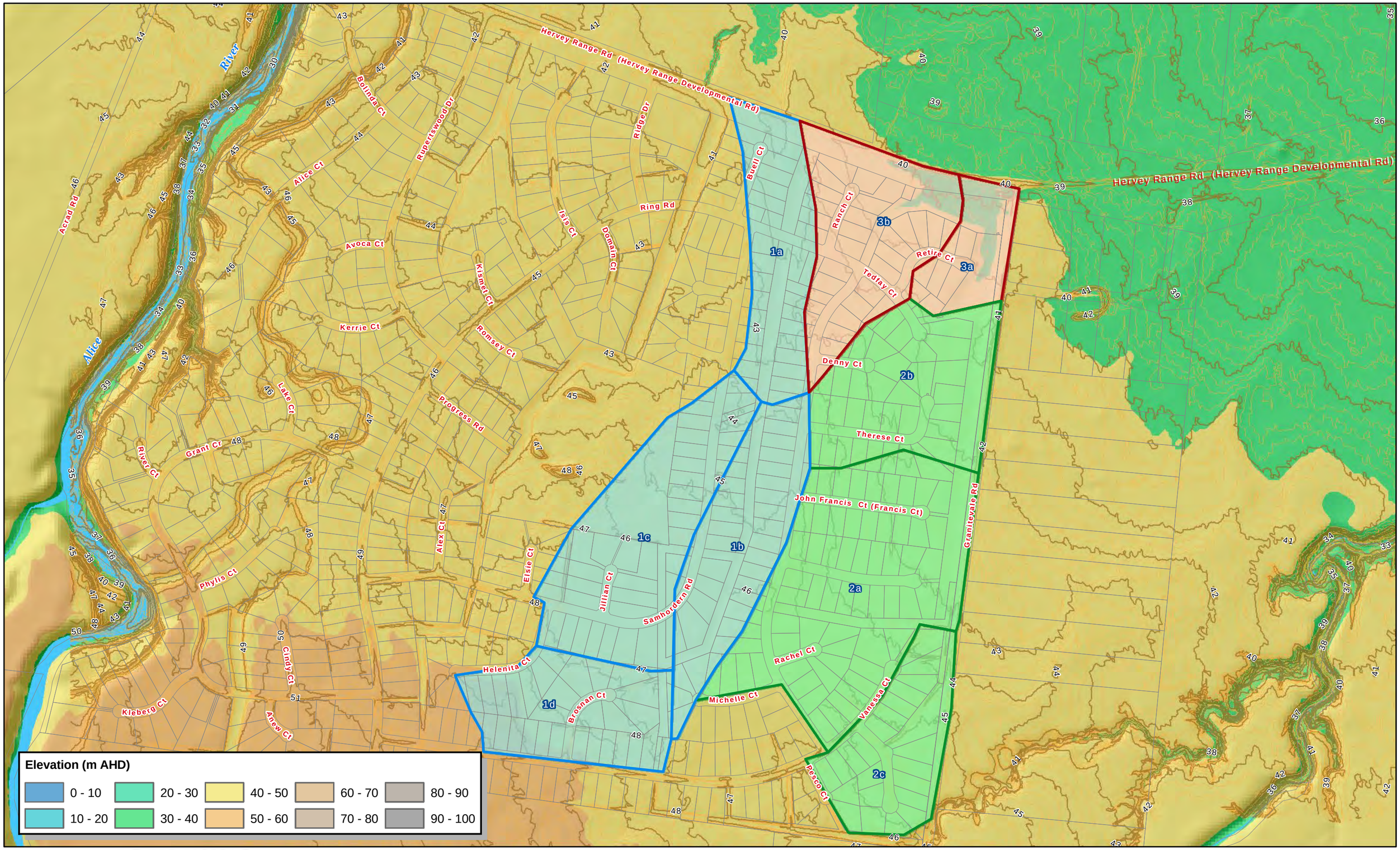

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(when printed at A3)

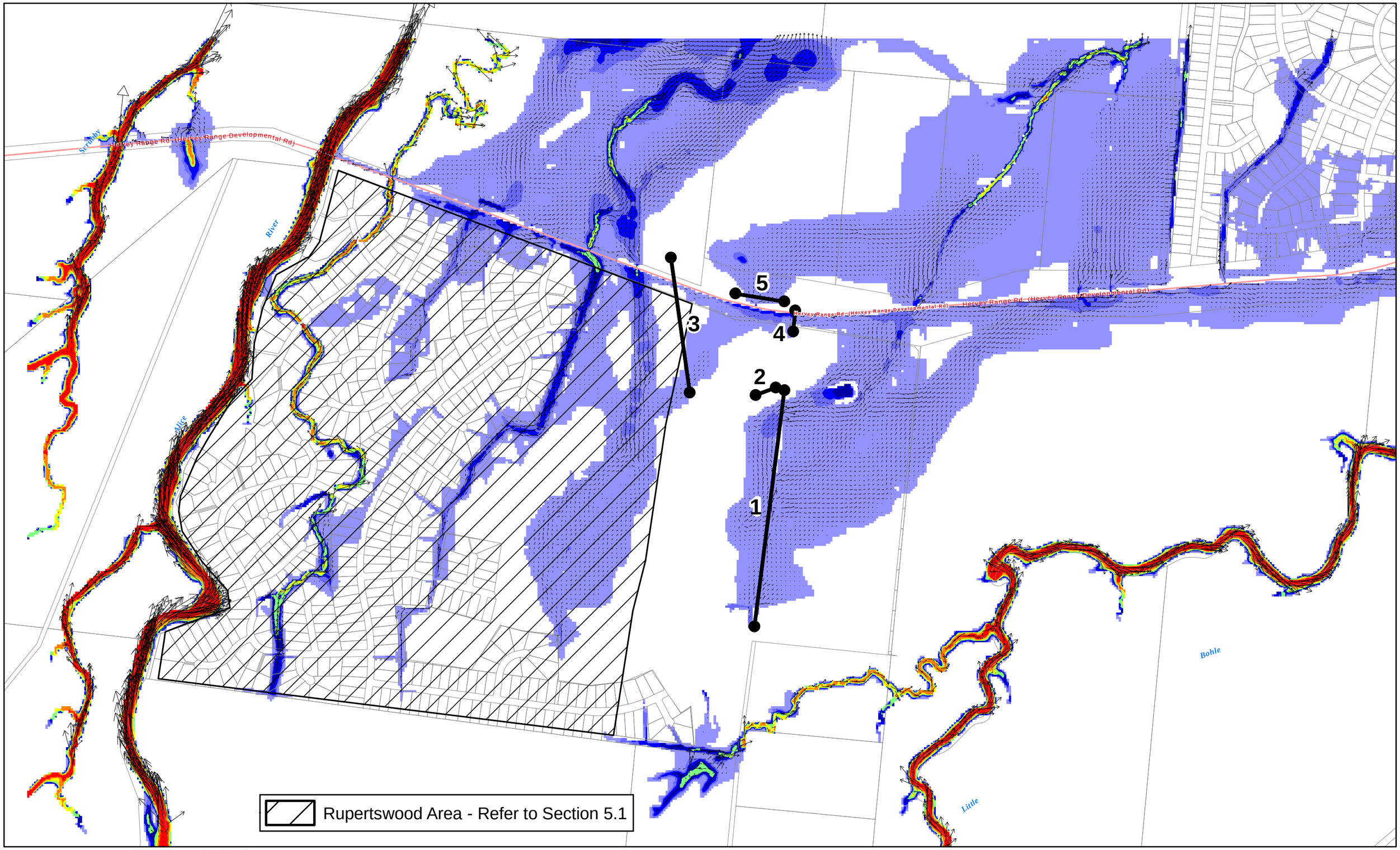
0 50 100 200 300 400 500 Metres

Legend

- Contours (1m)
- Contours (0.25m)
- Undeveloped Catchment 1
- Undeveloped Catchment 2
- Undeveloped Catchment 3

LITTLE BOHLE FLOOD MODEL
Pre-Existing Topography

Figure 27



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Scale: 1:15,000
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0 50 100 200 300 400 500 Metres

Water Depths (m)

0 - 0.3	0.5 - 0.75	1 - 1.5	2 - 3
0.3 - 0.5	0.75 - 1	1.5 - 2	> 3

Legend

Main Road
Minor Road
Watercourse
Discharge Section
Property Boundary

LITTLE BOHLE FLOOD MODEL
50 year ARI 24 Hour Duration Event
Pre-Existing Scenario

Figure 28

6.3 Weir Scenario

The 50 year critical duration event has been modelled for this scenario to determine the flow regime within the eastern portion of Rupertswood with the development as it was constructed before the development of Kens Court. The aim of this scenario is to assess the function of the Granitevale Road drain and detention basin with the check dam constructed and Rupertswood fully developed.

Generally the Granitevale Road drain collects runoff from the southern extent of the catchment and drains north to the detention basin. The check dam is located within the Granitevale Road drain at the southern extent of the detention basin. The elevation of Granitevale Road adjacent to this structure is approximately 4.18m AHD. This dam has been designed to ensure the water level backs up behind this structure and flow is diverted east over Granitevale Road as occurs in the undeveloped scenario.

A figure showing flood depth and velocity vectors near the peak of the flood is shown in **Figure 29**. Discharge hydrographs have been extracted at various locations to determine the flow regime. The location of these discharge calculation sections is also shown in **Figure 29**.

Table 29 shows the peak flow rates through each discharge section for the 50 year ARI event and details the changes in peak flow through the various sections from the pre-existing scenario.

Table 29 Peak Flows through discharge locations

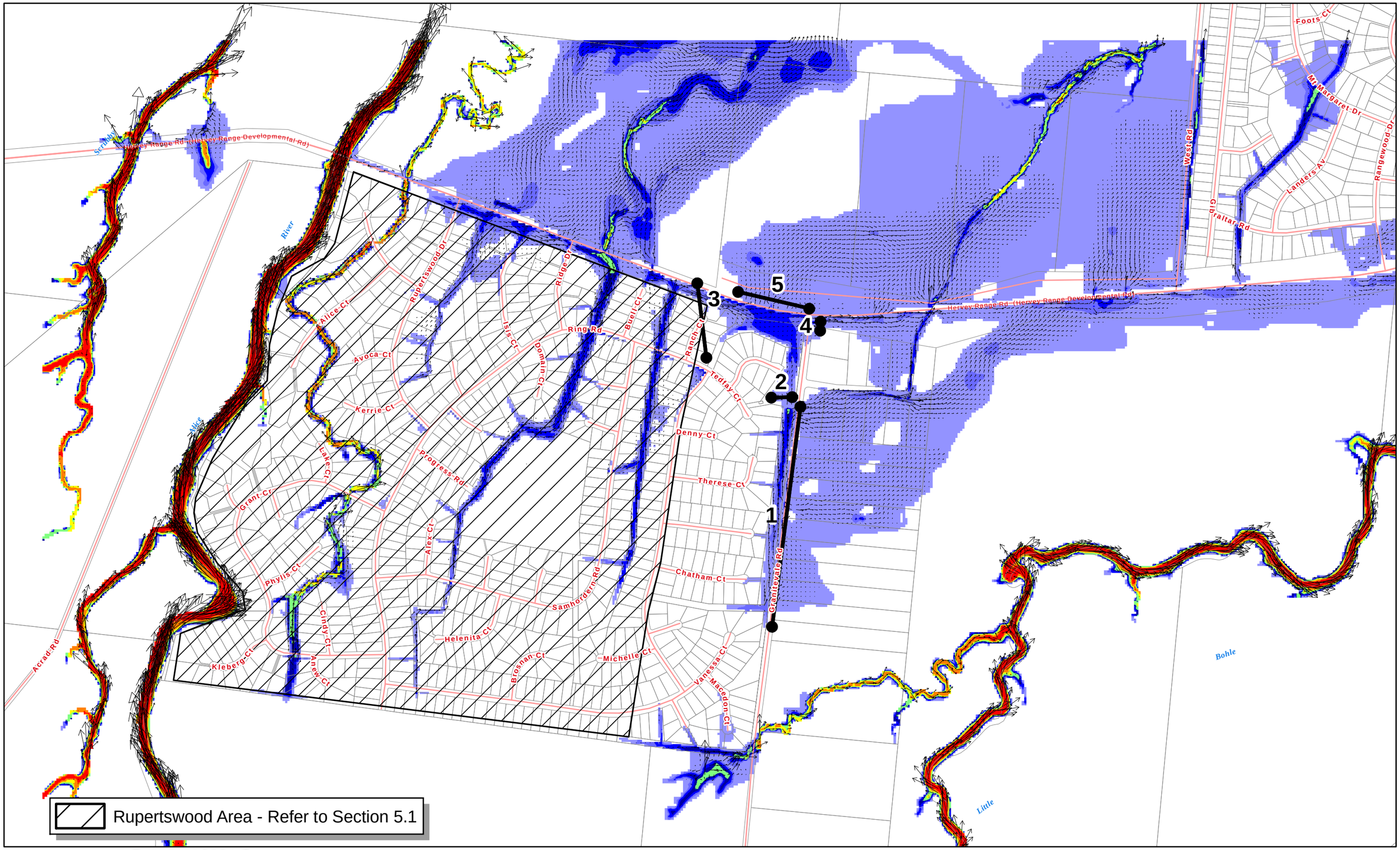
Section	Pre-Existing Scenario (m^3/s)	Weir Scenario (m^3/s)	Difference(m^3/s)
1	10.4	10.2	-0.2
2	0	2.4	2.4
3	0.4	9.4	9
4	3.8	8.4	4.6
5	2.6	4.6	2

This table indicates that increases in peak flows into the detention basin occur from the west through Section 3**.** This flow can be clearly seen by the velocity vectors shown in **Figure 29**. This catchment previously overflowed into the main Rupertswood drainage channel however due to urbanisation this flow is increased and a majority of this flow is directed into the detention basin. This increase in peak flow into the detention basin is approximately 9 m^3/s. Due to urbanisation of the catchment area, the peak flow from the south has also increased by 2.4 m^3/s.

The results indicate the detention basin does not adequately mitigate these increases in inflows and as a result the outflows from the detention basin to the north over Hervey Range are increased by 2 m^3/s, while the flow out of the detention basin to the east over Granitevale Road, is increased by 4.6 m^3/s.

Figure 30 shows the change in flood depth from the pre-existing undeveloped case for the 50 year ARI event. This figure shows the impact of the increased flow over Hervey Range Road with maximum flood levels to the north increased by between 50 and 100mm over a significant area. There are also some areas where the flood level has increased by up to 140mm. Hervey Range Road is also significantly inundated during this event. The decrease in flow over Granitevale Road has generally decreased the maximum flood levels on properties to the east of the roadway.

