (m AHD)		Length (m)
		Upstream	Downstream	
0561K	4/750 RCP	3.47	3.46	16.20
Alick_Trib4Percheron	2/1200x600 RCBC	9.68	9.50	13.20
Alick_Trib5Clydesdale	2/1200 RCP	3.87	3.77	12.20
AlickCk_Percheron	1/1800 RCP	7.45	7.36	12.41
ArabianPl_Culv	3/1200x300 RCBC	8.28	8.00	9.60
BH 11A	3/400 RCP	11.48	11.43	17.00
BH 14A	9/1200x750 RCBC	11.52	11.41	20.00
BH 14A1	4/450 RCP	11.69	11.52	17.00
BH 3A	5/1200x900 RCBC	8.19	7.95	17.00
BH 4A	5/1200x600 RCBC	11.42	10.82	11.00
BH 5A	5/1800x1200 RCBC	10.64	10.49	12.00
BH MLPU_02	4/1650 RCP	10.18	9.97	37.85
BH MLPU_03	1/525 RCP	11.73	11.14	39.04
BH MLPU_04	3/375 RCP	11.66	11.58	18.59
BH MLPU_05	2/750 RCP	11.90	11.84	32.94
BH MLPU_06	3/525 RCP	12.28	12.07	21.96
BH MLPU_07	1/375 RCP	12.29	12.11	17.69
BH MLPU_08	1/600x300 RCBC	12.50	12.41	22.68
BH MLPU_09	1/600x300 RCBC	12.46	12.35	22.71

Culvert Reference	Configuration	Invert level (m AHD)		Length (m)
		Upstream	Downstream	
BH MLPU_10	1/375 RCP	12.10	11.89	19.86
BH_2C	4/600x300 RCBC	11.50	11.37	12.20
BH_2D	11/1200x600 RCBC	11.50	11.37	12.20
BH_2E	4/600x300 RCBC	11.50	11.37	12.20
BH_2F	4/600x300 RCBC	11.75	11.40	12.20
BH_2G	4/600x300 RCBC	11.75	11.45	12.20
BH_2H	1/1200x450 RCBC	12.25	12.00	11.70
BH_2I	1/375 RCP	11.94	11.78	14.70
BH_3A	2/1200x450 RCBC	12.25	12.00	11.00
BH_3B	2/1200x450 RCBC	12.50	12.25	11.00
BH_3C	2/1200x450 RCBC	13.00	12.87	13.40
BH_3D	1/1200x450 RCBC	13.25	13.05	16.30
BH_3E	2/450 RCP	15.22	14.90	14.00
BH_3F	2/750 RCP	17.00	16.75	14.00
BH_TMR_16400	1/375 RCP	12.11	12.10	17.70
BonnettRd1	6/1200x900 RCBC	7.40	7.00	24.00
BonnettRd2	8/1200x300 RCBC	10.08	9.97	24.00
CouttsDr	6/900x600 RCBC	2.20	2.16	9.76
East1	1/600x600 RCBC	4.34	4.29	22.00
Holstein_Culv1	2/1200x300 RCBC	9.96	9.75	9.60
KregorSt	4/750 RCP	9.01	8.94	17.29
Main1	2/1800x1200 RCBC	3.34	3.32	20.00
Main2	2/1800x1200 RCBC	2.65	2.61	20.00
MarinaDr	4/1200x600 RCBC	2.97	2.88	15.86
MLP_1B	1/1200x375 RCBC	10.41	10.36	16.80
MLP_6A	1/900 RCP	9.71	9.40	27.30
MLP_7A	5/825 RCP	7.72	7.66	13.50
MLP_7B	1/900 RCP	6.03	5.96	14.80
QR_1356.97	8/1200x1200 RCBC	9.58	9.57	9.00
QR_1358.17	2/1200x600 RCBC	11.22	11.21	7.30
QR_1358.23	6/1200x600 RCBC	11.52	11.51	7.20
QR_1358.25	3/1200x600 RCBC	11.14	11.23	7.38
QR_1358.30	2/1200x600 RCBC	11.31	11.28	7.28
QR_1358.39	1/1200x600 RCBC	11.39	11.39	7.31
QR_1358.91	1/1200x600 RCBC	12.21	12.20	7.20
QR_1359.05	1/900x600 RCBC	12.15	12.14	7.20
QR_1359.16	1/1200x600 RCBC	12.33	12.28	7.20

Culvert Reference	Configuration	Invert level (m AHD)		Length (m)
		Upstream	Downstream	
QR_1359.18	1/1200x600 RCBC	12.12	12.11	7.20
QR_1359.25	1/900x450 RCBC	12.23	12.20	7.20
QR_1359.33	1/900x450 RCBC	12.01	12.00	7.20
QR_1359.52	1/900x450 RCBC	11.86	11.81	7.20
QR_1359.63	1/900x450 RCBC	11.60	11.60	7.20
QR_1359.71	1/1200x450 RCBC	11.61	11.59	7.20
QR_1359.82	1/1200x450 RCBC	11.61	11.60	7.20
QR_1359.85	1/900x450 RCBC	11.53	11.52	7.20
QR_1360.04	2/1200x600 RCBC	11.14	11.12	7.20
QR_1360.09	3/1200x600 RCBC	11.05	11.04	7.20
QR_1360.12	1/1200x600 RCBC	10.98	10.97	7.20
QR_1360.14	1/900x600 RCBC	11.23	11.22	7.20
QR_1360.16	1/1200x900 RCBC	10.90	10.85	7.20
QR_1360.19	2/1200x600 RCBC	11.06	11.05	7.20
QR_1360.52	2/900x600 RCBC	11.78	11.77	7.20
QR_1360.62	2/900x600 RCBC	11.44	11.43	7.20
QR_1360.75	1/1200x600 RCBC	11.50	11.47	7.20
QR_1360.79	2/1200x600 RCBC	11.38	11.36	7.20
QR_1360.82	1/1200x600 RCBC	11.39	11.39	7.20
QR_1360.99	1/900x450 RCBC	11.73	11.72	7.20
QR_1361.34	1/1200x450 RCBC	12.33	12.32	7.20
QR_1361.36	1/1200x600 RCBC	12.38	12.37	7.20
QR_1363.67	1/900x600 RCBC	11.65	11.63	7.20
RumbulaCt	2/750x600 RCBC	2.40	2.35	9.76
SDC_NSB_2D	2/1800x1200 RCBC	2.27	2.20	30.00
SDC_NSB_2G	7/750 RCP	3.96	3.91	26.80
SDC_NSB_3A	4/750 RCP	4.34	4.29	29.20
SDC_NSB_3B	4/750 RCP	4.61	4.56	26.80
SDC_NSB_4A	4/2100x600 RCBC	3.70	3.65	50.00
SDC_NSB_4B	3/1500x600 RCBC	4.05	4.00	15.60
SDC_NSB_4C	2/450 RCP	4.31	4.21	14.60
SDC_NSB_5A	7/3600x1500 RCBC	1.70	1.66	17.80
SDC_NSB_5B	2/1200x750 RCBC	2.47	2.42	23.50
SDC_NSB_6B	5/2700x750 RCBC	2.86	2.82	13.20
SDC_NSB_6C	3/600 RCP	3.29	3.24	14.60
SDC_NSB_7A	10/1200 RCP	2.36	2.31	16.10
SDC_NSB_8B	2/1200 RCP	2.35	2.30	18.60

