5 MODEL DEVELOPMENT

Computer models are the most accurate, cost-effective and efficient tools to assess a catchment's flood behaviour. For this study, two types of models were used:

- A hydrologic model of the entire Woolgoolga Lake catchment; and
- A hydraulic model covering the lower half of the study catchment, including Woolgoolga Lake, Woolgoolga Creek, Poundyard Creek and Jarrett Creek.

The **hydrologic model** simulates the catchment rainfall-runoff processes, producing the river/creek flows which are used in the hydraulic model.

The **hydraulic model** simulates the flow behaviour of the channel and floodplains, producing flood levels, flow discharges and flow velocities.

Both of these models were calibrated interactively.

Information on the topography and characteristics of the catchments, watercourses and floodplains are built into the models. Recorded historical flood data, including rainfall, flood levels and river flows, are used to simulate and validate (calibrate and verify) the models. The models produce as output, flood levels, flows (discharges) and flow velocities.

Development of a hydraulic model follows a relatively standard procedure:

1. Discretisation of the catchment, watercourses, floodplain, etc.
2. Incorporation of physical characteristics (river cross-sections, floodplain levels, structures etc).
3. Establishment of hydrographic databases (rainfall, river flows, flood levels) for historic events.
4. Calibration to one or more historic floods (calibration is the adjustment of parameters within acceptable limits to reach agreement between modelled and measured values).
5. Verification to one or more other historic floods (verification is a check on the model's performance without further adjustment of parameters).
6. Sensitivity analysis of parameters to measure dependence of the results upon model assumptions.

Once model development is complete it may then be used for:

- Establishing design flood conditions;
- Determining levels for planning control; and
- Modelling development or management options to assess the hydraulic impacts.

5.1 Hydrological Model

The hydrologic model simulates the rate at which rainfall runs off the catchment. The amount of rainfall runoff and the attenuation of the flood wave as it travels down the catchment is dependant on:

- The catchment slope, area, vegetation and other characteristics;

- Variations in the distribution, intensity and amount of rainfall; and
- The antecedent conditions (dryness/wetness) of the catchment.

These factors are represented in the model by:

- Sub-dividing (discretising) the catchment into a network of sub-catchments inter-connected by channel reaches representing the creeks and rivers. The sub-catchments are delineated, where practical, so that they each have a general uniformity in their slope, landuse, vegetation density, etc;
- The amount and intensity of rainfall is varied across the catchment based on available information. For historical events, this can be very subjective if little or no rainfall recordings exist.
- The antecedent conditions are modelled by varying the amount of rainfall which is “lost” into the ground and “absorbed” by storages. For very dry antecedent conditions, there is typically a higher initial rainfall loss.

The output from the hydrologic model is a series of flow hydrographs at selected locations such as at the boundaries of the hydraulic model. These hydrographs are used by the hydraulic model to simulate the passage of the flood through the Woolgoolga Lake catchment.

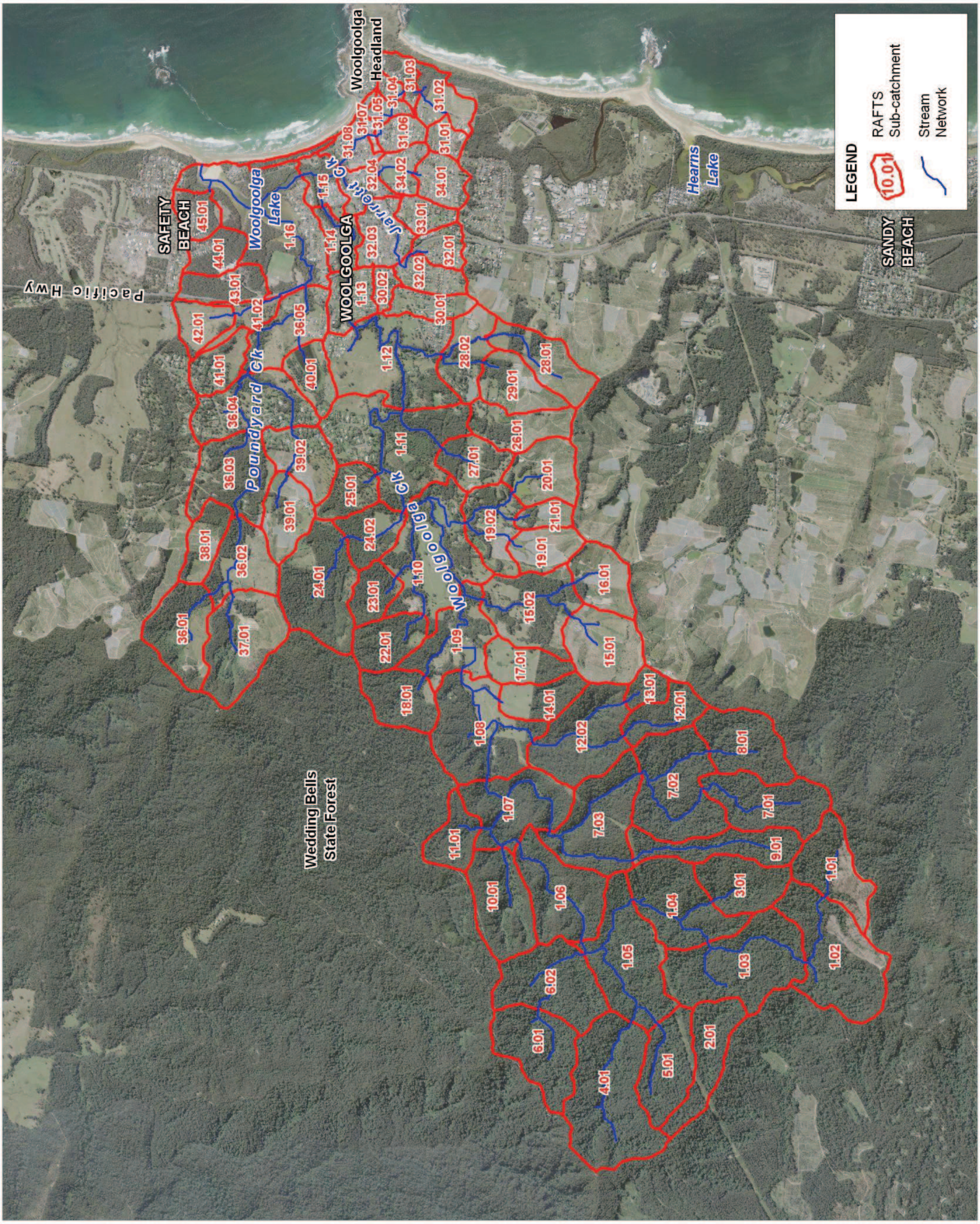
The RAFTS-XP software was used to develop the hydrologic model using the physical characteristics of the catchment including catchment areas, ground slopes and vegetation cover as detailed in the following sections.