Figure 31 shows the change in flood level for the 5 year ARI critical duration event. These results indicate that flood levels are increased by up to 0.05m on properties north of Rupertswood and up to 0.1m on the properties to the northeast of Rupertswood.



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Water Depths (m)

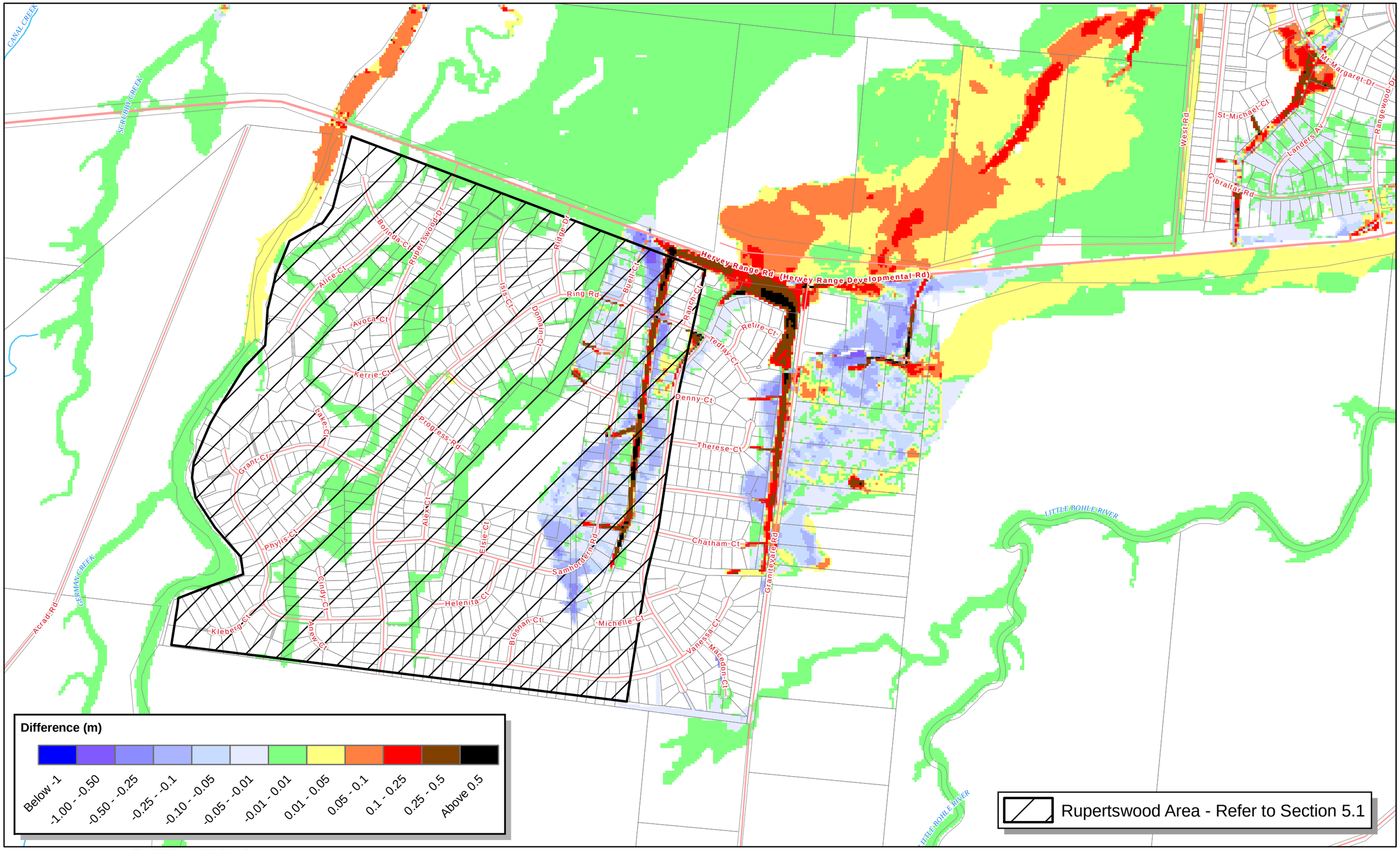
0 - 0.3	0.5 - 0.75	1 - 1.5	2 - 3
0.3 - 0.5	0.75 - 1	1.5 - 2	> 3

Legend

Main Road
Minor Road
Watercourse
Discharge Section
Property Boundary

LITTLE BOHLE FLOOD MODEL
50 year ARI 24 Hour Duration Event
Weir Scenario

Figure 29



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Scale: 1:15,000
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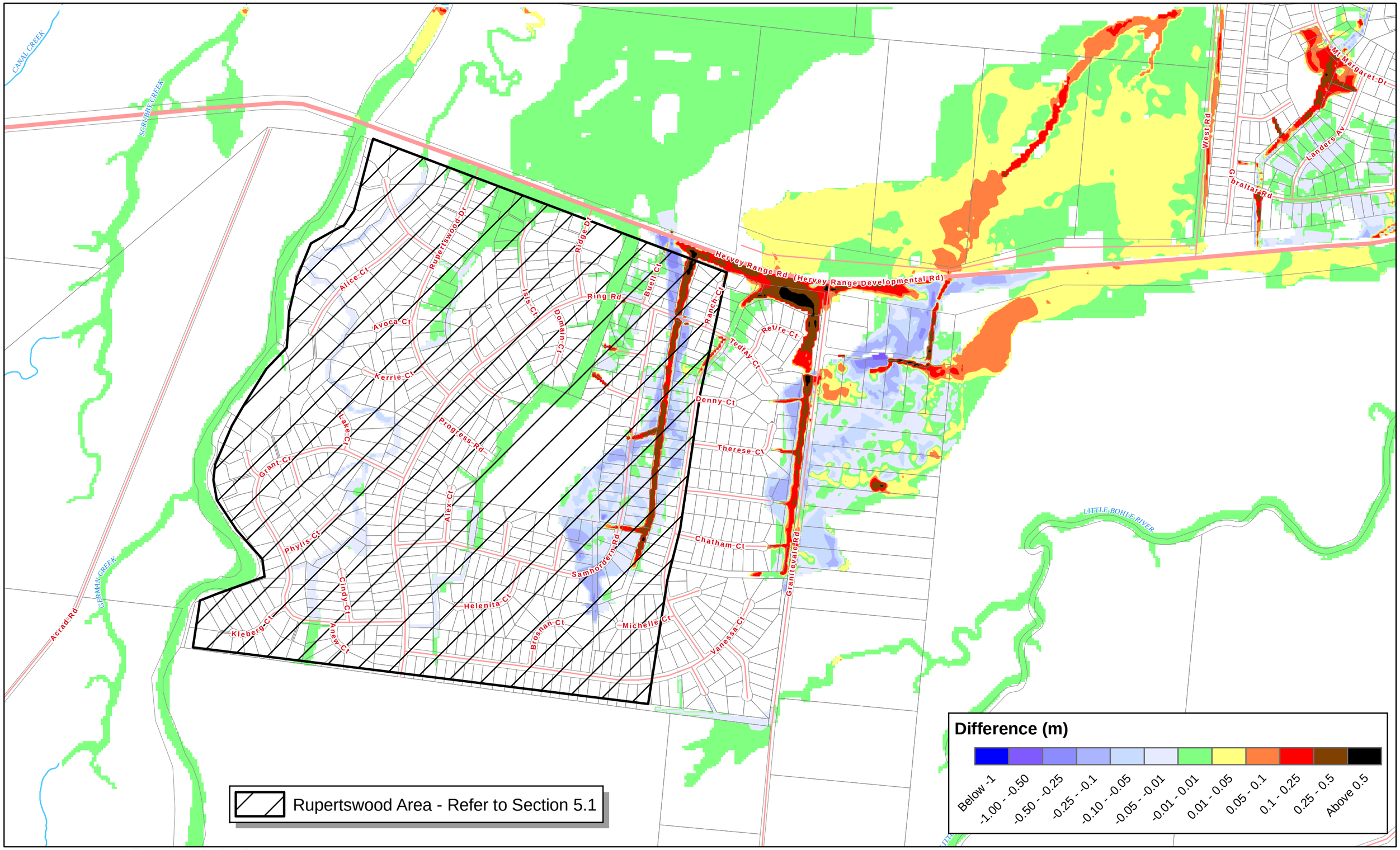
0 50 100 200 300 400 500 Metres

Legend

Main Road
Minor Road
Watercourse
Property Boundary

LITTLE BOHLE FLOOD MODEL
50 year ARI 24 Hour Duration Event
Change in Flood Level
Weir - Pre-existing Scenario

Figure 30



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0 50 100 200 300 400 500 Metres

Legend

Main Road
Minor Road
Watercourse
Property Boundary

LITTLE BOHLE FLOOD MODEL
5 year ARI 24 Hour Duration Event
Change in Flood Level
Weir - Pre-existing Scenario

Figure 31

6.4 Existing Scenario

The existing scenario represents the current configuration of the site and includes a number of changes that were constructed as part of the Kens Court development. The check dam in the Granitevale Road drain has been removed and 5 / 1200 x 600 RCBC's have been installed beneath Granitevale Road immediately to the south of the Hervey Range Road intersection. The northern section of Granitevale Road has also been raised by varying amounts however the road is raised by up to 320mm adjacent to the check dam location.

Figure 32 shows the maximum flood level for the 50 year 24 hour event for the existing scenario and also shows discharge sections where peak discharges have been extracted.

Table 30 summarises the peak flow rates through each discharge section for the 50 year ARI event and details the changes in peak flow through the various sections from the pre-existing scenario.

Table 30 Peak Flows through discharge locations

Section	Pre-Existing Scenario (m^3/s)	Existing Scenario (m^3/s)	Difference(m^3/s)
1	10.4	1.2	-9.2
2	0	12.5	12.5
3	0.4	9.4	9
4	3.8	10.1	6.3
5	2.6	16.4	13.8

This table indicates that the increases in peak flows into the detention basin from the west remains the same as the weir scenario and is 9 m^3/s greater than pre-existing.

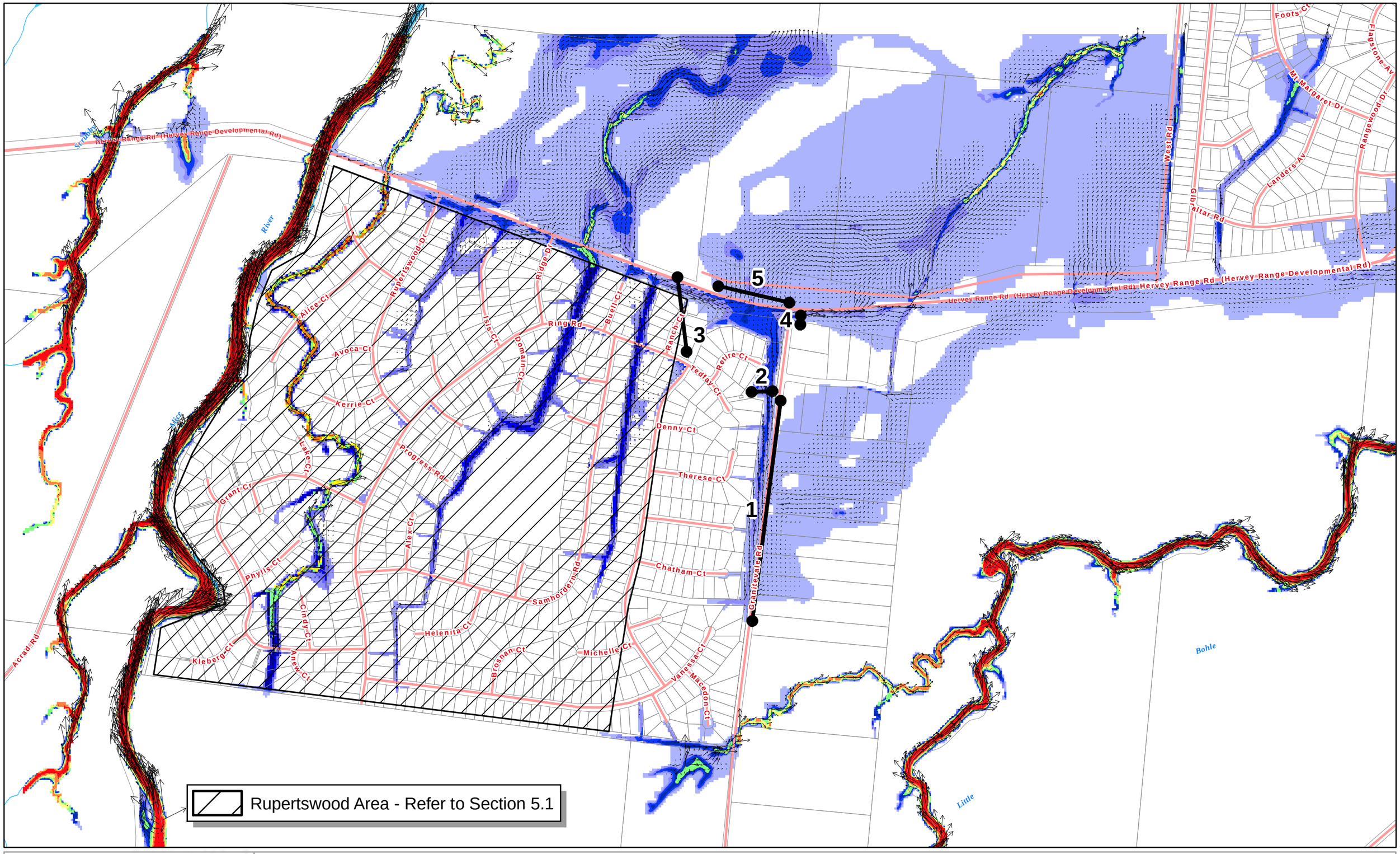
Removing the check dam increases the flow into the detention basin from the south by 12.5 m^3/s. The capacity of the culvert installed under Granitevale Road cannot accommodate this increase and consequently the flow north over Hervey Range is again increased. The final peak flow over Hervey Range Road of 16.4 m^3/s is more than 6 times the pre-existing flow.

The outflow from the detention basin east over Granitevale Road is also increased by 6.3m^3/s.

There is a significant reduction of 9.2 m^3/s in peak flow across Granitevale Road south of Kens Court.