Culvert Reference	Configuration	Invert level (m AHD)		Length (m)
		Upstream	Downstream	
SDC_NSB_8C	3/3000x2100 RCBC	2.83	2.78	16.40
SDC_NSB_8D	3/2100x600 RCBC	3.07	3.01	23.50
SiteVisit09	10/1200x450 RCBC	13.41	13.35	9.70
SiteVisit11	9/1200x1200 RCBC	6.49	6.37	14.40
SiteVisit12	4/1200x600 RCBC	9.54	9.35	10.20
STC_NSB_11A	2/1500x1200 RCBC	4.34	4.33	19.00
STC_NSB_11B	8/2400x900 RCBC	4.50	4.40	34.50
STC_NSB_9A	9/2400x1200 RCBC	1.78	1.70	34.20
Stony_4	2/475 RCP	11.36	11.33	6.30
Stony_5	2/475 RCP	11.36	11.34	6.30
SW1	4/600x300 RCBC	7.36	7.22	20.00
SW2	2/900x600 RCBC	6.24	6.12	20.00
SW3	2/1500x900 RCBC	5.88	5.76	20.00
TCC_868-871	4/1050 RCP	3.52	3.50	18.80
TCCSurvey_1	7/1820x1220 RCBC	9.60	9.49	12.29
TCCSurvey_10_1	1/610x320 RCBC	6.35	6.27	8.48
TCCSurvey_10_2	1/610x320 RCBC	5.59	5.52	10.82
TCCSurvey_2	2/740 RCP	2.82	2.62	18.50
TCCSurvey_3	2/1400 RCP	13.18	12.75	36.81
TCCSurvey_7	5/1400 RCP	8.01	7.71	27.09
TCCSurvey_8	5/575 RCP	3.78	3.68	16.15
West2-1	2/1500x900 RCBC	6.00	5.80	20.00
West2-2	3/2100x1200 RCBC	4.27	4.23	30.00
WongableCt	2/900x450 RCBC	7.60	7.47	19.95
Yab3_Rail	1/900x600 RCBC	13.06	13.04	7.20
NS_add	3/900x900 RCBC	3.90	3.83	34.52

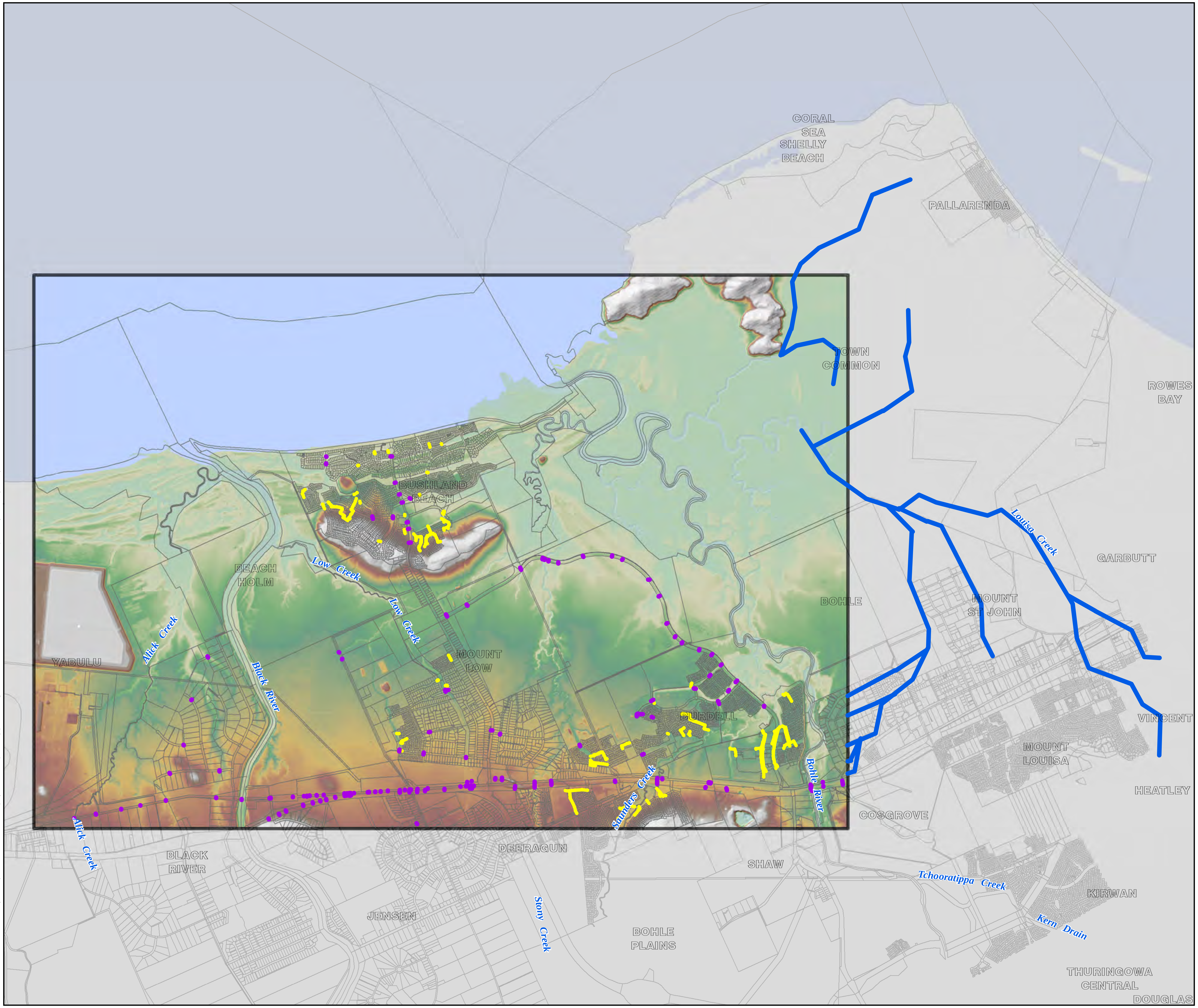
Note:
RCBC = Reinforced Concrete Box Culvert
RCP = Reinforced Concrete Pipe