5.1.1 Flow Path Mapping and Catchment Delineation

The Woolgoolga Lake catchment drains an area of approximately 22km^2 to the lake entrance at the Tasman Sea. For the hydrological model this area has been delineated into 86 sub-catchments as shown in Figure 5-1. The sub-catchment delineation provides for generation of flow hydrographs at key confluences or inflow points to the hydraulic model.

Table 5-1 summarises the key catchment parameters adopted in the RAFTS-XP model, including catchment area, vectored slope and PERN (roughness) value estimated from the available topographic information and aerial photography. The adopted PERN values considered the proportion of forested catchment to cleared/pasture area. As indicated in the table and evident from aerial photography, the greater proportion of the upper Woolgoolga Creek catchment is forested. The lower Woolgoolga Creek and Poundyard Creek catchments are a mix of forested and cleared land uses. The Jarrett Creek catchment is predominantly urban.

The PERN values provided in Table 5-1 represent the largely undeveloped catchment area of Woolgoolga Lake. For sub-catchments 30.01 to 34.02, that contain regions of urban development, lower PERN values have been adopted to reflect the increased responsiveness of the urban land use types. These urban sub-catchments have also been modelled using a second sub-catchment approach, where the impervious areas are treated separately. The PERN value for these impervious areas has been set to 0.015 accordingly.



Title:

RAFTS Model Sub-catchment Layout

Figure:

5-1

Rev:

A

N

0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2245_Woolgoolga_Flood_Study\MapInfo\Workspaces\DRG_007_120312_Subcatchments.WOR

Table 5-1 RAFTS Sub-catchment Properties

Catchment Label	Area (ha)	Slope (%)	PERN	Catchment Label	Area (ha)	Slope (%)	PERN
1.01	28.5	7.0	0.12	23.01	13.8	8.3	0.12
1.02	55.6	3.8	0.12	24.01	46.4	5.9	0.12
1.03	57.9	8.3	0.12	24.02	18.4	3.5	0.10
1.04	40.7	5.5	0.12	25.01	14.7	5.4	0.08
1.05	50.0	4.0	0.12	26.01	22.0	5.3	0.08
1.06	40.5	6.8	0.12	27.01	18.1	4.4	0.08
1.07	38.9	4.5	0.12	28.01	24.6	4.7	0.08
1.08	52.1	2.1	0.10	28.02	21.7	2.4	0.08
1.09	31.9	1.3	0.10	29.01	21.9	6.1	0.08
1.10	56.3	1.1	0.08	30.01	12.5	2.5	0.04
1.11	63.3	1.2	0.08	30.02	5.6	1.2	0.04
1.12	59.6	1.1	0.06	31.01	7.0	4.5	0.04
1.13	16.1	2.2	0.04	31.02	16.2	1.2	0.06
1.14	12.5	0.6	0.04	31.03	7.9	1.9	0.08
1.15	12.4	0.1	0.06	31.04	3.7	3.5	0.04
1.16	70.3	0.2	0.08	31.05	4.9	1.0	0.04
2.01	27.1	5.3	0.12	31.06	9.0	1.7	0.04
3.01	26.2	16.9	0.12	31.07	3.7	0.9	0.04
4.01	65.8	3.0	0.12	31.08	10.7	0.6	0.04
5.01	30.1	10.5	0.12	32.01	10.8	3.7	0.04
6.01	35.9	10.6	0.12	32.02	12.4	2.8	0.04
6.02	41.4	5.9	0.12	32.03	19.2	0.9	0.04
7.01	35.6	5.4	0.12	32.04	10.3	0.3	0.06
7.02	49.7	8.9	0.12	33.01	9.9	5.4	0.04
7.03	44.2	11.9	0.12	34.01	14.0	6.0	0.04
8.01	31.5	11.2	0.12	34.02	10.7	2.5	0.04
9.01	28.4	3.2	0.12	35.01	3.4	0.0	0.12
10.01	33.7	11.8	0.12	36.01	31.3	8.3	0.10
11.01	16.3	18.1	0.12	36.02	25.4	3.6	0.10
12.01	17.3	14.0	0.12	36.03	34.7	3.0	0.10
12.02	42.4	8.9	0.12	36.04	37.3	1.6	0.06
13.01	8.0	16.5	0.12	36.05	26.9	1.5	0.06
14.01	17.3	9.5	0.08	37.01	41.3	9.2	0.10
15.01	30.8	11.7	0.08	38.01	15.8	3.7	0.10
15.02	38.8	3.5	0.10	39.01	20.4	3.6	0.08
16.01	21.1	10.8	0.08	39.02	22.8	2.8	0.06
17.01	17.2	7.0	0.08	40.01	15.3	1.7	0.06
18.01	23.3	11.5	0.12	41.01	15.2	1.6	0.06
19.01	16.5	6.1	0.08	41.02	9.6	1.0	0.06
19.02	24.6	3.1	0.08	42.01	13.5	3.4	0.06
20.01	23.9	3.2	0.08	43.01	16.4	2.5	0.12
21.01	8.6	8.3	0.08	44.01	13.3	4.7	0.10
22.01	20.0	7.9	0.12	45.01	10.9	3.9	0.08

5.1.2 Rainfall Data

Rainfall information is the primary input and driver of the hydrological model, which simulates the catchments response in generating surface run-off. Rainfall characteristics for both historical and design events are described by:

- Rainfall depth – the depth of rainfall occurring across a catchment surface over a defined period (e.g. 270mm in 36hours or average intensity 7.5mm/hr); and
- Temporal pattern – describes the distribution of rainfall depth at a certain time interval over the duration of the rainfall event.