The changes to the flow regime within this area impacts the flood levels and **Figure 33** shows the change in flood level between the existing and pre-existing scenarios. This figure shows the increase in flow across Hervey Range Road has increased maximum flood levels by up to 250mm north of Hervey Range Road from the pre-existing undeveloped scenario. It also shows the reduction in flood levels east of Granitevale Road due to the reduction in flows across Granitevale Road south of Kens Court.

Figure 31 shows the change in flood level from the pre-existing to the existing scenario for the 5 year ARI critical duration event. Flood levels are generally increased by up to 0.1m north of Hervey Range Road, with some areas experiencing increases up to 0.15m.



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0 50 100 200 300 400 500 Metres

Water Depths (m)

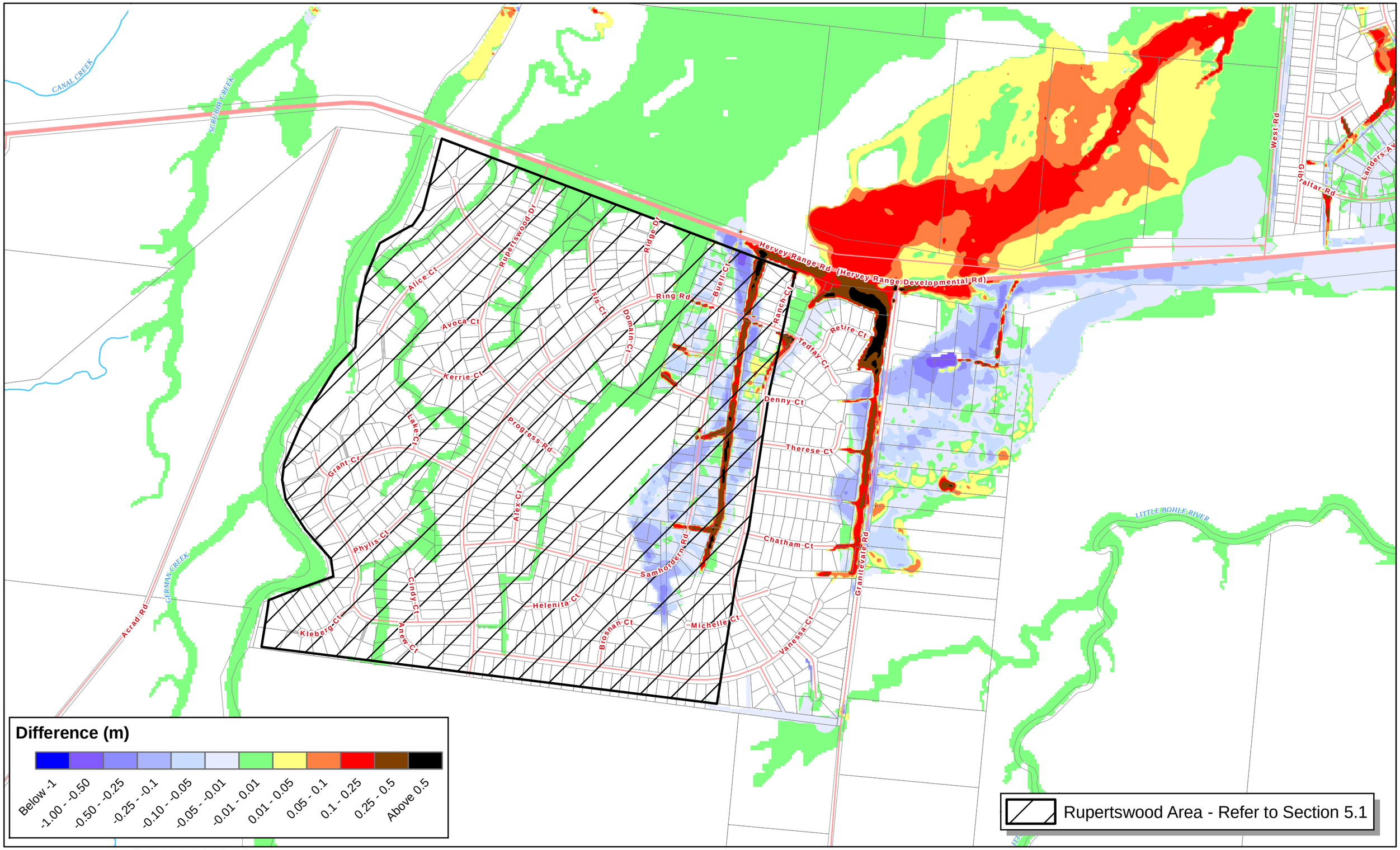
0 - 0.3	0.75 - 1	2 - 3
0.3 - 0.5	1 - 1.5	> 3
0.5 - 0.75	1.5 - 2	

Legend

Main Road
Minor Road
Watercourse
Discharge Section
Property Boundary

LITTLE BOHLE FLOOD MODEL
50 year ARI 24 Hour Duration Event
Existing Scenario

Figure 32



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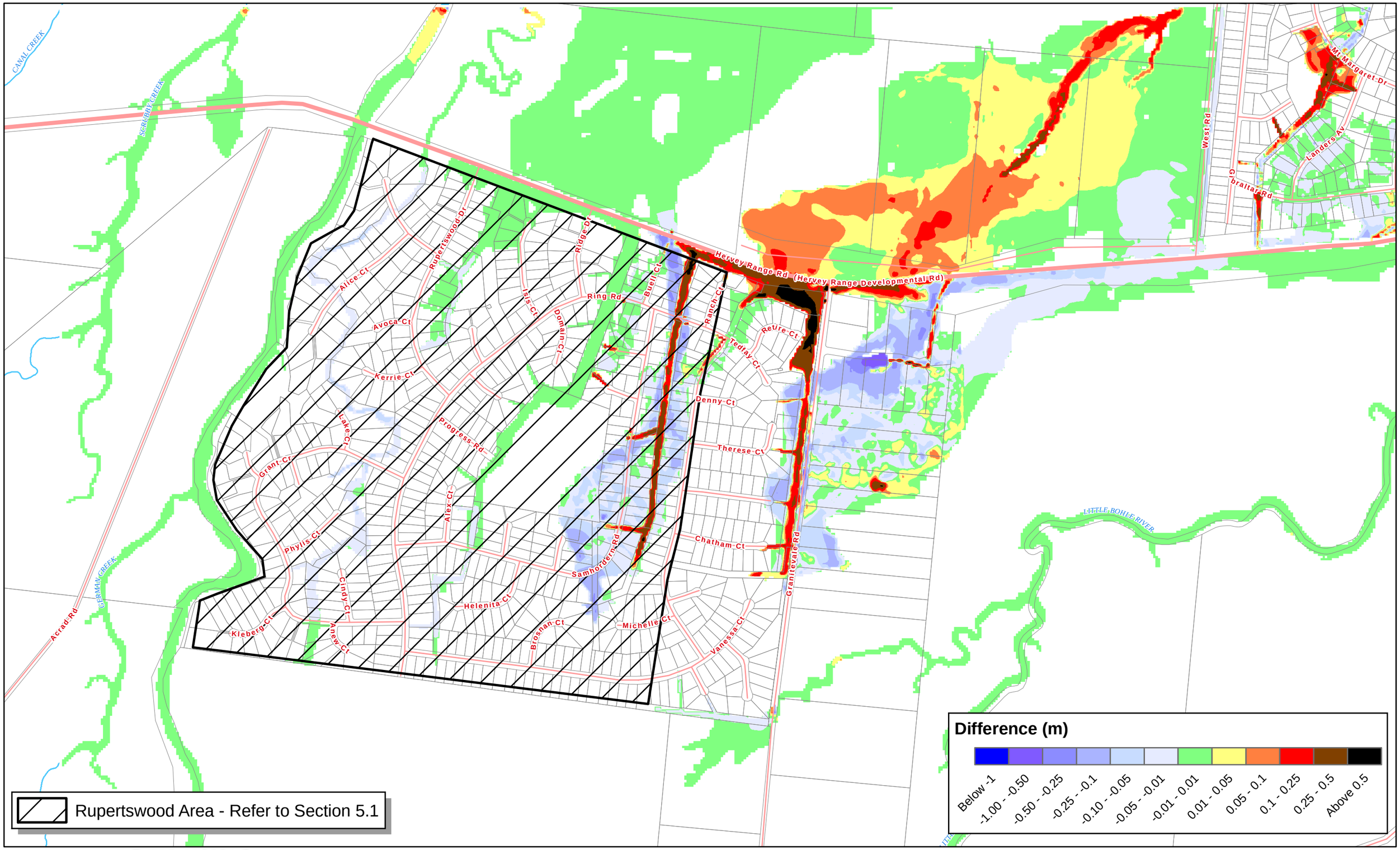
0 50 100 200 300 400 500 Metres

Legend

Main Road
Minor Road
Watercourse
Property Boundary

LITTLE BOHLE FLOOD MODEL
50 year ARI 24 Hour Duration Event
Change in Flood Level
Existing - Pre-existing Scenario

Figure 33



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Scale: 1:15,000
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0 50 100 200 300 400 500 Metres

Legend

Main Road
Minor Road
Watercourse
Property Boundary

LITTLE BOHLE FLOOD MODEL
5 year ARI 24 Hour Duration Event
Change in Flood Level
Existing - Pre-existing Scenario

Figure 34

7.0 Summary and Conclusions

Hydrologic and hydraulic models of the Little Bohle and surrounding catchment areas have been developed using the latest LiDAR topographic data.

A hydrologic model of the Black, Saunders and Stony Creek catchments have been updated from those developed for the *BPFPS*.

A MIKEFLOOD model of the Little Bohle River area extending past Rupertswood in the west and including Black and Alice River has been developed.

The 2, 5, 10, 20, 50, 100 year ARI and Probable Maximum Precipitation (PMP) critical duration events have been modelled to determine base line flood flows for the Little Bohle River and upstream sections of Stone Creek, Saunders Creek and Black River. Maximum flood envelopes have been developed for the 50 and 100 year ARI events for a range of durations.

There are rural and rural residential properties located within the study area and the flooding impacts for each of the modelled events are described. There are rural and rural residential properties located within the study area and the flooding impacts for each of the modelled events are described.

2 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road;
- 15 properties are affected by overland flow east of Granitevale Road. Flood depths are less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.2m. Flood depths up to 2.5m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.3m. Flood depths up to 1.6m occur within the watercourses on the property.

5 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road;
- 15 properties are affected by overland flow east of Granitevale Road. Flood depths are less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.3m. Flood depths up to 2.8m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.4m. Flood depths up to 1.7m occur within the watercourses on the property;

10 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road;
- 15 properties are affected by overland flow east of Granitevale Road. Flood depths are less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.3m. Flood depths up to 2.8m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.4m. Flood depths up to 1.8m occur within the watercourses on the property.

20 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road. Results indicate existing buildings may be affected on 1 property;

- 15 properties are affected by overland flow east of Granitevale Road with flood depths less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.4m. Flood depths up to 2.9m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.5m. Flood depths up to 1.9m occur within the watercourses on the property.

50 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road. Results indicate existing buildings may be affected on 2 properties;
- 15 properties are affected by overland flow east of Granitevale Road with flood depths up to 0.2m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.4m. Flood depths up to 3m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.6m. Flood depths up to 1.9m occur within the watercourses on the property.

100 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road. Results indicate existing buildings may be affected on 3 properties;
- 15 properties are affected by overland flow east of Granitevale Road with flood depths up to 0.2m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.4m. Flood depths up to 3m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.6m. Flood depths up to 2.0m occur within the watercourses on the property.

Granitevale Road Area

Using the MIKEFLOOD model developed for this study, historic contour data representing floodplain conditions in 2000, were used to develop a pre-existing model in order to assess the impacts of various development stages within the eastern section of Rupertswood. The 50 and 5 year 24 hour critical duration events have been modelled for the following scenarios (which are further detailed in the report), to assess these impacts:

- **Pre-existing Undeveloped Scenario -** The pre-existing scenario assuming the eastern portion of Rupertswood is not developed;
- **Weir Scenario** - This scenario represents the development prior to development of Kens Court; and
- **Existing Scenario** – This scenario represents the existing development including the changes to the drainage system to accommodate development of Kens Court.

The following table summarises the change in flow regime between the pre-existing scenario and the two development scenarios for the 50 year ARI event. The five sections represent locations where the peak flow rate has been determined as detailed in **Figure 29**. Section 1 represents the flow east over Granitevale Road. Section 2 and 3 represent the inflow to the detention basin from the south and west respectively, Sections 4 represents the flow out of the basin to the east and Section 5 represents the flow out of the detention basin and north over Hervey Range Road.

Section	Pre-Existing Scenario (m^3/s)	Weir Scenario (m^3/s)	Difference Weir – Pre-existing(m^3/s)	Existing Scenario (m^3/s)	Difference Existing – Pre-existing (m^3/s)
1	10.4	10.2	0.2	1.2	9.2
2	0	2.4	2.4	12.5	12.5
3	0.4	9.4	9	9.4	9
4	3.8	8.4	4.6	10.1	6.3
5	2.6	4.6	2	16.4	13.8

Assuming the development was constructed as detailed in the weir scenario, the table above shows that during the 50 year ARI event:

- the pre-existing flow over Granitevale Road is maintained however the increase in flow due to urbanisation results in an increase in peak flow of 2.4 m^3/s in Granitevale Road drain, over the check dam and north to the detention basin;
- peak flow from the catchment to the west is increased by 9 m^3/s. Previously this catchment overflowed into the main Rupertswood drainage channel however due to urbanisation the flow is increased and, a majority of this flow is directed into the detention basin;
- the detention basin does not adequately mitigate these increases in inflows and the flow north over Hervey Range Road is increased by 2 m^3/s while the flow east over Granitevale Road is increased by 4.6 m^3/s; and
- this increased flow over Hervey Range Road increases flood levels to the north by between 50 and 100mm over a significant area. With maximum flood level immediately north of Hervey Range Road increased by up to 140mm; and

Flood levels are increased by up to 0.1m north of Hervey Range Road during the 5 year ARI event.

With the existing development currently in place, the previous table shows that for the 50 year ARI existing scenario:

- the increases in peak flows into the detention basin from the west remains the same as the weir scenario and is 9 m^3/s greater than pre-existing;
- removing the check dam from Granitevale Road drain increases the flow from the south by 12.5 m^3/s and significantly reduces the flow across Granitevale Road, south of Kens Court;
- the capacity of the culvert installed under Granitevale Road cannot accommodate this increase and consequently the flow north over Hervey Range is again increased.
- the final peak flow over Hervey Range Road is 16.4 m^3/s, which is more than 6 times the pre-existing flow; and
- the changes to the flow regime has increased maximum flood levels by up to 0.25m north of Hervey Range Road compared to the pre-existing scenario for the 50 year ARI event;

Flood levels are increased by up to 0.15m north of Hervey Range Road during the 5 year ARI event.