Table 3-2 Details of Bridges Modelled Using MIKE11

Bridge Reference	Bridge Level (Top) (m AHD)
BlackR_Rail	13.60
AlickCk_Rail	13.23
Alick_Trib3Rail	11.78
Alick_Trib2Rail	11.50
Alick_Trib1Rail	14.10
QR Stony	12.15
Stony Hwy Nbound	13.49
Stony Hwy Sbound	12.45
SDC_NSB_Bridge	7.81
QR Bohle	8.05
Bohle Hwy Nbound	5.84
Bohle Hwy Sbound	9.17
Bohle Hwy Sbound chute	9.17
QR Bohle chute	8.05
QR Saunders	10.60
Saunders Hwy Nbound	11.20
Saunders Hwy Sbound	11.20
STC_NSB_Bridge	5.83

TOWNSVILLE CITY COUNCIL
LOWER BOHLE/STONY CREEK FLOOD STUDY
Model Geometry

Figure 3-2



Legend

- Mike 11 Branches
- Mike 11 Structures
- MIKE Urban Structures

0 500 1,000 2,000
Metres

1:55,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

Data sources:
Roads © 2012 (StreetPro)
Localities © 2012 (Queensland Govt)

AECOM
www.aecom.com

3.3.2 Boundary Conditions

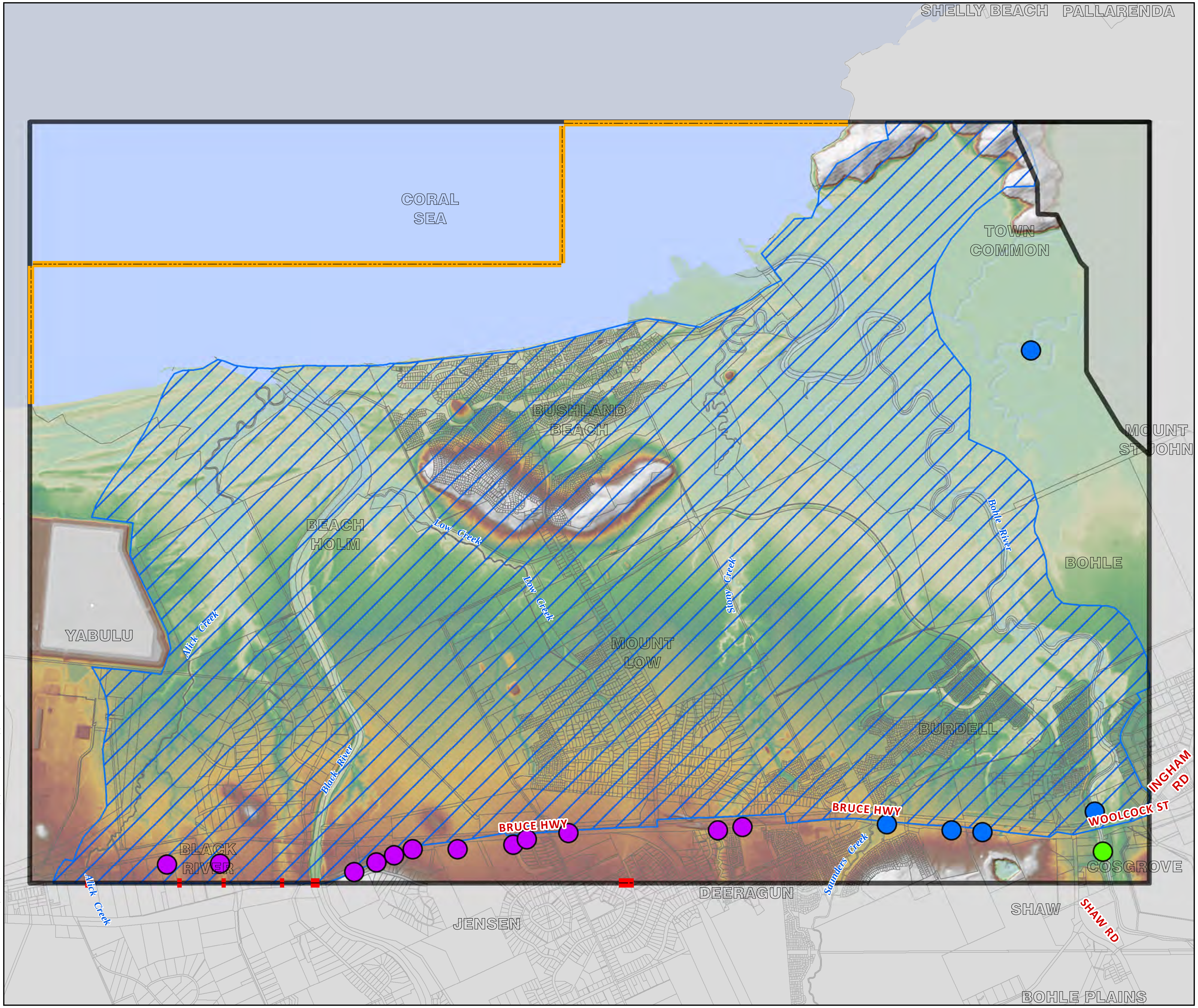
A downstream boundary was applied as a fixed water level of 1.254 m AHD which represents the Mean High Water Springs (MHWS) level for the Townsville area obtained from the Queensland Tide Tables (2011). For the 100 year ARI events, inflow hydrographs at the upstream boundary were generally taken from outflow hydrographs from the Black River hydraulic model, however inflows to Bohle River were taken from the Middle Bohle hydraulic model. Rain-on-grid was applied across the more urban and relatively flat areas of the model extent. The locations of all boundary conditions for this model can be seen in Figure 3-3.

The exceptions are the Louisa Creek and Saunders Creek inflows taken from the output of XP-RAFTS hydrologic models. Along the eastern boundary of the 2D model domain, storage provided by the Town Common has been represented using a series of linked one dimensional (Mike 11) branches. These links have been located at critical breakout locations. Flows into the Town Common from Louisa Creek have been represented using design discharge hydrographs for the Louisa Creek XP-RAFTS model.

For ARIs other than the 100 year, inflow boundaries were taken from discharge hydrographs from the Black River, Saunders Creek, Louisa Creek, Bohle River 2 and Bohle River 3 XP-RAFTS models.

