Cardno LawsonTreloar

Shaping the Future

GLENELG FLOOD INVESTIGATIONS

LJ5580 RM2187 Ver. 1.0 FINAL

November 2008
Job No. LJ5580

Glenelg Shire Council

Cardno Lawson Treloar Pty Ltd

ABN 55 001 882 873

150 Oxford Street Collingwood

Victoria 3066 Australia

Telephone: 03 8415 7500

Facsimile: 03 8415 7788

International: +61 3 8415 7500

cltvic@cardno.com.au

www.cardno.com.au

Document Control

Version	Date	Author		Reviewer	
		Name	Initials	Name	Initials
0.1 Draft	October 2008	Jacqui Reid	JLR	Rob Swan	RCS
1.0 FINAL	19 November 2008	Jacqui Reid	JLR	Rob Swan	RCS

GLENELG FLOOD INVESTIGATIONS

LJ5580 RM2187 VER. 1.0 FINAL

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1. INTRODUCTION

Cardno Lawson Treloar were engaged by Glenelg Shire Council (GSC) to investigate flooding in the Glenelg shire.

The Glenelg Shire is located in south west Victoria. The main urban centre is Portland. Other significant townships include Heywood and Casterton, located approximately 25km and 85km north of Portland, respectively. These three areas will be studied in detail, whilst taking into account the hydrology of the wider area.

The Shire is located within the Glenelg Catchment and the relevant catchment authority is the Glenelg Hopkins Catchment Management Authority (GHCMA).

In the Glenelg Shire Planning Scheme, Portland has an Urban Floodway Zone (UFZ), and Casterton has a Rural Floodway Overlay (RFO) and a Land Subject to Inundation Overlay (LSIO). Indicative 1 in 100 year flood extents and floodway areas, as determined by the Department of Sustainability and Environment (DSE), also exist throughout the three subject townships. Flood zones and overlays in the Glenelg Shire Planning Scheme are not always consistent with the available flood data or ground level information, with notable discrepancies in some areas. The currently identified flood extents do not fully represent the extent of the floodplain and their quality is uncertain. A reassessment of the existing flood data, making use of historic records and recently acquired high resolution aerial photography and digital terrain modelling (DTM) data, is required to determine the accuracy of flood extents and to identify areas where flood data may be improved through more rigorous flood modelling.

The purpose of this investigation is to conduct an assessment and re-interpretation of the existing flood data for Casterton, Heywood and Portland in order to provide Glenelg Shire with refined flood extents for the townships.

1.1 Scope of Works

The scope of services as defined in the tender documents includes the following:

- Incorporation of the LIDAR data (provided by Glenelg Shire Council (GSC)) and other ground survey data (where appropriate) to create a Digital Terrain Model of the catchment.
- Create a RORB model for Portland to determine hydrological flows for the existing flooding conditions.
- Undertake flood frequency analyses on the Glenelg and Fitzroy Rivers.
- Develop 2D hydraulic models for Portland, Heywood and Casterton to assess extent and depth of flooding for the storm events specified in the project brief.
- Provide discharge information and detailed water surface elevation information in the towns for the range of storm events.

2. CATCHMENT AND STORMWATER SYSTEM DATA

2.1 Summary of Data Sources

The following data was acquired for use in the study:

- Aerial survey, (supplied via CD by GSC, June 2008)
- Aerial LIDAR survey (supplied by Digital Mapping, July and September 2008)
- NASA Shuttle Radar Topography Mission (SRTM) 3-arc second DEM version 2 (from ftp://e0srp01u.ecs.nasa.gov)
- Flow Data for the Glenelg River at Casterton (www.vicwaterdata.net)
- Flow Data for the Fitzroy River at Heywood (www.vicwaterdata.net)
- Glenelg River cross sections at Casterton (supplied via CD by GHCMA via GSC, July, 2008)
- Google Earth aerial images (accessed 1/8/2008)

2.2 Site Inspections

A site reconnaissance was undertaken in order to become familiar with local topography and physical features of the site. The field inspection was carried out on 5-6 June 2008. The location of significant floodplain features was noted. These included:

- Bridges
- Culverts
- Roadways

2.3 Survey Data and Digital Terrain Model

LIDAR (Aerial Laser Survey) data and 10m contour data were supplied by GSC, enabling the development of a fine scale Digital Terrain Model (DTM) to define the existing overland drainage network. The NASA SRTM digital elevation model was used to define the topography for the greater Portland catchment area where LIDAR data was not available. The SRTM data has greater definition than the VicMap 10m contour data available for the area.

2.3.1 Digital Terrain Model

A comprehensive digital terrain model (DTM) was compiled from the Lidar data for Portland and Heywood. In Casterton the Lidar data did not cover the entire model extent and hence the less well defined contour data was used in its place. The digital elevation models (DEMs) were constructed as rectangular grids of elevations that were sampled from the DTMs. This defined the topography of the catchment. The DEM extents used in the study are shown in Figures 2.1, 2.2 and 2.3 for Portland, Heywood and Casterton respectively. A 10 m horizontal grid cell size was adopted for each town, as this is considered to offer a resolution fine enough to appropriately define topographical features such as overland drainage paths, within the catchment area.

3. SURFACE HYDROLOGY

3.1 Introduction

The general approach to hydrologic modelling differed for each town depending on the available data. The methods used were the traditional hydrological routing method and flood frequency analysis on measured stream data.

3.2 Catchment Conditions

Portland is situated on the south-western coast of Victoria. The catchment of Portland is predominantly rural, with the upstream areas being rural and the downstream end being the town of Portland. Wattle Hill Creek is the major watercourse that runs through the catchment, outletting into Fawthrop Lagoon. There is also the small Finn St Creek that discharges into the lagoon, which runs north along Finn St. The lagoon is tidally influenced; however this tidal effect does not translate upstream into the creeks.

The catchments of Heywood and Casterton are very similar. They are mostly rural, with small townships and both are traversed by moderately sized rivers. In the case of Heywood, the Fitzroy River passes through the township and is met just downstream of the town by Sunday Creek. The Glenelg River passes through the north-eastern edge of Casterton.

The flows in the Fitzroy River and the Glenelg River are gauged and have reasonably long records and hence a flood frequency analysis is suitable to ascertain the ARI event flows in the rivers. Wattle Hill Creek, Finn St Creek and Sunday Creek are all ungauged and it is therefore most appropriate to undertake a RORB hydrological routing method to determine flows in the catchments.

3.2.1 Catchment and Sub-catchment Definition

Catchment boundaries were ascertained using contour and DEM information. The NASA Shuttle Radar Topography Mission (SRTM) data set was used to define catchment boundaries. A total of 12 sub-catchments were used to define the drainage properties of the Portland catchment, whilst 4 sub-catchments were used to define the Sunday Creek catchment. A summary of the sub-catchment characteristics is provided in table 3.2 and shown in figures 3.1 and 3.2 for Portland and Heywood respectively.

Table 3.1 – RORB sub-catchment parameters

Sub-Area	Portland : Area (km^2)	Heywood : Area (km^2)
A	16.5	13.2
B	17.3	20.4
C	18.8	22.2
D	11.4	25.3
E	17.2	
F	17.0	
G	7.4	
H	6.3	
I	4.3	
J	21.2	
K	21.7	
L	5.4	
Total	**164.4**	**81.0**

3.3 Hydrological Model Establishment

3.3.1 RORB Model Establishment

The RORB hydrological model version 5.33 (Laurenson, Mein and Nathan, 2005) was used for this study. RORB calculates flood hydrographs from storm rainfall hyetographs and can be used for modelling natural, part urban and fully urban catchments. RORB is an industry standard model that has been used widely in previous studies undertaken by Melbourne Water.

The sub-catchment characteristics described in table 3.2 were used in the RORB model.

RORB allows for the modification of a number of hydrological parameters for calibration purposes including:

- Coefficient of runoff;
- Initial rainfall loss;
- Variation of the stream lag parameter 'k_c' (affecting the routing time of flow through a sub-catchment);
- The non-linearity factor 'm'.

The RORB parameters used in the modelling are shown in table 3.2. The 'Intensity Frequency Duration' (IFD) coefficients listed in table 3.3 were used for the generation of design storm events. The IFDs are taken from AR&R Vol 2 (1987).

As the Portland waterway catchments are ungauged, RORB was calibrated to the flow calculated in the *Portland Floodplain Management* Study (Rural Water Commission of Victoria & City of Portland, 1988). This report estimated a total of 113m^3/s entering Fawthrop Lagoon in the 1946 flood event and was considered to be the 100-yr ARI event.

As the Fitzroy River is gauged, it is possible to calibrate a RORB model upstream of the gauge using a real event. It was assumed that the short reach downstream of the gauge and the Sunday Creek catchment can be represented by the same K_c and m values. These parameters were calibrated using the November 2007 as well as the RORB model for the Fitzroy River provided by GSC.

Table 3.2 – RORB Parameters

RORB Vector	kc	m	Initial Loss (mm)	Continuing Loss (mm/h)
Portland	12.5	0.8	20	2
Sunday Creek	45	0.8	15	1.5

Table 3.3 – IFD Coefficients (after AR&R 1987)

Parameter	Portland Value	Heywood Value
${}^{2}I_{1}$	15.25	15.7
${}^{2}I_{12}$	3.5	3.5
${}^{2}I_{72}$	1	0.95
${}^{50}I_{1}$	25	29
${}^{50}I_{12}$	5	5.4
${}^{50}I_{72}$	1.6	1.7
G	0.62	0.6
F2	4.34	4.36
F50	14.60	14.65

The results of these RORB model runs are shown in appendix B.

3.3.2 Flood Frequency Analysis

A flood frequency analysis (FFA) was undertaken to determine the AEP flows in the Glenelg River at Casterton and the Fitzroy River at Heywood. There are gauging stations located in both Heywood (gauge I.D. 237202) and Casterton (gauge I.D. 238212) , which can be used in a flood frequency analysis (FFA) The locations of these gauging stations can be found at http://www.vicwaterdata.net/vicwaterdata/home.aspx

There are 15 years of complete gauged flow data for the Glenelg River at Casterton, ranging from 1974-1988.This amount of data is considered sufficient to undertake Annual Flood Series Analyses as described in AR&R Vol. 1 (1987); however it is short enough that verification through the FLIKE software (Kuczera, 1999) was used to corroborate the results. FLIKE uses Bayseian statistical methods to extrapolate the gauged data to form a longer time series, which is then used in a flood frequency analysis. The results of the analysis are shown in table 3.4 and the FFA plot is shown in figure 3.3. .

Table 3.4 – FFA Flows, Glenelg River at Casterton

ARI Event	Flow (m^3/sec) AR&R	Flow (m^3/sec) FLIKE
100-yr	240	307
50-yr	239	297
20-yr	237	273
10-yr	231	244
5-yr	213	200
1-yr	16	2

It can be seen from the analysis that the estimates of flow in rare ARI events do not change significantly. This is not the expected catchment behaviour and is further discussed in Section 3.4 below.

There are 38 years of complete flow gauge data for the Fitzroy River at Heywood, ranging from 1969-2005. There is also 33 years of average daily flow data ranging from 1949-1981. A correlation between the instantaneous flows and average daily flows for 1969 to 1981 was calculated to be 1.18 and is shown in figure 3.4. This correlation factor was applied to the flow in the years 1949 to 1968, allowing for the inclusion of these years in the FFA, resulting in 58 years in the series and hence a more accurate FFA. The results of the analysis are shown in table 3.5 and figure 3.5.

Table 3.5 – FFA Flows, Fitzroy River at Heywood

ARI Event	Flow (m^3/sec) AR&R
100-yr	108
50-yr	94
20-yr	73
10-yr	56
5-yr	39
1-yr	2

3.4 Regional Flow Analysis at Casterton

As stated in Section 3.3.2, the ratio between the 5-year and 100-year ARI flows is lower than would be expected by experience. To examine the catchment response, flows at two other gauging stations on the Glenelg River were obtained from the CMA, where the period of record was significantly longer than at Casterton. The Fulham gauge is upstream of Casterton and the Dartmoor gauge is downstream of Casterton. The ARI flows at each location and their relation to the 5-year ARI flow at that location are shown in table 3.6.

Table 3.6 – Regional Flow Relationships Glenelg River

ARI (yr)	5	10	20	50	100
Dartmoor Flow (m^3/s)	289	384	481	615	722
5-yr Multiplier	1.00	1.33	1.67	2.13	2.50
Fulham Flow (m^3/s)	78	108	138	178	209
5-yr Multiplier	1.00	1.39	1.77	2.29	2.68
Average Catchment 5-yr Multiplier	1.00	1.36	1.72	2.21	2.59

The flood frequency analysis undertaken in Section 3.3.2 is likely to give a reasonable estimation of the 5-year ARI flow. Using the average multiplier above, flows for each ARI at Casterton can then be estimated. Figure 3.6 shows the ARI flows at Casterton for both the FFA flows and the regional estimate, as well as the Dartmoor and Fulham flows. The figure shows that the regional method appears to give a better representation of the flows for rare flood events. As such, the regional flows estimates have been adopted for use in the study.

3.5 Modelled Flows

Peak flows used in each hydraulic model are shown in table 3.6. Steady-state models were run for Casterton and Heywood, whilst Portland used inflow hydrographs as the storm volumes are important to the flood regime in Fawthrop Lagoon.

Table 3.7 – Modelled Flows

ARI Event	Peak Flow used in Casterton model (m^3/sec)	Peak Flow used in Heywood model (m^3/sec)		Peak Flow used in Portland model (m^3/sec)	
	Glenelg River	Fitzroy River	Sunday Creek	Wattle Hill Creek	Finn St Creek
100-yr	520	108	30.7	105.7	25.4
10-yr	272	50	10.7	37.7	6.5

4. HYDRAULIC MODELLING

4.1 Introduction

The results from the hydrologic modelling (Section 3) were used as inputs to the hydraulic models as described in section 4.2.4 below. Both overland and channel flows were modelled simultaneously.

The WL|Delft 1D2D modelling system, SOBEK, was used to compute the channel (1D) and overland flow (2D) components of the study. SOBEK is a professional software package developed by WL|Delft Hydraulics Laboratory, which is one of the largest independent hydraulic institutes in Europe (situated in The Netherlands) and is world-renowned in the fields of hydraulic research and consulting (WL|Delft, 2005).

This combined package allows for the computation of channel and pipe flow (including structures such as culverts, weirs, gates and pumps, and pipe details such as inverts, obverts, pipe sizes and pipe material) by the 1D module, which is then dynamically linked to the 2D overland flow module. The 1D and 2D domains are automatically coupled at 1D-calculation points (such as manholes) whenever they overlap each other. The model commences with the 1D component operating as the inflow increases until such time as the pipe or channel is full and overflows, with the flow then moving to the 2D domain. The 1D network and the 2D grid hydrodynamics are solved simultaneously using the robust Delft scheme that handles steep fronts, wetting and drying processes and subcritical and supercritical flows (Stelling, 1999).

The advantages of this system are that the channel/pipe system is explicitly modelled as a sub-system within the two-dimensional overland flow computation. This means that generalised assumptions regarding the capacity of the channel/pipe system are not required. This system employs a unique implicit coupling between the one and two-dimensional hydraulic components that provides high accuracy and stability within the computation.

4.2 Hydraulic Model Establishment

The hydraulic models consist of two main hydraulic components:

- The channel network; and
- 2D grid of the surface topography.

The establishment of these two components of the model is described in the following section.

4.2.1 Channel System

Each stream system was created differently based on the availability and quality of data. In Heywood the stream system was described explicitly within the hydraulic model by 1D channel sections created in 12D using the DEM (section 2.3.1). Providing some conservatism in the analysis, a roughness coefficient (Manning's 'n') of 0.08 was used for that channel in the model. In Casterton the DEM was considered fine enough that the stream was able to be explicitly described within the hydraulic model by the 2D model grid topography (section 4.2.2 below). However, the upstream area of the catchment is less defined (for reasons outlined in section 2.3) and therefore not accurate enough to describe explicitly the channel. These sections of the river were then described explicitly within the hydraulic model by 1D channel sections provided by GHCMA and connected to the 2D model grid. As within Casterton, the Portland DEM was considered fine enough that the stream was able to be described explicitly within the hydraulic model by the 2D model grid topography (section 4.2.2 below). Culverts and bridges were included in the model as required as discrete elements.

Figures 4.1 to 4.3 show the modelled hydraulic channel network, the 2D model topography (Section 4.2.2), the inflow points (where the flows generated in the hydrological models are applied to the hydraulic model) and the overland flow reporting stations for Portland, Heywood and Casterton respectively.

4.2.2 Topography

The major component of the two-dimensional model is the grid that describes the topography of the area. In order to accurately represent the topography within Portland, Heywood and Casterton, detailed Digital Terrain Models (DTMs) were compiled from the LIDAR and contour data as described in Section 2.3. The model grid parameters are listed in table 4.1.

Table 4.1 – Two-Dimensional Grid Parameters

Grid Parameter	Portland	Heywood	Casterton
Grid Size	10 * 10 metres	10 * 10 metres	10 * 10 metres
X-dimension	401 columns	297 columns	413 columns
Y-dimension	329 rows	406 rows	526 rows

4.2.3 Hydraulic Roughness

The hydraulic roughness for the overland flow model was described using a two-dimensional roughness map of Manning's "n" values. This was developed by digitising different land-use zones from the digital aerial images within a GIS environment (MapInfo). Table 4.2 summarises the land-use for determining roughness. The catchments are generally rural surrounding the towns with large areas of residential development within the towns. Figures 4.4, 4.5 and 4.6 show the hydraulic roughness parameters (Mannings 'n') assumed for Portland, Heywood and Casterton respectively. The roughness parameters shown are after the calibration process.

Table 4.2 – Two-Dimensional Grid Roughness Classification

Land Use	Calibrated Hydraulic Roughness Casterton	Calibrated Hydraulic Roughness Heywood	Calibrated Hydraulic Roughness Portland
Car Park	-	0.022	-
Industrial	-	0.5	-
Rural areas	0.05	0.05	0.08
Residential	0.15	0.15	0.15
Roads	0.018	0.018	0.018
Railway	-	0.08	-
River\channel	0.08	0.08	0.05
Lake	-	-	0.03

4.2.4 Boundary Conditions

In order to set the downstream boundary conditions for each model, stage-discharge relationships were calculated at the downstream model boundary. The 100-yr and 20-yr flows were then compared with these relationships and the corresponding downstream boundary levels were calculated. The values used are shown in table 4.3.

Table 4.3 – Downstream boundary conditions in each model

ARI event	Water Level – Portland	Water Level – Heywood (m AHD)	Water Level – Casterton (m AHD)
100-yr	Stage-discharge in 1986	23.2	41.04
10-yr	Stage-discharge in 1986	23.13	40.90
Calibration	Stage-discharge in 1946	22.8	41.0*

*This downstream water level includes allowance for known flooding in the Wannon River, which is a tributary of the Glenelg River that joins the Glenelg just downstream of Casterton.

Figure 4.7 shows the stage-discharge relationships for Fawthrop Lagoon in 1946 and 1986, which were taken from the Portland Floodplain Management Study (1988).

4.3 Calibration

Calibration events were run for each of the Portland, Heywood and Casterton Models. Casterton had Flood Data Transfer Project (FDTP) historic flood levels and extents for the 1983 flood events, to which the model was calibrated. Heywood has recorded flood heights for the November 2007 flood event which were used in calibration. The Portland model was calibrated to the 1946 flood extent as defined in the Portland Floodplain Management Study (1988). The 1983 flood in Casterton had a recorded flood peak of 250m^3/s in the Glenelg River near Casterton. The peak in the Fitzroy River near Heywood was recorded at 30m^3/s. Sunday Creek near Heywood is ungauged and a RORB model was used to estimate the flows at this location (Section 3.3.1). The flow was assumed to be 14m^3/s.

The modelled calibration flood extent for Portland is shown in figure 4.8. The modelled flood depth and known flood marks for Heywood and Casterton are shown in figures 4.9 and 4.10 respectively. Table 4.4 and 4.5 show the calibration results for Casterton and Heywood respectively.

4.3.1 Portland

In the absence of recorded flood levels, anecdotal evidence reported in the Portland Floodplain Management Study (1988) was used to calibrate the model. This evidence came from residents as well as reporting from the local paper. The major conclusions that were reached in the report were:

- Flood level west of West Boundary Rd was approximately 3.7m AHD
- Flood level at the downstream end of Fawthrop Lagoon was in the order of 2.5m AHD
- Floods along Finn St Creek pooled at Wyatt St at a level of 2.6m AHD

The report also calculated the peak inflow into Fawthrop Lagoon as being 114m^3/s. We have assumed this flow occurred over a 2 day period and is split between Finn St Creek and Wattle Hill Creek. The assumed inflows are shown in figure 4.11.

Figure 4.9 shows that a reasonable calibration has been achieved. The levels in Fawthrop Lagoon and surrounding Wyatt St are slightly, but not significantly, higher than estimated in the Portland FMP, due to the uncertainty and assumptions made in the inflow conditions. The levels on the western side of West Boundary Rd are within the range measured in the 1946 flood, being around 3.7m on the western edge of the property.

4.3.2 Casterton

Table 4.4 – Model Calibration at Casterton September 1983 Flood Event

Location	FDTP ID	Modelled Flood Level (m AHD)	Measured Flood Level (m AHD)	Difference (m)
Upstream of Glenelg Highway Bridge	40002	44.92	45.03	-0.11
	40003	44.92	45.01	-0.09
	40008	44.92	45.08	-0.16
	40009	44.89	45.04	-0.15
	40010	44.87	44.95	-0.08
	40011	44.81	44.88	-0.07
	40012	44.94	45.1	-0.16
	40014	45.75	46.03	-0.28
	40016	44.92	44.9	0.02
	40017	44.92	44.97	-0.05
	40018	44.91	45.04	-0.13
	40019	44.92	45.15	-0.23
	40020	44.91	45.06	-0.15
	40021	44.86	44.93	-0.07
	40022	44.86	44.98	-0.12
	40025	44.91	45.02	-0.11
	40027	44.90	44.99	-0.09
	40028	44.90	44.99	-0.09
	40029	44.91	44.98	-0.07
	40030	44.91	44.99	-0.08
	40032	44.94	44.99	-0.05
	40033	44.87	44.94	-0.07
	40034	44.81	44.92	-0.11
	40035	44.80	44.78	0.02
	40046	44.82	44.93	-0.11
	40047	44.72	44.87	-0.15
	40048	44.76	44.95	-0.19
Downstream of Glenelg Highway Bridge	40005	43.96	44.39	-0.43
	40006	43.53	44.23	-0.70
	40001	43.30	43.94	-0.64
	40015	43.30	42.86	0.44
	40036	43.94	44.49	-0.55
	40037	43.94	44.49	-0.55
	40043	43.84	44.59	-0.75
	40045	43.75	44.3	-0.55
Downstream of railway bridge alignment	40038	43.37	44.02	-0.65
	40039	43.30	43.4	-0.10
	40041	43.30	43.37	-0.07

Table 4.4 shows that a reasonable calibration has been achieved. The modelled Water Surface Elevation (WSE) tends to be slightly lower than the measured WSE upstream of the Glenelg Highway Bridge but is still within 0-15cm. This indicates that the roughness parameter may be too low or that the gauged flows are reported as lower than actually occurred. The floodplain roughness is at the higher end of the accepted range of values and there are known issues with the gauge data at Casterton, so an under-reporting of flow is more likely.

The modelled levels between the Glenelg Highway bridge and the old railway bridge location are significantly lower than the measured levels. It should be noted that the railway bridge was not included in the model. This discrepancy is likely due to the changed floodplain conditions between when the flood occurred and when the aerial survey data was taken. During the 1983 flood there was a railway bridge and embankment downstream of the Anderson Rd Bridge, which was removed sometime after the 1983 event. This railway bridge would have raised the flood levels downstream of the Glenelg Highway bridge. Typical head loss through bridge structures is in the range of 0.5 to 1.5 metres. Hand calculations of the floodplain capacity downstream of the Glenelg Highway bridge are consistent with the calibration results.

4.3.3 Heywood

Table 4.5 – Model Calibration at Heywood November 2007 Flood Event

Location	Flood Mark ID	Modelled Flood Level (m AHD)	Measured Flood Level (m AHD)	Difference (m)
Upstream of Princes Hwy Bridge	WM14	24.96	24.99	-0.03
	WM15	25.04	25.00	0.04
	WM 9CAMERON ST	NA	25.23	NA
	WM16	25.16	25.07	0.09
	WM17	25.18	25.12	0.06
	WM19	25.40	25.64	-0.24
Between Princes Hwy Bridge and Railway Bridge	WM3	24.44	24.49	-0.05
	WM3 EAGLE	24.45	24.52	-0.07
	WM3 SHED	24.44	24.46	-0.02
	PK3 SHED	24.44	24.48	-0.04
	WM3 SEC	24.45	24.55	-0.10
	WM5	24.46	24.57	-0.12
	WM7	24.52	24.66	-0.13
	WM8	24.57	24.69	-0.13
	WM8A	24.56	24.70	-0.14
Downstream of Railway Bridge	WM1	23.52	24.15	-0.63
	WM2	23.34	23.97	-0.63
Near Sunday Creek	WM11	N/A	24.76	N/A
	WM11A	23.31	23.77	-0.46

Table 4.5 shows that a reasonable calibration has been achieved. Upstream of the Princes Highway Bridge and between the Princes Highway Bridge and the Railway Bridge most modelled WSEs are within 10cm of the recorded levels. The one exception is WM 9 Cameron St, where the flood mark is higher than the flood marks surrounding it. It is likely that this higher level was caused by a local drainage effect as opposed to flooding from the Fitzroy River.