7.1 Recommendations for Future Work

The results of the modelling indicate the flood levels and extents within Rupertswood are influenced by drainage features which are not represented in the model developed for this study. For this reason the flood model results within Rupertswood should not be relied upon and are considered indicative only. In order to provide accurate flood level and extent information, it is recommended that the model be refined in this area in the future. This refinement should include:

- Obtaining survey data for the drainage channels within the Rupertswood area and using this information to represent the drainage channels as one-dimensional elements within the hydraulic model;
- increasing the resolution of the two-dimensional component of the model to ensure all local drainage features can be represented; and
- Ensuring all culverts, drains and drainage paths that impact the flows within the development are represented in the model;

A sensitivity analysis of various model parameters was also undertaken to determine the sensitivity of flood levels to increases in model roughness parameters, the timing of flood peaks and downstream boundary conditions. This analysis indicates the maximum Bohle River flood levels are particularly sensitive to the timing of the Little Bohle River flows which can increase flood levels by more than 0.3m within the Bohle River.

Therefore it is recommended a more detailed analysis of the impacts of these timing effects should be undertaken as part of any future flood studies for the Bohle River.

8.0 References

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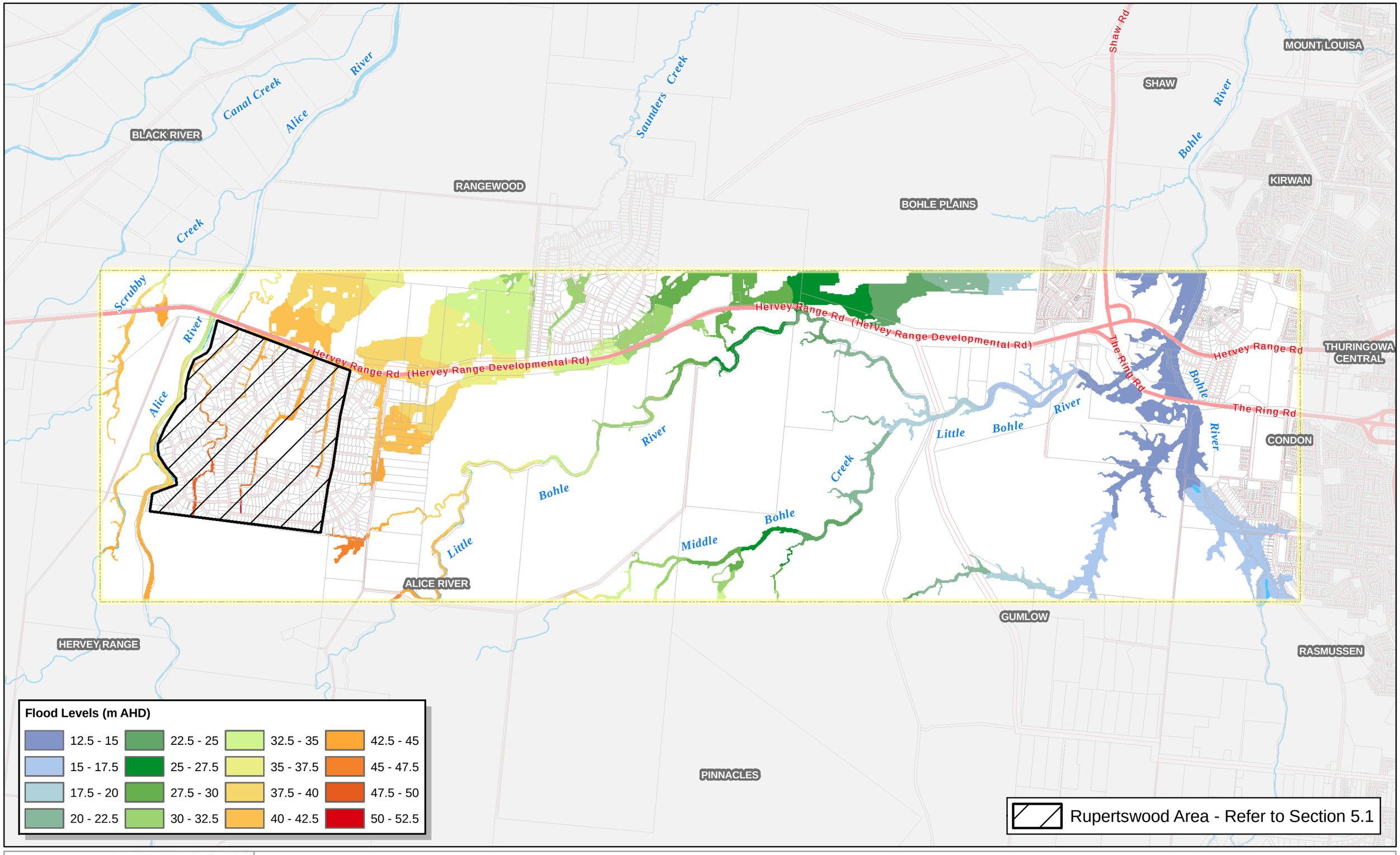
Willowbank Estate Stages 19 to 24 Operational Works Flood Assessment (2008) Maunsell AECOM

Appendix A

Flood Level, Depth and Velocity Maps



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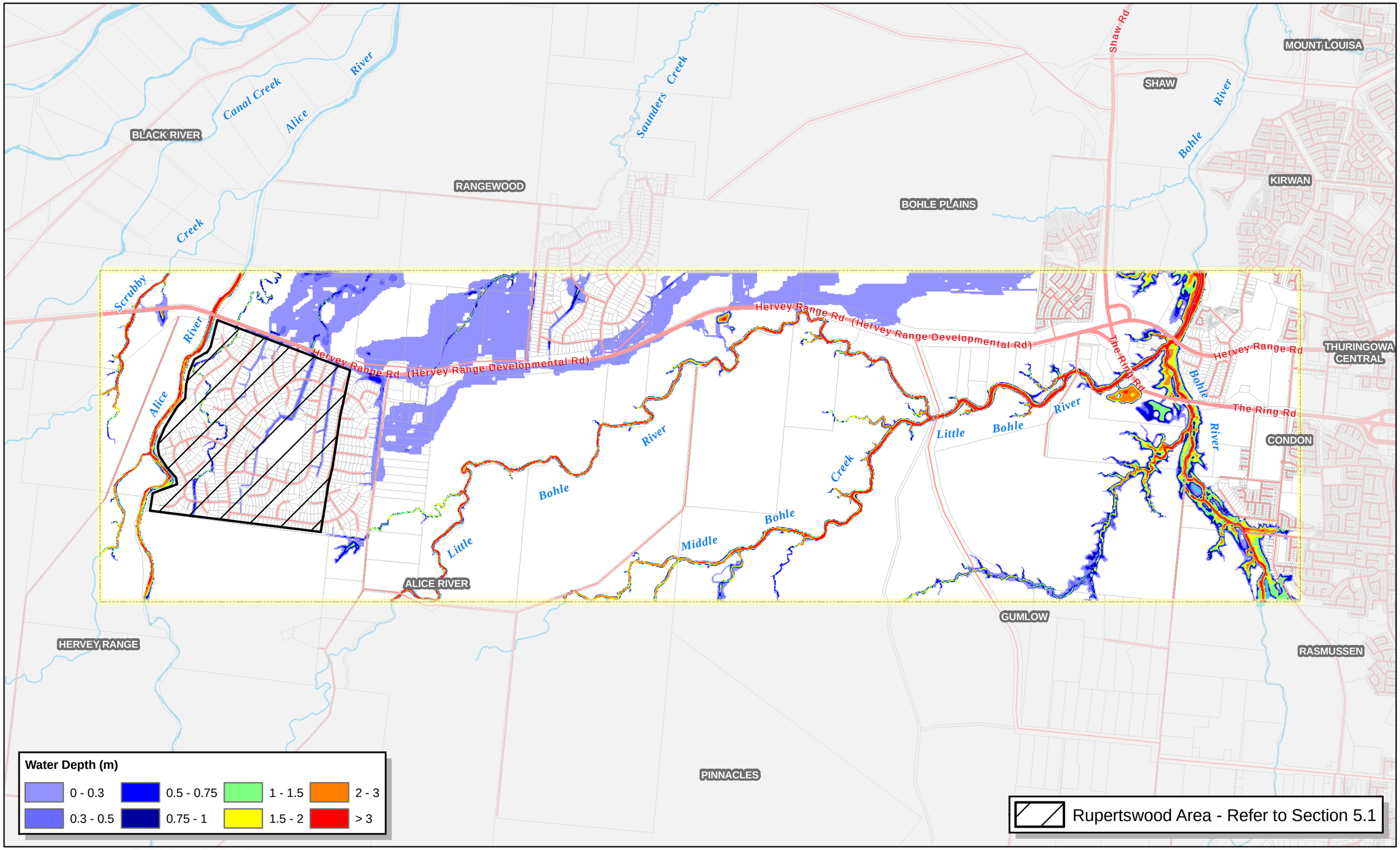
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Flood Level
2 year 24 hour event

Figure A1



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Scale: 1:40,000
(when printed at A3)

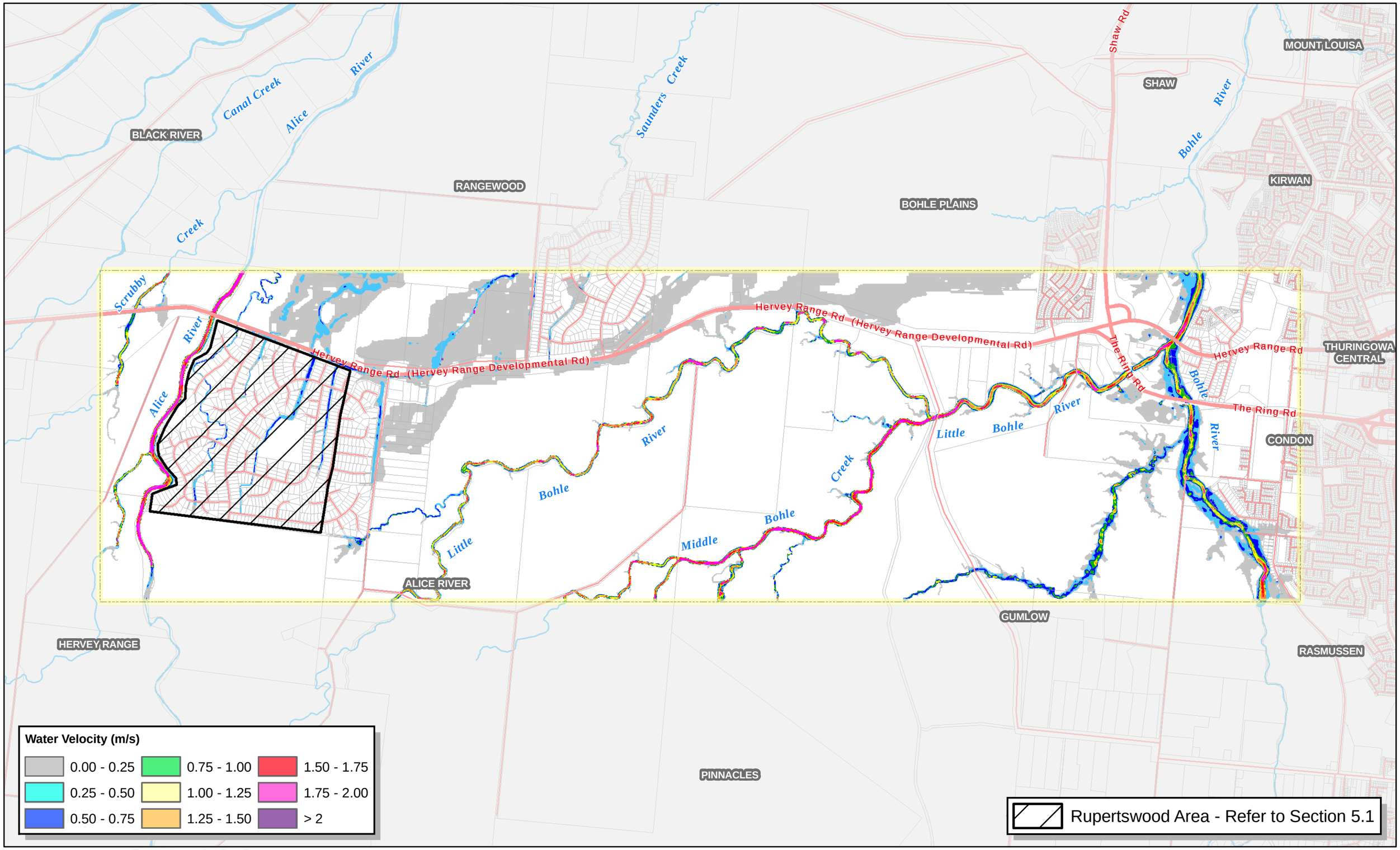
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Water Depth
2 year 24 hour event

Figure A2



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FILE NAME 60188958G_WR_18

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Scale: 1:40,000
(when printed at A3)