TOWNSVILLE CITY COUNCIL
LOWER BOHLE/STONY CREEK
FLOOD STUDY
Boundary Conditions

Figure 3-3



Legend

- Inflow Boundaries from Black River hydraulic model
- Water Level
- Source Location (XP-RAFTS)
- Source Location (Black River Hydraulic Model)
- Source Location (Middle Bohle Hydraulic Model)
- Rain on Grid Area Net Precipitation

0 500 1,000 2,000
Metres

1:40,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Data sources:
Roads © 2012 (StreetPro)
Localities © 2012 (Queensland Govt)

AECOM
www.aecom.com

User: mathieu-burrym | Date Saved: 6/05/2014 | FileName: J:\MMPL\60249277\4. Tech Work Area\4.99 GIS\02-Rework\mxd\Report_20140501\Fig3-3_BoundaryConditions_v2.mxd

3.3.3 Roughness

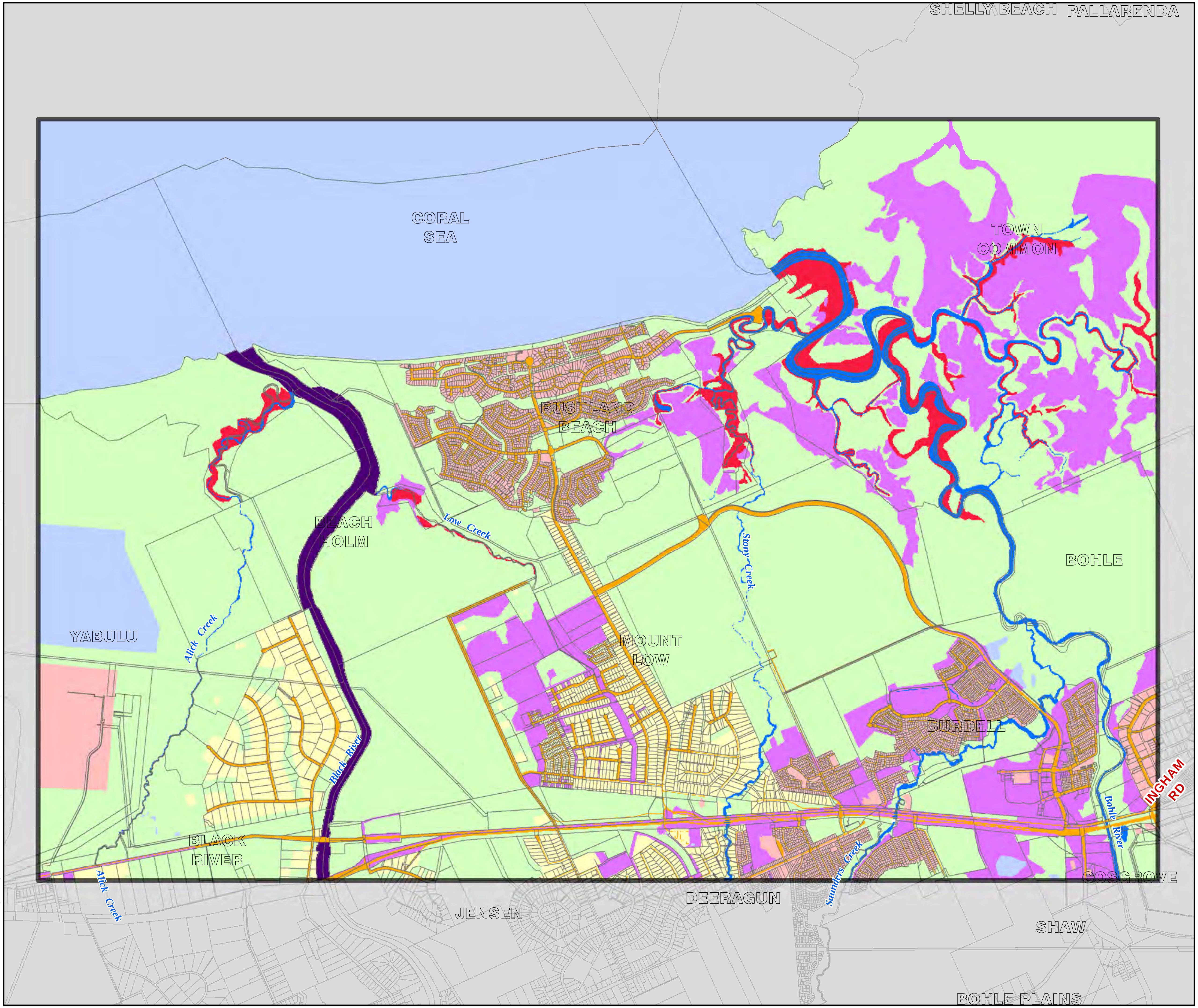
Hydraulic roughness (Manning's n value) is a measure of the resistance to flow and is primarily dependent on land use. Values selected for each land use are provided in Table 3-3 and a roughness map is shown in Figure 3-4. The values are consistent with previous flood study reports undertaken as part of the *City Wide Flood Constraints Project* in the Bohle Flood Plains area. The roughness map used in the Lower Bohle Flood Study was refined to account for development included in the 2011 aerial photography and 2012 LiDAR.

Table 3-3 Hydraulic Roughness Values

Land Use	Manning's n Value
Bush Land	0.07
River Channel	0.03
Riparian Zone	0.08
Roads/Rail	0.025
Urban Areas	0.06
Open Space/Sandy area	0.05
Dense Forest	0.1
Pond	0.011
Farm Land	0.035
Rural Residential	0.055

TOWNSVILLE CITY COUNCIL
LOWER BOHLE/STONY CREEK
FLOOD STUDY
Roughness Map

Figure 3-4



Mannings (n)
0.011
0.02
0.025
0.030
0.050
0.055
0.060
0.070
0.080

0 500 1,000 2,000
Metres

1:40,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Data sources:
Roads © 2012 (StreetPro)
Localities © 2012 (Queensland Govt)

AECOM
www.aecom.com

User: mathieu-burrym | Date Saved: 14/05/2014 | FileName: J:\MMPL\60249277\4. Tech Work Area\4.99 GIS\02-Rework\mxd\Report_20140514_FINAL\Fig3-4_RoughnessMap.mxd

3.3.4 Rain-on-Grid and Source Inflow Comparison

A test was carried out to compare the Rain-on-Grid method with the traditional approach of using source point hydrographs obtained from XP-RAFTS to simulate localised runoff. The two different approaches were tested on one of the major sub-catchments in the model. The sub-catchment is primarily an urban area with moderate to steep terrain and adjacent to the ocean boundary. This sub-catchment was strategically chosen to test the model stability using Rain-on-Grid method on the steeper area, as well as the flow behaviour on the flatter area.