The modelled flood levels near Sunday Creek are also lower than the measured flood levels. This is due to the uncertainty of flows in Sunday Creek. The RORB parameters were calibrated to the Fitzroy River catchment (as described in section 3.3.1) as this was the best possible information. However, it may not be completely accurate and hence it is possible that the flows in Sunday Creek could be underestimated.

5. RESULTS

5.1 Portland

Flooding in Portland has been estimated through two main methods; an analysis using a RORB hydrological model to define the input hydrographs (100-yr and 10-yr ARI)and using the assumed 1946 inflow hydrographs (shown in figure 4.11).

The maximum depths, velocities and depth X velocity for the 100-yr ARI RORB flows in Portland are shown in figures 5.1, 5.2 and 5.3 respectively, whilst the 10-yr ARI maximum depths and velocities are shown in figures 5.4 and 5.5 respectively. The depth x velocity is an indication of the safety risk due to the floodwaters. These figures show very strong flowpaths surrounding both Wattle Hill Creek and Finn St Creek. There is also extensive flooding at the confluence of these creeks, starting at Fawthrop Lagoon spreading as far north as Otway St and as far west as West Boundary Rd. Water pools up significantly behind the culverts at Bridgwater Rd and West Boundary Rd creating high safety risks in those areas. Flood depth in the 100-yr ARI event is greater than 2m in a majority of the floodplain, however velocities are generally low downstream of West Boundary Rd.

The modelled depths for the RORB 100-yr ARI event are shallower than the 1946 flood event. This is due to differences in the volumes of water produced in each storm. Pluviograph and stream flow data is not available for the 1946 flood requiring the use of the assumed input hydrographs. The inflow hydrographs have been estimated for Finn St and Wattle Hill Creek through volumetric methods, as per the Portland Floodplain Management Study (1988).

This flood peak was used to calibrate the hydrological model (section 3.3); however the shape of the hydrograph is estimated and likely to be different to that of the actual event. The volume of water has a significant impact upon flooding in Portland due to the outlet conditions of Fawthrop Lagoon. We have therefore modelled the 1946 storm event with the current outlet conditions to Fawthrop Lagoon, which is likely to be a conservative estimate 100-yr ARI event. The maximum depths, velocities and depth x velocity for this event are shown in figures 5.6, 5.7 and 5.8 respectively. The extent of the flooding is similar to the 100-yr ARI event but the water is generally deeper. Council and GHCMA should determine which flood level they wish to use for flood planning.

5.2 Heywood

The maximum depths, velocities and depth X velocity for the 100-yr ARI event in Heywood are shown in figures 5.9, 5.10 and 5.11 respectively, whilst the 10-yr ARI maximum depths and velocities are shown in figures 5.12 and 5.13 respectively. These figures show that the extent of the flooding is quite wide, 500m wide on average in the 100-yr ARI events. The depths are shallow on the majority of the floodplain, less than 40cm, with depths increasing towards the river. Flow passes through the Princes Highway Bridge effectively, however it does pool up behind the railway bridge. There is also a strong breakout flowpath to the north of the Fitzroy River. Figure 5.11 shows that the majority of the floodplain has a low safety risk except areas in and around the river, where safety risk increases to high. The majority of the flooding occurs to the north of the river, where the land-use is mostly rural; very little flooding occurs in residential or commercial areas.

As expected, the depths, extents and velocities are all much reduced in the 10-yr ARI event. The breakout flow is still present but not as prevalent and water still pools up behind the railway bridge but is much shallower and not as widespread.

5.3 Casterton

The maximum depths, velocities and depth X velocity for the 100-yr ARI event in Casterton are shown in figures 5.14, 5.15 and 5.16 respectively, whilst the 10-yr ARI maximum depths and velocities are shown in figures 5.17 and 5.18 respectively. These figures show that significant flooding occurs in the 100-yr and 10-yr ARI events. Apart from the main Glenelg River channel there are significant anabranches that are present across the entire floodplain. Significant depths and velocities are found in these anabranches, creating high safety hazards. Floodwaters pond up behind the Glenelg Highway, causing heavy flooding and increased flood depths along Murray St.

As expected, the depths and velocities are lower in the 10-yr ARI event; however the extent of inundation is very similar. The flow dynamics are also similar to those in the 100-year event.

5.4 Discussion

The results presented above provide the most up to date and accurate information that can be used to define the floodways in Portland, Casterton and Heywood and hence create floodway overlays in these towns. The floodway is defined in the Victorian *Advisory Notes for Delineating Floodways* as:

'Floodways are those areas of the floodplain where significant discharge or storage of water occurs during major floods and they are often associated with a significant flood hazard. They are often aligned with naturally defined channels and include areas which, if filled or even partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily always, areas of deeper flow or areas where higher velocities occur. The extent and behaviour of floodways may change with flood severity. Floodway areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods'.

The correct determination of floodway zones is of the utmost importance as it has significant impacts upon planning and development as well as current land-use practices. The process of determination is a complex process and for further information refer to ‘Defining the Floodway - Can One Size Fit All?’ by Howells et al (2003), found in Appendix B of this report. A general approach that has been used in the past would define the 10-year ARI extent as the floodway.

6. REFERENCES

Chow, (1973), *Open Channel Hydraulics,* McGraw-Hill.

Department of Natural Resources and Environment (1998) *Advisory Notes for Delineating Floodways*, Prepared by Edwards, M., Floodplain Management Unit.

Howells, et al., (2003), *Defining the Floodway – Can One Size Fit All, 2003 NSW Floodplain Management Authorities Conference*

Kuczera, G., (1999), *FLIKE Version 4.5*, University of Newcastle

Laurenson, Mein and Nathan, (2006), *RORB Version 5.32*, SKM and Monash University

Pilgrim, D. H. (ed). (1987), *Australian Rainfall and Runoff,* Volume 1 & 2, The Institute of Engineers, Australia.

Stelling, G.S. Kernkamp, H.W.J and Laguzzii M.M. (1999) Delft Flooding System - A Powerful Tool for Inundation Assessment Based Upon a Positive Flow Simulation, Hydroinformatics Conference, Sydney NSW.

WL|Delft Hydraulics Laboratory, (2005) Sobek Advanced Version 2.10.000.RC01, WL|Delft Hydraulics Laboratory.