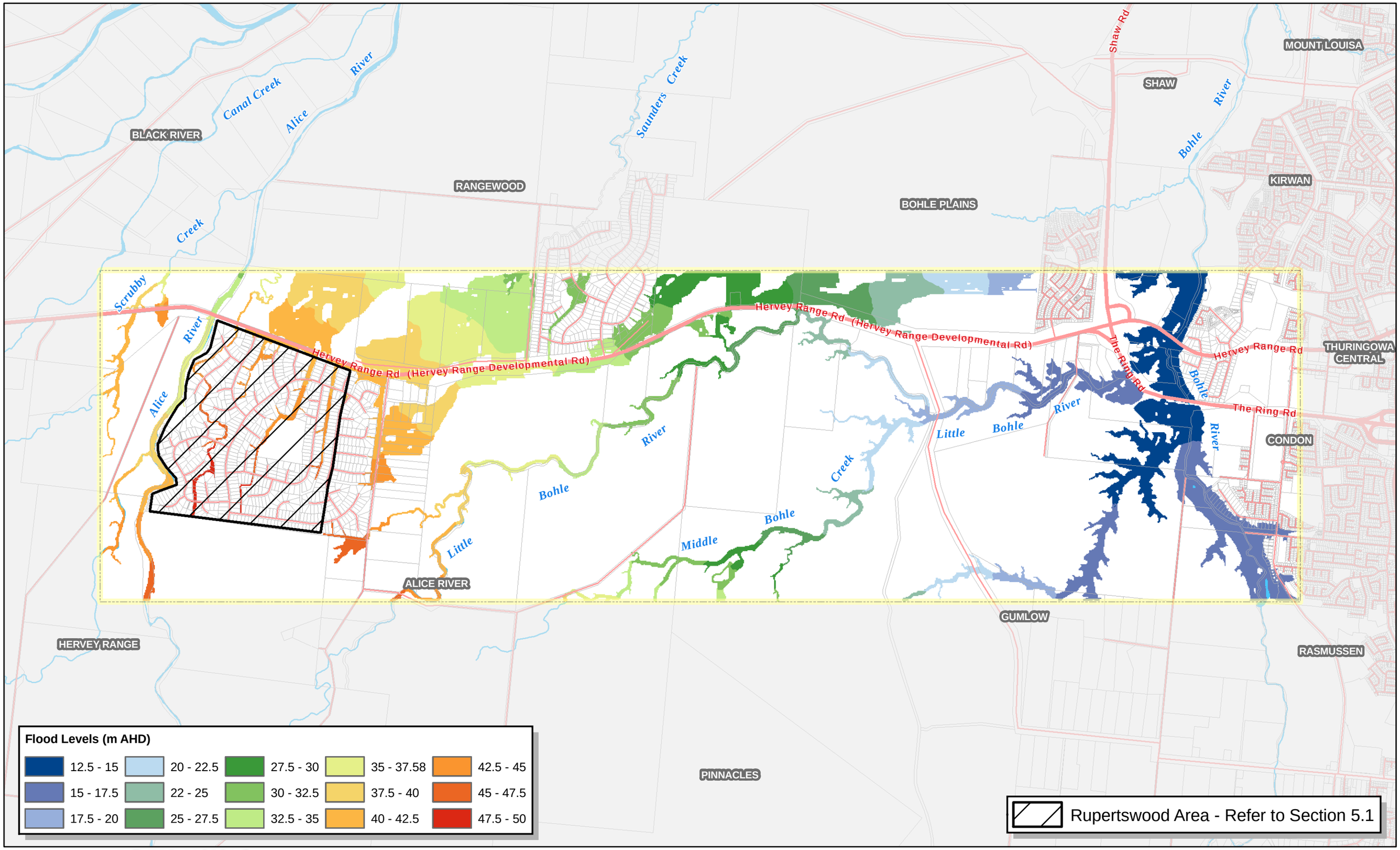
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Water Velocity
2 year 24 hour event

Figure A3



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Scale: 1:40,000
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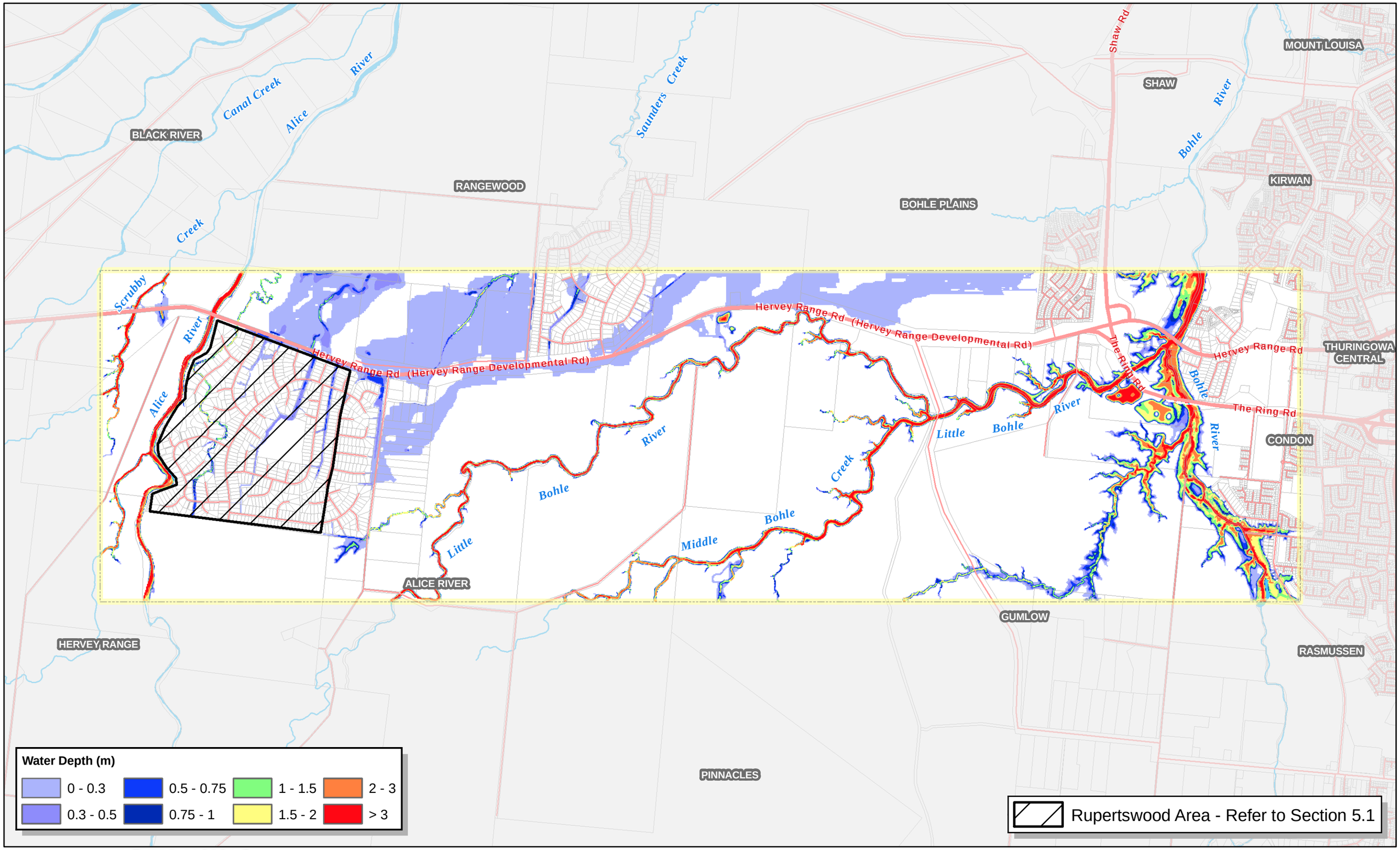
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Flood Level
5 year 24 hour event

Figure A4



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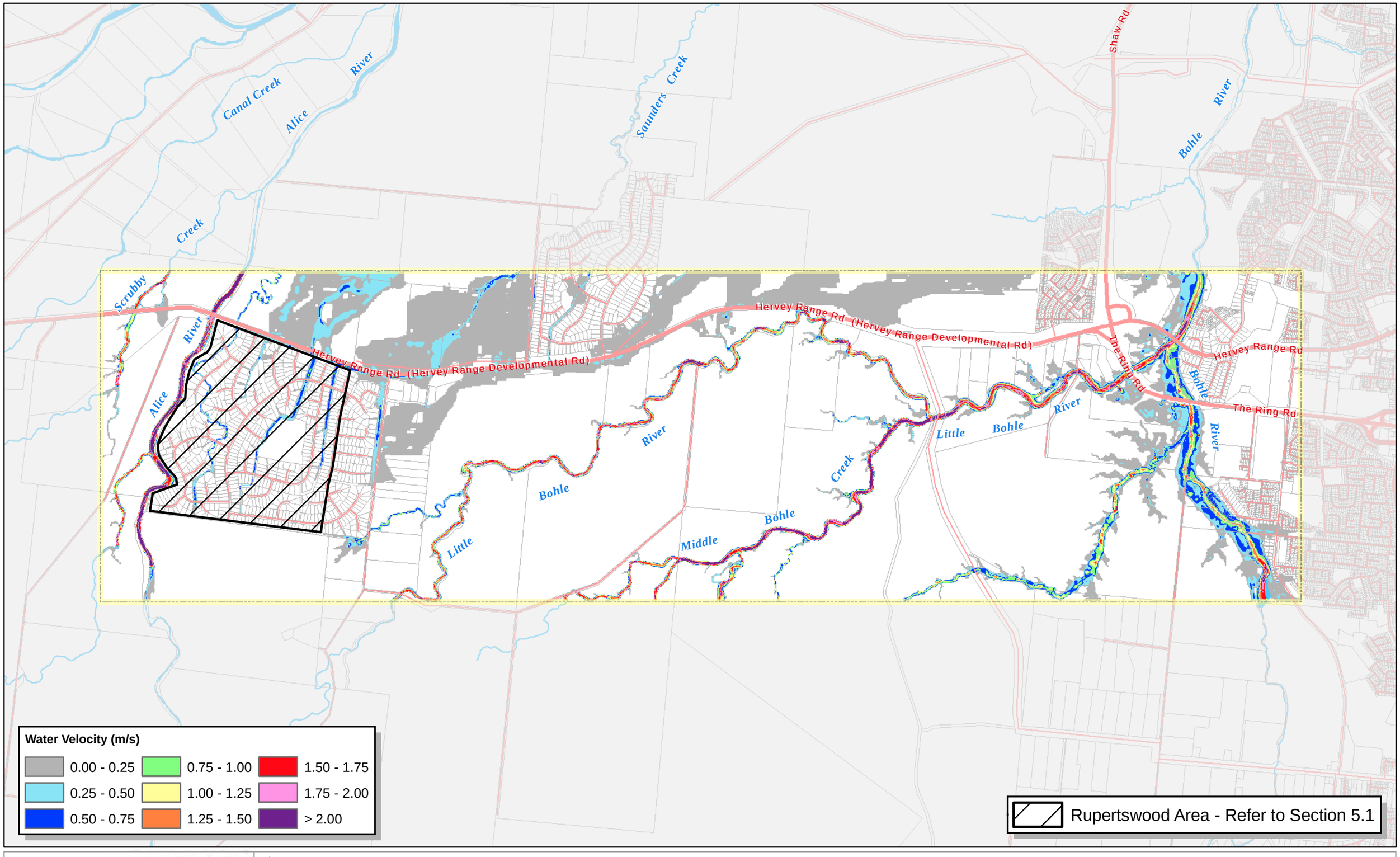
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Water Depth
5 year 24 hour event

Figure A5



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Scale: 1:40,000
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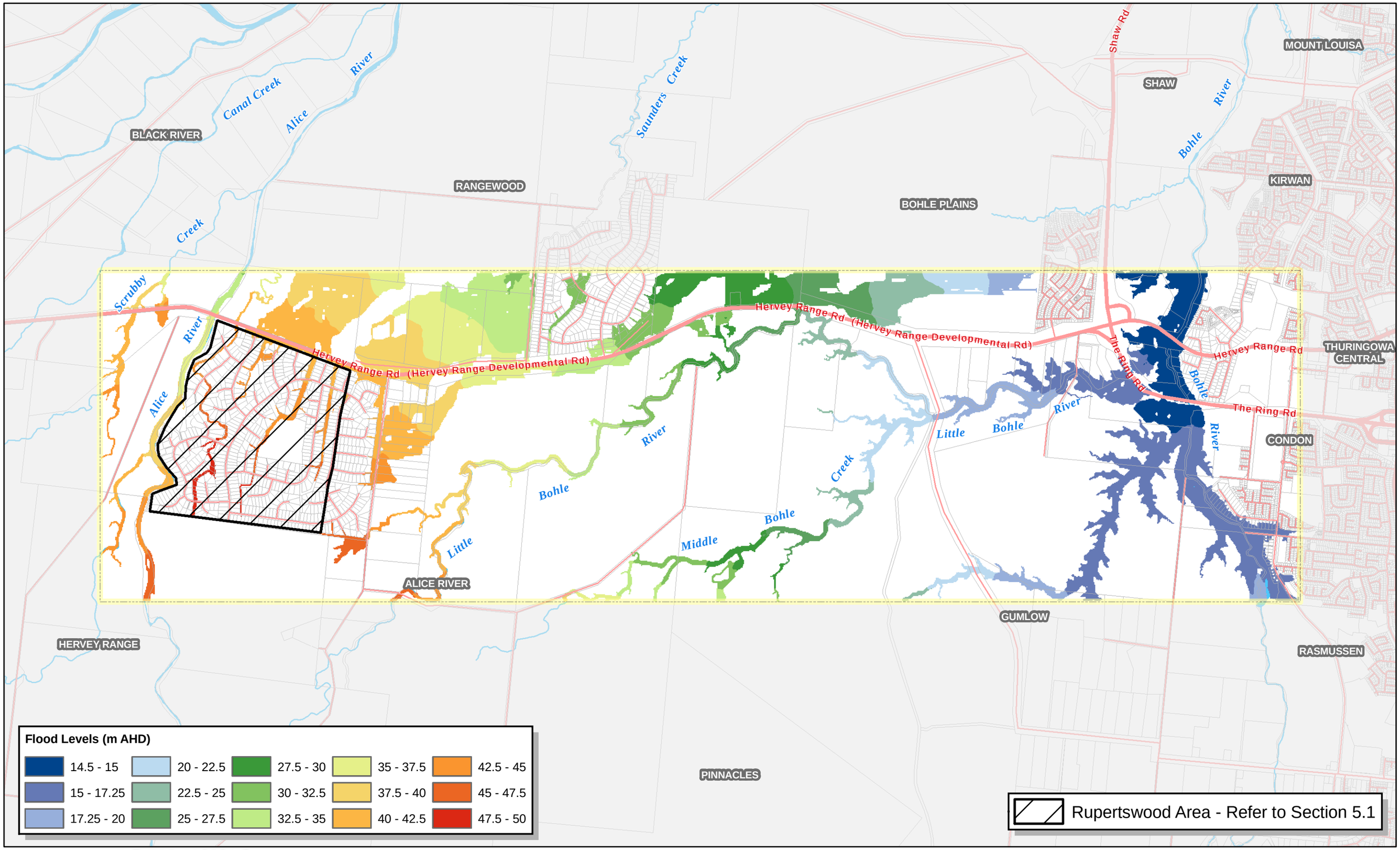
0 500 1,000 2,000 Metres

Legend

- Hydraulic Model Extent
- Property Boundary
- Minor Road
- Main Road
- Watercourse

LITTLE BOHLE FLOOD MODEL
Water Velocity
5 year 24 hour event

Figure A6



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Scale: 1:40,000
(when printed at A3)