Both of these properties may vary spatially across the catchment.

The procedure for defining these properties is different for historical and design events. For historical events, the recorded hyetographs at continuous rainfall gauges provide the observed rainfall depth and temporal pattern. Where only daily read gauges are available within a catchment, assumptions regarding the temporal pattern may need to be made.

For design events, rainfall depths are most commonly determined by the estimation of intensity-frequency-duration (IFD) design rainfall curves for the catchment. Standard procedures for derivation of these curves are defined in AR&R (2001). Similarly AR&R (2001) defines standard temporal patterns for use in design flood estimation.

The rainfall inputs for the historical calibration/validation events are discussed in further detail in Section 6 and design events discussed in Section 7.

5.2 Hydraulic Model

BMT WBM has applied the fully 2D software modelling package TUFLOW. The 2D model has distinct advantages over 1D and quasi-2D models in applying the full 2D unsteady flow equations. This approach is necessary to model the complex interaction between rivers, creeks and floodplains and converging and diverging of flows through structures. The channel and floodplain topography is defined using a high resolution DEM for greater accuracy in predicting flows and water levels and the interaction of in-channel and floodplain areas.

5.2.1 Topography

The ability of the model to provide an accurate representation of the flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. For the Woolgoolga Lake catchment, a 2m by 2m gridded DEM was derived from the LiDAR survey and hydrographic survey datasets provided by Council.

As discussed in Section 4.1, additional cross section survey of the watercourses was required to supplement the existing cross sections and LiDAR data and provide the necessary detail on channel shape and dimensions for representation in the hydraulic model. The channel topography has been incorporated into the 2D model representation and is discussed further in Section 5.2.4.

5.2.2 Extents and Layout

Consideration needs to be given to the following elements in constructing the model:

- Topographical data coverage and resolution;
- Location of recorded data (eg. levels/flows for calibration);
- Location of controlling features (eg. dams, levees, bridges);
- Desired accuracy to meet the study's objectives; and
- Computational limitations.

With consideration to the available survey information and local topographical and hydraulic controls, a 2D model was developed extending from the Woolgoolga Lake entrance at the downstream limit, upstream along the major tributary routes. The model incorporates the whole of Woolgoolga Lake and Woolgoolga Creek to upstream of the stream gauge, some 5.7km in length. Around 3.7km of Poundyard Creek is modelled, as is the full 1.2km length of Jarrett Creek. The area modelled within the 2D domain comprises a total area of some 9km^2 which represents the lower 40% of the entire Woolgoolga Lake catchment. The model layout is presented in Figure 5-2.

5.2.3 Hydraulic Roughness

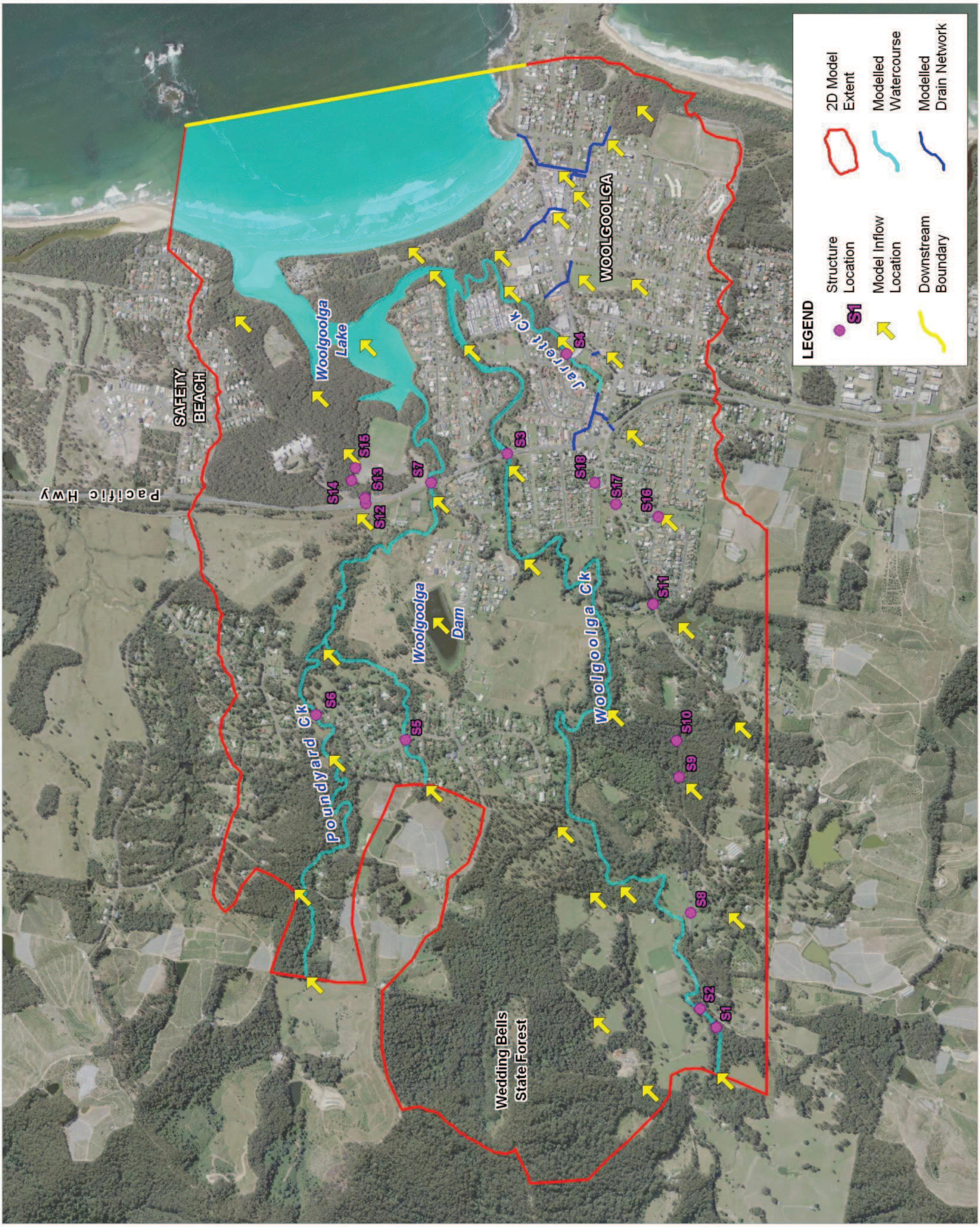
The development of the TUFLOW model requires the assignment of different hydraulic roughness zones. These zones are delineated from aerial photography and cadastral data identifying different land-uses (eg. forest, cleared land, roads, urban areas, etc) for modelling the variation in flow resistance.