FIGURES

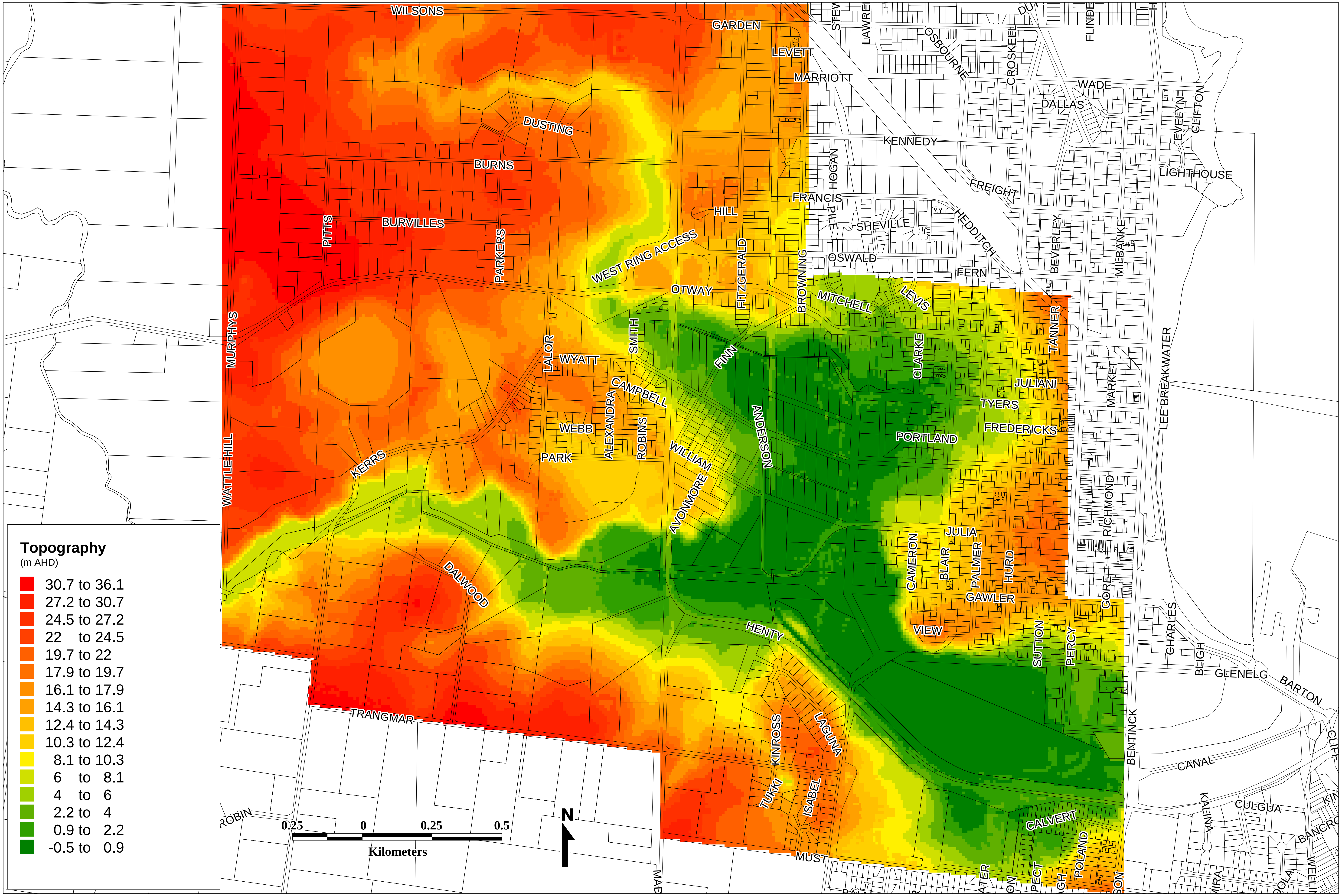

Figure 2.1 Study Area and Digital Elevation Model Portland

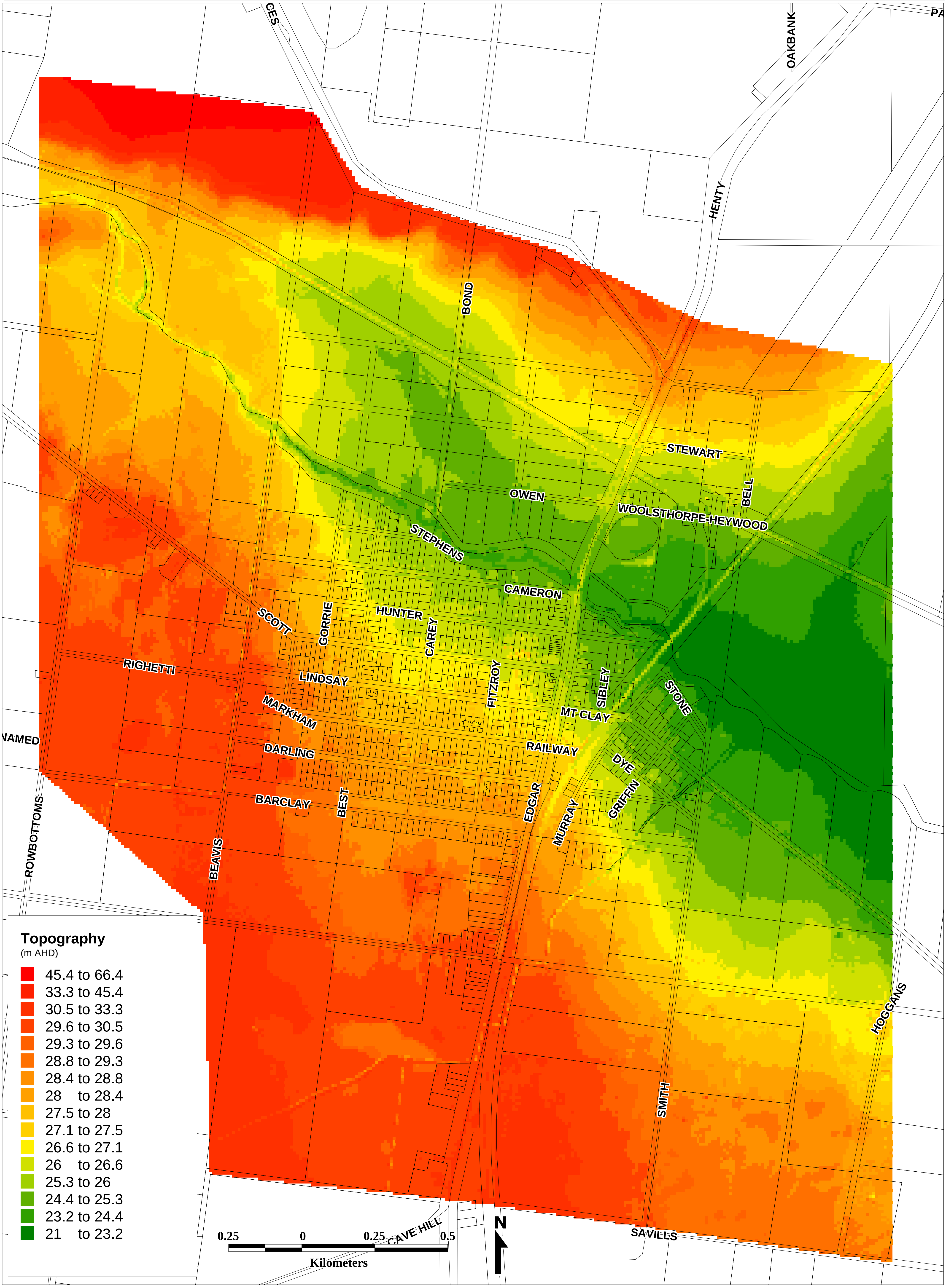

Figure 2.2 - Study Area and Digital Elevation Model Heywood

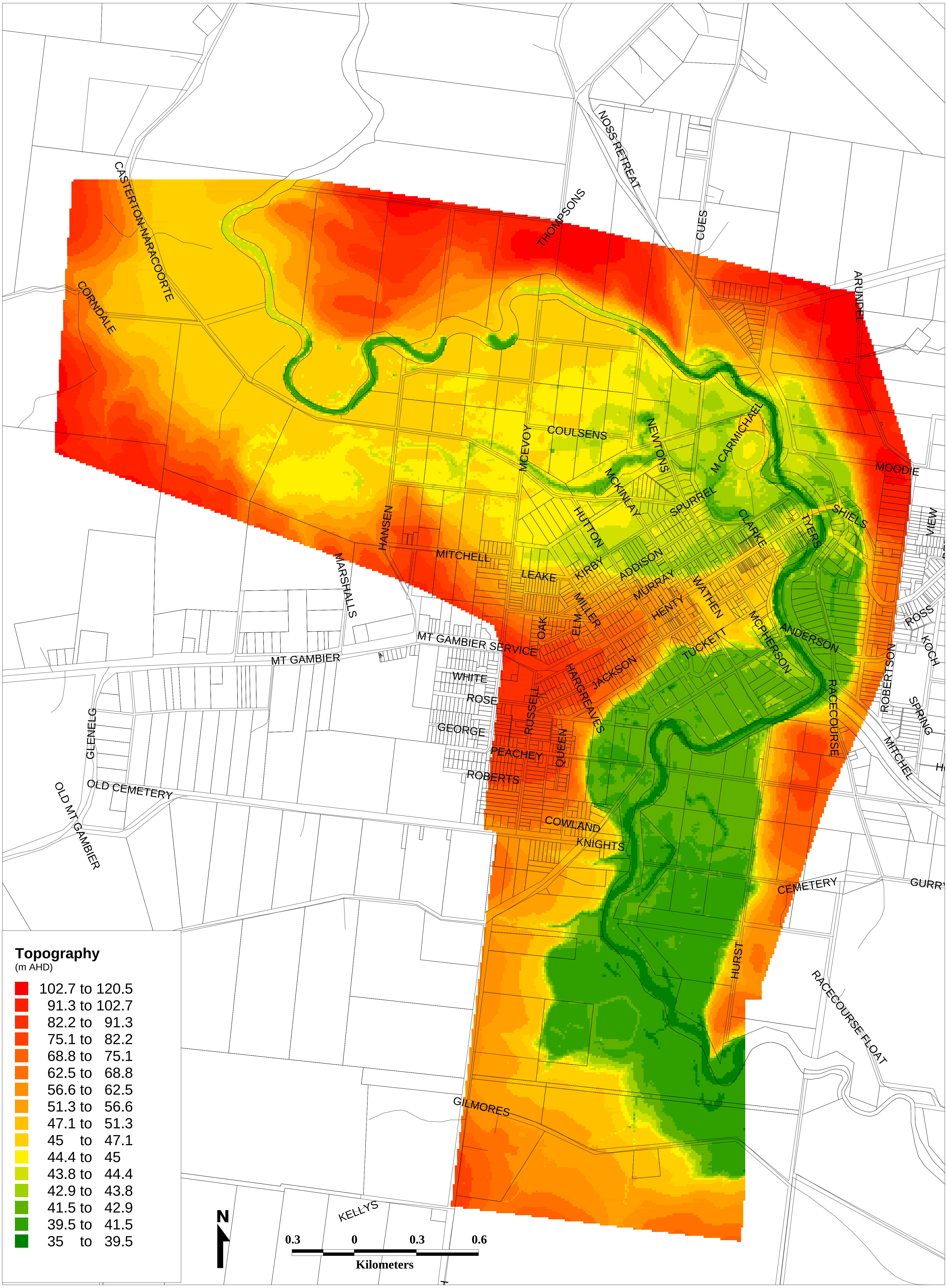

FIgure 2.3 - Study Area and Digital Elevation Model Casterton

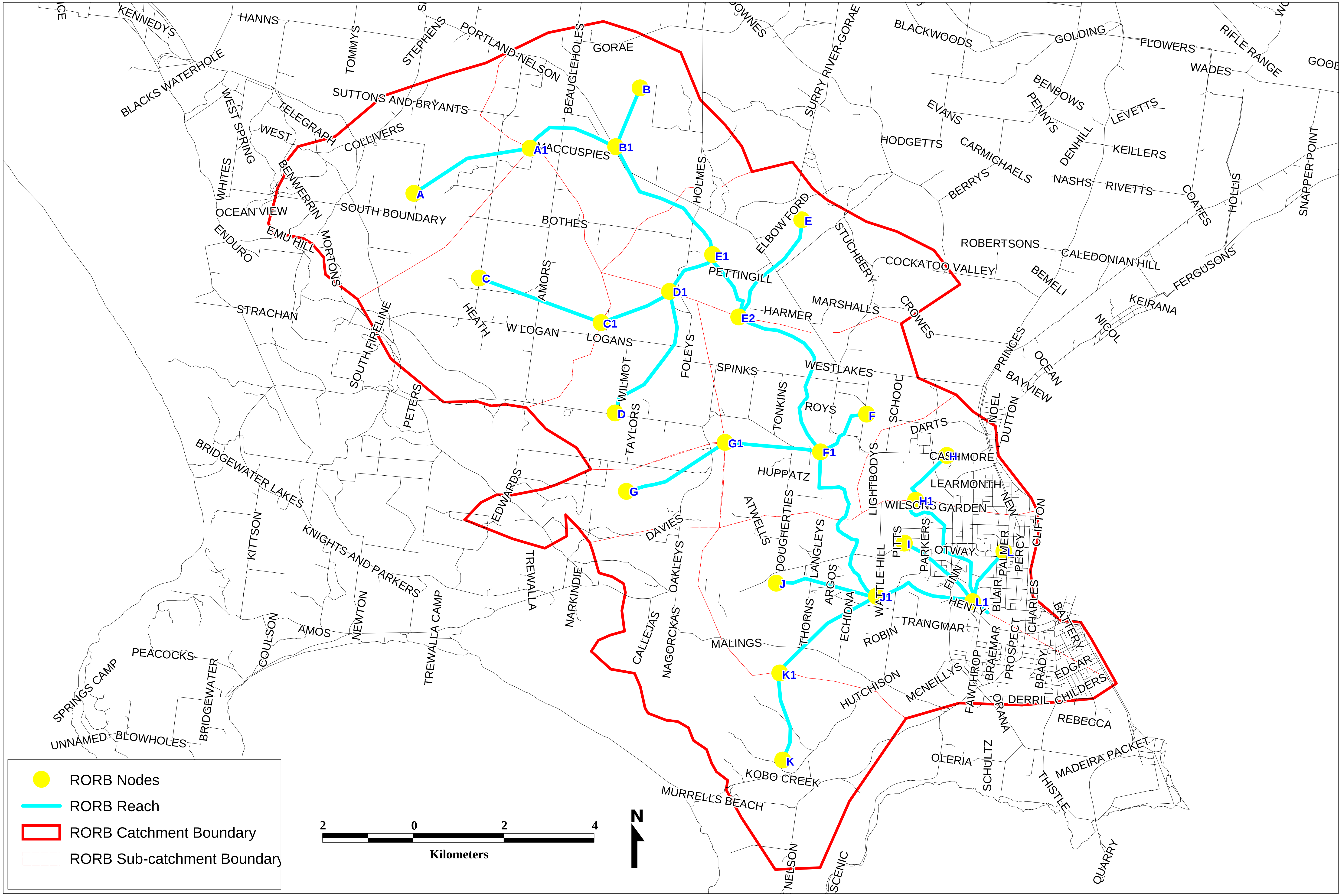

Figure 3.1 - RORB Catchment Layout Portland

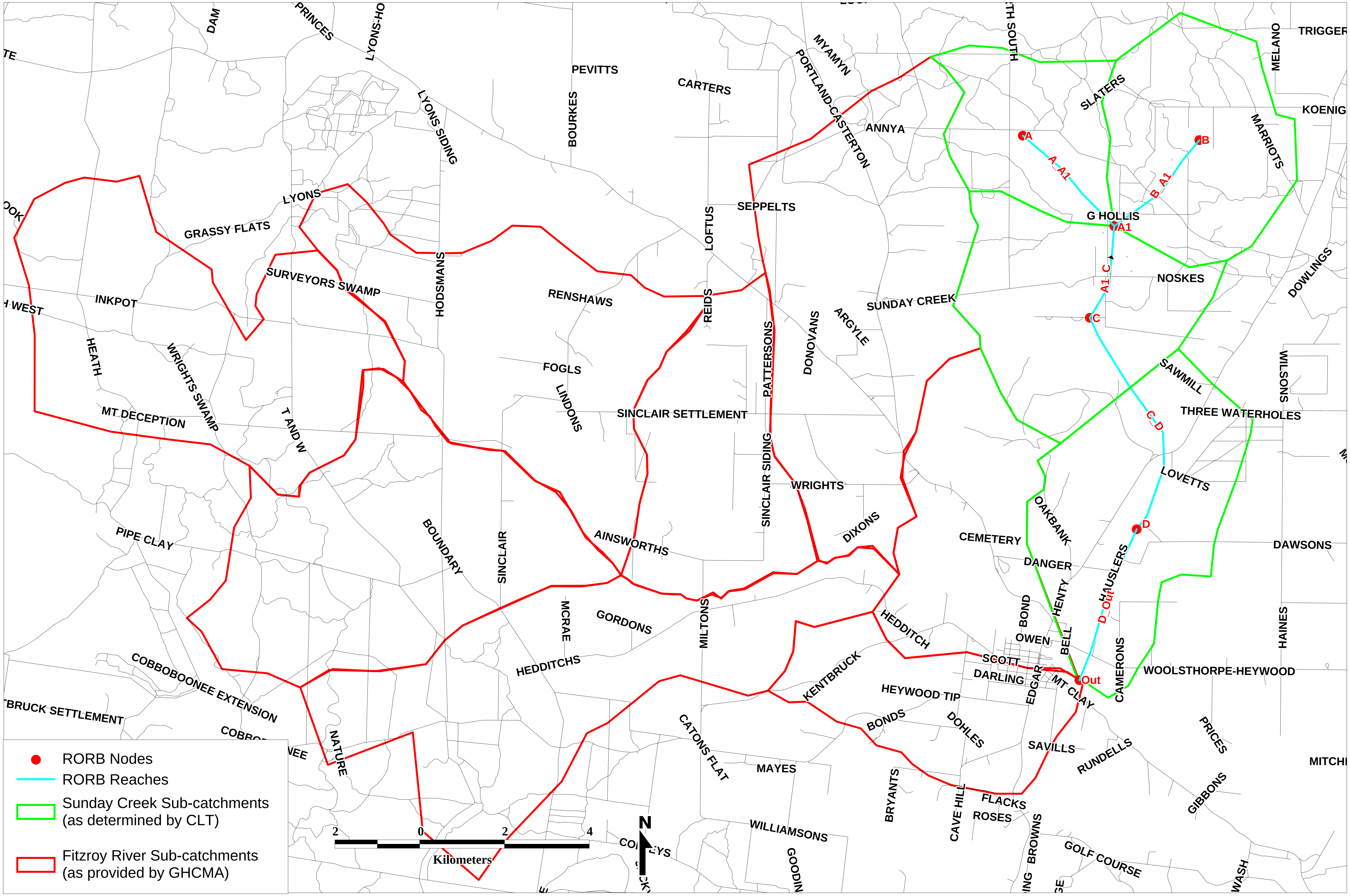

Figure 3.2 - RORB Catchment Layout Heywood

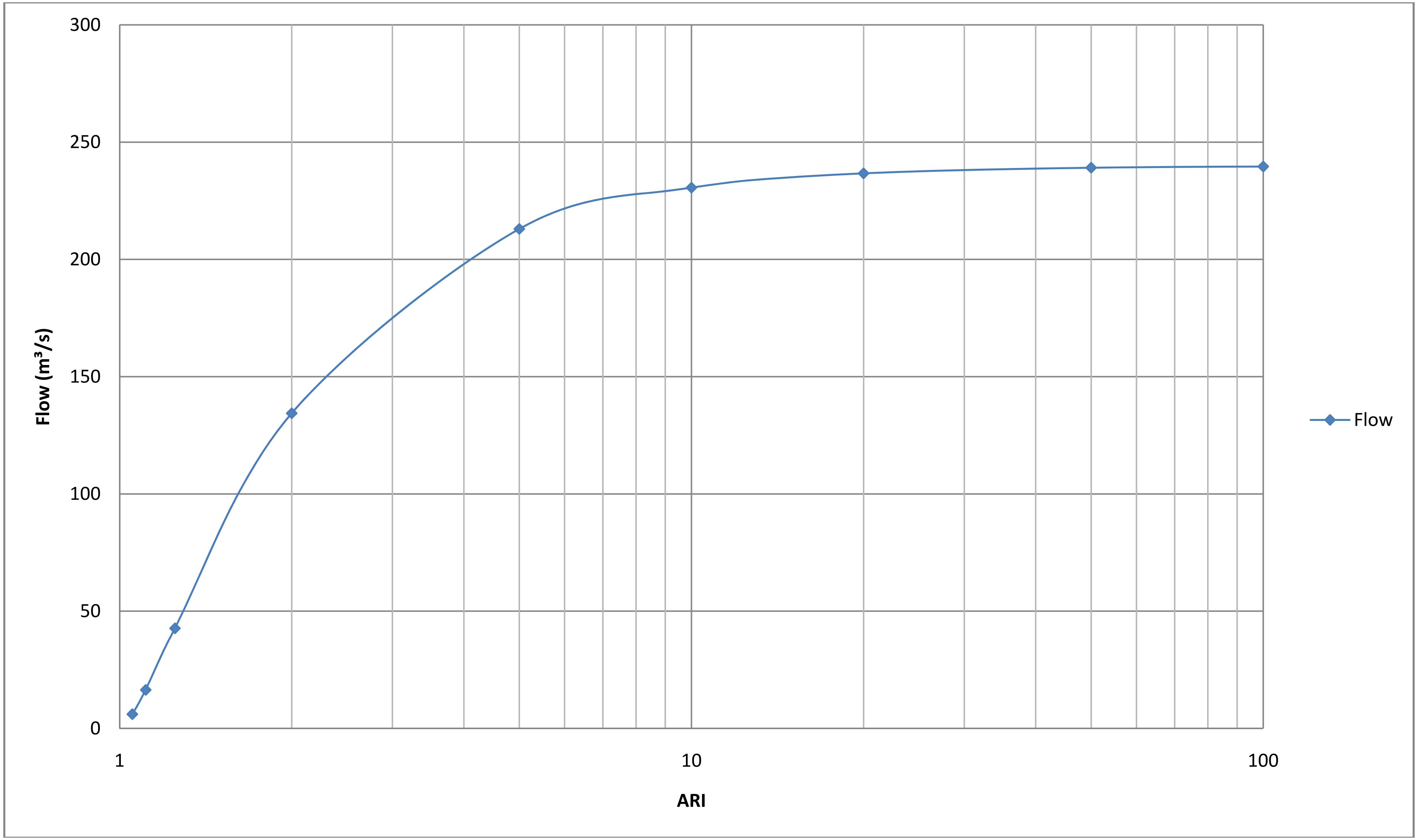

Figure 3.3 – Flood Frequency Analysis for Casterton

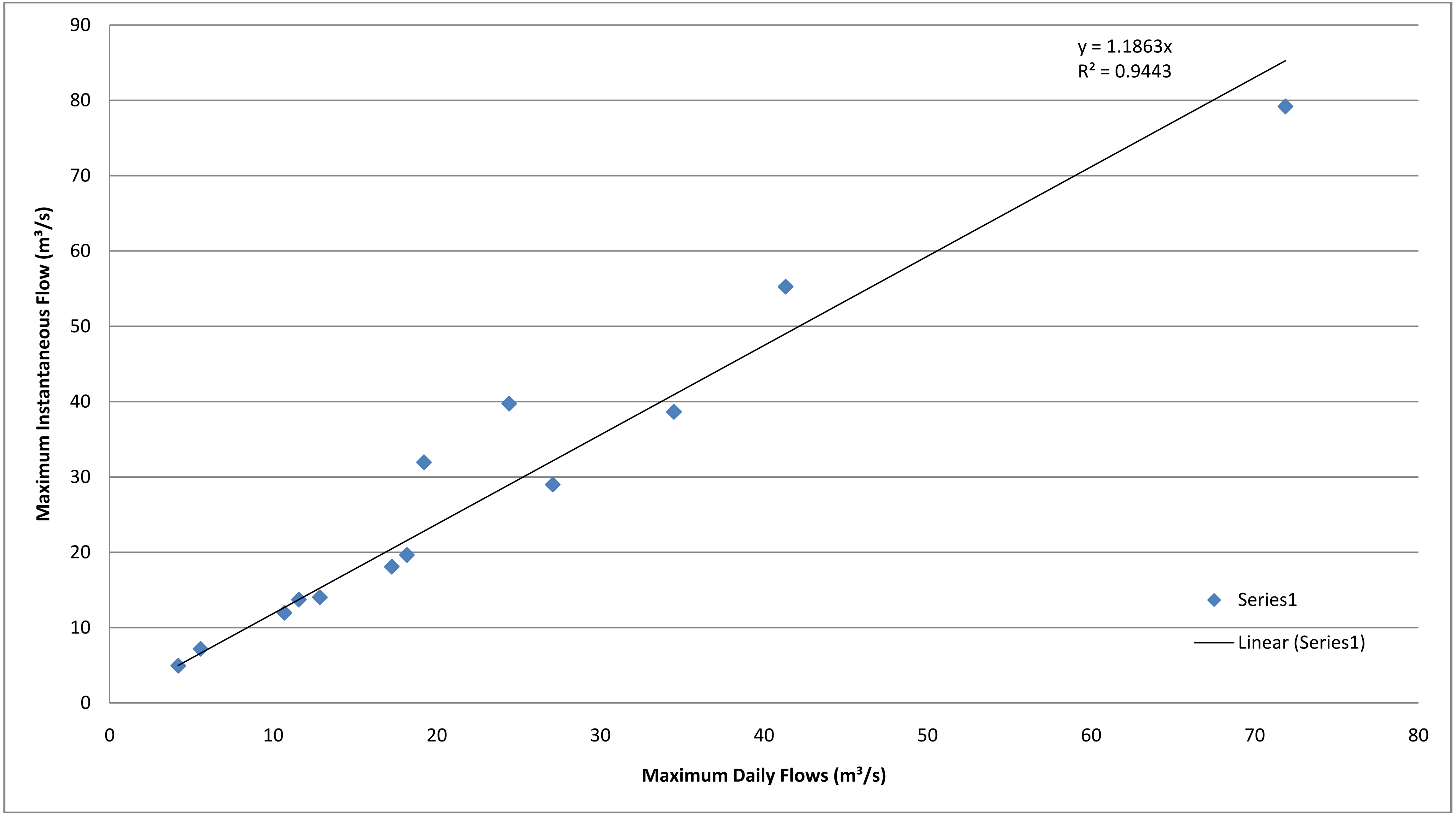

Figure 3.4 – Heywood Maximum Daily Flow Vs Maximum Instantaneous Flow