The results of the test showed that the Rain-on-Grid method distributes the flow across the model in a more realistic way producing similar results to those obtained with the source point method. The results of this test for the source point and rain on grid methods are shown in Figure 3-5 and Figure 3-6 respectively. Differences in water level are relatively minor between the two methods as shown in Figure 3-7. The results suggest that the source point method concentrates the flow within a localised channel which could result in an overestimation of flood levels on areas near the source points and an underestimation away from the major flow path. The Rain-on-Grid method was selected to simulate localised runoff for this study.

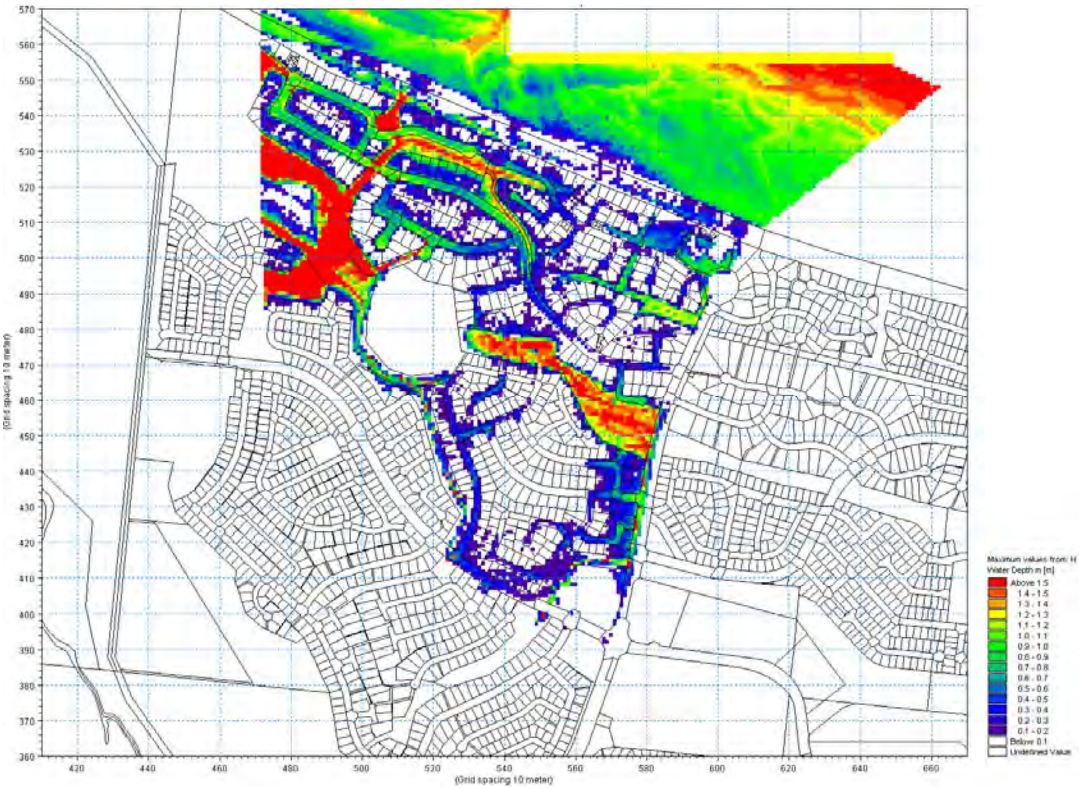