The hydraulic roughness is one of the principal calibration parameters within the hydraulic model and has a major influence on flow routing and flood levels. The roughness values adopted from the calibration process is discussed in Section 6.

5.2.4 Channel Network

The study required the modelling of the Woolgoolga Creek, Poundyard Creek and Jarrett Creek. The extents of the required modelling were defined by Council and additional cross section survey data was acquired to cover these extents, as discussed in Section 4. The actual modelled reaches of Woolgoolga Creek and Poundyard Creek have been extended by around 1.5km and 1.2km respectively. This was undertaken to extend the hydraulic model coverage upstream of the stream gauge on Woolgoolga Creek and the Woolgoolga bypass alignment on Poundyard Creek. The extents of the modelled watercourses and available cross section data are presented in Figure 4-1.

The existing cross section data was extracted from the HEC-RAS model which was developed for the Woolgoolga Creek Flood Study (Enginuity Design, 2002). The cross sections surveyed for this study were provided by Council in both CAD and xyz point co-ordinate formats. Figure 4-1 shows the distribution of the surveyed cross-section locations in relation to the modelled watercourse extent.



Title:

Linked 1D/2D TUFLOW Model Layout

Figure:

5-2

Rev:

A

N

0 750m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2245_Woolgoolga_Flood_Study\MapInfo\Workspaces\DRG_008_120313_Model_Layout.WOR

The available cross section data was used to embed the channel topography into 2D domain of the TUFLOW model. Channel topography upstream of the available survey data on Woolgoolga Creek and Poundyard Creek was extrapolated using the LiDAR survey data and the relationship between LiDAR and surveyed elevations for the downstream reaches. Figure 5-3 shows a long section of the Woolgoolga Creek channel topography. The LiDAR elevations have been extracted along the channel centreline. The channel survey location marks indicate the surveyed creek bed elevations. The modelled channel bed elevation has been derived from the cross section survey at a channel width of 2m. Figure 5-4 presents similar information for Poundyard Creek.

Embedding the channel topography within the 2D model domain provides several advantages over a 1D channel representation, including:

- A smoother transition between channel and floodplain conveyance;
- A more spatially rich representation of the high-flow in-channel flood conveyance, taking account of local topographic controls both at and beneath bank-full level;
- An inherent representation of the channel sinuosity;
- Spatial variation of velocities across the width of the channel; and
- Improved flood mapping output for in-channel areas.

Sample cross sections of the modelled topography, combining channel survey and LiDAR data are provided for Woolgoolga Creek and Poundyard Creek in Figure 5-5 and Figure 5-6 respectively.