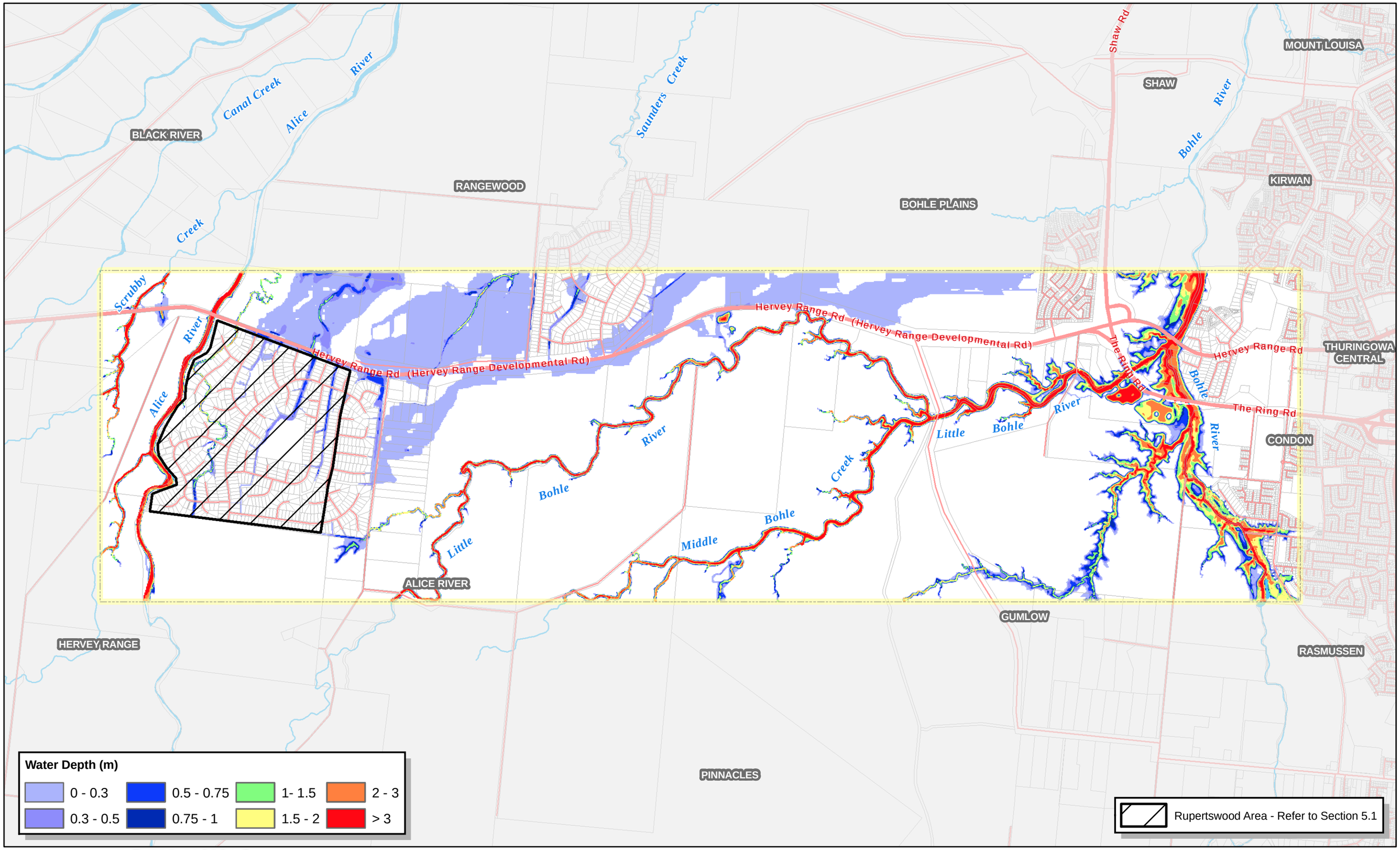
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Flood Level
10 year 24 hour event

Figure A7



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Scale: 1:40,000
(when printed at A3)

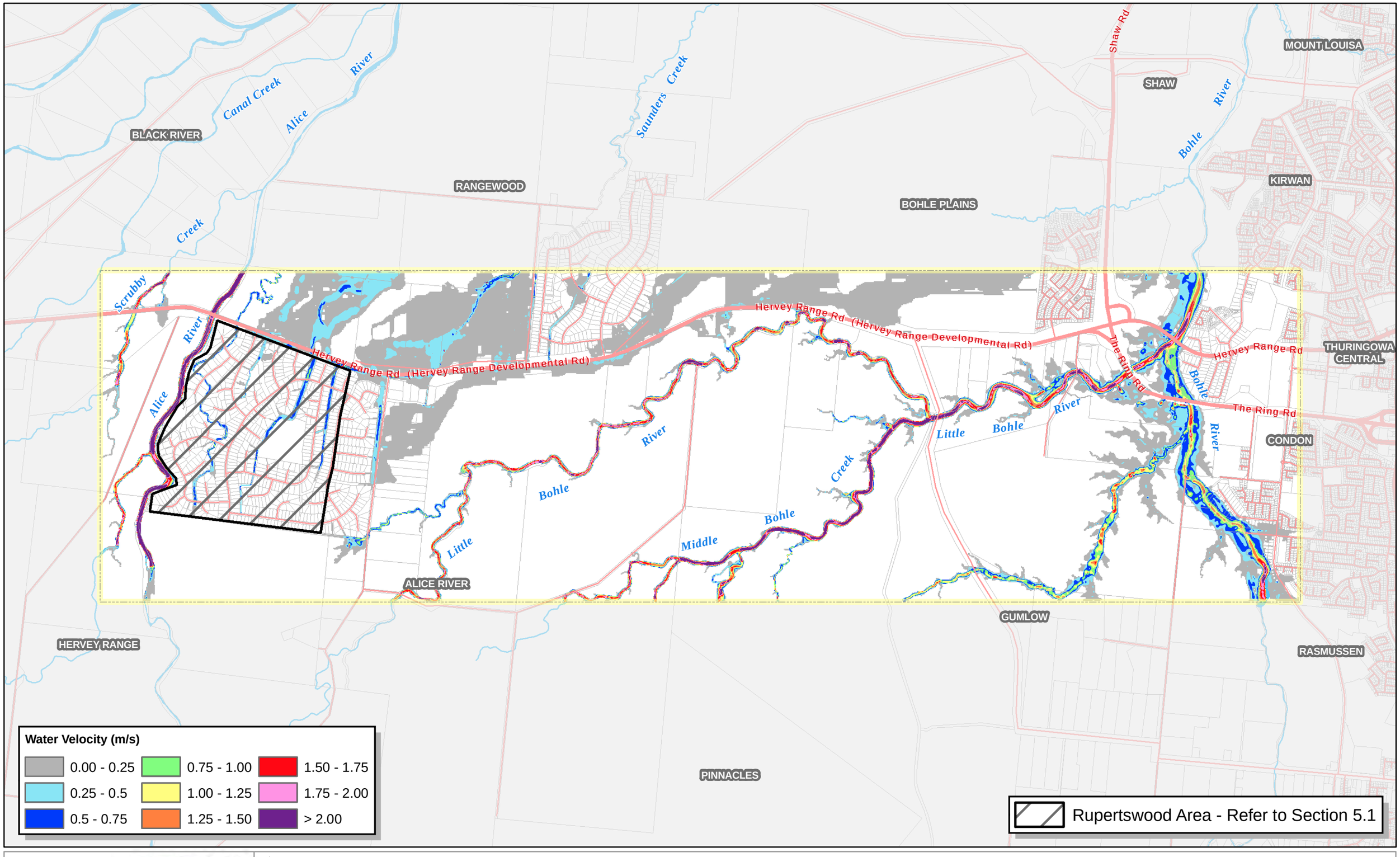
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Hydraulic Model Extent
- Property Boundary

LITTLE BOHLE FLOOD MODEL
Maximum Water Depth
10 year 24 hour event

Figure A8



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FILE NAME 60188958G_WR_27

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N

Scale: 1:40,000
(when printed at A3)

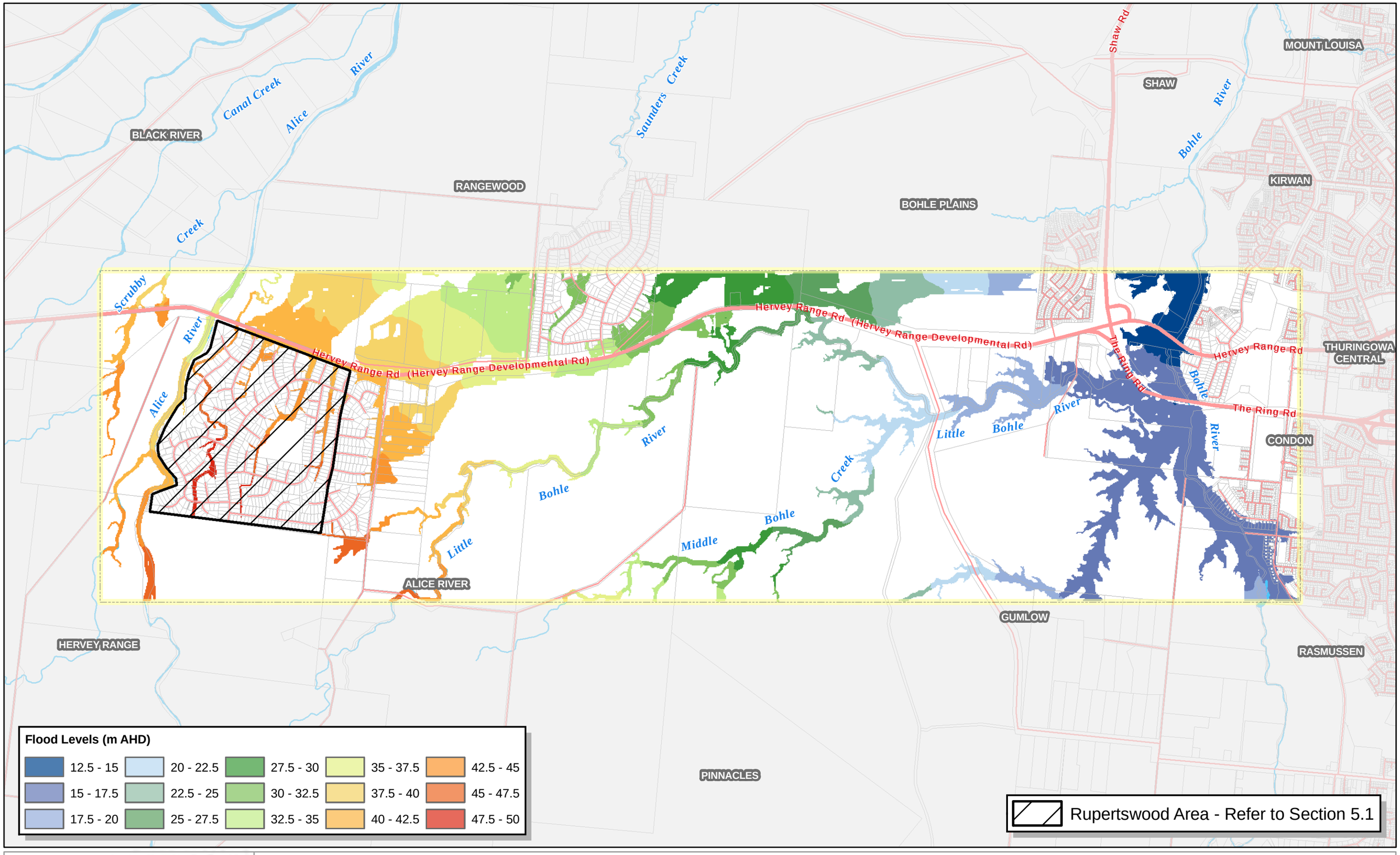
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Water Velocity
10 year 24 hour event

Figure A9



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Scale: 1:40,000
(when printed at A3)

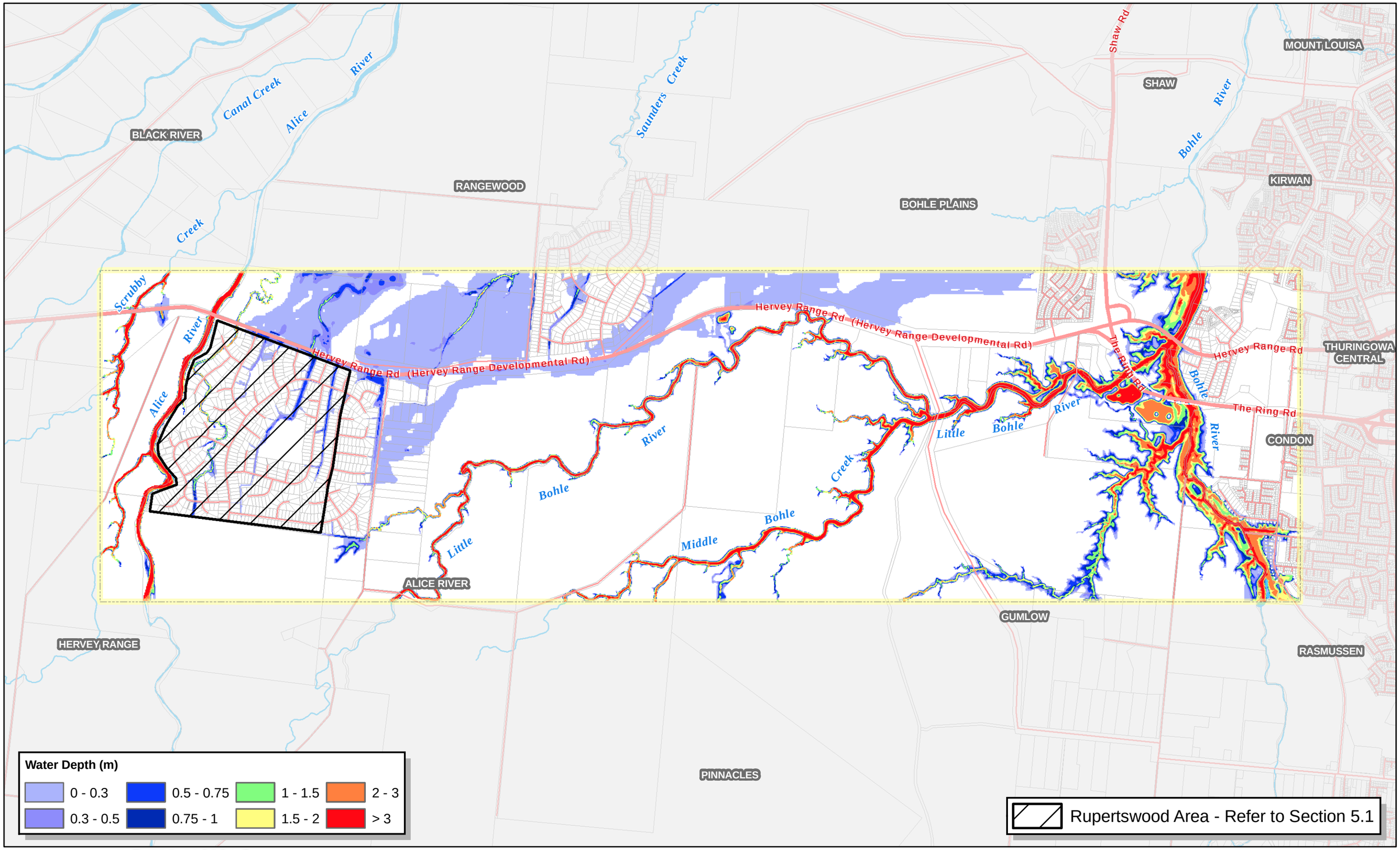
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Flood Level
20 year 24 hour event