Figure 3-5 Modelled Water Depth Test Results using Source Point Method

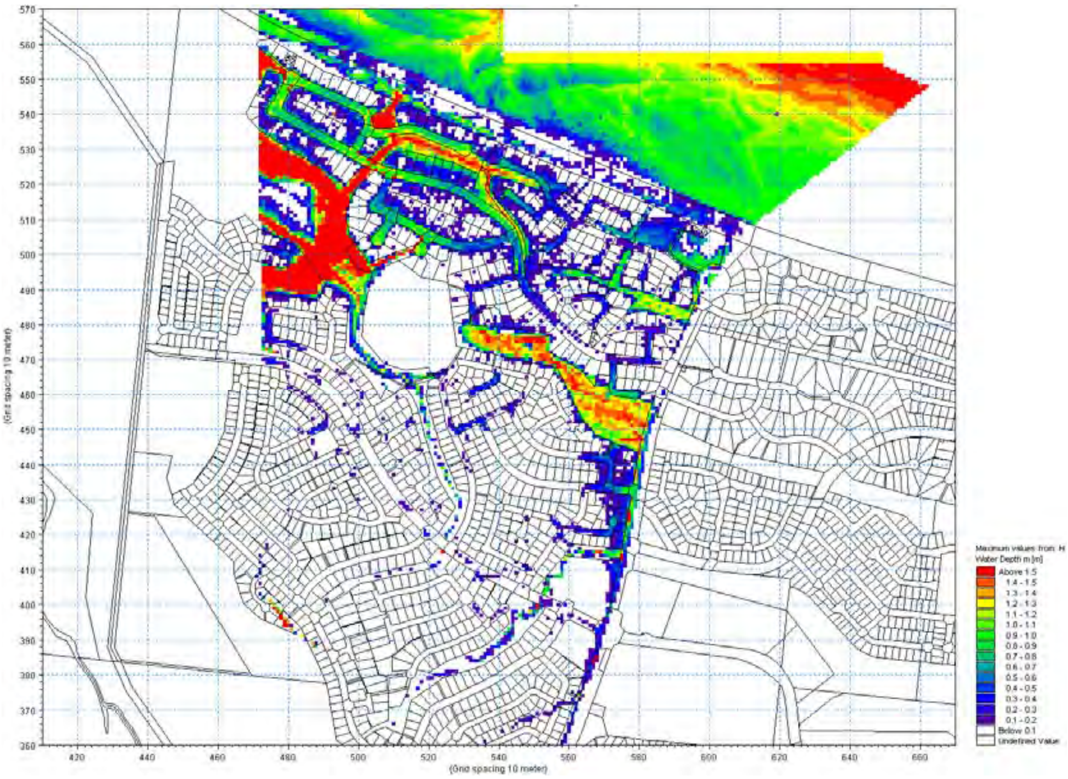


Figure 3-6 Modelled Water Depth Test Results using Rain-on-Grid Method

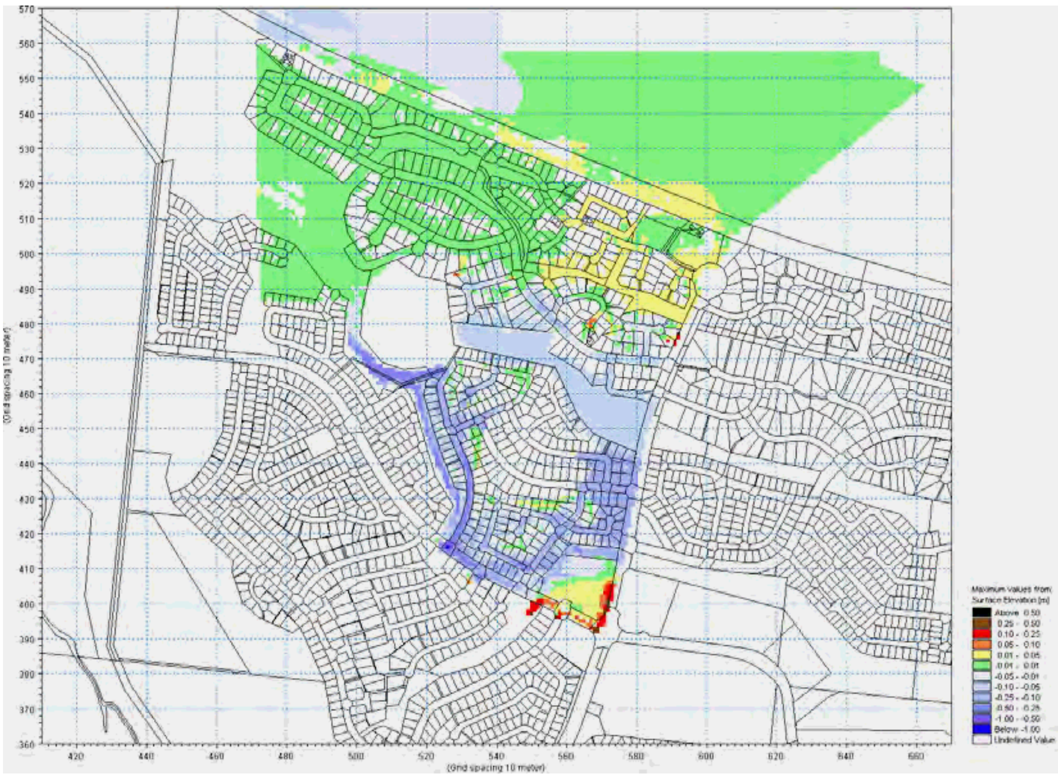


Figure 3-7 Difference in Water levels between Rain-on-Grid and Source Point Methods

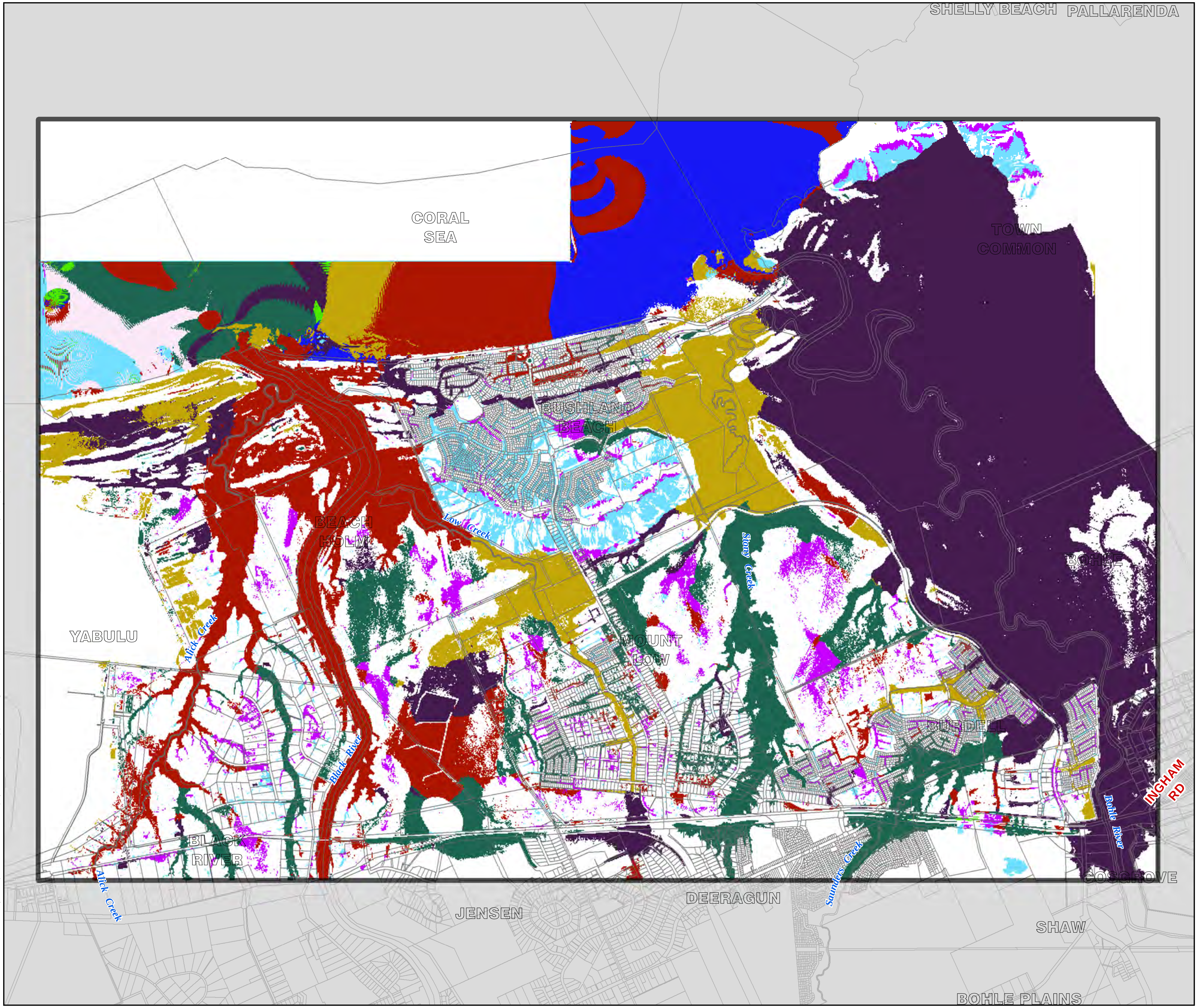
3.4 Design Flood Critical Duration Assessment

The 1, 2, 3, 4.5, 6, 9, 12, 18 and 24 hour storm durations for the 100 year ARI flood event were simulated using the MIKE FLOOD model. These runs were undertaken to determine the maximum flood envelope and the critical durations throughout the various catchments within the model. Figure 3-8 shows the critical duration results for the 100 year ARI base case event.