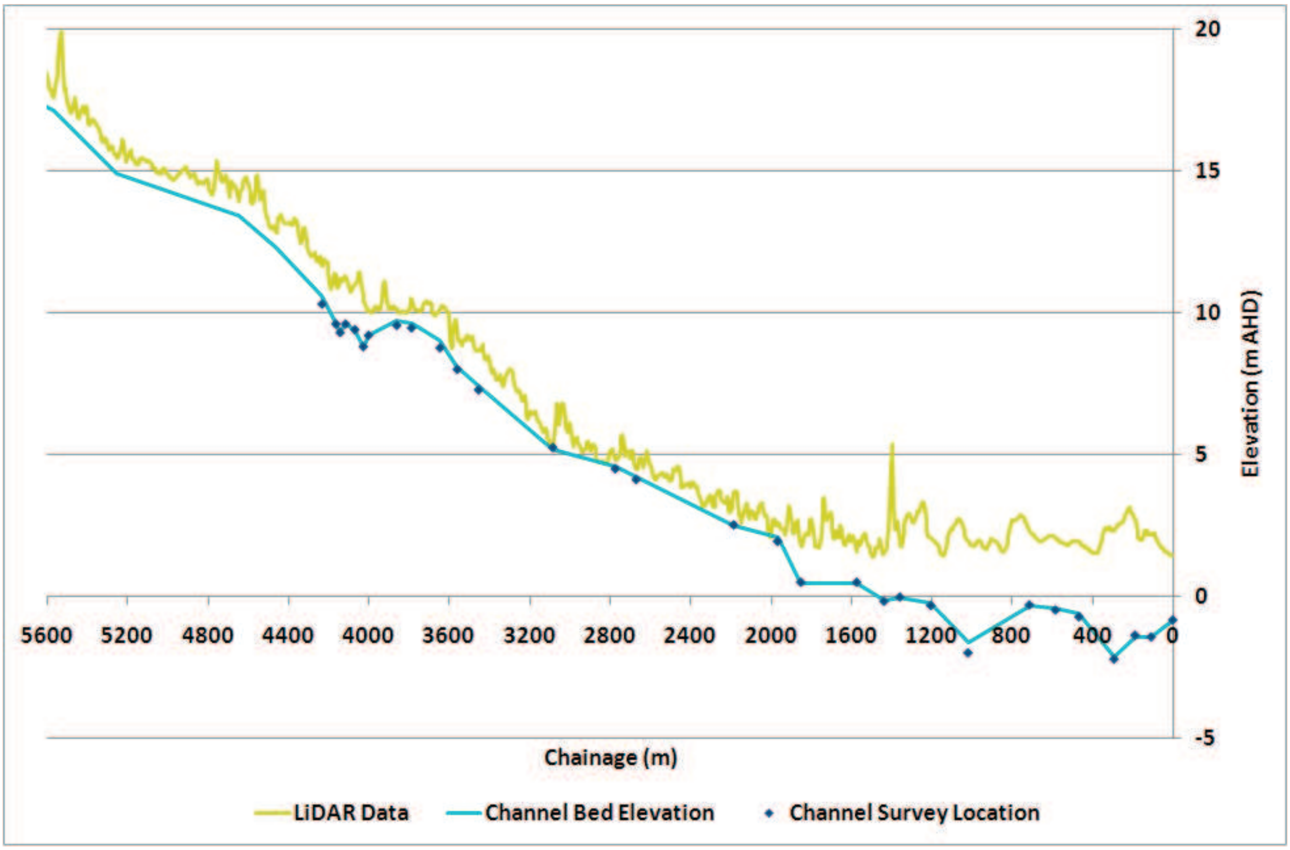


Figure 5-3 Long Section of Woolgoolga Creek Channel Topography

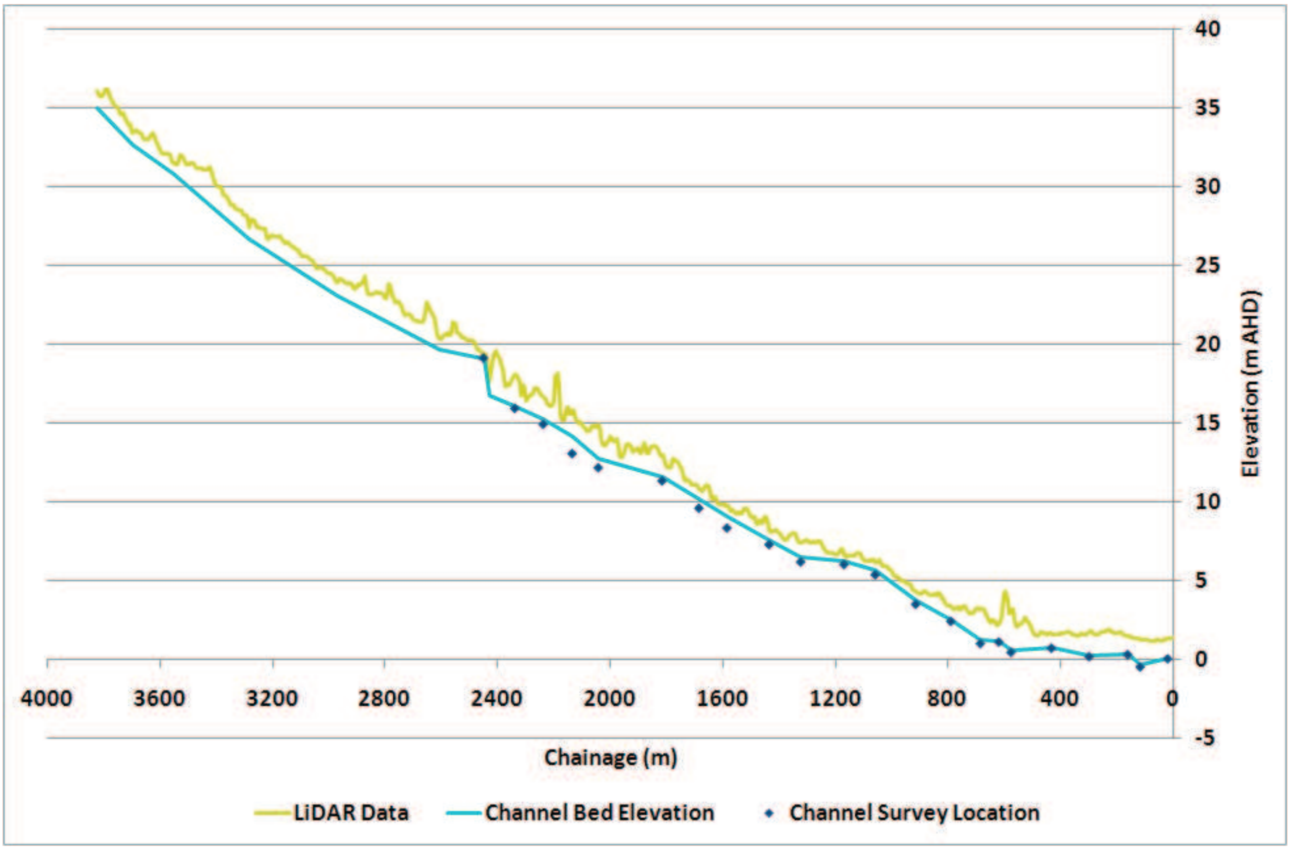


Figure 5-4 Long Section of Poundyard Creek Channel Topography

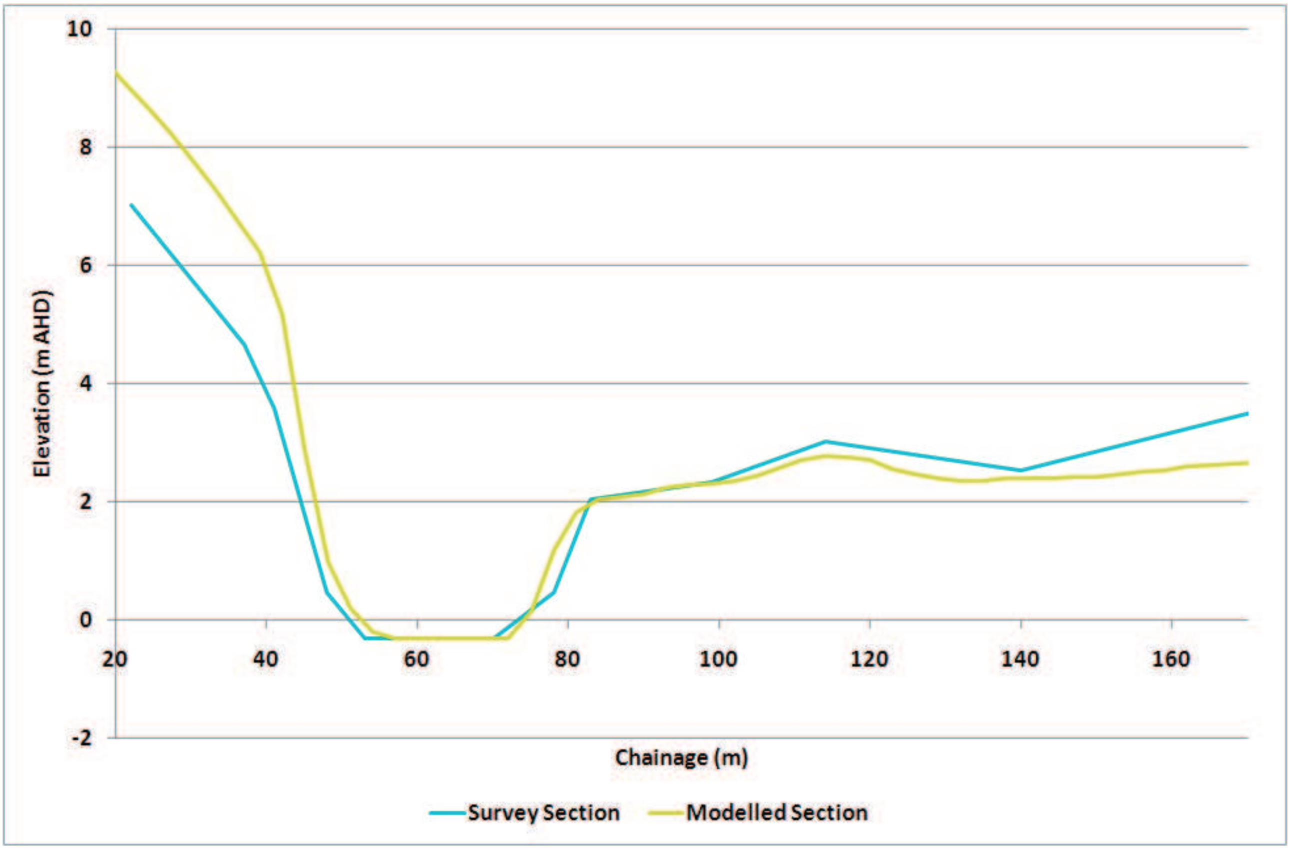


Figure 5-5 Sample Cross Section of Woolgoolga Creek Channel Topography

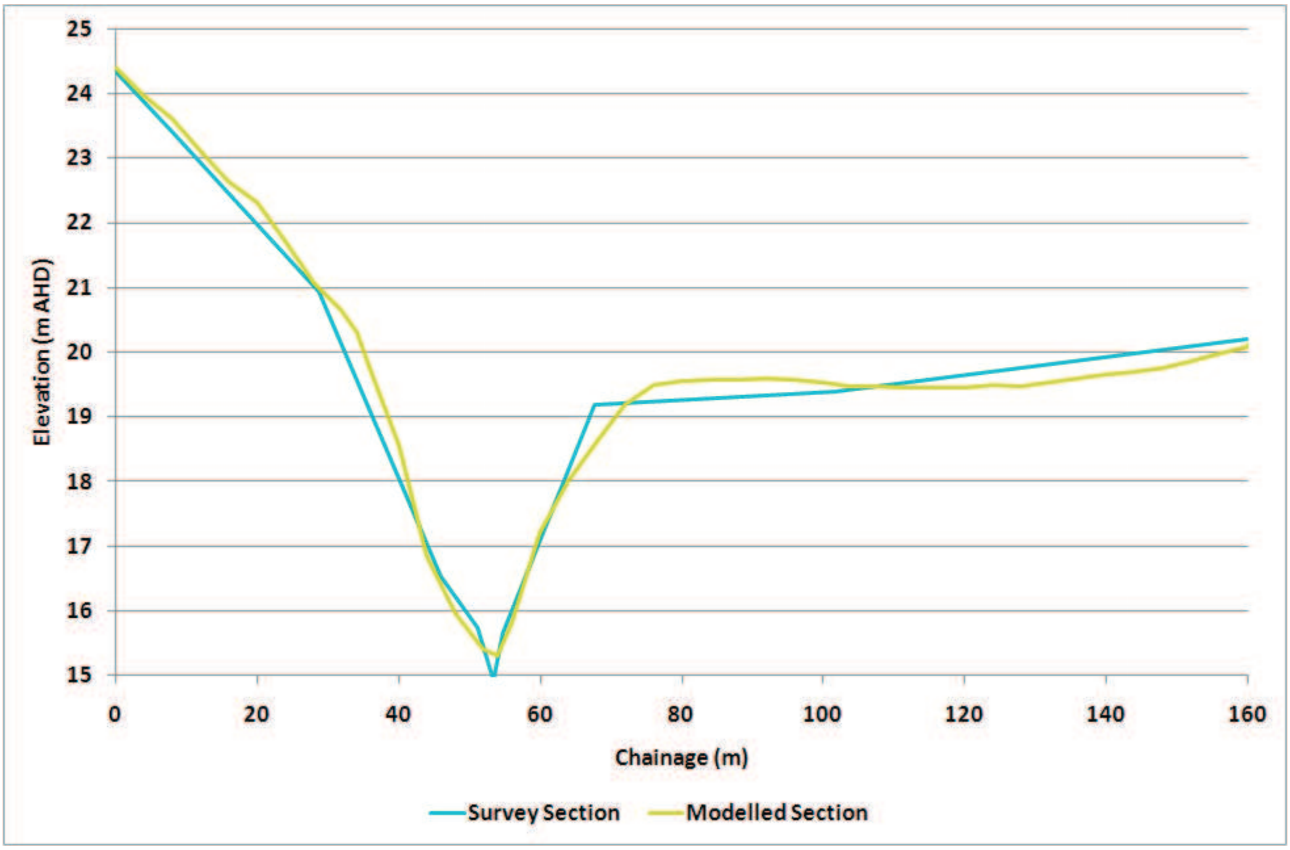


Figure 5-6 Sample Cross Section of Poundyard Creek Channel Topography

5.2.5 Structures

There are a number of bridge and culvert crossings over the main channel alignments and tributaries within the model extents as detailed in Table 5-2 (refer to Figure 5-2 for locations). These structures vary in terms of construction type and configuration, with varying degrees of influence on local hydraulic behaviour. Incorporation of these major hydraulic structures in the models provides for simulation of the hydraulic losses associated with these structures and their influence on peak water levels within the study area.

The larger bridge structures have been modelled as flow constrictions within the 2D domain. Culverts, which are typically smaller, have been modelled using 1D structures, embedded within the 2D domain.

No data was available for a number of culvert crossings on Woolgoolga Creek Road. An assumed culvert arrangement of triple 1.05m diameter pipes has been adopted at these locations. This provides capacity for the hydrological model inputs upstream of the