Figure A10



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N

Scale: 1:40,000
(when printed at A3)

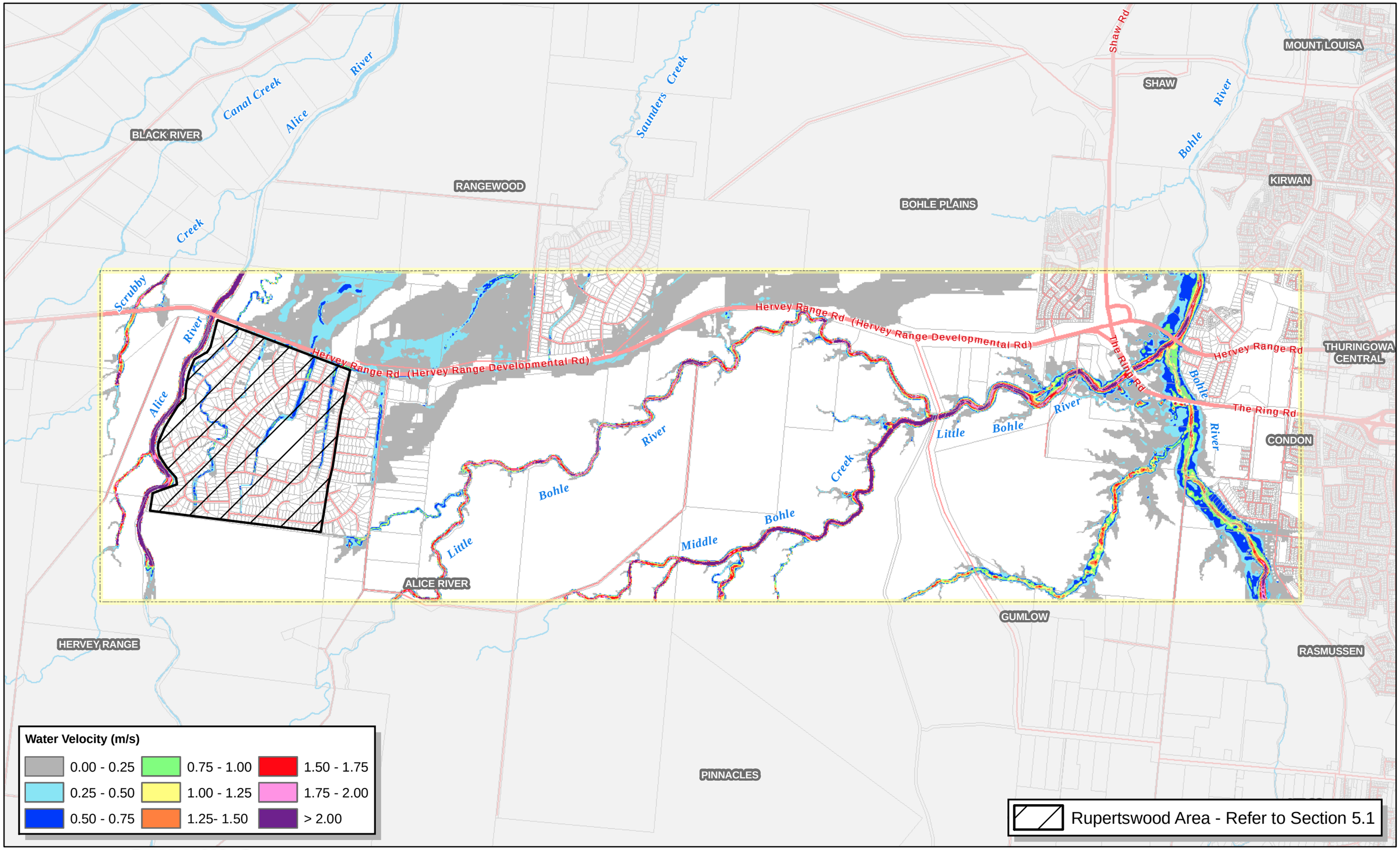
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Water Depth
20 year 24 hour event

Figure A11



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Scale: 1:40,000
(when printed at A3)

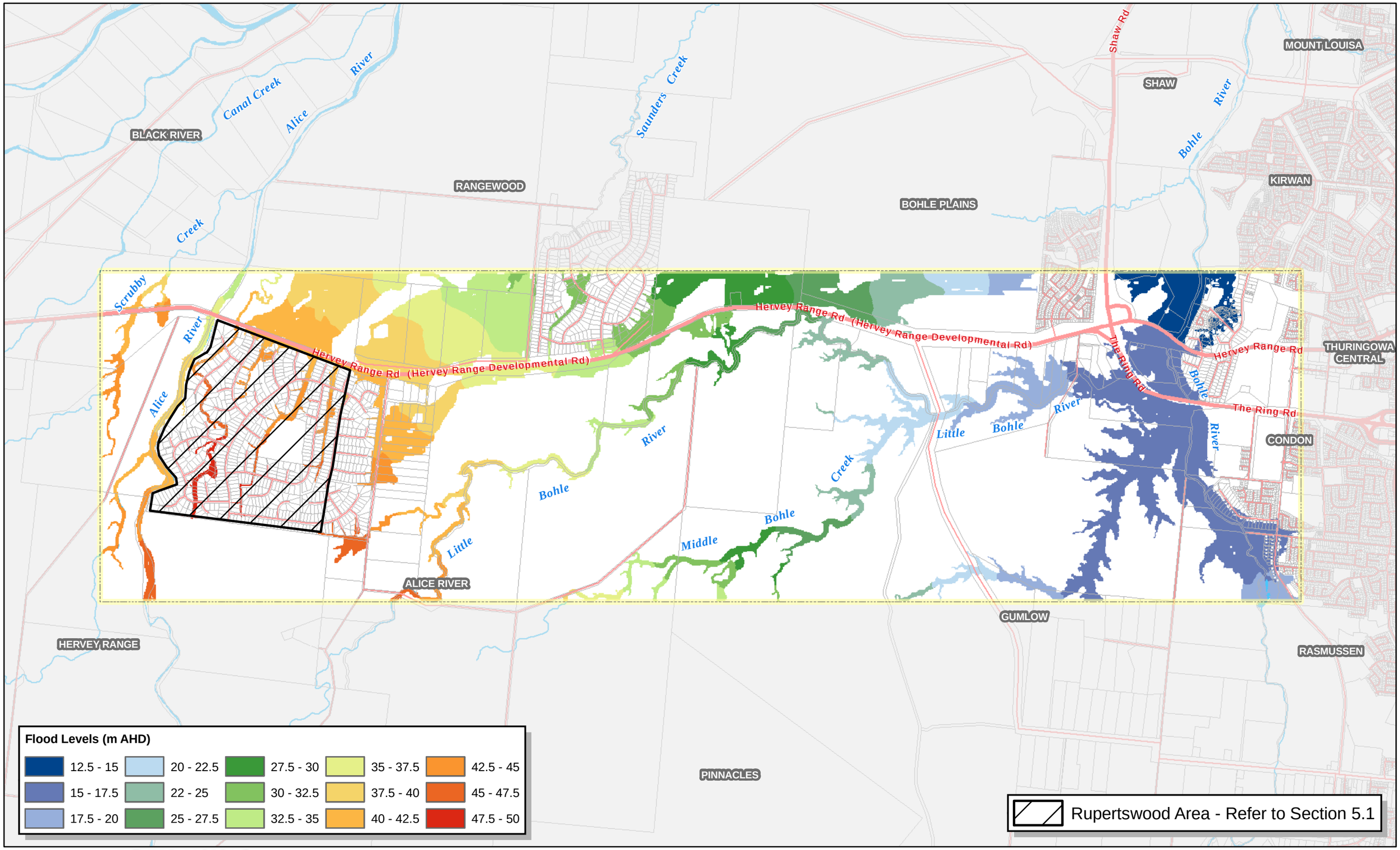
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Water Velocity
20 year 24 hour event

Figure A12



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N

Scale: 1:40,000
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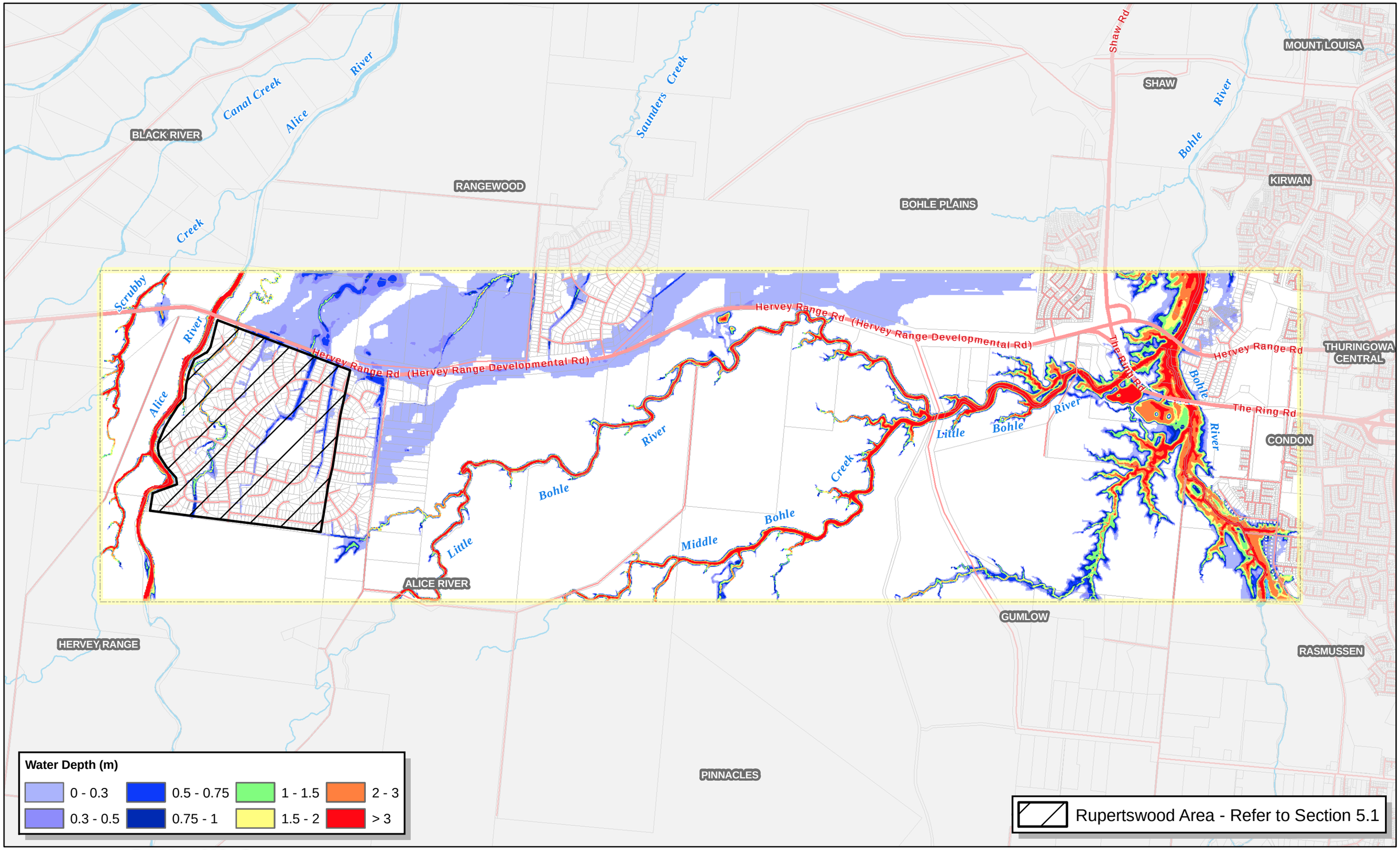
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Flood Level
50 year 24 hour event

Figure A13



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Scale: 1:40,000
(when printed at A3)