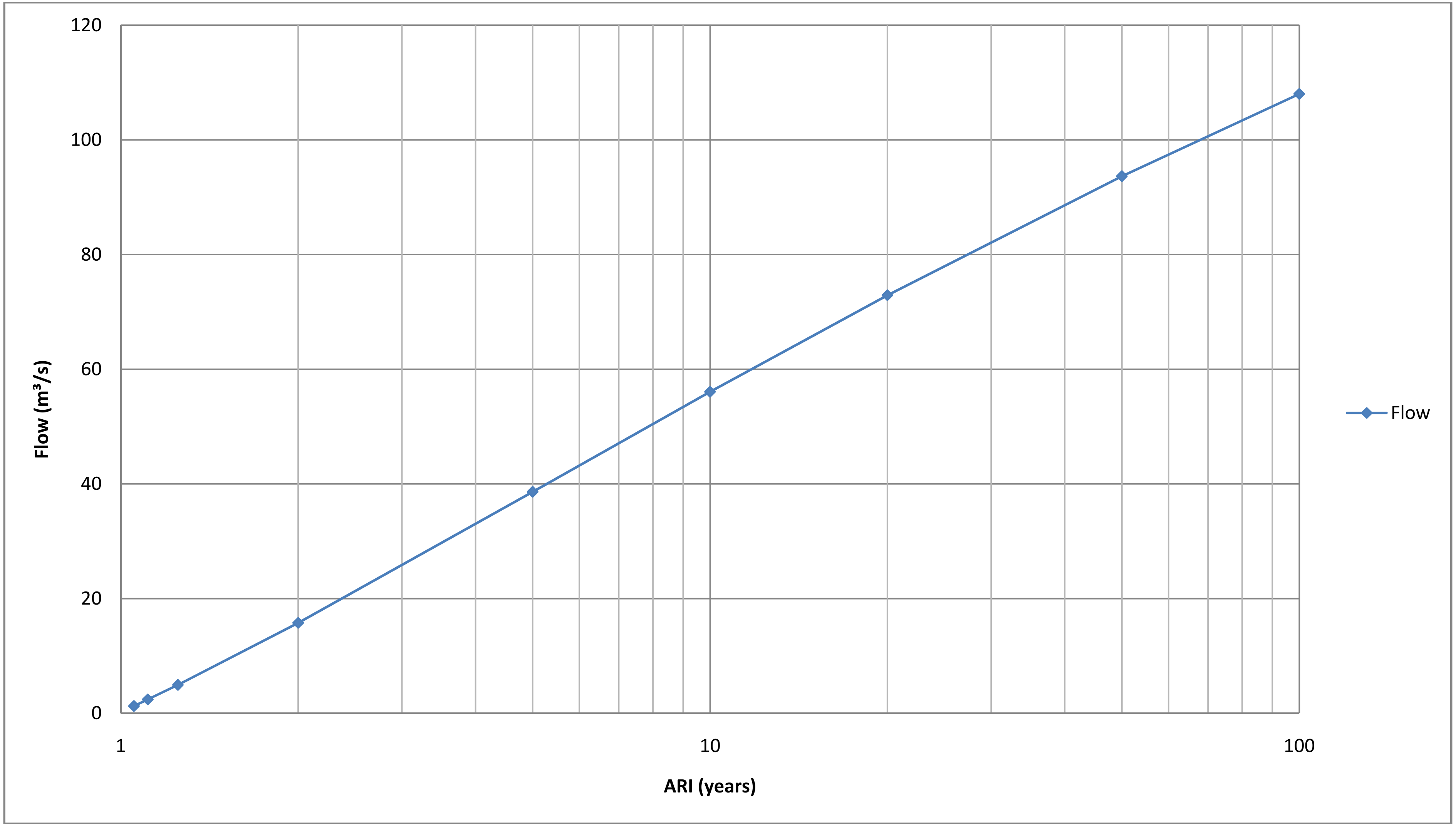

Figure 3.5 – Flood Frequency Analysis for Heywood

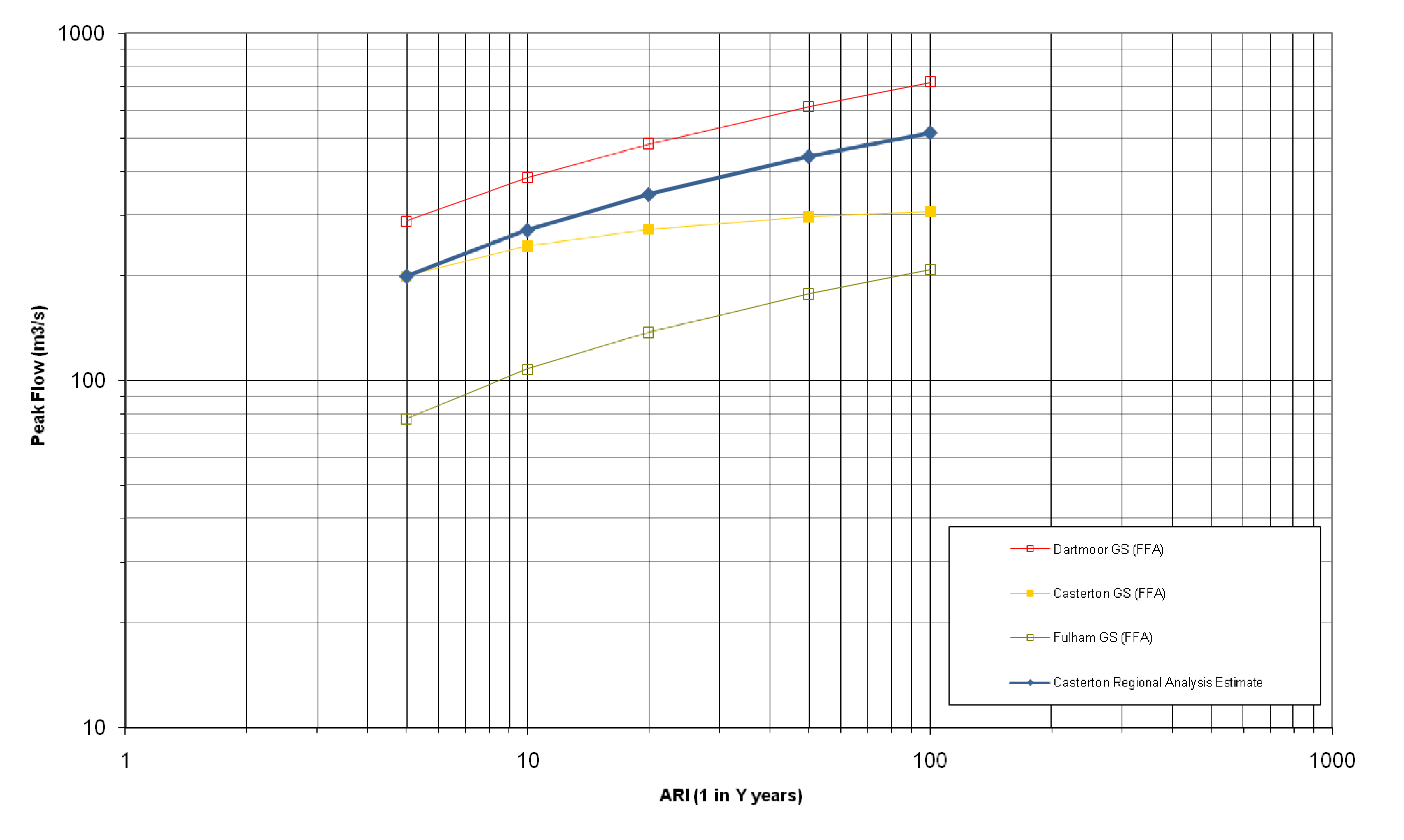

Figure 3.6 – Glenelg River Regional Flow Analysis

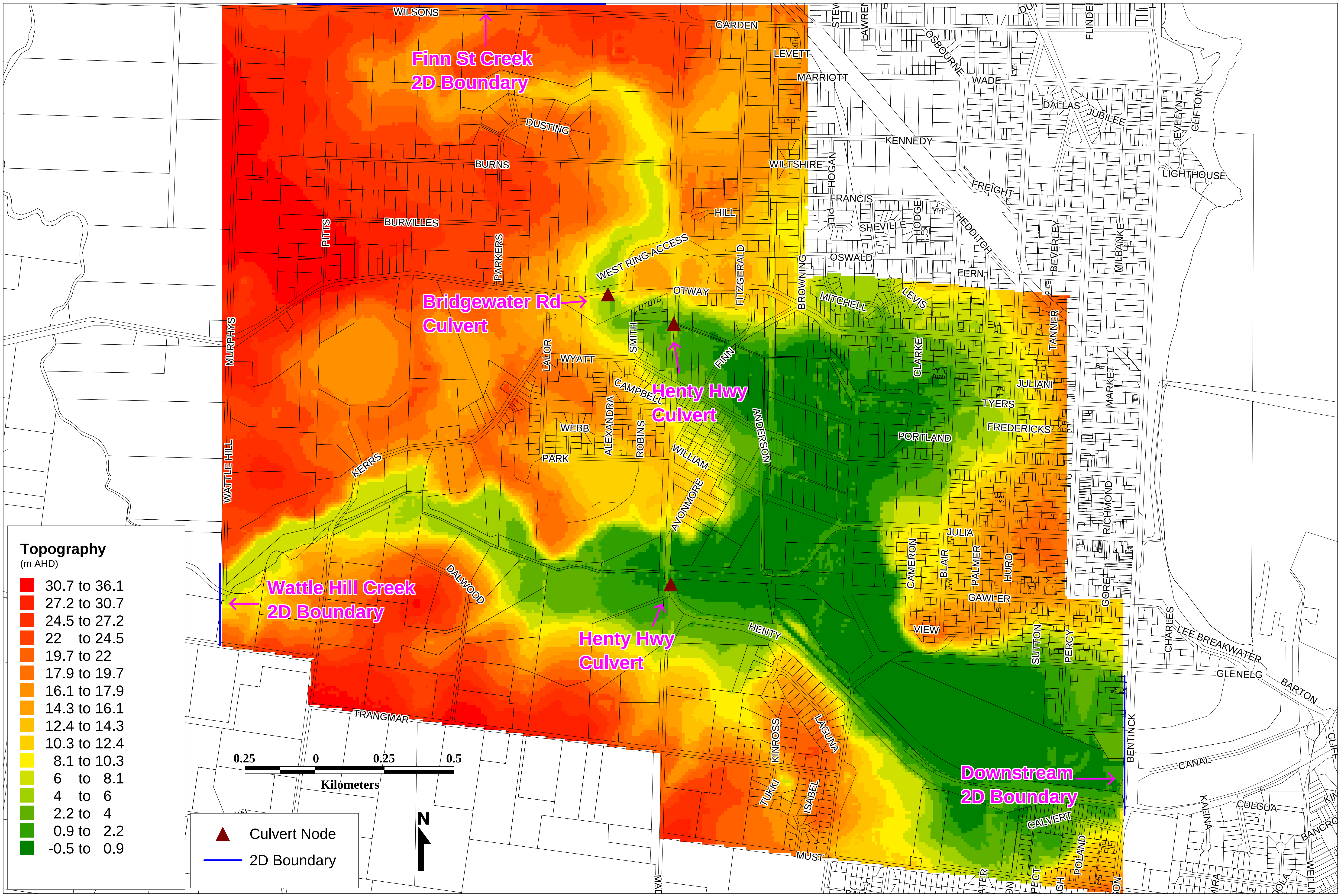

Figure 4.1 - SOBEK Model Setup Portland

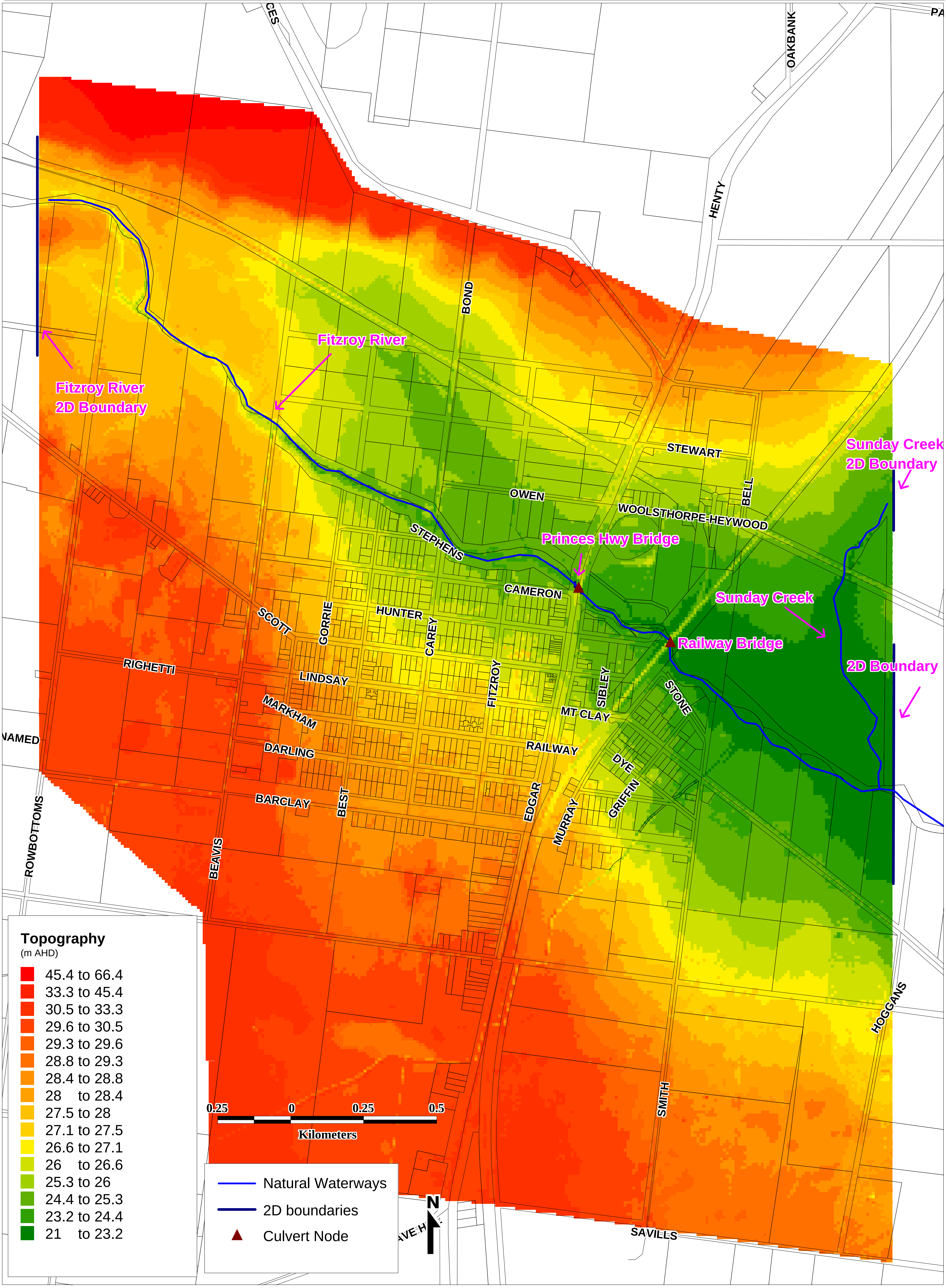

Figure 4.2 - SOBEK Model Setup Heywood

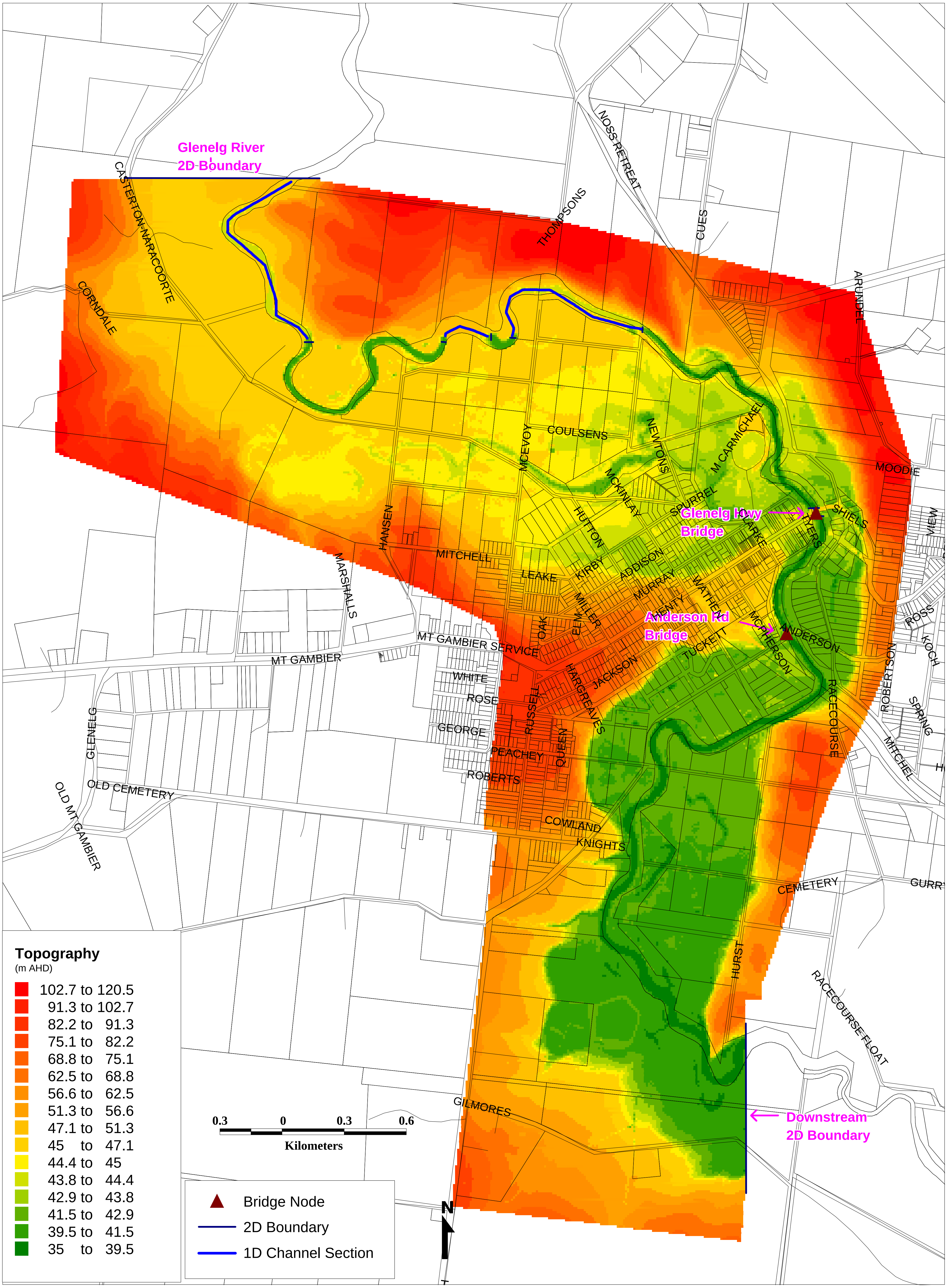

Figure 4.3 - SOBEK Model Setup Casterton

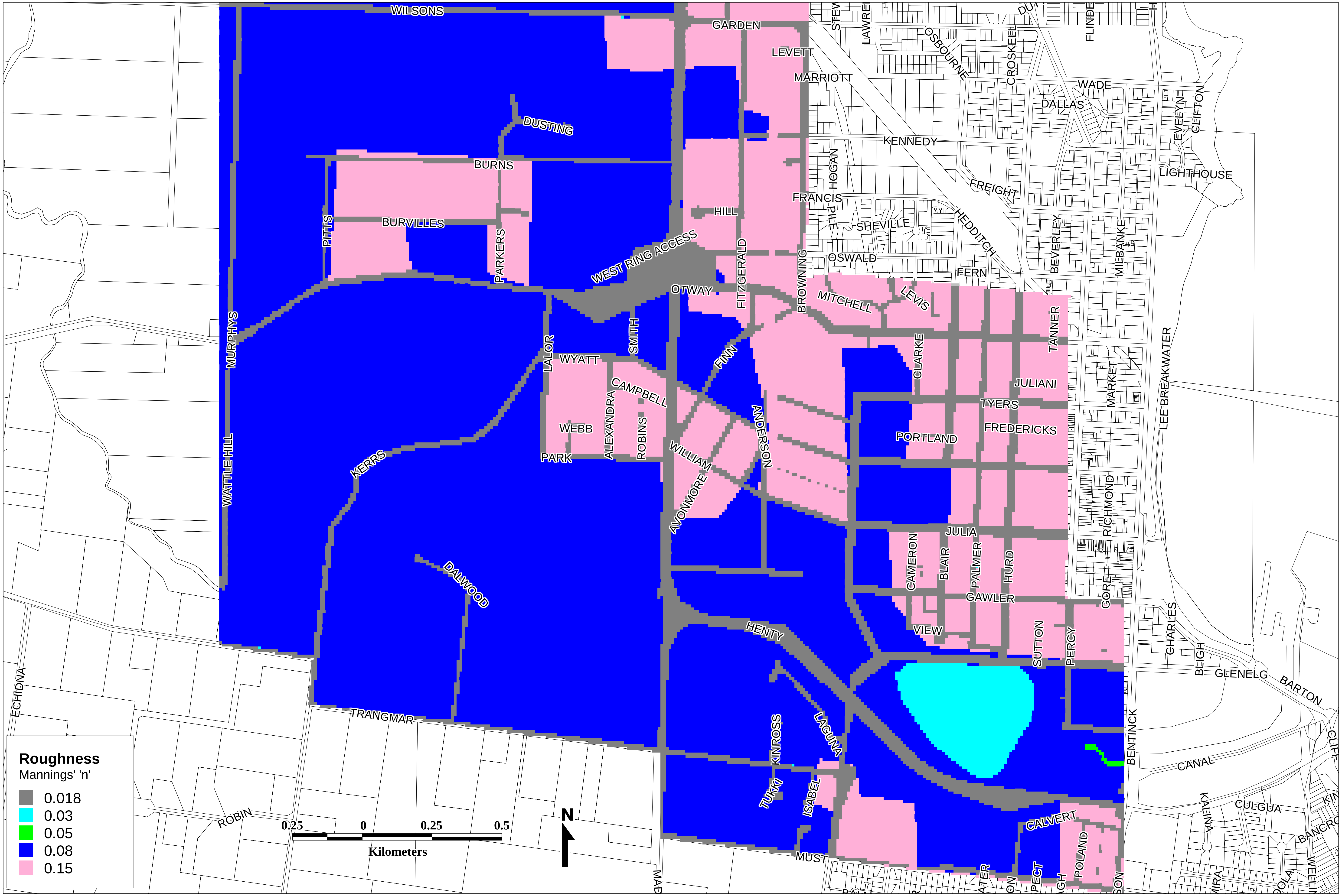

Figure 4.4 - Roughness Portland

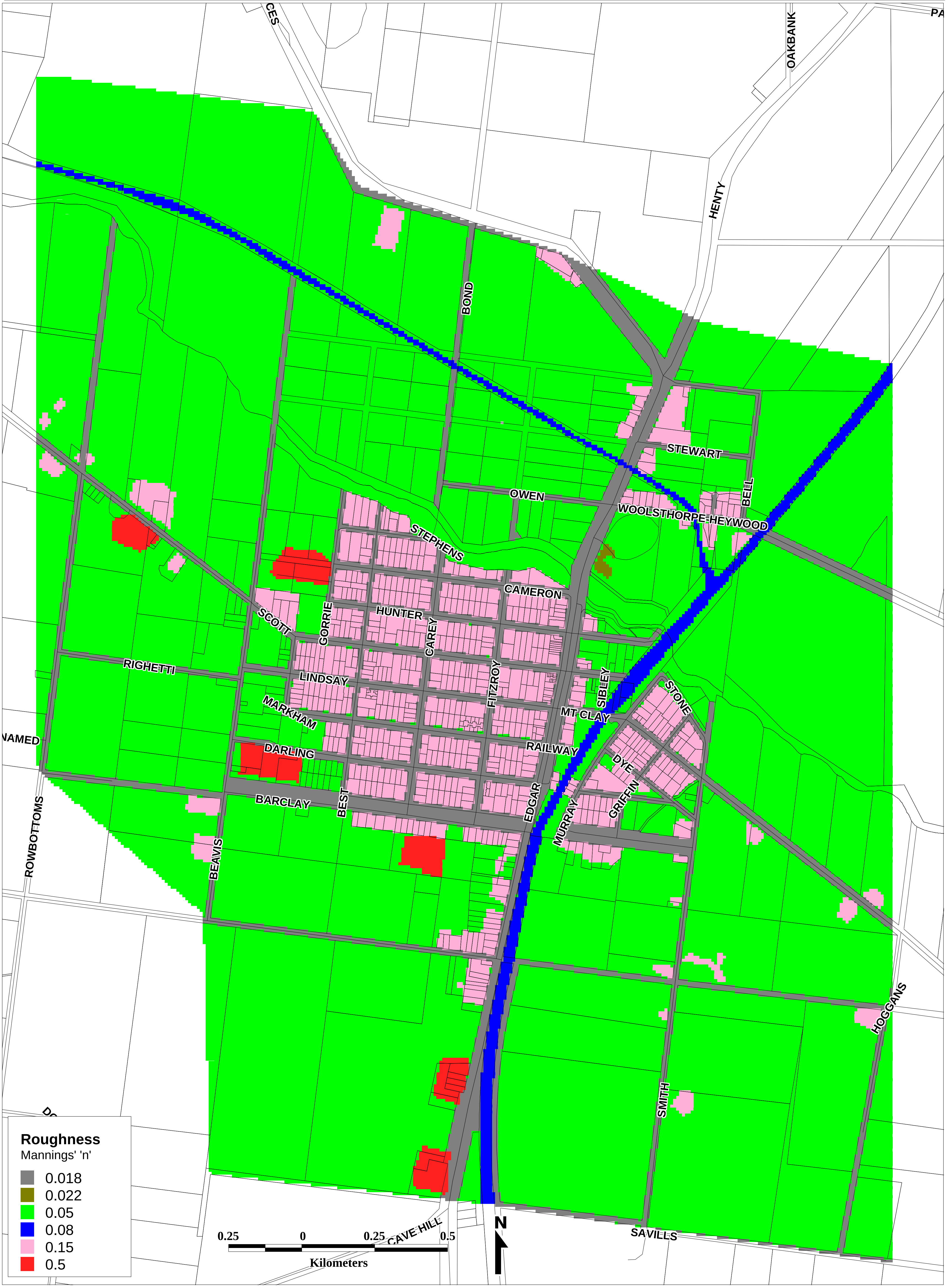

Figure 4.5 - Roughness Heywood

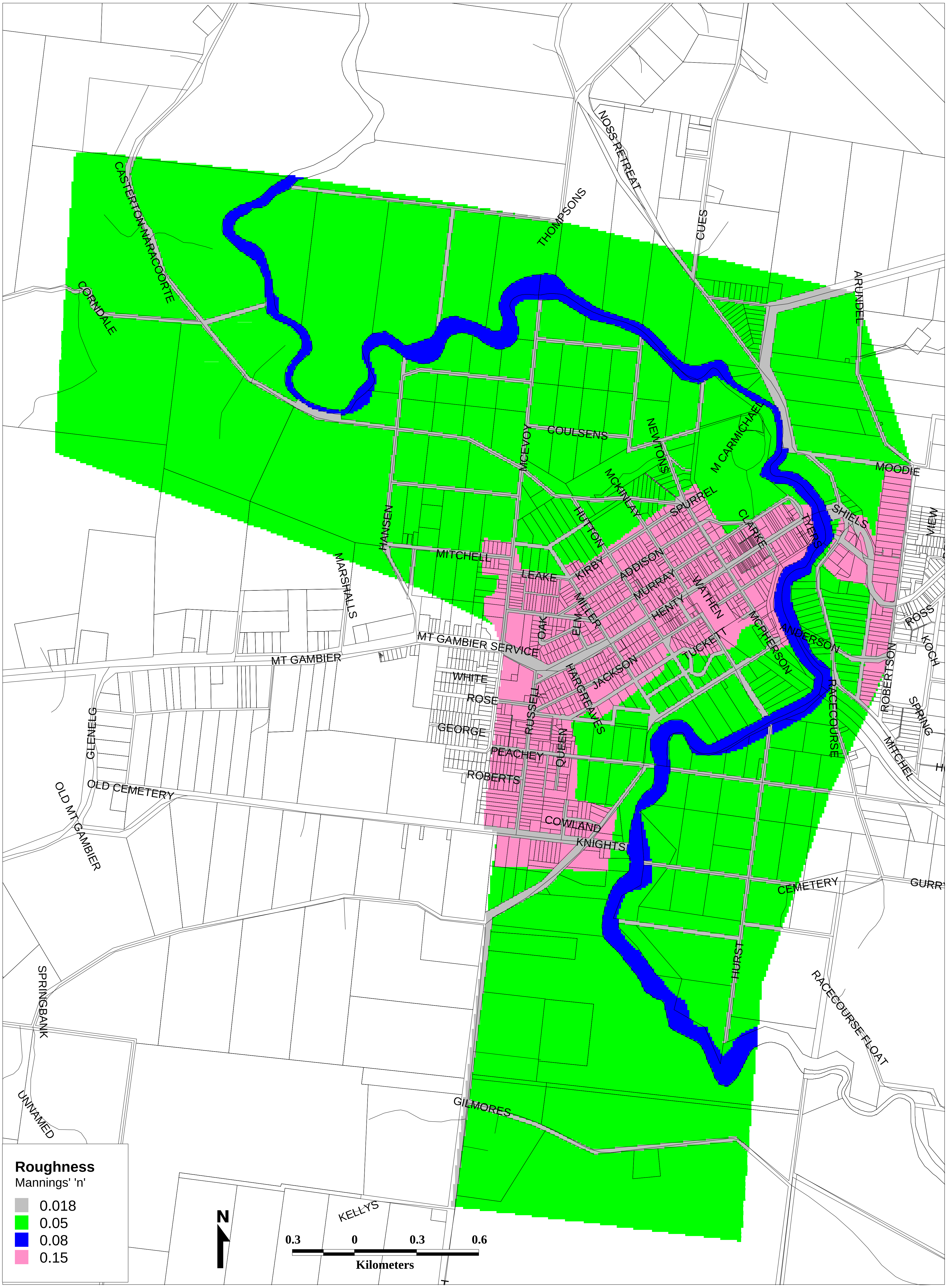

Figure 4.6 - Roughness Casterton

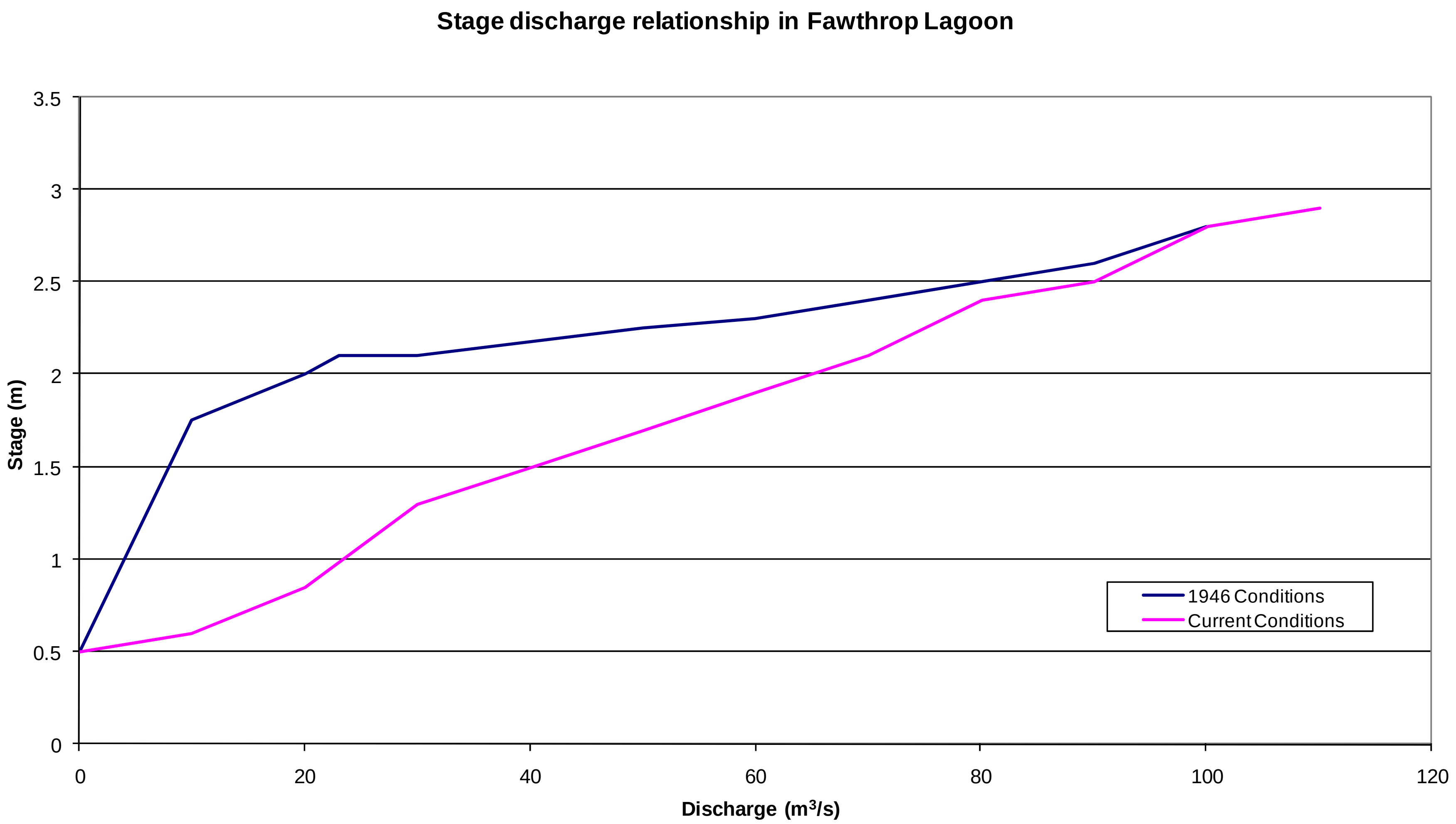

Figure 4.7 – Outlet conditions at Fawthrop Lagoon