The critical durations for the base case 100 year ARI storms were generally 9 hours for the Black River and 12 hours for the Bohle River flood plain. From a local catchment perspective, within Mount Low and Bushland Beach the critical duration ranged from 1 to 24 hours. Two critical durations (12 and 24 hours) were selected as representative of the area of interest to run the remaining base case ARIs (2, 5, 10, 20 and 50 year).

Graphical displays of maximum water depth, surface elevation and flow velocity magnitude for each event modelled are provided in Appendix A.

TOWNSVILLE CITY COUNCIL
LOWER BOHLE/STONY CREEK
FLOOD STUDY
Critical Duration Assessment
100-year ARI
Figure 3-8



Duration (hours)

- 1
- 2
- 3
- 4.5
- 6
- 9
- 12
- 18
- 24

0 500 1,000 2,000
Metres

1:40,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Data sources:
Roads © 2012 (StreetPro)
Localities © 2012 (Queensland Govt)

AECOM
www.aecom.com

User: mathieu-burrym | Date Saved: 14/05/2014 | FileName: J:\MMPL\60249277\4. Tech Work Area\4.99 GIS\02-Rework\mxd\Report_20140514_FINAL\Fig3-8_CriticalDuration.mxd

4.0 Baseline Flooding Summary

4.1 Flooding across the Study Area – Summary

Base case flood maps for design ARI storms are provided in Appendix A. The maps show maximum water depth, surface elevation and flow velocity magnitude produced for the following storms:

- 2 year ARI
- 5 year ARI
- 10 year ARI
- 20 year ARI
- 50 year ARI
- 100 year ARI
- 500 year ARI
- Probable Maximum Flood.

For mapping purposes the criteria adopted involves:

- including water depths greater than or equal to 0.1 m; or
- including water velocities greater than or equal to 0.3 m/s.

Therefore, only areas predicted to experience water depths lower than 0.1 m and water velocities lower than 0.3 m/s are shown as free from flooding in the mapping undertaken. This is in line with TCC's Flood Hazard Mapping Criteria.

To facilitate reading of flood modelling results, the majority of labels have been left out of the flood maps. The key areas mentioned in the assessment included in this section are shown in the locality map Figure 1-1 and therefore it is recommended that this is used as a reference when reviewing the flood maps.

Description of the flooding for the various design events are provided in Table 4-1. Assessment for out of bank flow, ponding across developed areas and high velocities within channels has been undertaken for each ARI being assessed.

Table 4-1 Lower Bohle/Stony Creek – Flooding Assessment Summary

Event	Description	Map Ref
2 year ARI	- Overbank flow predicted for sections of the Bohle River and Stony Creek area. - No significant impact predicted for residential areas (i.e. water depth generally below 0.3 m). - Velocities of up to 0.75 m/s predicted at Bushland Beach in localised areas within channels and over roads.	A1, A9 and A17
5 year ARI	- Low Creek, tributary of the Black River, experiences overbank flow at the downstream end. - No significant impact predicted for residential areas (i.e. water depth generally below 0.3 m). - Velocities of up to 1 m/s predicted at Bushland Beach. - Relatively high velocities (greater than 2 m/s) predicted in the Black River channel.	A2, A10 and A18
10 year ARI	- No significant impact predicted for residential areas (i.e. water depth generally below 0.3 m). - Velocities of up to 1 m/s predicted at Bushland Beach.	A3, A11 and A19
20 year ARI	- No significant impact predicted for residential areas (i.e. water depth generally below 0.3 m). - Velocities of up to 1 m/s predicted at Bushland Beach.	A4, A12 and A20
50 year ARI	- No significant impact predicted for residential areas (i.e. water depth generally below 0.3 m). - Velocities of up to 1 m/s predicted at Bushland Beach. - Velocities of up to 2 m/s predicted over Bruce Highway at Bohle River.	A5, A13 and A21
100 year ARI	- No significant impact predicted for residential areas (i.e. water depth generally below 0.3 m). - Velocities of up to 1.25 m/s predicted at Bushland Beach. - Velocities of up to 2 m/s predicted over Bruce Highway at Bohle River.	A6, A14 and A22
500 year ARI	- No significant impact predicted for the residential areas of Bushland Beach and Mount Low (i.e. water depth generally below 0.3 m). - Properties in Burdell near Saunders Creek inundated with water depths of up to 0.5 m. - Velocities of up to 1.25 m/s predicted at Bushland Beach. - Velocities of up to 1.75 m/s predicted across Bruce Highway at Black River. - Velocities of up to 2 m/s predicted over Bruce Highway at Bohle River.	A7, A15 and A23
PMF	- Properties in Burdell inundated with water depths of up to 2 m. - Properties in Bushland Beach and Mount Low inundated with water depths of up to 0.75 m. - Velocities of up to 1.25 m/s predicted at Bushland Beach. - High velocities greater than 2 m/s predicted over Bruce Highway at Bohle River and Black River.	A8, A16 and A24

4.2 Major Arterial Roads

An indication of the estimated level of flooding over major roadways within the area of interest under different flood events is provided in Table 4-2. This table it shows that during the PMP event, all roadways listed will flood to different water depths. For the Bruce Highway and Mount Low Parkway the estimated flood immunity is in excess of the 100 year ARI. For North Shore Boulevard the estimated flood immunity is greater than the 20 year ARI.

Table 4-2 Flooding Affecting Major Arterial Roads within the Area of Interest

Description	Water Depth (m)							
	Event((Year ARI)							PMF
	2	5	10	20	50	100	500	
North Shore Boulevard	-	-	-	-	0.31	0.43	0.63	1.66
Bruce Highway at Saunders Creek	-	-	-	-	-	0.19	0.38	0.35
Bruce Highway at Stony Creek	-	-	-	-	-	-	0.1	0.42
Mount Low Parkway	-	-	-	-	-	-	-	0.39
Bruce Highway at Black River	-	-	-	-	-	-	0.13	2.72

Note: It must be noted that for the purposes of the above table only water depths in excess of 0.1 m have been considered. This is due to the fact that rainfall is directly applied across the vast majority of the model extent and therefore water depths lower than this threshold can be attributed to the use of the rain-on-grid method rather than actual flooding.