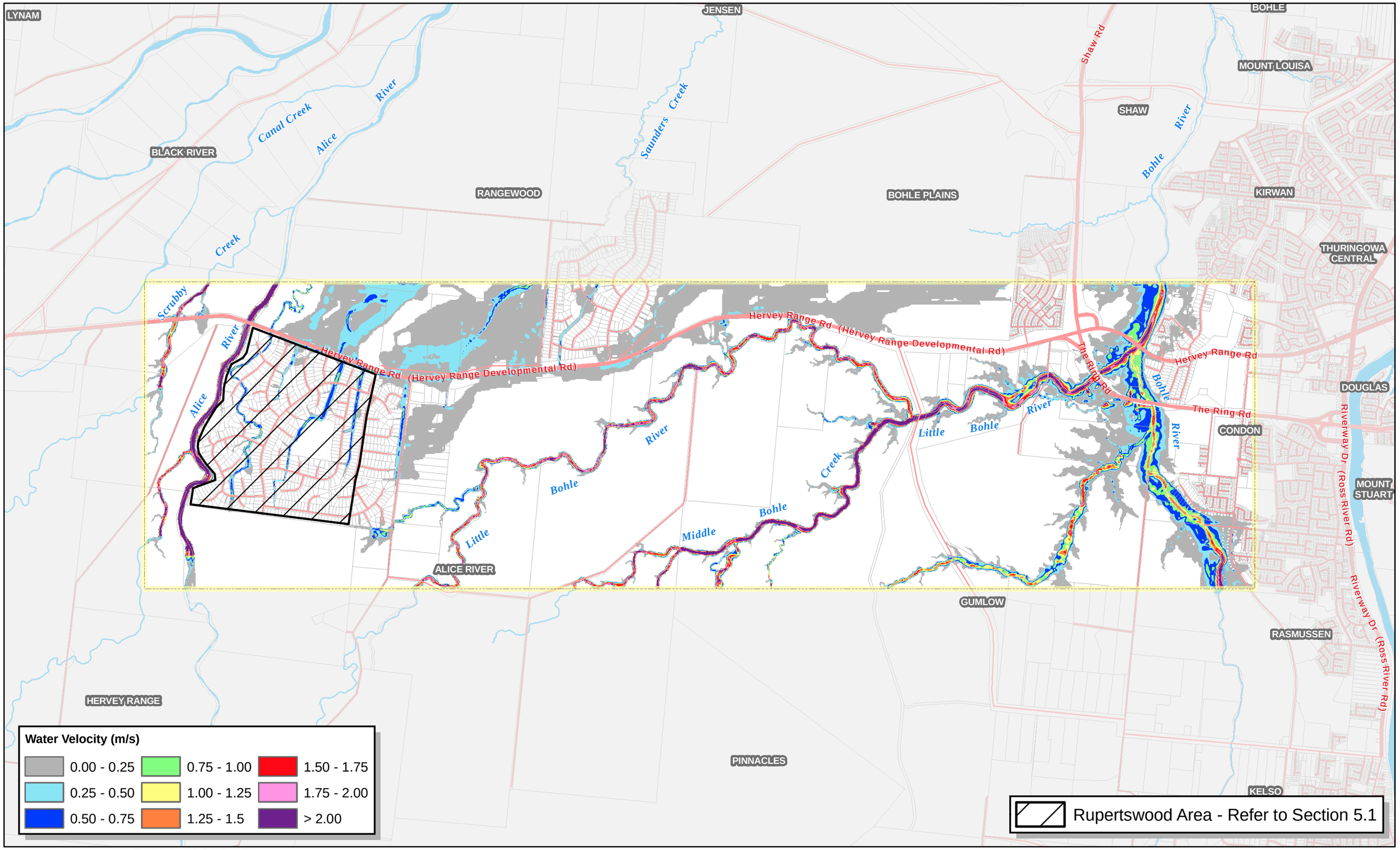
0 500 1,000 2,000 Metres

Legend

- Hydraulic Model Extent
- Property Boundary
- Minor Road
- Main Road
- Watercourse

LITTLE BOHLE FLOOD MODEL
Maximum Water Depth
50 year 24 hour event

Figure A14



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Scale: 1:43,293
(when printed at A3)

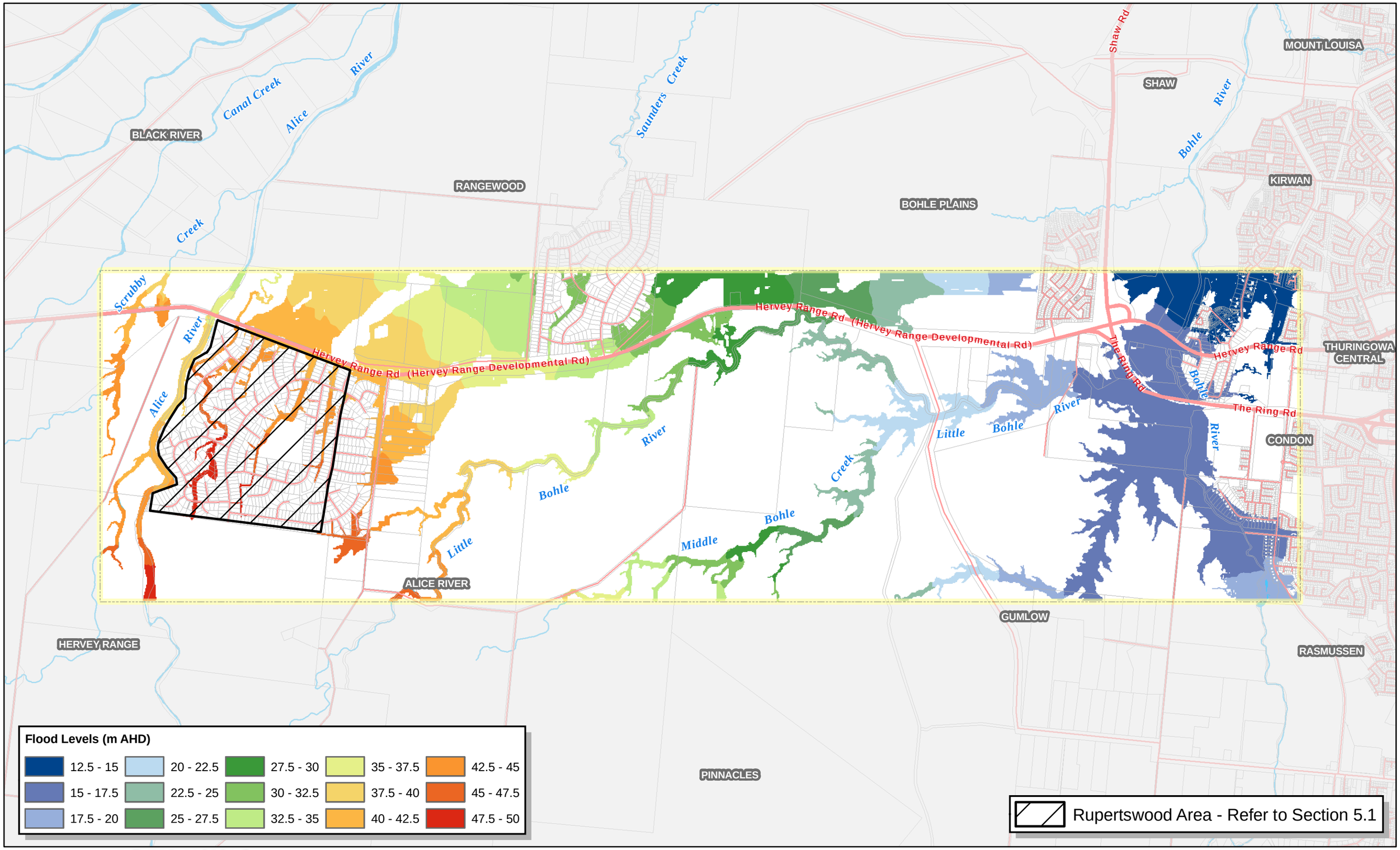
0 500 1,000 2,000 Metres

Legend

- Hydraulic Model Extent
- Property Boundary
- Minor Road
- Main Road
- Watercourse

LITTLE BOHLE FLOOD MODEL
Water Velocity
50 year 24 hour event

Figure A15



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N

Scale: 1:40,000
(when printed at A3)

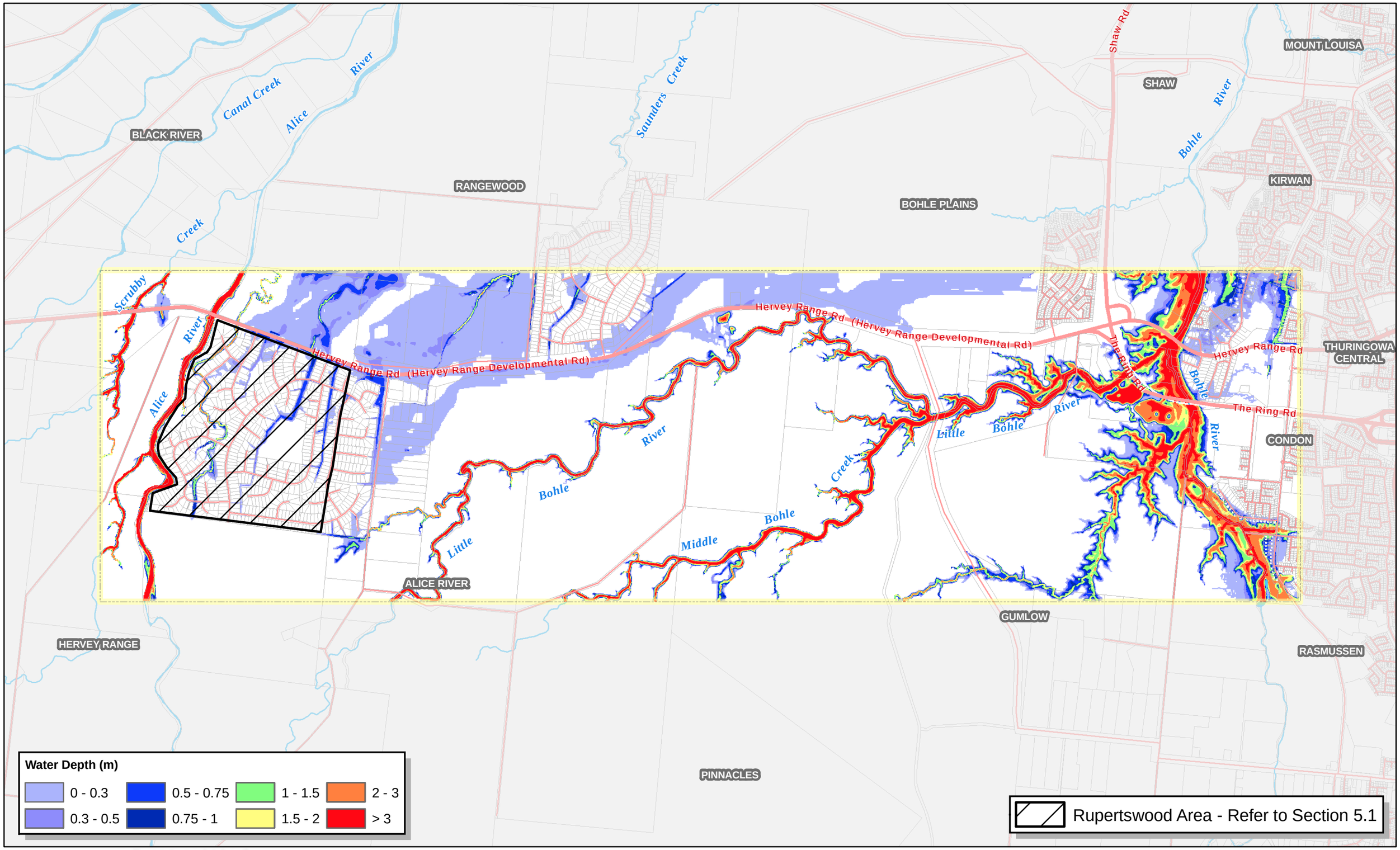
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Flood Level
100 year 24 hour event

Figure A16



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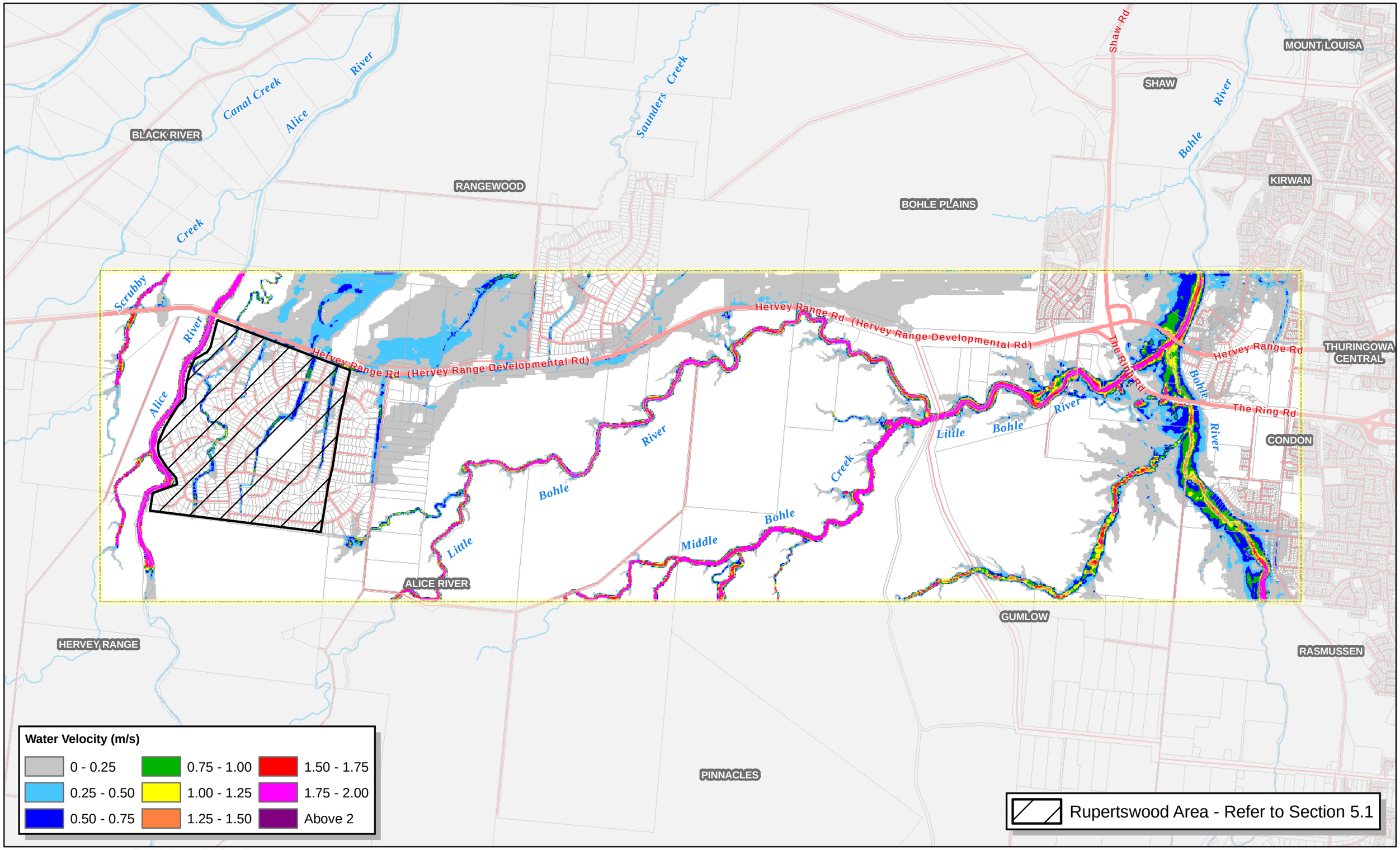
0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Maximum Water Depth
100 year 24 hour event

Figure A17



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0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Water Velocity
100 year 24 hour event

Figure A18