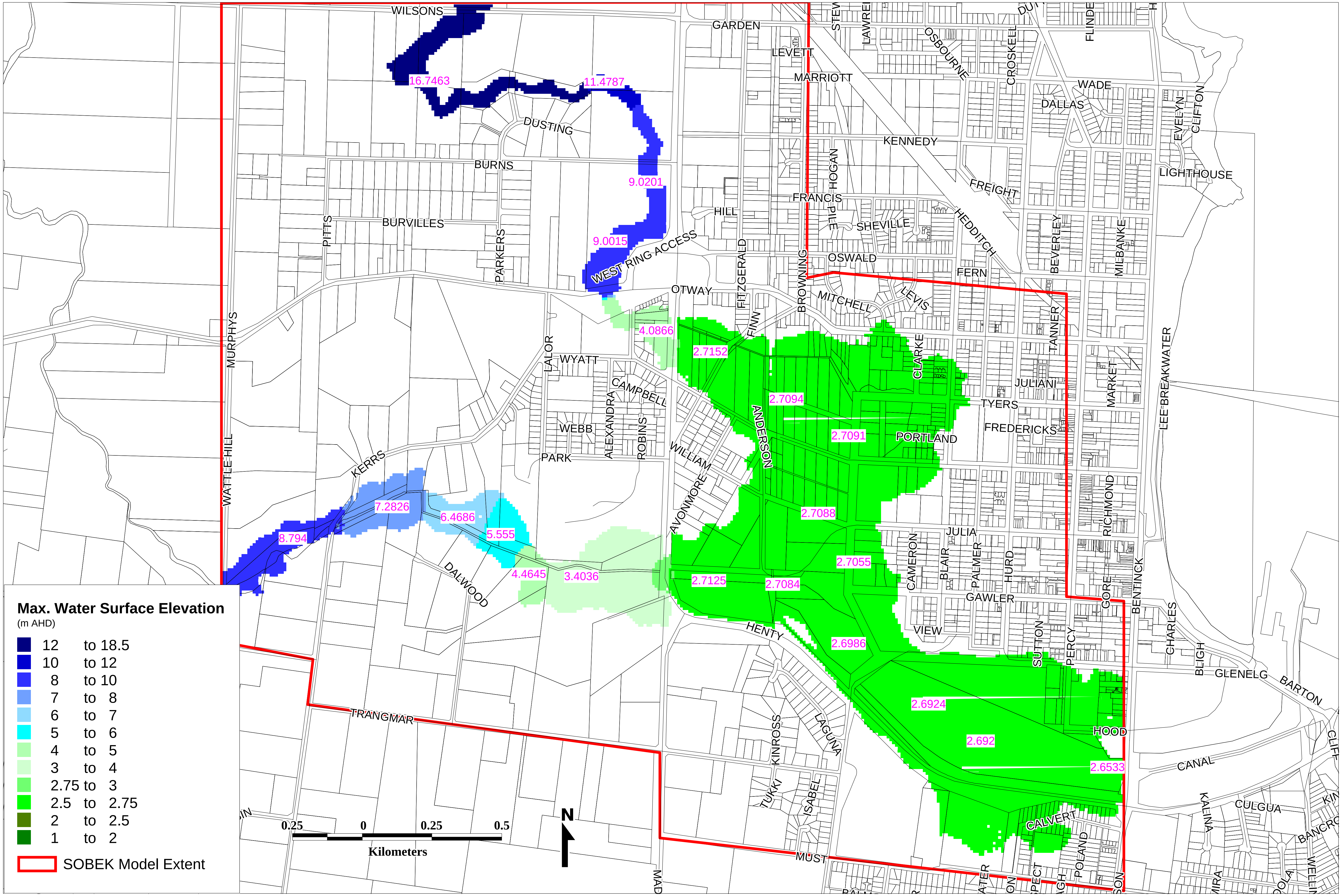

Figure 4.8 - Calibration Results Portland 1946 Flood Event

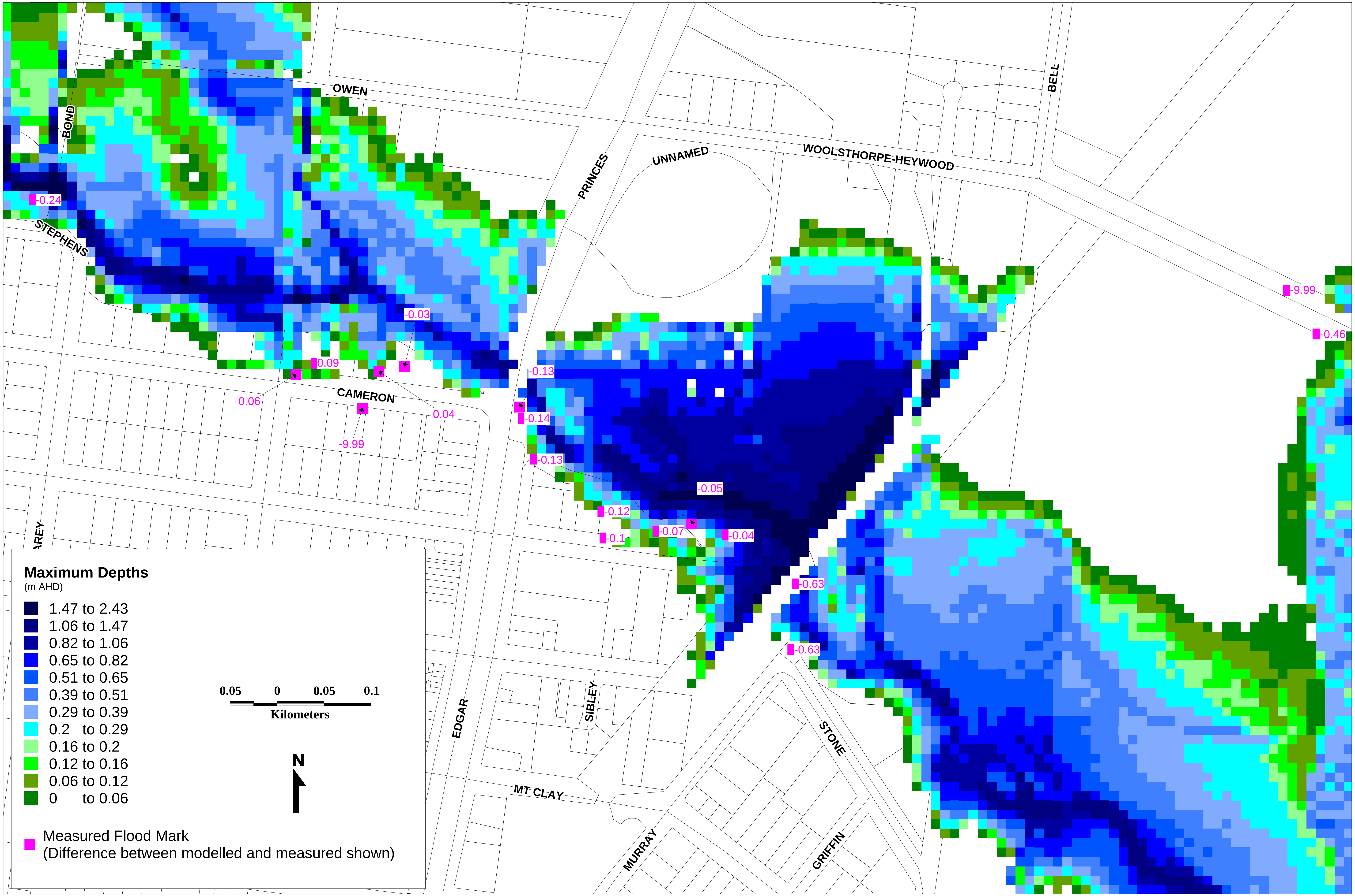

Figure 4.9 - Calibration Results Heywood for September 1983 Flood

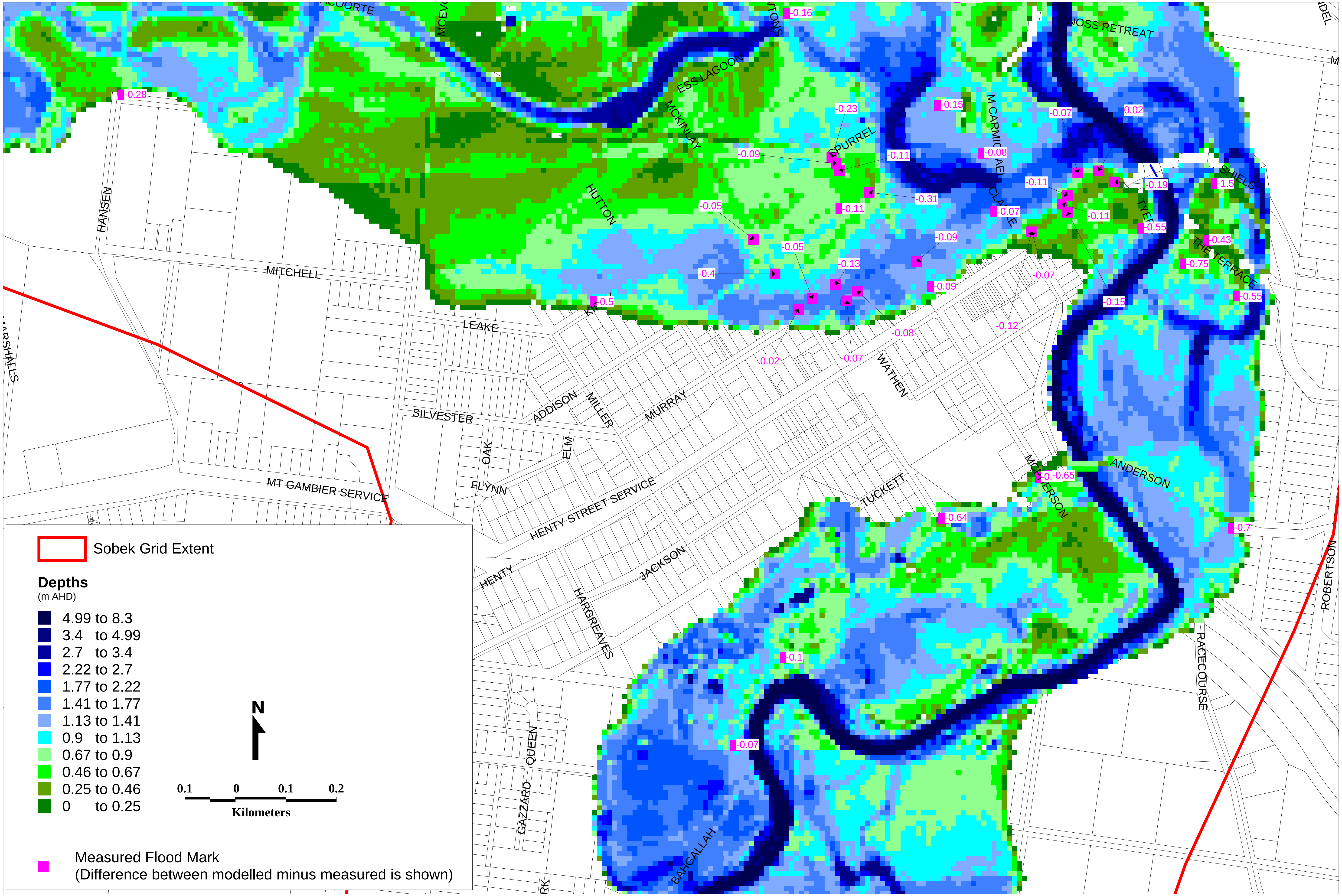

Figure 4.10 - Calibration Results Casterton November 2007 Flood Event

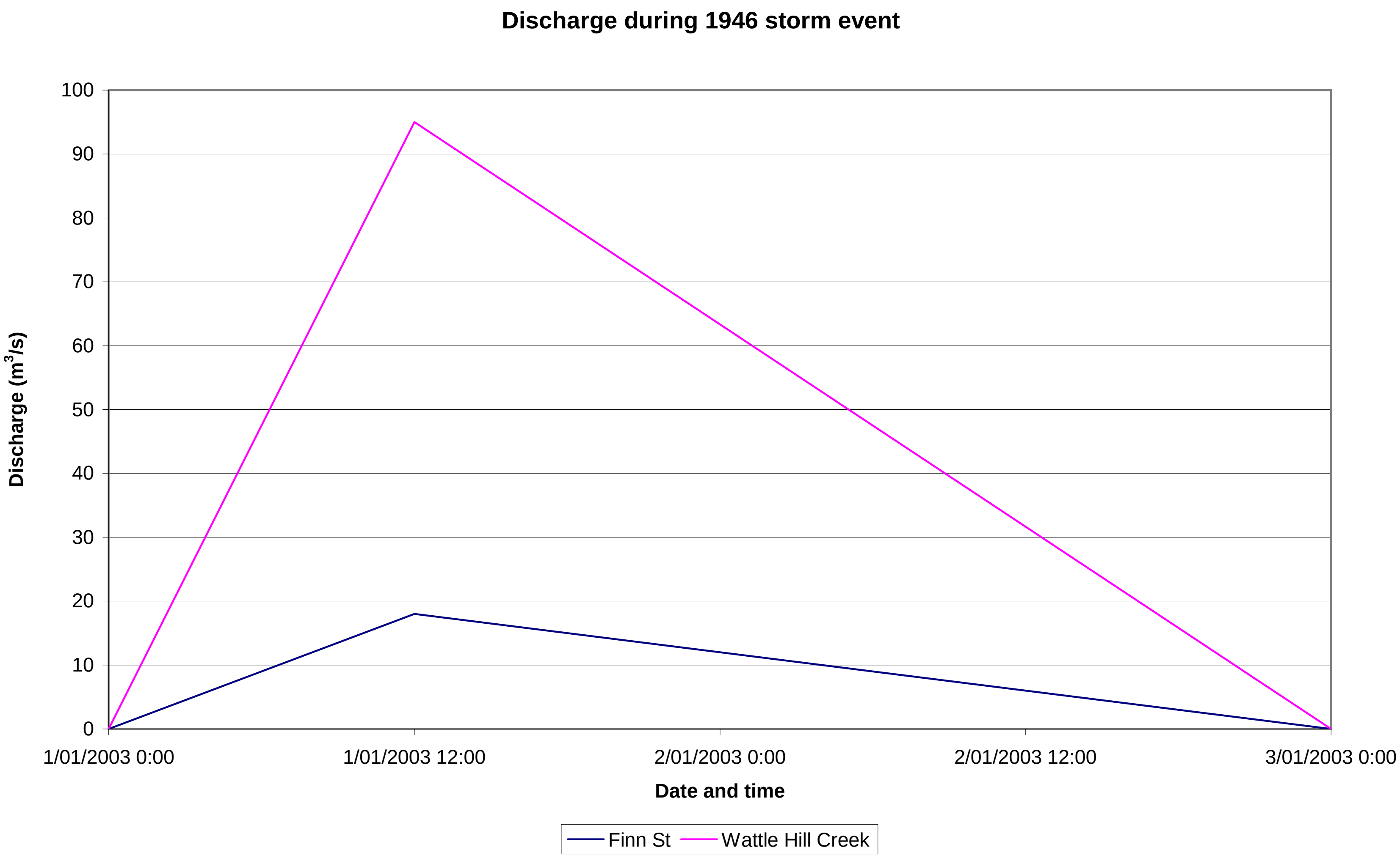

Figure 4.11 – Assumed inflows into the Portland Calibration event

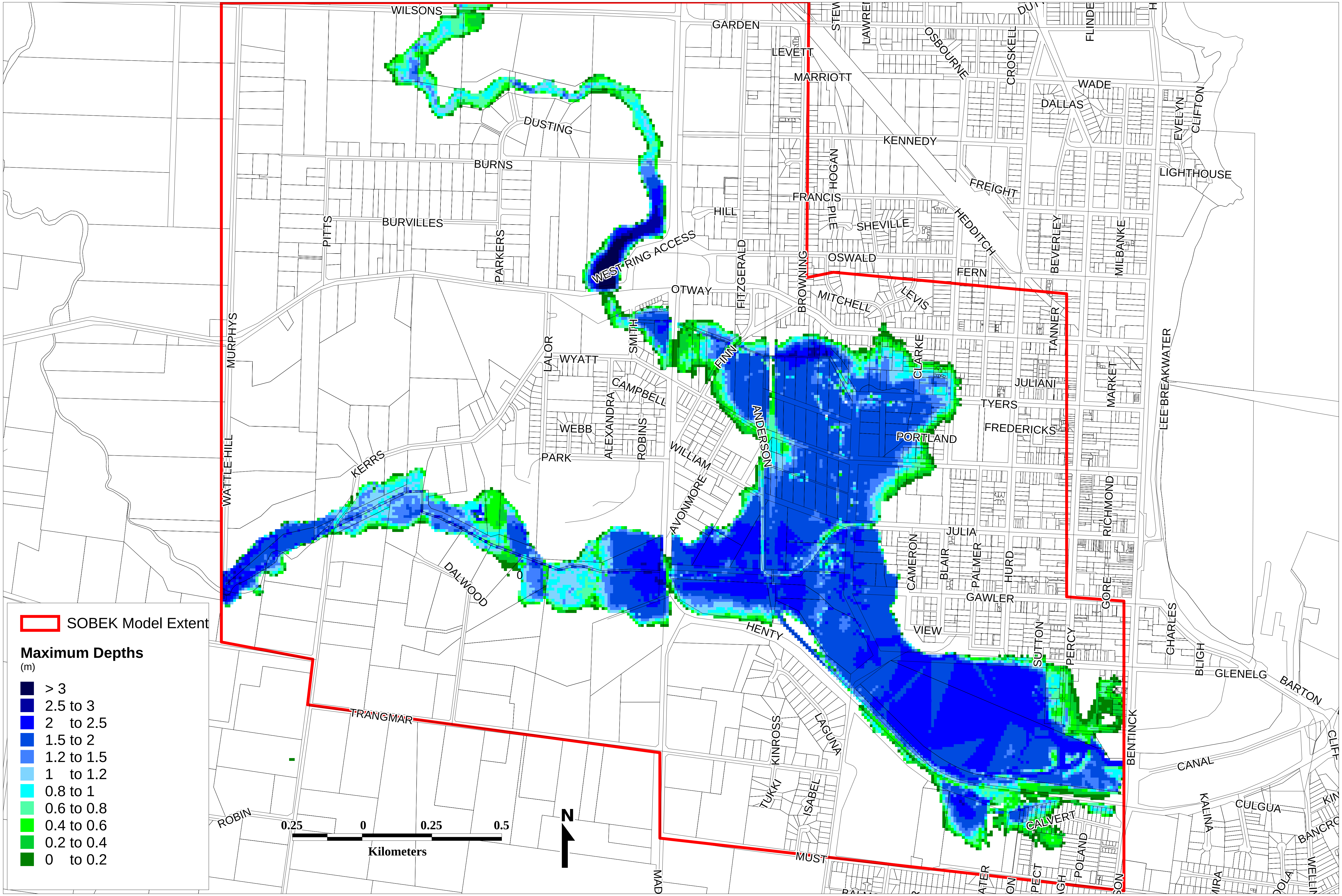

Figure 5.1 - 100 Year ARI Flood Depths and Extents for Portland

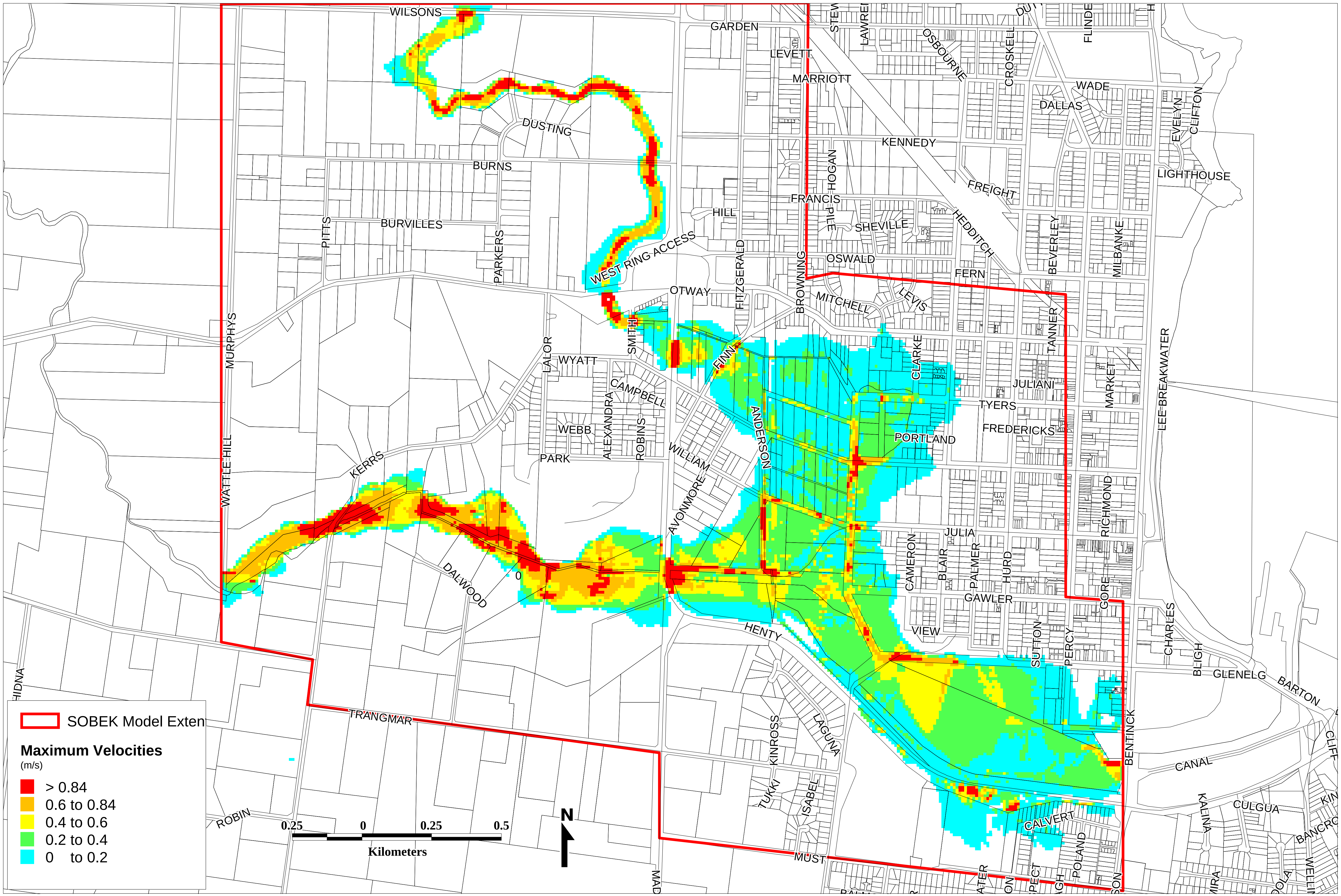

Figure 5.2 - 100 Year ARI Flood Velocities for Portland

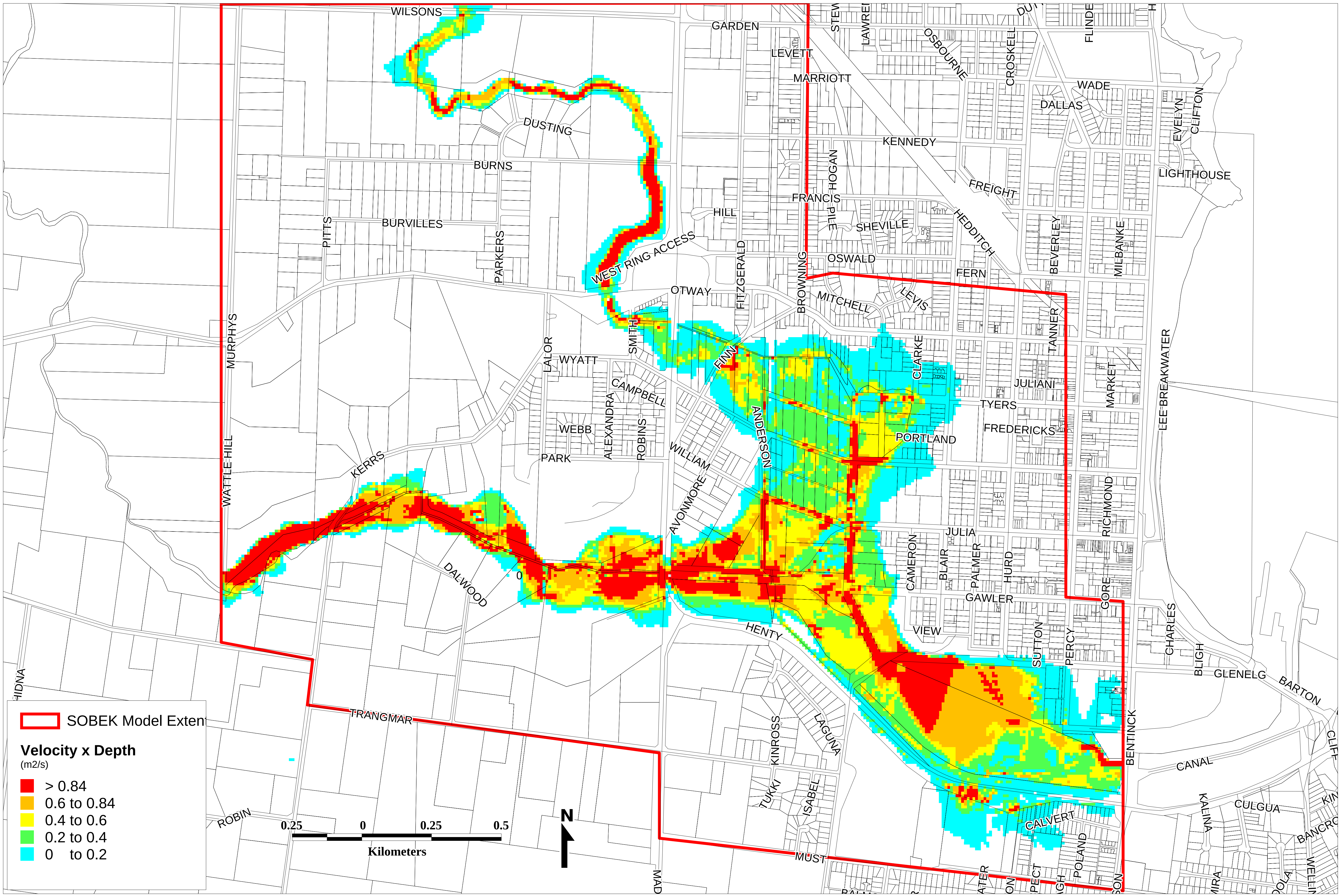