road to flow under the road without an overly high level of attenuation. Caution should therefore be taken when interpreting model results upstream of these culvert locations. Localised impacts on the modelled flood results could result from differences to the adopted culvert configuration. However, impacts on the broader flood behaviour of Woolgoolga Creek would be negligible.

Table 5-2 Major Hydraulic Structures within the Model Area

ID	Location	Structure
S1	Stream Gauge (Woolgoolga Creek)	Broad-crested weir (approx. 11m wide)
S2	Woolgoolga Ck Rd Bridge (Woolgoolga Creek)	Concrete bridge (approx. 16m span)
S3	Pacific Hwy Bridge (Woolgoolga Creek)	Concrete bridge (approx. 32m span)
S4	Bultitude St Culvert (Jarrett Creek)	Concrete culvert (triple 0.8m x 1.2m box)
S5	Shearer Dr Culvert (Un-named Tributary)	Concrete culvert (triple 1.05m pipe)
S6	Shearer Dr Culvert (Poundyard Creek)	Concrete culvert (triple 1.8m pipe)
S7	Pacific Hwy Bridge (Poundyard Creek)	Concrete bridge (approx. 20m span)
S8	Woolgoolga Ck Rd Culvert (Un-named Tributary)	Assumed culvert (triple 1.05m pipe)
S9	Woolgoolga Ck Rd Culvert (Un-named Tributary)	Assumed culvert (triple 1.05m pipe)
S10	Woolgoolga Ck Rd Culvert (Un-named Tributary)	Assumed culvert (triple 1.05m pipe)
S11	Woolgoolga Ck Rd Culvert (Un-named Tributary)	Assumed culvert (triple 1.05m pipe)
S12	Pacific Hwy Culvert (Un-named Tributary)	Concrete culvert (triple 0.75m pipe)