4.3 Comparison to Previous Modelling Results

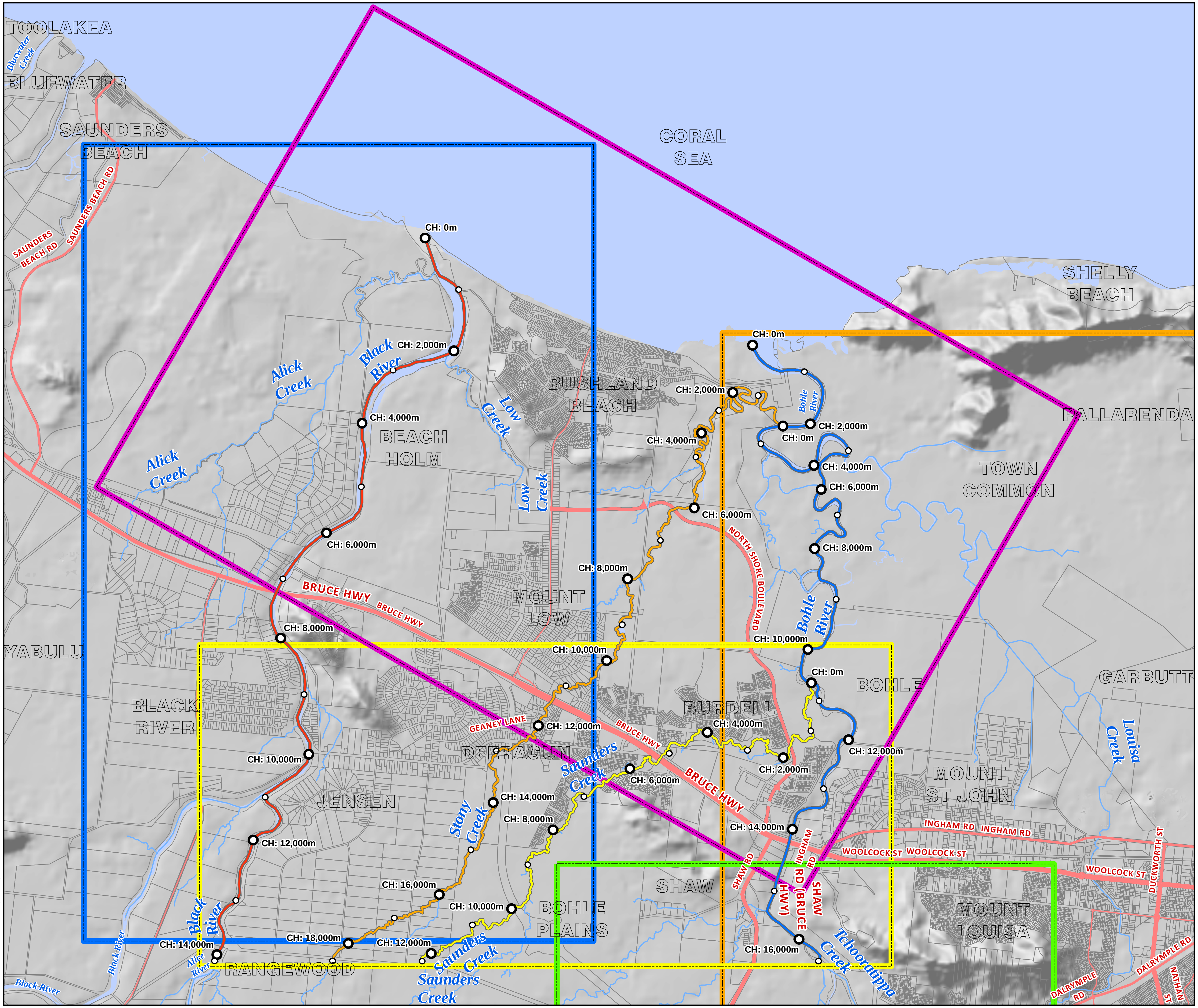
Results of the flood modelling undertaken as part of this project have been used to derive hydraulic grade lines for Lower Bohle/Stony Creek. Long sections showing these hydraulic grade lines and how they compare to the hydraulic grade line derived for other projects undertaken in the area are shown in Appendix B. Locations of the model boundaries and also chainages for these long sections are shown in Figure 4-1.

Modelled Bohle River flood levels were compared against the *Bohle Plains Flood Planning Report (BPFPR, 2010)* and *Upper and Middle Bohle Flood Study (2014)* for the 100 year 12 hour storm. In the *Upper and Middle Bohle River Flood Study (2014),* the overlapping section of the Bohle River is outside the model extent and is represented as a Mike 11 branch acting as a downstream boundary.

Flood levels in the Town Common are lower in the current study than the predicted flood levels in the Upper and Middle Bohle flood study. This can be attributed to the storage provided by the town common that is considered in the Lower Bohle Model. Directly downstream of the Bruce Highway crossing, higher water levels were obtained in the current flood study. This can be attributed to the representation of a flood control levee associated with the North Shore Stage 1 development and additional development of the Bohle River industrial precinct.

Black River was included in the model to ensure breakout flows from this River are captured and represented. A comparison of the section of Black River included in the model against the *Black River Flood Study (2014)* model suggests that the results obtained as part of the current study are similar. The *Black River Flood Study (2014)* was calibrated to stream gauge data for the Black River gauge (112002A) near the Bruce Highway. It is recommended that the values obtained from the Black River section of the model are taken as indicative only and that the *Black River Flood Study (2014)* is used as the main reference point for any flood levels along Black River. However, similar levels obtained in the current study suggest tail water levels and breakout flows from the Black River are being well represented in the current model.

Flood levels along Stony Creek and Saunders Creek were compared to modelled flood levels within the extents of the *Deeragun Flood Study* for the 100 year 24 hour storm. Note that the *Lower Bohle/Stony Creek Study* includes hydrographic survey for the lower reaches of Stony Creek and the *Deeragun Flood Study* does not. Levels compared well for locations within the area of interest for this study. Model parameters within the extents of the Deeragun Flood model were calibrated to the February 2008 flood event, agreement with flood levels within the area of interest suggest model parameters adopted for the current study are providing suitable representation of flood levels.



TOWNSVILLE CITY COUNCIL
LOWER BOHLE/STONY CREEK
FLOOD STUDY
Longitudinal Profile
Plan View
Figure 4-1

Legend

- Longitudinal Section - Black River
- Longitudinal Section - Bohle River
- Longitudinal Section - Saunders Creek
- Longitudinal Section - Stoney Creek
- Major Chainage
- Minor Chainage
- Lower Bohle Model Extent
- Deeragun Model Extent
- Black River Model Extent
- Louisa Creek Model Extent
- Middle Bohle Model Extent
- Highways
- Main Roads
- Watercourse

0 500 1,000 2,000
Metres

1:55,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Data sources:
Roads © 2012 (StreetPro)
Localities © 2012 (Queensland Govt)

AECOM
www.aecom.com

User: mathieu-burrym | Date Saved: 14/05/2014 | FileName: J:\MMPL\60249277\4. Tech Work Area\4.99 GIS\02-Rework\mxd\Report_20140514_FINAL\Fig4-1_LongProfilePlanView.mxd