Figure 5.3 - 100 Year ARI Flood Velocity x Depth for Portland

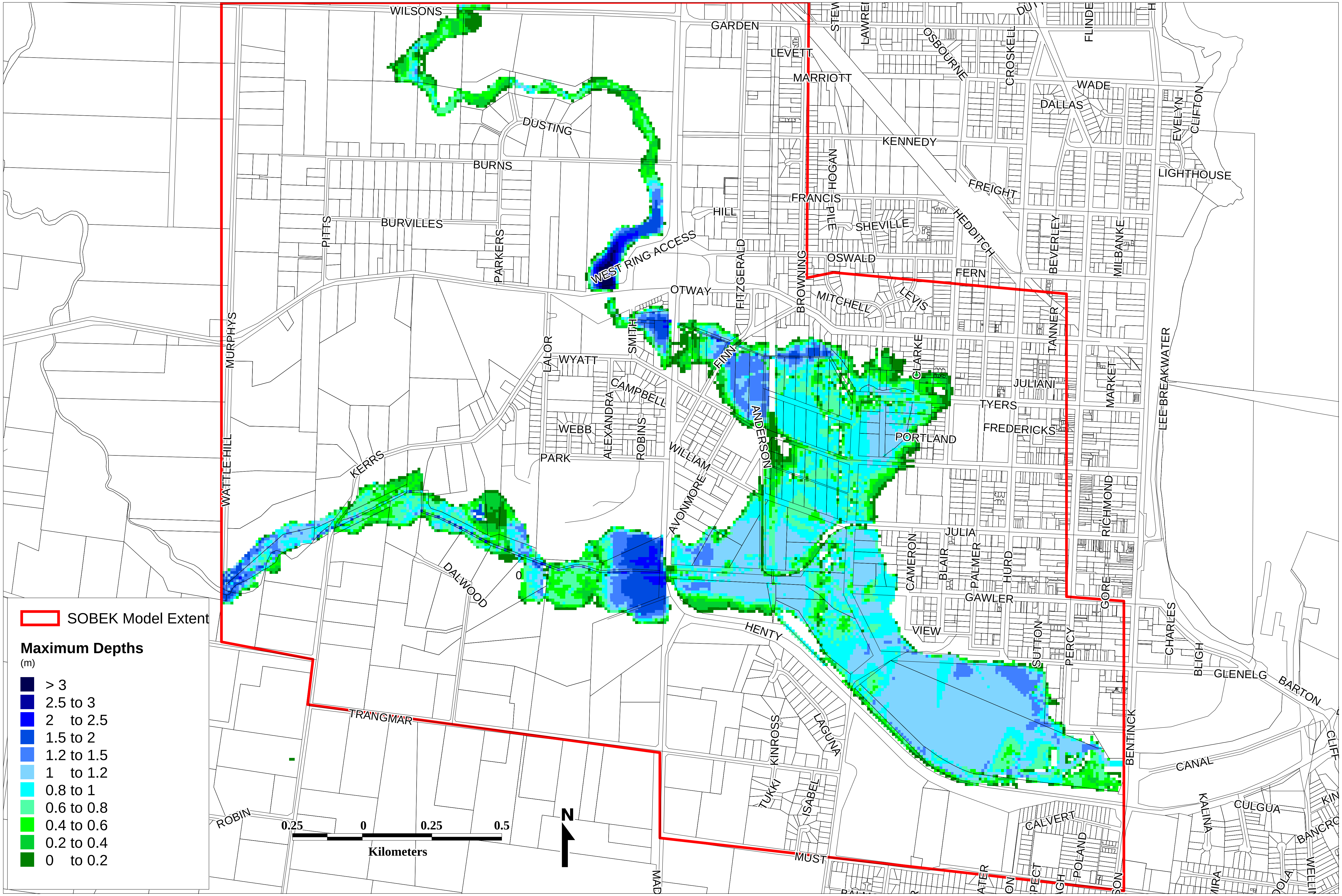

Figure 5.4 - 10 Year ARI Flood Maximum Depths for Portland

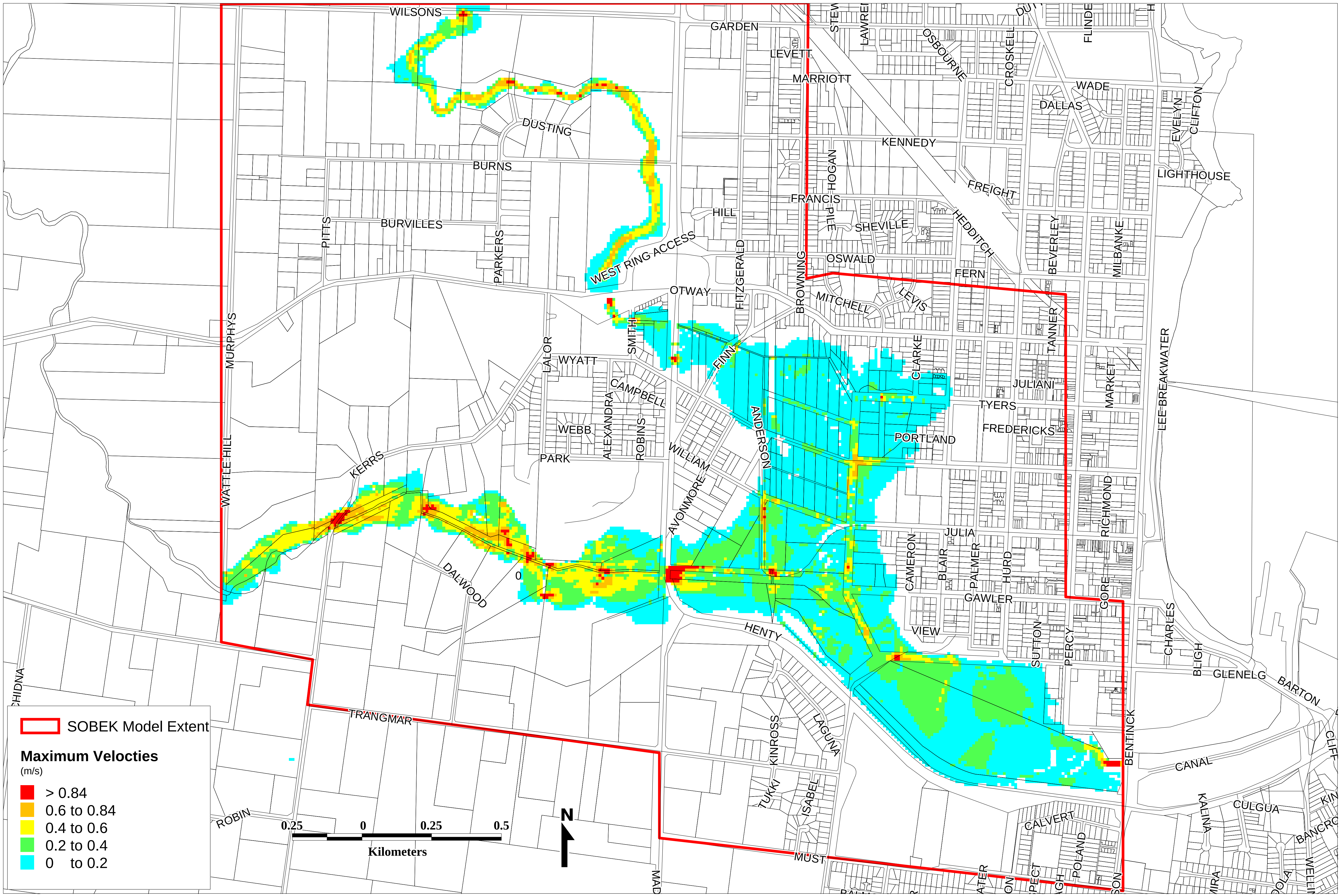

Figure 5.5 - 10 Year ARI Flood Maximum Velocities for Portland

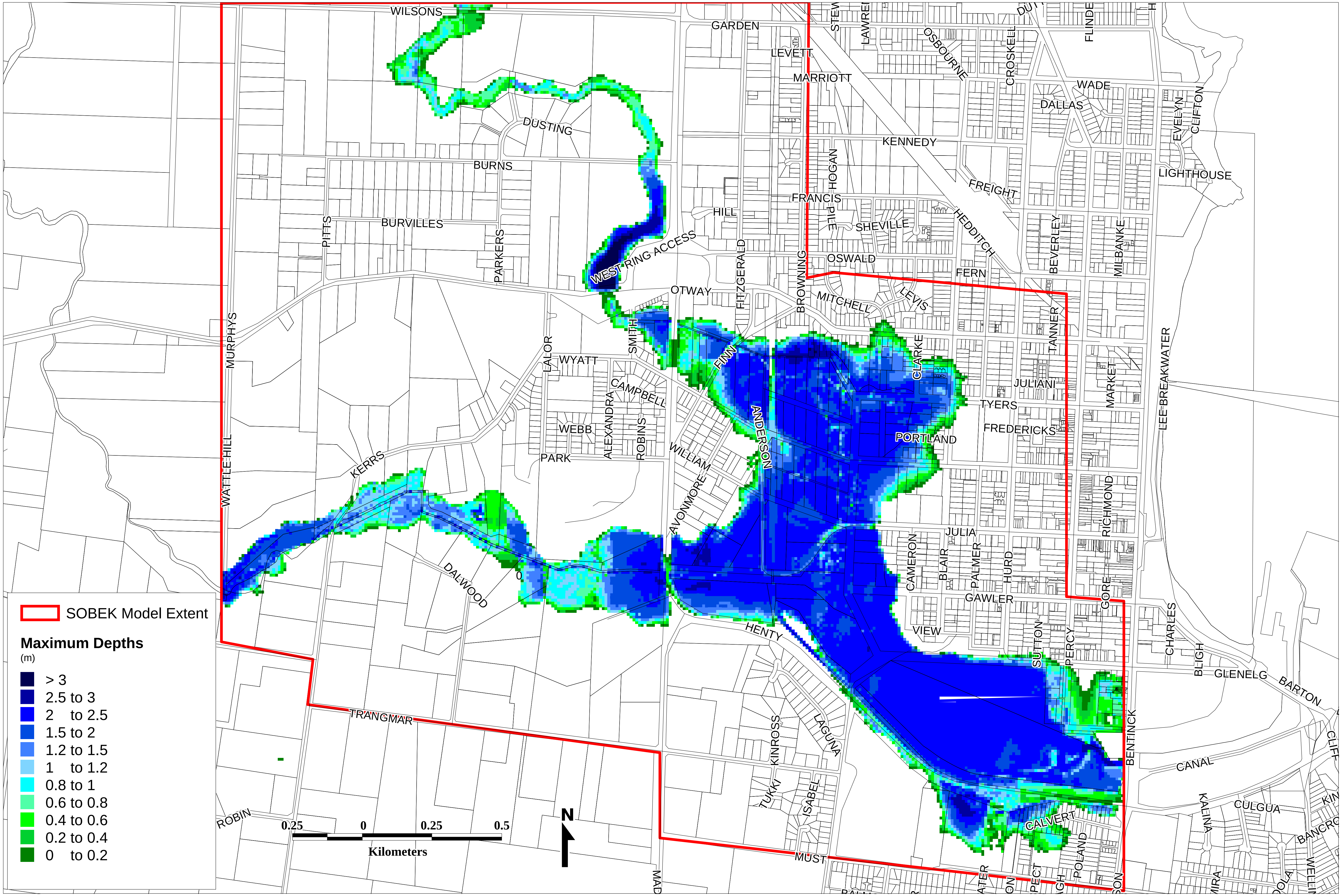

Figure 5.6 - 1946 Flood Event Maximum Depths for Portland using Current Outlet Conditions at Fawthrop Lagoon

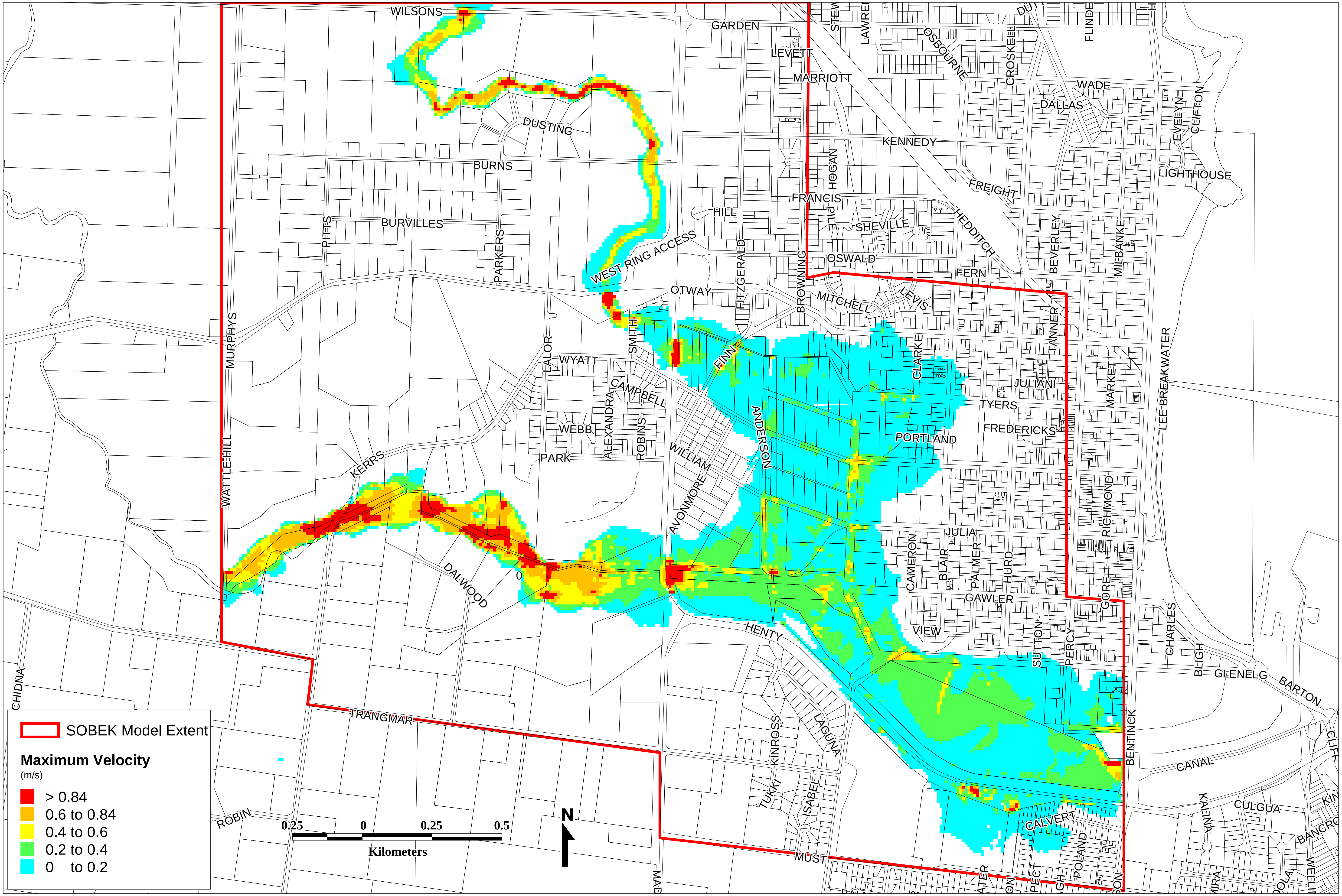

Figure 5.7 - 1946 Flood Event Maximum Velocities for Portland using Current Outlet Conditions at Fawthrop Lagoon

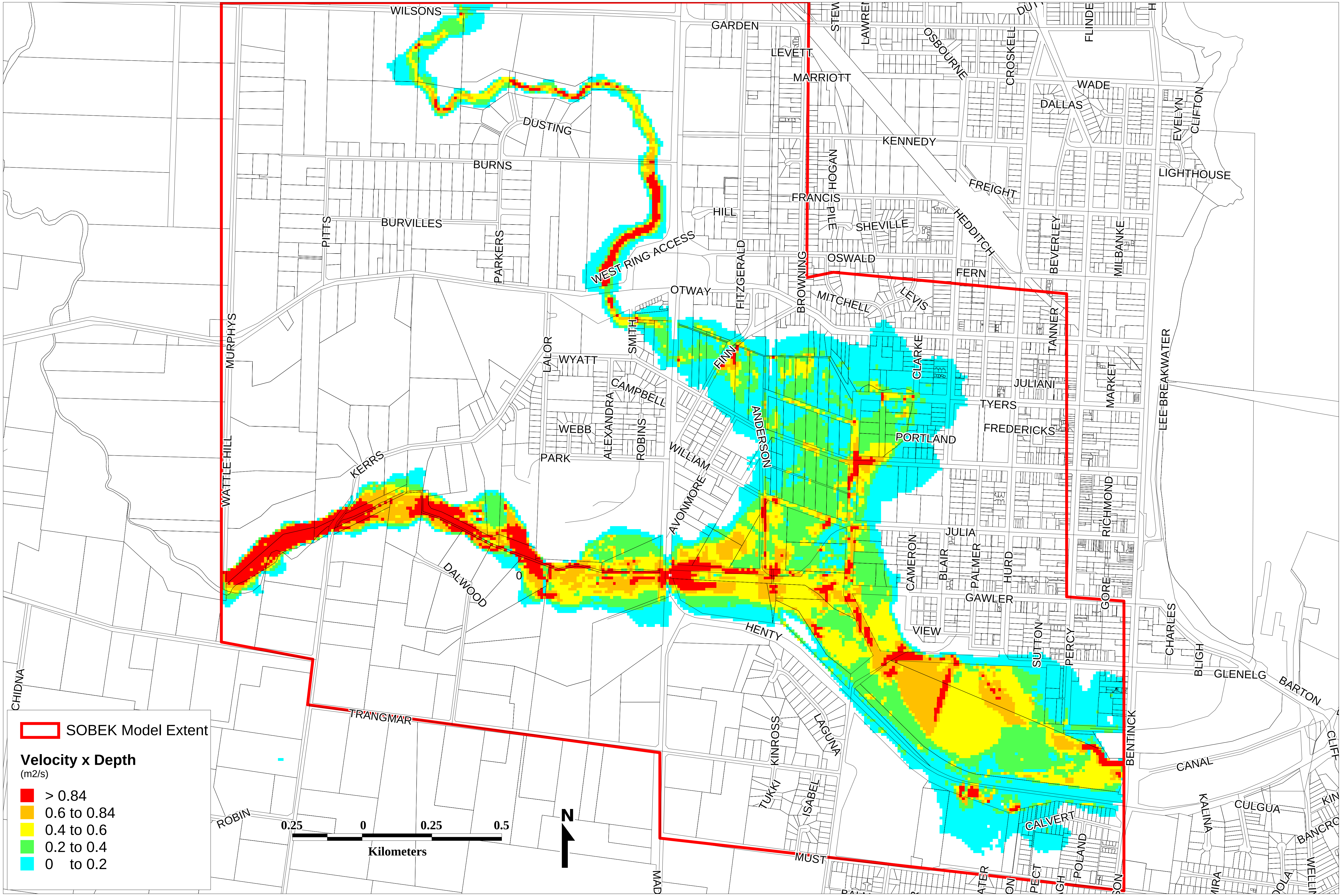

Figure 5.8 - 1946 Flood Event Maximum Velocity x Depth for Portland using Current Outlet Conditions at Fawthrop Lagoon