S13	Access Road Culvert (Un-named Tributary)	Concrete culvert (triple 0.75m pipe)
S14	Access Road Culvert (Un-named Tributary)	Concrete culvert (double 0.75m pipe)
S15	Access Road Culvert (Un-named Tributary)	Concrete culvert (single 1.05m pipe)
S16	Crabbe St Culvert (Un-named Tributary)	Concrete culvert (double 1.05m pipe)
S17	Pullen St Culvert (Un-named Tributary)	Concrete culvert (single 0.75m pipe)
S18	Moore St Culvert (Un-named Tributary)	Concrete culvert (double 0.9m pipe)

5.2.6 Drainage Network

The study requires the modelling of the drainage system in some of the urban sub-catchments. Council provided survey information on the existing drainage system where modelling was required. This data comprised CAD data detailing pit/pipe locations, pipe sizes and invert levels.

A sample longsection of a modelled drainage line is shown in Figure 5-7. The figure shows the invert levels and obvert according to culvert dimension, the ground surface level as derived from the DEM, and a typical minimum cover level of 600mm.

The pipe network, represented as a 1D layer in the model, is dynamically linked to the 2D domain at specified pit locations for inflow and surcharging. Pit inlet configurations have been modelled using dimensions estimated through a combination of site inspections, photographs and aerial imagery. The modelled pipe network, which consists of 43 pipes with a combined run length of approximately 1.7km, is shown in Figure 5-2.