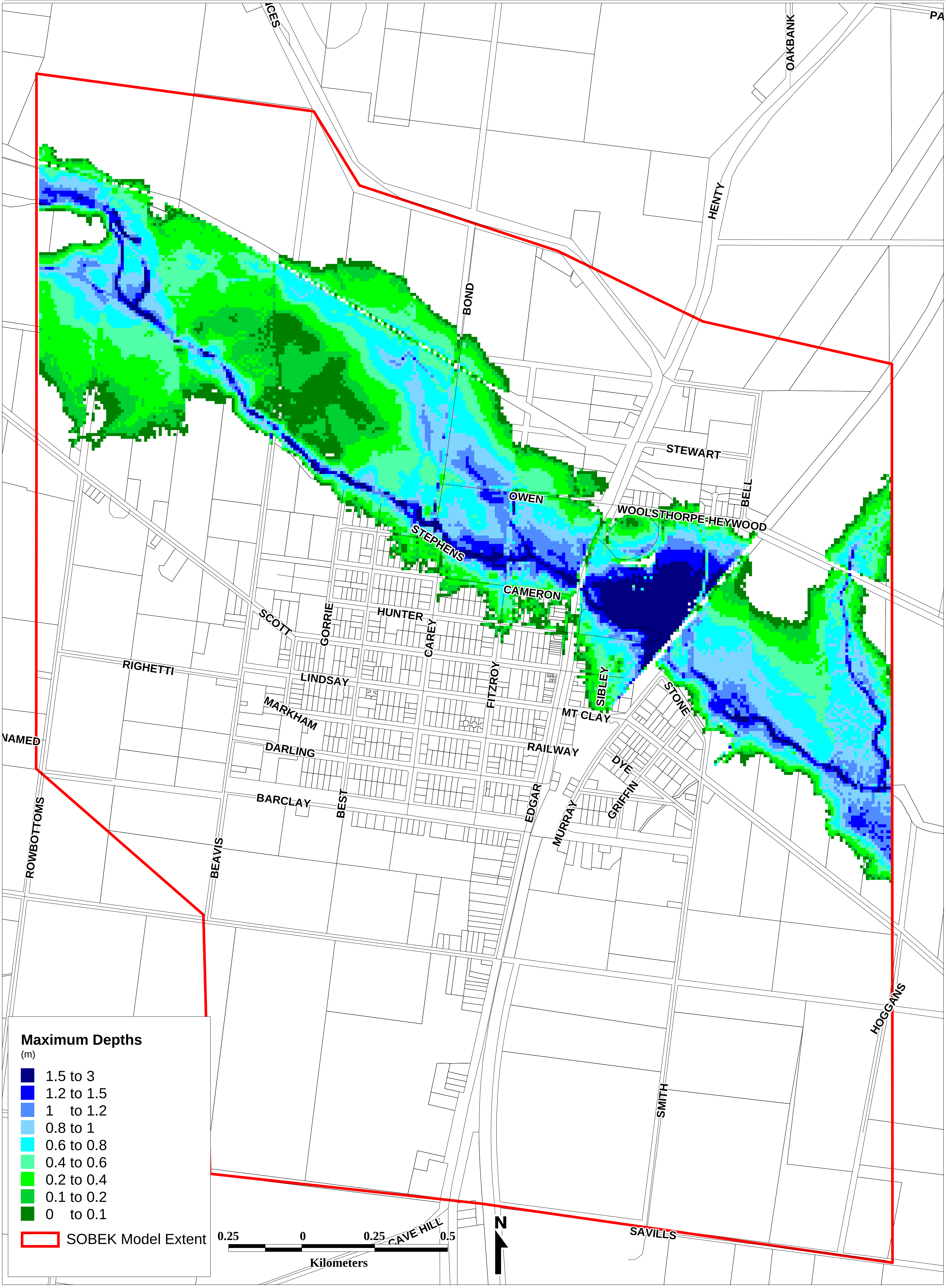

Figure 5.9 - 100 year ARI Flood Depths and Extent for Heywood

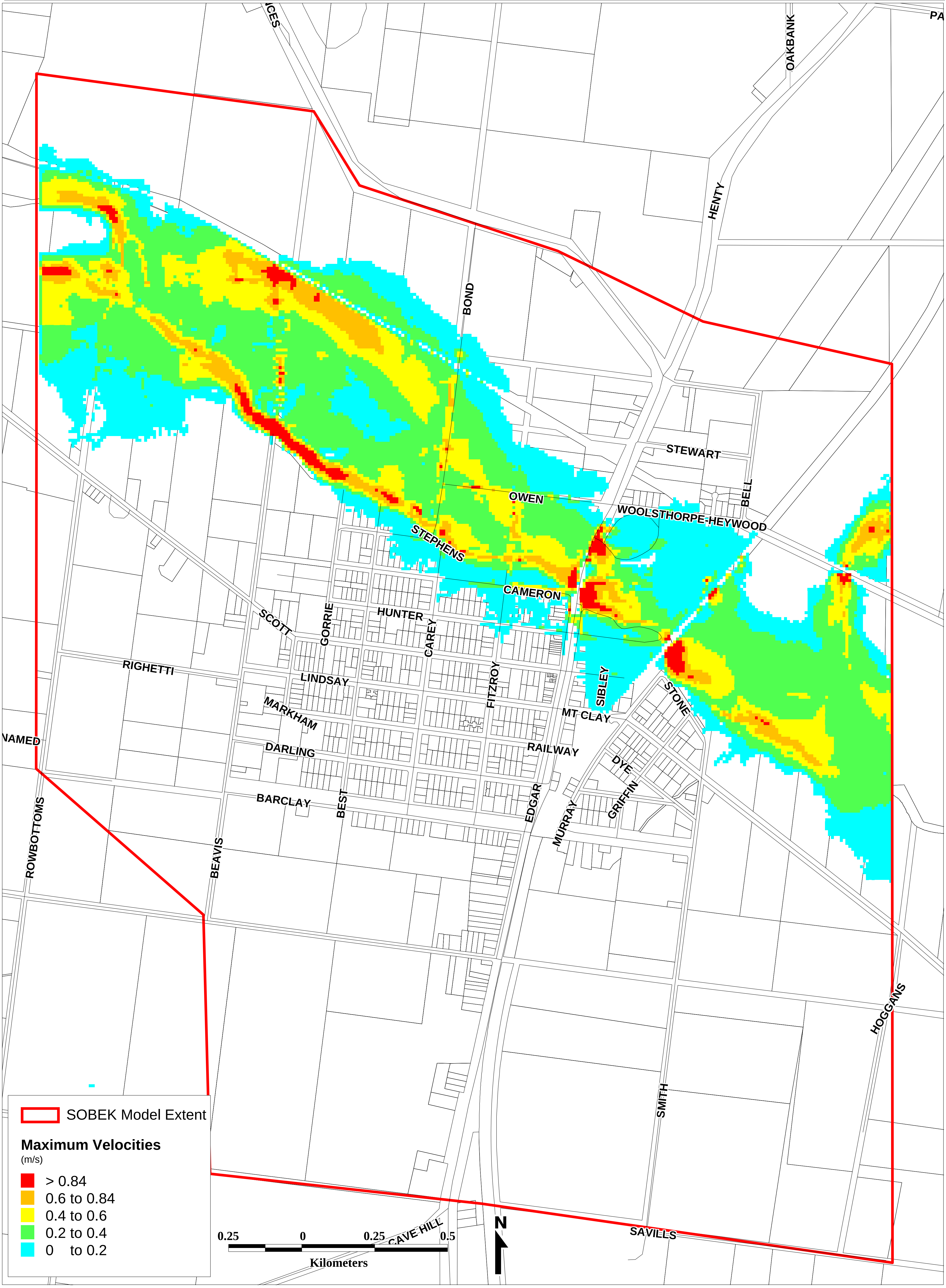

Figure 5.10 - 100 year ARI Flood Maximum Velocities for Heywood

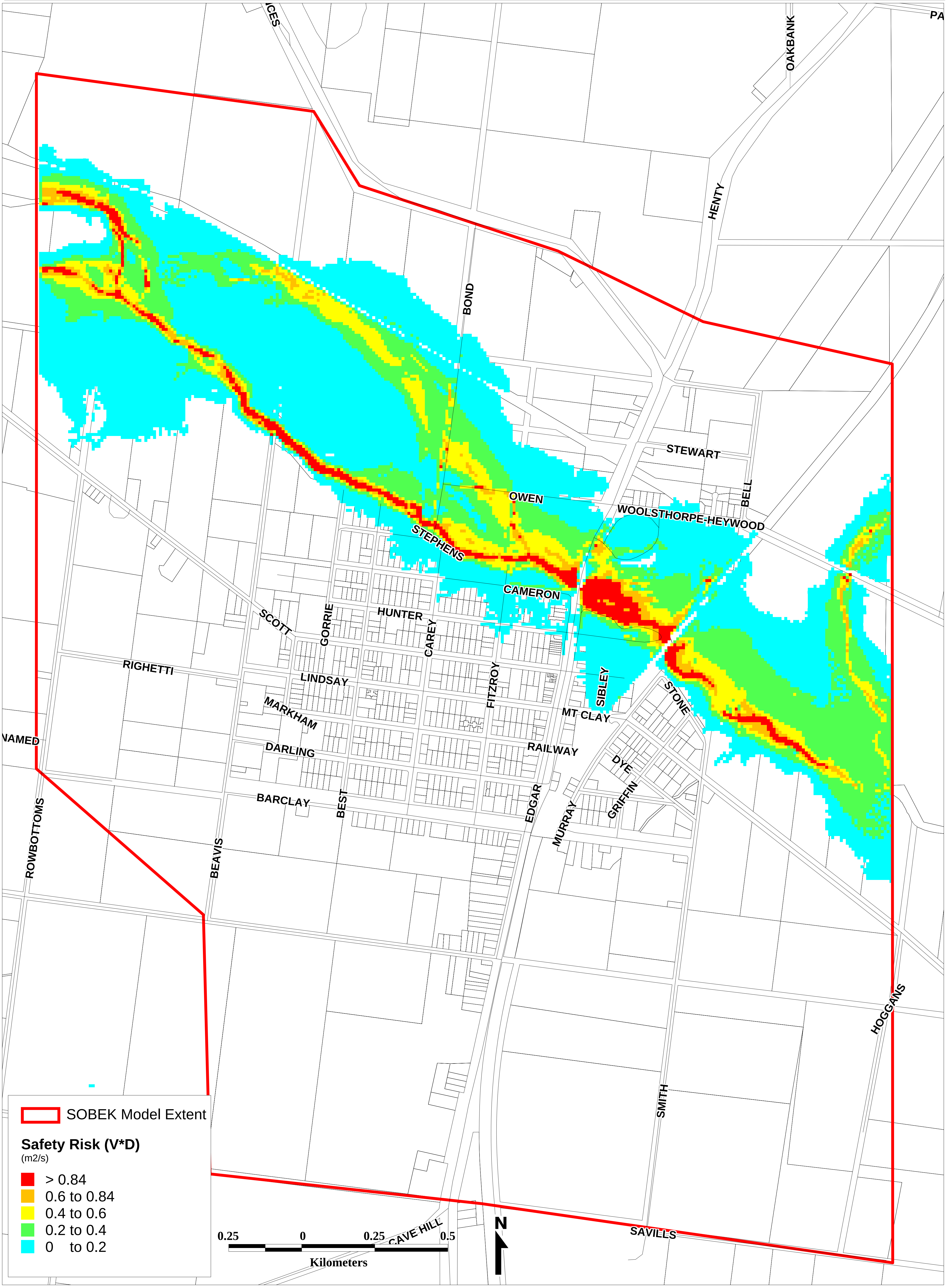

Figure 5.11 - 100 year ARI Flood Safety Risk for Heywood

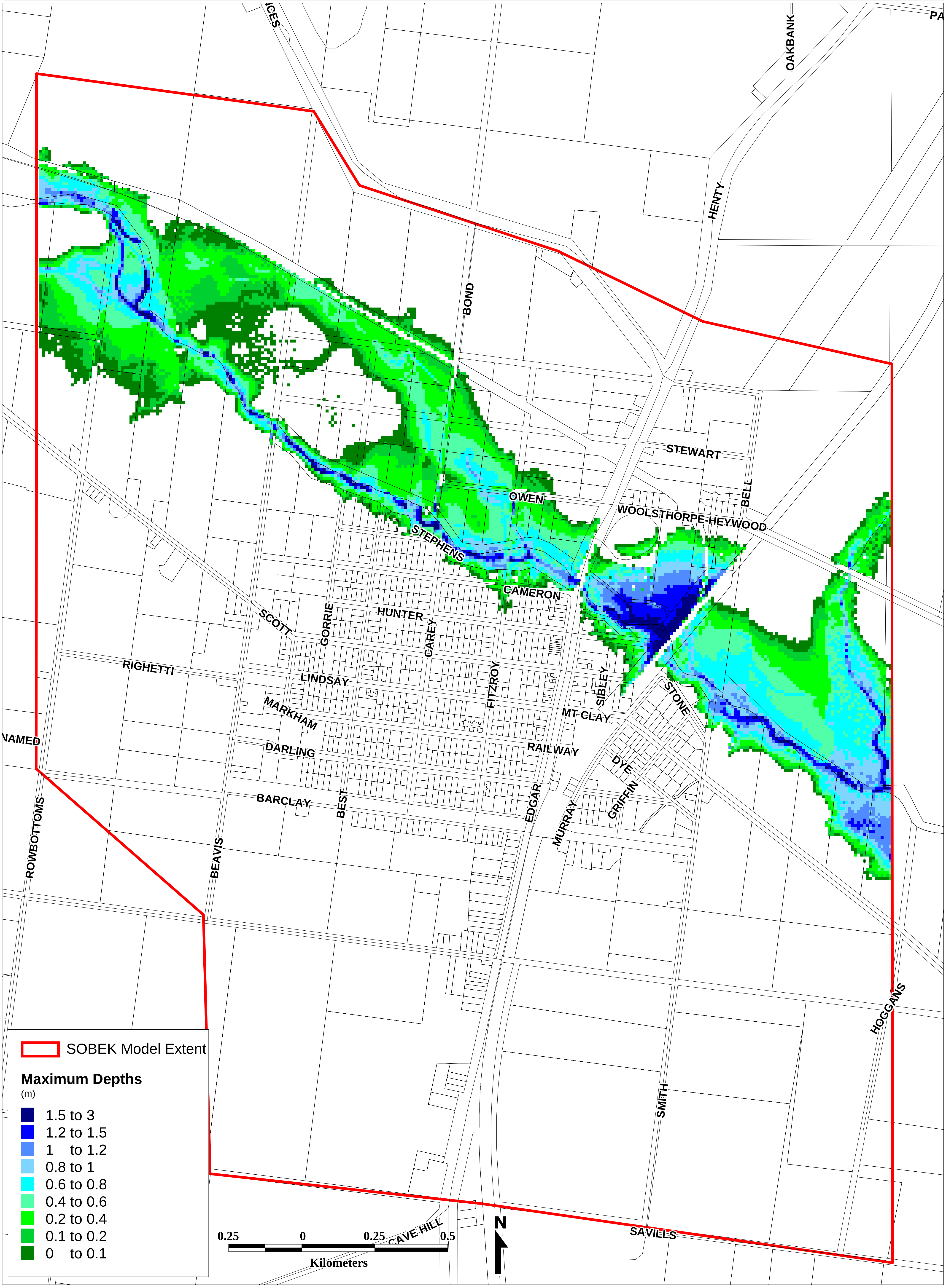

Figure 5.12 - 10 year ARI Flood Depths and Extents for Heywood

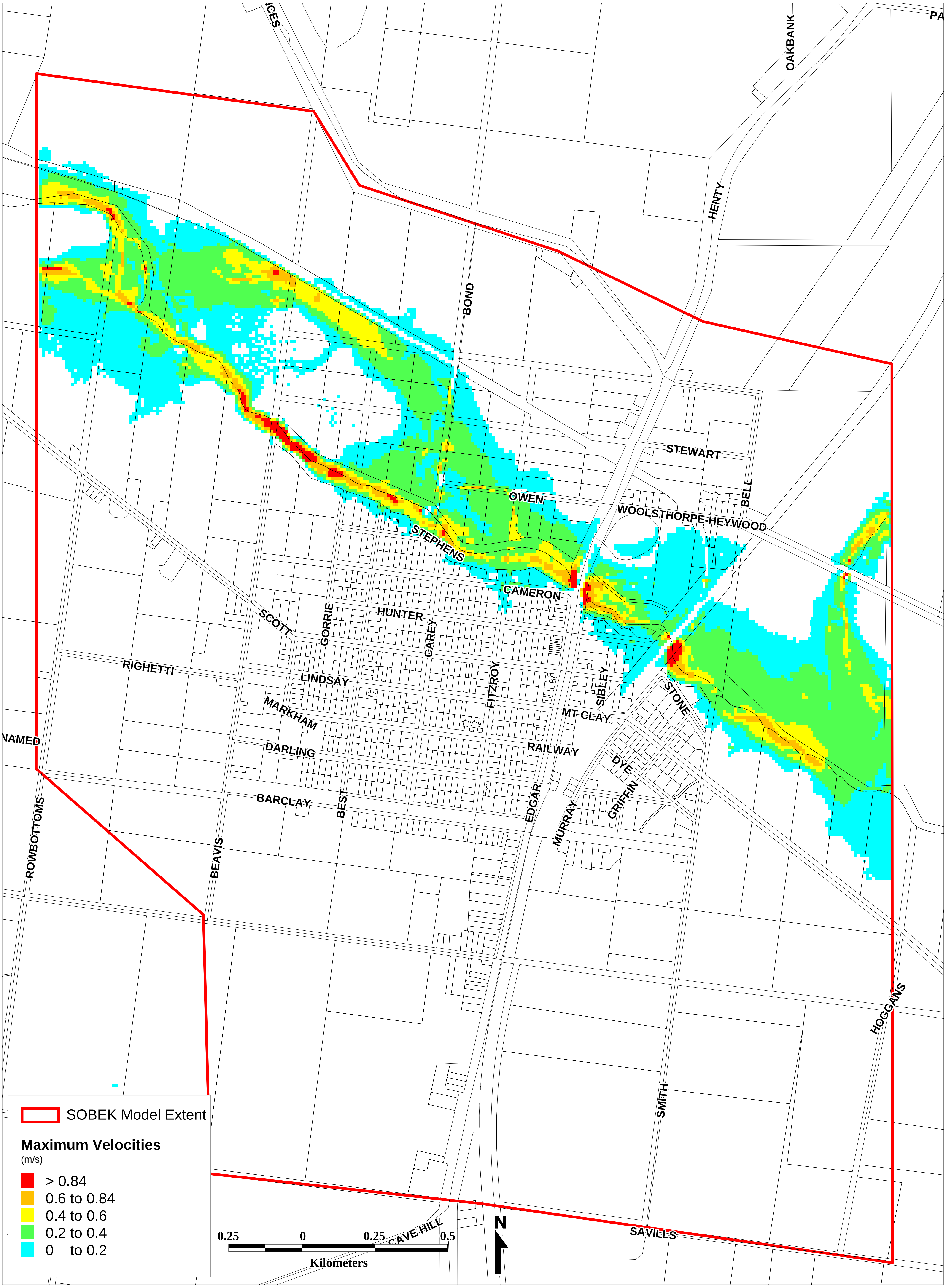

Figure 5.13 - 10 year ARI Flood Maximum Velocities for Heywood

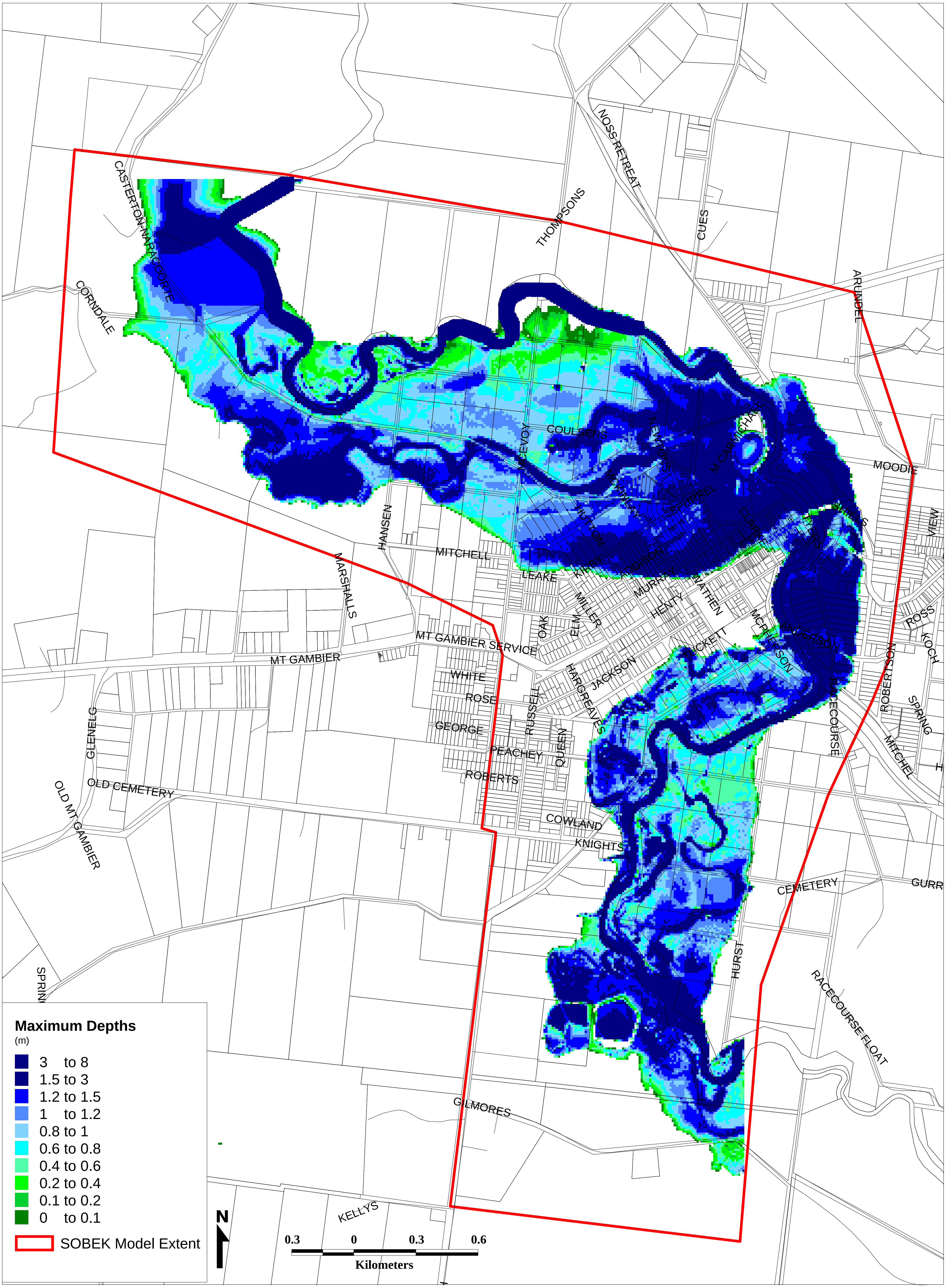

Figure 5.14 - 100 Year ARI Flood Depths and Extent for Casterton

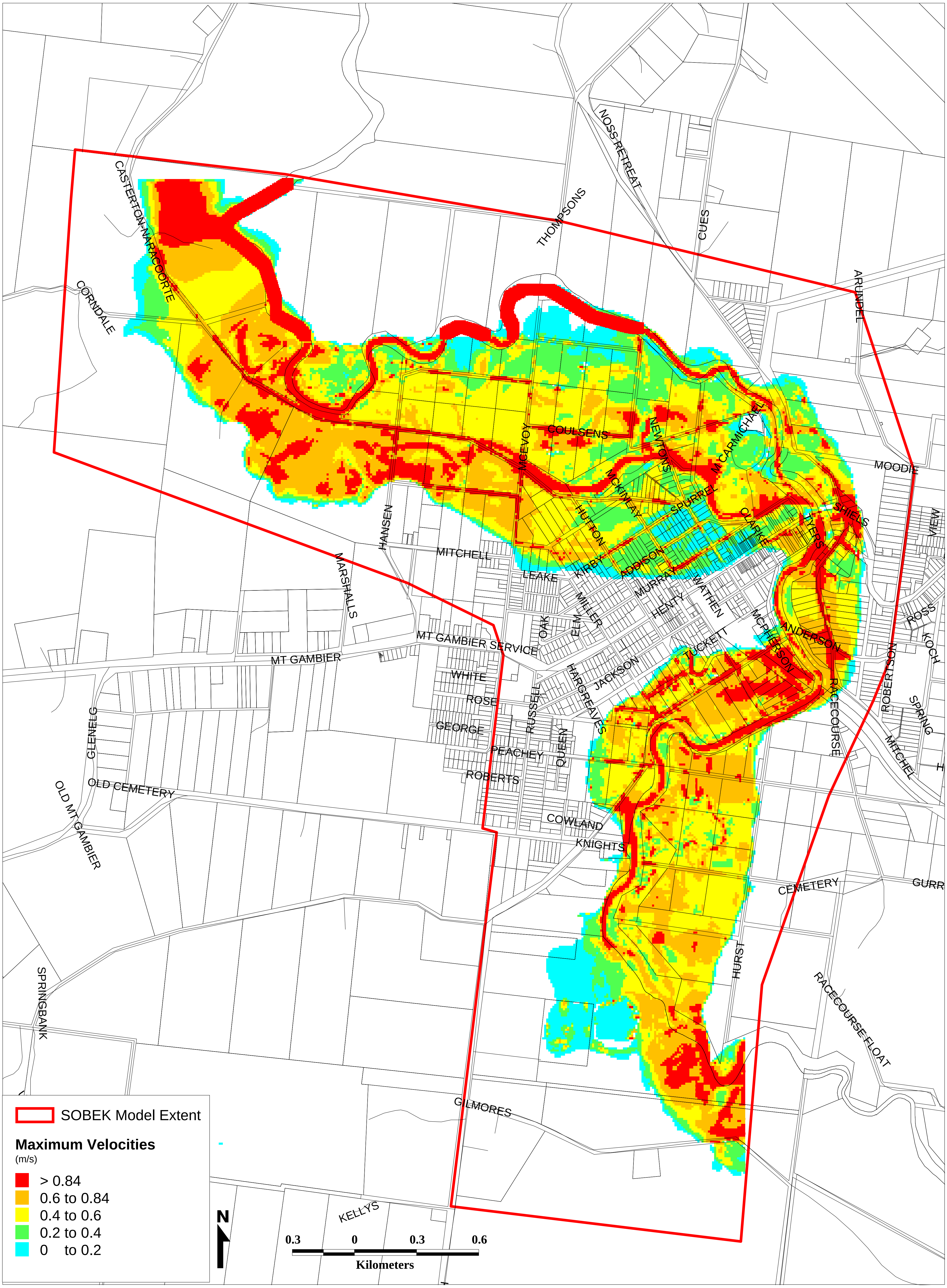

Figure 5.15 - 100 Year ARI Flood Maximum Velocities for Casterton

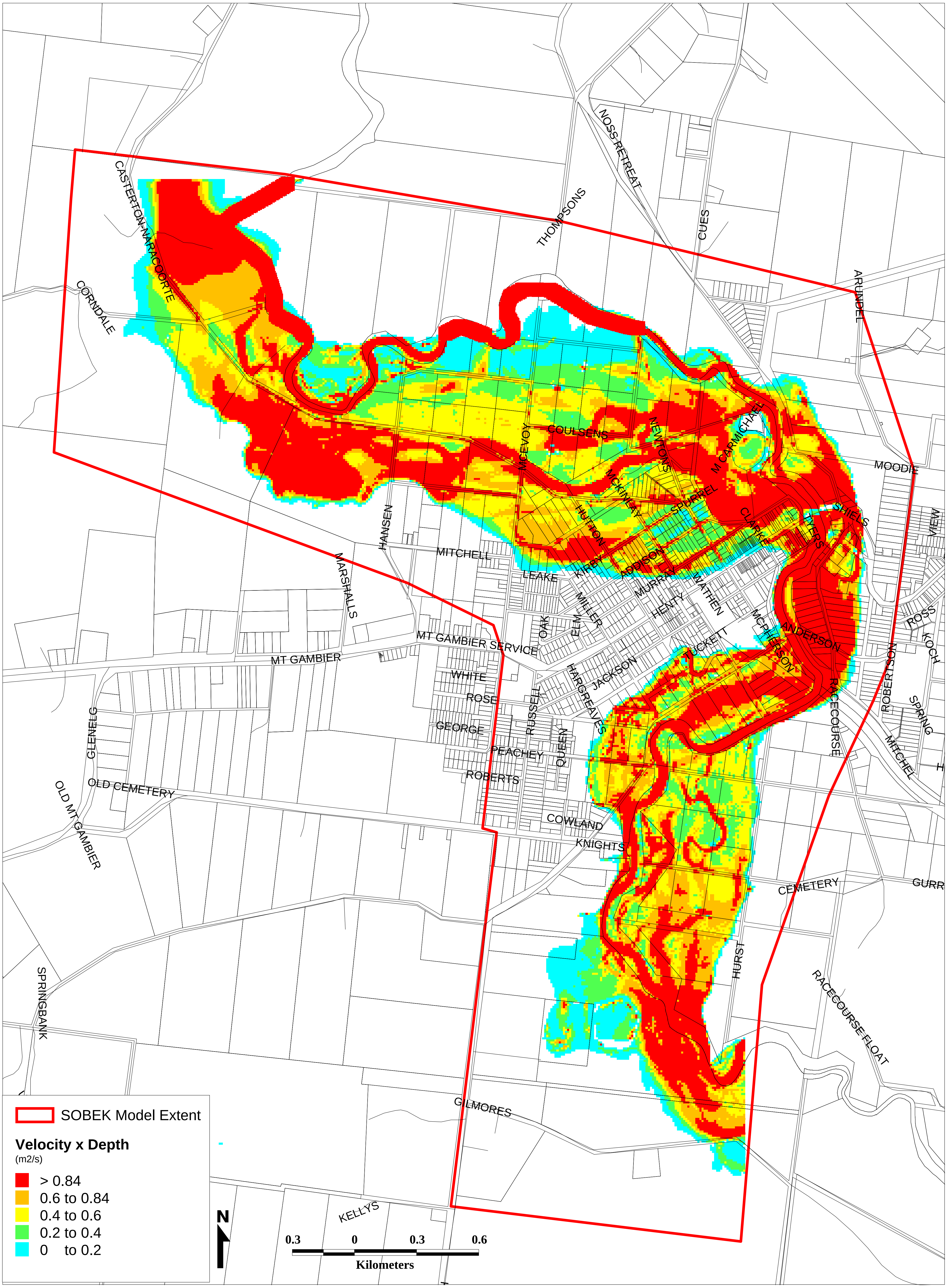

Figure 5.16 - 100 Year ARI Flood Velocity x Depth for Casterton

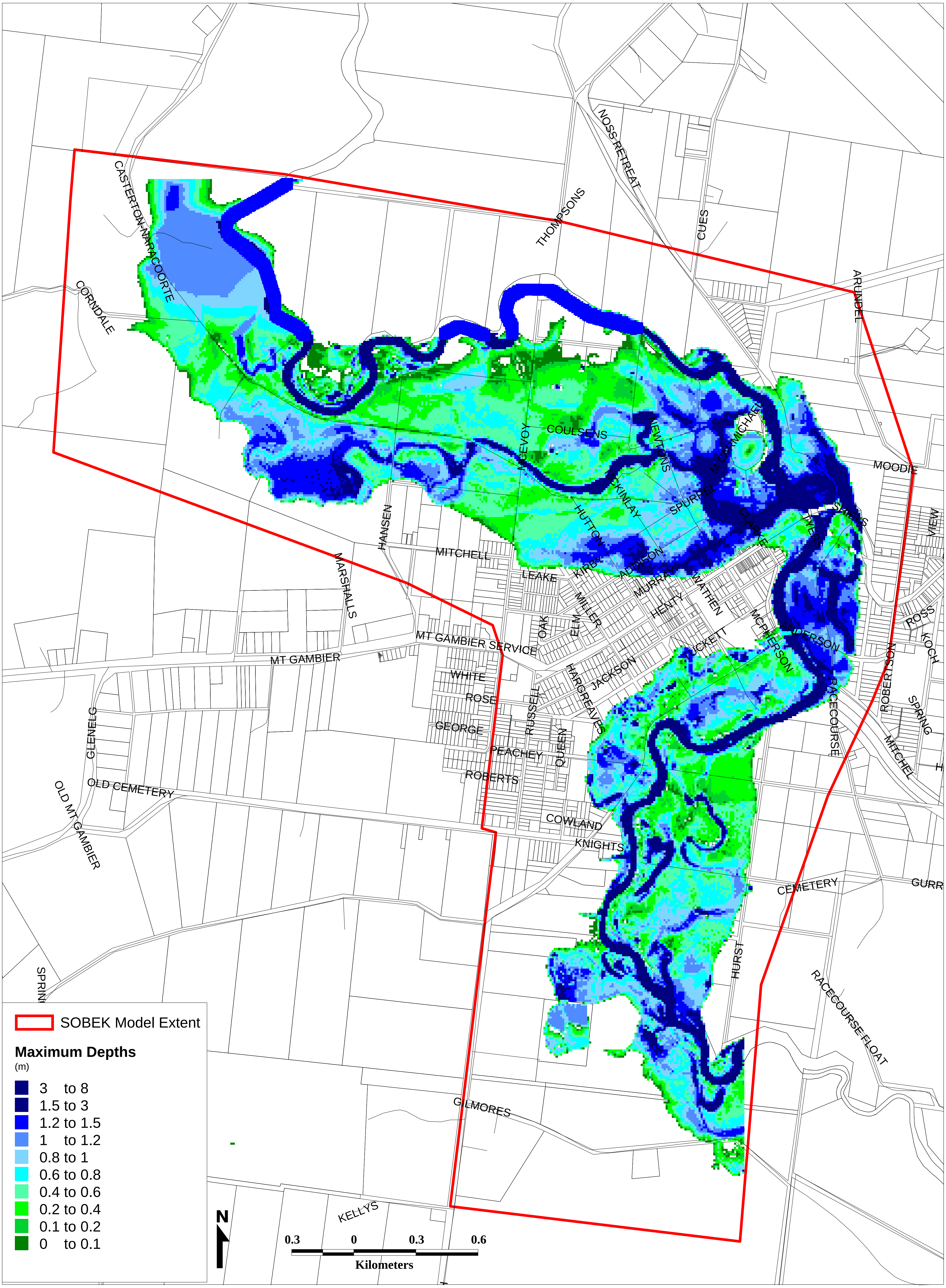

Figure 5.17 - 10 Year ARI Flood Maximum Depths and Extent for Casterton

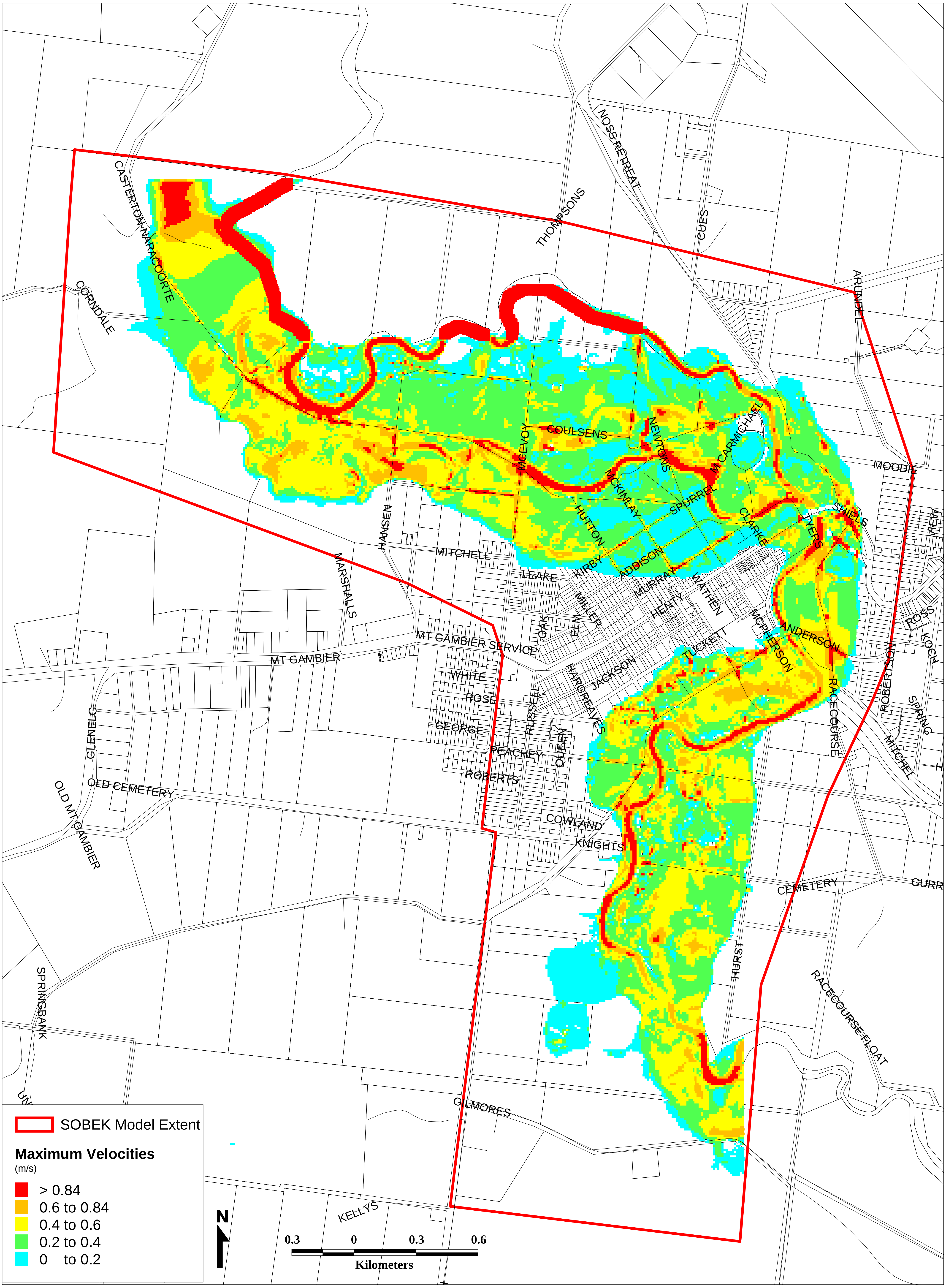

Figure 5.18 - 10 Year ARI Flood Maximum Velocities for Casterton

APPENDIX A

RORB Vectors

Portland FS
C Created Aug 2008, PJB, Cardno Lawson Treloar, Melbourne
C Reach Type Flag
1
C The Control Vector

1,2.83,-99,	Gen H'graph from Sub area A_A1
7	
A	
5,2.20,-99,	Route H'graph from A1_B1
3,	Store H'graph
1,1.40,-99,	Gen H'graph from Sub area B
7	
B	
4,	Add running H'graph
7	
A-B	
5,3.41,-99,	Route H'graph from B1_E1
3,	Store H'graph
1,2.87,-99,	Gen H'graph from Sub area C
7	
C	
5,1.68,-99,	Route H'graph from C1_D1
3,	Store H'graph
1,3.28,-99,	Gen H'graph from Sub area D
7	
D	
4,	Add running H'graph
7	
C-D	
5,1.32,-99,	Route H'graph from D1_E1
4,	Add running H'graph
7	
A-D	
5,1.66,-99,	Route H'graph from E1_E2
3,	Store H'graph
1,2.64,-99,	Gen H'graph from Sub area E
7	
E	
4,	Add running H'graph
7	
A-E	
5,4.29,-99,	Route H'graph from E2_F1
3,	Store H'graph
1,2.47,-99,	Gen H'graph from Sub area G
7	
G	
5,2.12,-99,	Route H'graph G1_F1
4,	Add running H'graph
3,	Store H'graph
1,1.46,-99,	Gen H'graph from Sub area F
7	
F	
4,	Add running H'graph
7	
A-G	

5,4.38,-99,	Route H'graph F1_J1
3,	Store H'graph
1,2.01,-99,	Gen H'graph from Sub area K
7	
K	
5,2.73,-99,	Route H'graph from K1_J1
4,	Add running H'graph
3,	Store H'graph
1,2.35,-99,	Gen H'graph from Sub area J
7	
J	
4,	Add running H'graph
7	
Wattlehill	
5,2.75,-99,	Route H'graph from J1_L1
3,	Store H'graph
1,1.37,-99,	Gen H'graph from Sub area H
7	
H	
5,3.30,-99,	Route H'graph from H1_L1
3,	Store H'graph
1,1.34,-99,	Gen H'graph from Sub area L
7	
L	
4,	Add running H'graph
3,	Store H'graph
1,2.00,-99,	Gen H'graph from Sub area I
7	
I	
4,	Add running H'graph
7	
Finn Creek	
4,	Add running H'graph
7	
Portland	
0	

C Subcatchment data
16.51,17.33,18.79,11.35,17.22,7.35,16.97,21.74,21.18,6.31,5.41,4.27,-99
C Subarea flag and fractions impervious
0
-99

```
FitzRiv
C RORB_GE 002
C
C FitzRiv
C
C #FILE COMMENTS
C   1
C Fitzroy River, Heywood
C
C #SUB-AREA AREA COMMENTS
C   1
C Sub areas A-G are predominately natural reaches. Sub-area H is predominately open
earthern drain
C
C #IMPERVIOUS FRACTION COMMENTS
C   0
C
C #BACKGROUND IMAGE
C  T  F
C
C #NODES
C    16
C     1    15.271    65.209    1.000 1 0    2 A    39.380    0.000  0  0
C
C     2    30.294    68.060    1.000 0 0    3      0.000     0.000  0  0
C
C     3    42.830    56.323    1.000 0 0    6      0.000     0.000  0  0
C
C     4    29.896    55.820    1.000 1 0    3 B    39.110    0.000  0  0
C
C     5    36.263    80.300    1.000 1 0    3 C    36.890    0.000  0  0
C
C     6    50.391    53.137    1.000 0 0    8      0.000     0.000  0  0
C
C     7    42.631    41.903    1.000 1 0    6 D    40.090    0.000  0  0
C
C     8    57.852    54.814    1.000 0 0   10      0.000     0.000  0  0
C
C     9    55.067    70.407    1.000 1 0    8 E    22.360    0.000  0  0
C
C    10    64.021    52.299    1.000 0 0   12      0.000     0.000  0  0
C
C    11    65.414    82.480    1.000 1 0   10 F    42.150    0.000  0
0
C
C    12    71.880    47.939    1.000 1 0   13 G    21.960    0.000  0
0
C
C    13    75.462    43.580    1.000 0 0   14      0.000     0.000 71  0
C
C    14    81.531    39.555    1.000 0 0   16      0.000     0.000  0  0
C
C    15    72.079    28.154    1.000 1 0   14 H    17.370    0.000  0
0
C
```

```
C    16        84.615        38.382        1.000 0 1     0                  0.000        0.000  0  0
C
C
C #REACHES
C    15
C     1               1    2        0 1 0      5.240      0.000    1  0
C        26.912
C        69.234
C     2               2    3        0 1 0      7.080      0.000    1  0
C        36.562
C        62.191
C     3               4    3        0 1 0      6.030      0.000    1  0
C        38.850
C        54.311
C     4               5    3        0 1 0      6.000      0.000    1  0
C        40.044
C        77.114
C     5               3    6        0 1 0      2.880      0.000    1  0
C        46.610
C        54.730
C     6               7    6        0 1 0      4.360      0.000    1  0
C        48.998
C        48.945
C     7               6    8        0 1 0      1.990      0.000    1  0
C        54.122
C        53.975
C     8               9    8        0 1 0      4.280      0.000    1  0
C        54.868
C        62.527
C     9               8   10        0 1 0      2.630      0.000    1  0
C        60.937
C        53.556
C    10              11   10        0 1 0      7.870      0.000    1  0
C        61.533
C        76.444
C    11              10   12        0 1 0      1.690      0.000    1  0
C        66.010
C        49.113
C    12              12   13        0 1 0      1.180      0.000    1  0
C        73.671
C        45.759
C    13              13   14        0 1 0      2.100      0.000    1  0
C        78.496
C        41.568
C    14              15   14        0 2 0      3.900      0.100    1  0
C        77.949
C        30.669
C    15              14   16        0 1 0      0.560      0.000    1  0
C        83.073
C        38.969
C
C #STORAGES
C     0
C
C #INFLOW/OUTFLOW
```

```
C     0
C
C END RORB_GE
C
C Fitzroy River, Heywood
0
1, 1, 5.240,  -99                   ,Reach 1 node 1              Sub-area A, Reach  -
Generate rainfall excess h'graph and route downstream
5, 1, 7.080,  -99                   ,Reach 2                  Reach  - Route running h'graph
downstream
3                              ,                   Store running hydrograph
1, 1, 6.030,  -99                   ,Reach 3 node 4              Sub-area B, Reach  -
Generate rainfall excess h'graph and route downstream
4                              ,                   Add running h'graph to last stored h'graph
3                              ,                   Store running hydrograph
1, 1, 6.000,  -99                   ,Reach 4 node 5              Sub-area C, Reach  -
Generate rainfall excess h'graph and route downstream
4                              ,                   Add running h'graph to last stored h'graph
5, 1, 2.880,  -99                   ,Reach 5                  Reach  - Route running h'graph
downstream
3                              ,                   Store running hydrograph
1, 1, 4.360,  -99                   ,Reach 6 node 7              Sub-area D, Reach  -
Generate rainfall excess h'graph and route downstream
4                              ,                   Add running h'graph to last stored h'graph
5, 1, 1.990,  -99                   ,Reach 7                  Reach  - Route running h'graph
downstream
3                              ,                   Store running hydrograph
1, 1, 4.280,  -99                   ,Reach 8 node 9              Sub-area E, Reach  -
Generate rainfall excess h'graph and route downstream
4                              ,                   Add running h'graph to last stored h'graph
5, 1, 2.630,  -99                   ,Reach 9                  Reach  - Route running h'graph
downstream
3                              ,                   Store running hydrograph
1, 1, 7.870,  -99                   ,Reach 10 node 11             Sub-area F, Reach  -
Generate rainfall excess h'graph and route downstream
4                              ,                   Add running h'graph to last stored h'graph
5, 1, 1.690,  -99                   ,Reach 11                  Reach  - Route running h'graph
downstream
2, 1, 1.180,  -99                   ,Reach 12 node 12             Sub-area G, Reach  -
Generate rainfall excess h'graph, add to running h'graph, and route downstream
7
1                             ,                   PRINT
5, 1, 2.100,  -99                   ,Reach 13                  Reach  - Route running h'graph
downstream
3                              ,                   Store running hydrograph
1, 2, 3.900, .100,  -99              ,Reach 14 node 15             Sub-area H, Reach  -
Generate rainfall excess h'graph and route downstream
4                              ,                   Add running h'graph to last stored h'graph
5, 1, .560,  -99                   ,Reach 15                  Reach  - Route running h'graph
downstream
7
Fitzroy
3
C Trib of Fitzroy Creek
C Created August 2008, JLR, Cardno Lawson Treloar, Melbourne
```

```
C The Control Vector
1,1,3.042,-99,          Gen H'graph from Sub-area A
3,                      Store H'graph
1,1,2.888,-99,          Gen H'graph from Sub-area B
4,                      Add running H'graph
5,1,2.298,-99,          Route H'graph from A1_C
2,1,5.658,-99,          Gen H'graph from Sub-area C
2,1,3.822,-99,          Gen H'graph from Sub-area D
7
trib
4
7
total
0
C Sub areas A-G are predominately natural reaches. Sub-area H is predominately open
earthern drain
  39.380,   39.110,   36.890,   40.090,   22.360,
  42.150,   21.960,   17.370,     13.16,     20.39,
  22.2,      25.25,
 -99
C Impervious Fraction Data
0,  -99                        ,No impervious areas in system
```

APPENDIX B

RORB Results Files

Portland 100-yr

RORBWin Batch Run Summary
****

Program version 6.00 (last updated 17th December 2007)
Copyright Monash University and Sinclair Knight Merz

Date run: 21 Oct 2008 13:59

Catchment file : Z:\Jobs\LJ5580_Glenelg_FS\Hydrology\RORB_portland.cat
Rainfall location: Portland
Temporal pattern : AR&R87 Volume 2 for zone 6 (filtered)
Spatial pattern : Uniform
Areal Red. Fact. : Based on ARR87 Bk II, Figs 1.6 and 1.7
Loss factors : Constant with ARI

Parameters: kc = 12.50 m = 0.80

Loss parameters	Initial loss (mm)	Cont. loss (mm/h)
	20.00	2.00

Peak	Description
01	Calculated hydrograph, A
02	Calculated hydrograph, B
03	Calculated hydrograph, A-B
04	Calculated hydrograph, C
05	Calculated hydrograph, D
06	Calculated hydrograph, C-D
07	Calculated hydrograph, A-D
08	Calculated hydrograph, E
09	Calculated hydrograph, A-E
10	Calculated hydrograph, G
11	Calculated hydrograph, F
12	Calculated hydrograph, A-G
13	Calculated hydrograph, K
14	Calculated hydrograph, J

15 Calculated hydrograph, Wattlehill
16 Calculated hydrograph, H
17 Calculated hydrograph, L
18 Calculated hydrograph, I
19 Calculated hydrograph, Finn Creek
20 Calculated hydrograph, Portland

Run	Dur	ARI	Rain(mm)	ARF	Peak01	Peak02	Peak03	Peak04	Peak05	Peak06	Peak07	Peak08	Peak09	Peak10	Peak11	Peak12	Peak13	Peak14	Peak15	Peak16	Peak17	Peak18	Peak19	Peak20
1	1h	100y	31.02	0.83	11.2314	23.4060	24.2594	12.9414	6.0848	10.1808	15.8954	12.6996	16.3608	4.8666	21.9599	22.8412	21.9302	18.3035	22.1191	7.1974	6.1239	3.1450	9.7577	18.1733
2	1.5h	100y	35.76	0.86	19.3525	34.0844	38.1215	22.2522	10.8590	20.6608	32.4400	21.5715	33.4846	8.4233	32.4850	36.5003	34.7038	30.0919	44.7282	11.0883	9.4487	5.3434	16.5001	37.2263
3	2h	100y	39.39	0.89	23.9083	38.7806	45.5547	27.4543	13.7749	29.9532	47.6176	26.4137	49.4587	10.4357	37.1340	44.3392	41.0832	36.1444	64.1489	12.8625	10.9790	6.5438	20.3192	55.1219
4	3h	100y	45.02	0.92	26.3416	38.2901	48.8670	30.1668	15.8406	38.9569	66.4174	28.5791	70.8775	11.5606	36.8791	60.1950	42.1110	38.1449	83.9569	12.9682	11.0744	7.0824	22.5975	80.0692
5	4.5h	100y	51.39	0.93	27.9143	37.3297	52.4071	31.9710	16.7356	41.9039	75.8296	30.3353	86.0062	12.2443	36.2916	76.1848	43.6115	40.0973	95.8572	13.1379	11.2409	7.5174	23.9746	99.1972
6	6h	100y	56.46	0.94	29.1343	42.7917	55.0044	33.4228	17.5884	44.7437	80.6686	31.9803	94.1285	12.7440	41.4007	90.1135	48.0607	43.2277	105.718	14.7453	12.6022	7.9237	24.8324	113.000
7	9h	100y	64.52	0.95	29.7730	44.7245	55.9079	34.1478	17.6042	44.2375	79.5090	32.6313	89.4225	13.0295	42.5357	88.2782	48.6486	43.9099	103.559	14.8617	12.7053	8.0852	25.3912	110.640
8	12h	100y	70.95	0.95	24.4472	37.7386	45.9204	28.0453	14.2803	36.2907	67.7270	26.8296	80.1003	10.6939	35.8519	82.0570	40.1419	36.1895	100.187	12.2900	10.5053	6.6476	20.8254	106.078
9	18h	100y	84.24	0.96	19.2359	30.5524	37.1801	21.9846	12.0593	30.9796	52.0477	20.8614	58.0806	8.4932	29.2858	68.8824	32.5032	28.6265	91.2853	10.1805	8.6884	5.1682	16.8638	97.2392
10	24h	100y	94.95	0.96	19.0810	24.5559	35.9413	21.8244	11.7647	29.1945	55.5109	20.5331	68.1686	8.4005	23.5513	71.4827	28.3658	26.6059	88.2420	8.3955	7.1908	5.0891	16.6427	95.0824
11	30h	100y	103.93	0.96	11.5693	15.7626	22.4870	13.1863	7.6367	20.9967	40.1674	12.1651	50.6421	5.1325	15.2291	62.0399	17.7486	16.1204	79.8971	5.4211	4.6338	3.0162	10.5994	87.4322
12	36h	100y	111.62	0.97	14.3718	17.8574	28.0788	16.3828	9.4500	25.6005	46.9330	15.1163	58.4939	6.3741	17.2748	63.2164	20.3057	18.7797	77.5338	6.1758	5.2804	3.7479	13.1502	83.3012
13	48h	100y	124.19	0.97	12.3897	15.8341	23.7672	14.1739	7.6296	20.2277	40.5626	13.3543	47.0304	5.4525	15.4120	53.7903	18.7182	17.3997	67.6597	5.6017	4.7946	3.3097	10.8669	72.8114

Elapsed Run Time (hh:mm:ss) = 00:00:02

Portland 10 year

RORBWin Batch Run Summary

****

Program version 6.00 (last updated 17th December 2007)
Copyright Monash University and Sinclair Knight Merz

Date run: 21 Oct 2008 14:00

Catchment file : Z:\Jobs\LJ5580_Glenelg_FS\Hydrology\RORB_portland.cat
Rainfall location: Portland
Temporal pattern : AR&R87 Volume 2 for zone 6 (filtered)
Spatial pattern : Uniform
Areal Red. Fact. : Based on ARR87 Bk II, Figs 1.6 and 1.7
Loss factors : Constant with ARI

Parameters: kc = 12.50 m = 0.80

Loss parameters	Initial loss (mm)	Cont. loss (mm/h)
	20.00	2.00

Peak	Description
01	Calculated hydrograph, A
02	Calculated hydrograph, B
03	Calculated hydrograph, A-B
04	Calculated hydrograph, C
05	Calculated hydrograph, D
06	Calculated hydrograph, C-D
07	Calculated hydrograph, A-D
08	Calculated hydrograph, E
09	Calculated hydrograph, A-E
10	Calculated hydrograph, G
11	Calculated hydrograph, F
12	Calculated hydrograph, A-G
13	Calculated hydrograph, K
14	Calculated hydrograph, J

15 Calculated hydrograph, Wattlehill
16 Calculated hydrograph, H
17 Calculated hydrograph, L
18 Calculated hydrograph, I
19 Calculated hydrograph, Finn Creek
20 Calculated hydrograph, Portland

Run	Dur	ARI	Rain(mm)	ARF	Peak01	Peak02	Peak03	Peak04	Peak05	Peak06	Peak07	Peak08	Peak09	Peak10	Peak11	Peak12	Peak13	Peak14	Peak15	Peak16	Peak17	Peak18	Peak19	Peak20
1	1h	10y	20.10	0.83	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1.5h	10y	23.53	0.86	0.0448	0.1120	0.1123	0.0517	0.0234	0.0359	0.0563	0.0514	0.0572	0.0193	0.1038	0.1040	0.0958	0.0767	0.0777	0.0328	0.0278	0.0127	0.0407	0.0646
3	2h	10y	26.22	0.89	3.7736	7.9685	8.3264	4.3496	2.0340	3.3479	5.2277	4.2762	5.3827	1.6340	7.4961	7.8206	7.4678	6.1947	7.2735	2.4675	2.0986	1.0589	3.2957	5.9784
4	3h	10y	30.44	0.92	8.0890	13.6914	15.8064	9.3019	4.5663	9.6846	15.3683	8.9982	15.9033	3.5232	13.0212	15.2037	14.3253	12.4913	20.5647	4.5133	3.8507	2.2290	6.8894	17.7203
5	4.5h	10y	35.30	0.93	10.7408	15.8940	19.9781	12.3078	6.3987	14.8582	24.4393	11.6992	25.6851	4.7097	15.0294	21.5672	17.3921	15.6460	31.5928	5.3286	4.5545	2.8991	9.1856	28.8377
6	6h	10y	39.23	0.94	9.9600	14.9066	18.6568	11.4213	6.0383	15.3983	27.4661	10.8987	30.6571	4.3575	14.2620	26.6059	16.1537	14.6247	34.6605	4.9234	4.2089	2.7005	8.5318	35.0047
7	9h	10y	45.55	0.95	9.5163	14.9987	17.6986	10.9091	5.6304	13.6640	24.4079	10.3921	29.1966	4.1690	14.3654	30.4259	15.7777	13.8764	35.7604	4.9734	4.2430	2.5751	8.1226	37.3449
8	12h	10y	50.65	0.95	8.6050	11.4791	16.0999	9.8499	5.2379	13.4284	24.2313	9.3072	27.8114	3.7819	11.0225	28.7118	13.1071	12.1823	33.3603	3.9544	3.3813	2.3066	7.4280	34.9662
9	18h	10y	59.13	0.96	7.6616	11.3311	14.5732	8.7894	4.4777	11.0197	22.1503	8.4106	27.4692	3.3513	10.9506	30.3511	12.6579	11.3628	37.7348	3.8901	3.3243	2.0839	6.5485	40.0130
10	24h	10y	65.84	0.96	6.7558	8.8912	13.0446	7.7136	4.3100	11.1411	21.0414	7.1867	25.3519	2.9857	8.5435	27.2963	9.5803	9.1071	32.7308	2.9876	2.5506	1.7815	6.0268	34.8276
11	30h	10y	71.37	0.96	5.3735	6.5495	10.1560	6.1451	3.3265	8.2535	16.6675	5.7763	20.7922	2.3667	6.4057	23.1853	7.9617	7.4733	27.8187	2.3578	2.0195	1.4317	4.7039	30.0457
12	36h	10y	76.05	0.97	6.9230	8.8045	13.1929	7.9207	4.2527	10.0594	19.9727	7.4659	22.5049	3.0460	8.5782	21.3889	10.4621	9.7315	26.3841	3.1260	2.6759	1.8503	6.0514	27.5824
13	48h	10y	83.51	0.97	3.5973	4.8737	6.8748	4.1199	2.1701	5.3538	10.3249	3.9053	11.4877	1.5793	4.7287	11.6315	5.6289	5.1609	13.7154	1.7026	1.4563	0.9678	3.1195	14.9055

Elapsed Run Time (hh:mm:ss) = 00:00:03

Heywood 100-yr
RORBWin Batch Run Summary
****

Program version 6.00 (last updated 17th December 2007)
Copyright Monash University and Sinclair Knight Merz

Date run: 08 Aug 2008 11:42

Catchment file : Z:\Jobs\LJ5580_Glenelg_FS\Hydrology\FitzRiv_clt.catg
Rainfall location: Heywood
Temporal pattern : AR&R87 Volume 2 for zone 6 (filtered)
Spatial pattern : Uniform
Areal Red. Fact. : Based on Siriwardena and Weinmann formulation
Loss factors : Constant with ARI

Parameters: kc = 45.00 m = 0.80

Loss parameters	Initial loss (mm)	Cont. loss (mm/h)
	15.00	1.50

Peak	Description
01	Calculated hydrograph, 1
02	Calculated hydrograph, trib**
03	Calculated hydrograph, total

Run	Dur	ARI	Rain(mm)	ARF	Peak01	Peak02	Peak03
1	15m	100y	23.21	0.65	0.0748	0.0206	0.0321
2	20m	100y	26.05	0.67	4.4994	1.2719	2.7734
3	25m	100y	28.31	0.68	9.2099	2.6649	5.7680
4	30m	100y	30.16	0.69	13.6877	4.0455	8.7638
5	45m	100y	34.34	0.71	23.0942	7.3130	15.9837
6	1h	100y	37.33	0.72	28.3410	9.6796	21.4096
7	1.5h	100y	42.45	0.74	35.8632	14.0019	31.6680
8	2h	100y	46.32	0.75	37.2925	16.6837	38.6321
9	3h	100y	52.20	0.77	42.0193	20.4652	52.1935

10	**4.5h**	**100y**	**58.75**	**0.79**	**51.8112**	**23.6867**	**64.3798**
11	**6h**	**100y**	**63.91**	**0.81**	**60.6028**	**26.2919**	**75.4728**
12	**9h**	**100y**	**72.02**	**0.83**	**67.1701**	**26.8176**	**83.9390**
13	**12h**	**100y**	**78.42**	**0.84**	**70.4986**	**26.4717**	**88.7907**
14	**18h**	**100y**	**93.01**	**0.86**	**80.7620**	**29.6874**	**104.303**
15	**24h**	**100y**	**104.75**	**0.87**	**84.8715**	**29.8768**	**110.215**
16	**30h**	**100y**	**114.59**	**0.89**	**84.7021**	**30.5957**	**111.387**
17	**36h**	**100y**	**123.01**	**0.90**	**85.1291**	**30.7301**	**111.900**
18	**48h**	**100y**	**136.75**	**0.92**	**83.1486**	**30.5912**	**112.331**
19	**72h**	**100y**	**155.87**	**0.93**	**81.5309**	**27.3530**	**112.878**

Elapsed Run Time (hh:mm:ss) = 00:00:00

Heywood 10-yr

RORBWin Batch Run Summary
****

Program version 6.00 (last updated 17th December 2007)
Copyright Monash University and Sinclair Knight Merz

Date run: 08 Sep 2008 15:07

Catchment file : Z:\Jobs\LJ5580_Glenelg_FS\Hydrology\FitzRiv_clt.catg
Rainfall location: Heywood
Temporal pattern : AR&R87 Volume 2 for zone 6 (filtered)
Spatial pattern : Uniform
Areal Red. Fact. : Based on Siriwardena and Weinmann formulation
Loss factors : Constant with ARI

Parameters: kc = 45.00 m = 0.80

Loss parameters	Initial loss (mm)	Cont. loss (mm/h)
	15.00	1.50

Peak	Description
01	Calculated hydrograph, 1
02	Calculated hydrograph, trib
03	Calculated hydrograph, total

Run	Dur	ARI	Rain(mm)	ARF	Peak01	Peak02	Peak03
1	15m	10y	13.03	0.65	0.0000	0.0000	0.0000
2	20m	10y	14.80	0.67	0.0000	0.0000	0.0000
3	25m	10y	16.25	0.68	0.0000	0.0000	0.0000
4	30m	10y	17.45	0.69	0.0000	0.0000	0.0000
5	45m	10y	20.26	0.71	0.0000	0.0000	0.0000
6	1h	10y	22.35	0.72	1.3530	0.3856	0.8374
7	1.5h	10y	25.93	0.74	6.8011	2.1519	4.7107
8	2h	10y	28.70	0.75	10.2136	3.6519	8.1120

9	3h	10y	33.02	0.77	13.5469	5.7829	13.4495
10	4.5h	10y	37.94	0.79	16.3499	8.1524	19.4961
11	6h	10y	41.88	0.81	20.2288	9.3758	25.1693
12	9h	10y	48.17	0.83	23.9825	10.2480	29.8976
13	12h	10y	53.22	0.84	25.8575	10.0368	32.5653
14	18h	10y	61.75	0.86	27.8242	10.6681	34.9405
15	24h	10y	68.46	0.88	26.8415	10.3777	33.6446
16	30h	10y	73.96	0.90	25.7039	9.5572	33.4257
17	36h	10y	78.57	0.91	24.0788	9.2526	30.2961
18	48h	10y	85.87	0.93	22.5214	8.4693	28.8073
19	72h	10y	95.39	0.94	17.1206	5.8012	22.1056

Elapsed Run Time (hh:mm:ss) = 00:00:00

APPENDIX C

Defining the Floodway - Can One Size Fit All?