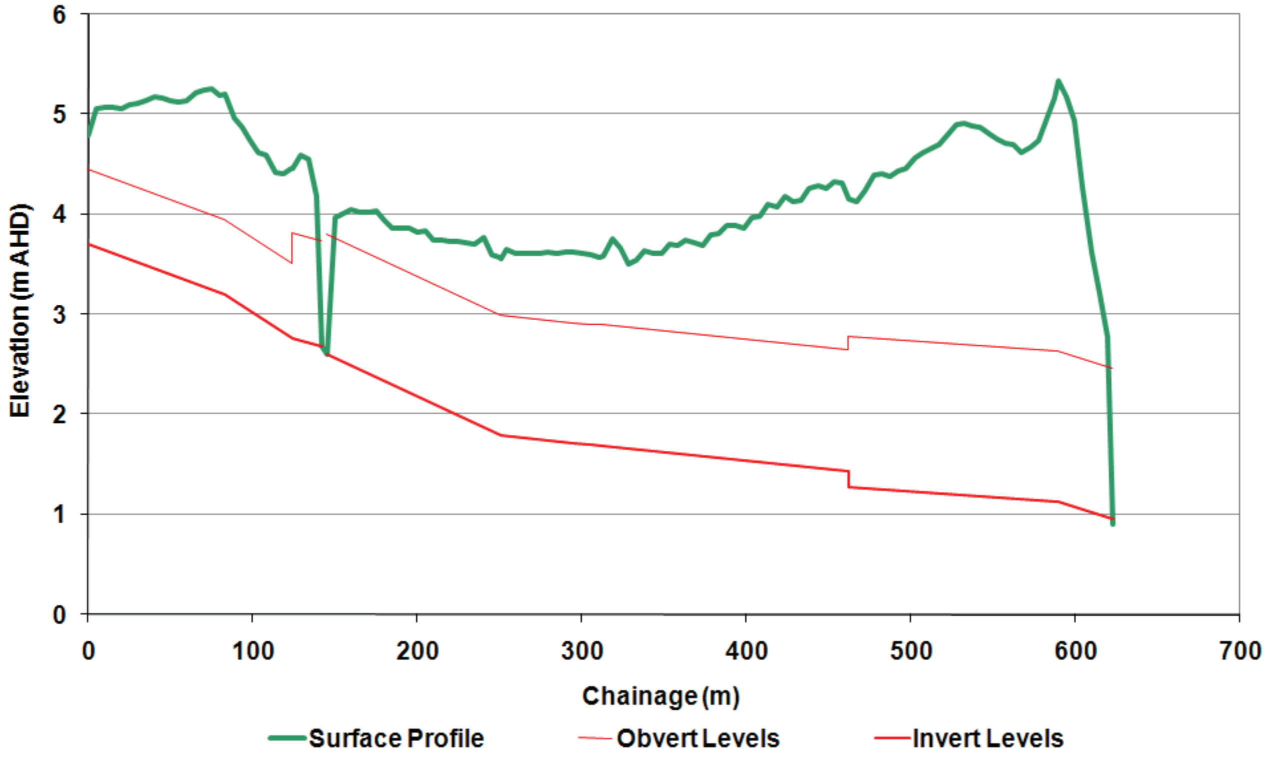


Figure 5-7 Sample Drainage Line Long Section

5.2.7 Boundary Conditions

The catchment runoff is determined through the hydrological model and is applied to the TUFLOW model as flow vs. time inputs. These are applied at the upstream modelled watercourse limits and also as distributed inflows along the modelled watercourse reaches. In the urban sub-catchments with modelled stormwater drainage the model inflows are applied directly to the 1D pipe network and will surcharge to the 2D surface representation when pipe full capacity is exceeded.

The downstream model limit corresponds to the water level in the Tasman Sea. The adopted water levels for the downstream boundary condition for the calibration and design events are discussed in Section 6 and Section 7 respectively.

5.2.8 Entrance Geomorphology

The lake entrance geometry was defined through a combination of available information in the LiDAR data and hydrographic survey. The crest level of the entrance berm in the available data sources varies between around 1.2m AHD to 1.5m AHD. However, the modelled entrance berm geometry was modified for both the calibration process and design flood conditions and is discussed further in Section 6 and Section 7 respectively.

The geomorphologic module within TUFLOW was used for this study to model the entrance scour during flood events. The module is based on the theory and methods described in Van Rijn (1990). The Van Rijn formulation of sand transport is generally accepted as being an appropriate method for estimating sand transport. However, it must be noted that sand transport is a complex interaction of processes with no universal sand transport formulation being available. In order to account for these uncertainties, it is necessary to make approximations related to a number of the process interactions. Although these approximations are unavoidable, the Van Rijn method is still appropriate to combine with the 2D (depth-averaged) TUFLOW hydrodynamic routines to achieve realistic time-varying entrance shoal and beach berm levels and the accompanying simulated flood discharges.

Quantification of sand transport rates is achieved by the use of two unifying and fundamental concepts:

(i) The combined action of currents and waves mobilises the bottom sands and sets them into motion; and

(ii) The bottom sediment, once mobilised, is moved in the direction of the prevailing net current. The net current can be the result of factors such as river flow, tides, wind, wave radiation stresses or asymmetry in the oscillatory wave motion, or a combination of these.

Inputs to the geomorphologic model include:

- D50 (median grain size of a representative sand sample): 0.25 mm;
- D90: 0.50 m (grain size which is exceeded by 10% of a representative sand sample);
- Fall Velocity (settling velocity of sand grains through water within a representative sand sample: 0.035 m/s);
- Sand Grain Density: 2650 kg/m^3; and
- Water Density: 1035 kg/m^3.

The selected parameters are deemed appropriate for typical conditions of the Woolgoolga Lake entrance berm sand. Sensitivity of the grain size parameters and corresponding fall velocity has been undertaken and is discussed in Section 8.6.6.