





WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Design Modelling Report

Great Western Flood Investigation

Northern Grampians Shire Council

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1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by North Grampians Shire Council (NGSC) to undertake the Great Western Flood Investigation. The investigation area covers the Great Western township, situated on the Western Highway in the upper reaches of Concongella Creek, a tributary of the Wimmera River. The surrounding local catchments include Concongella Creek, Allanvale Creek and Hyde Park Creek. The study area is shown in Figure 1-1.

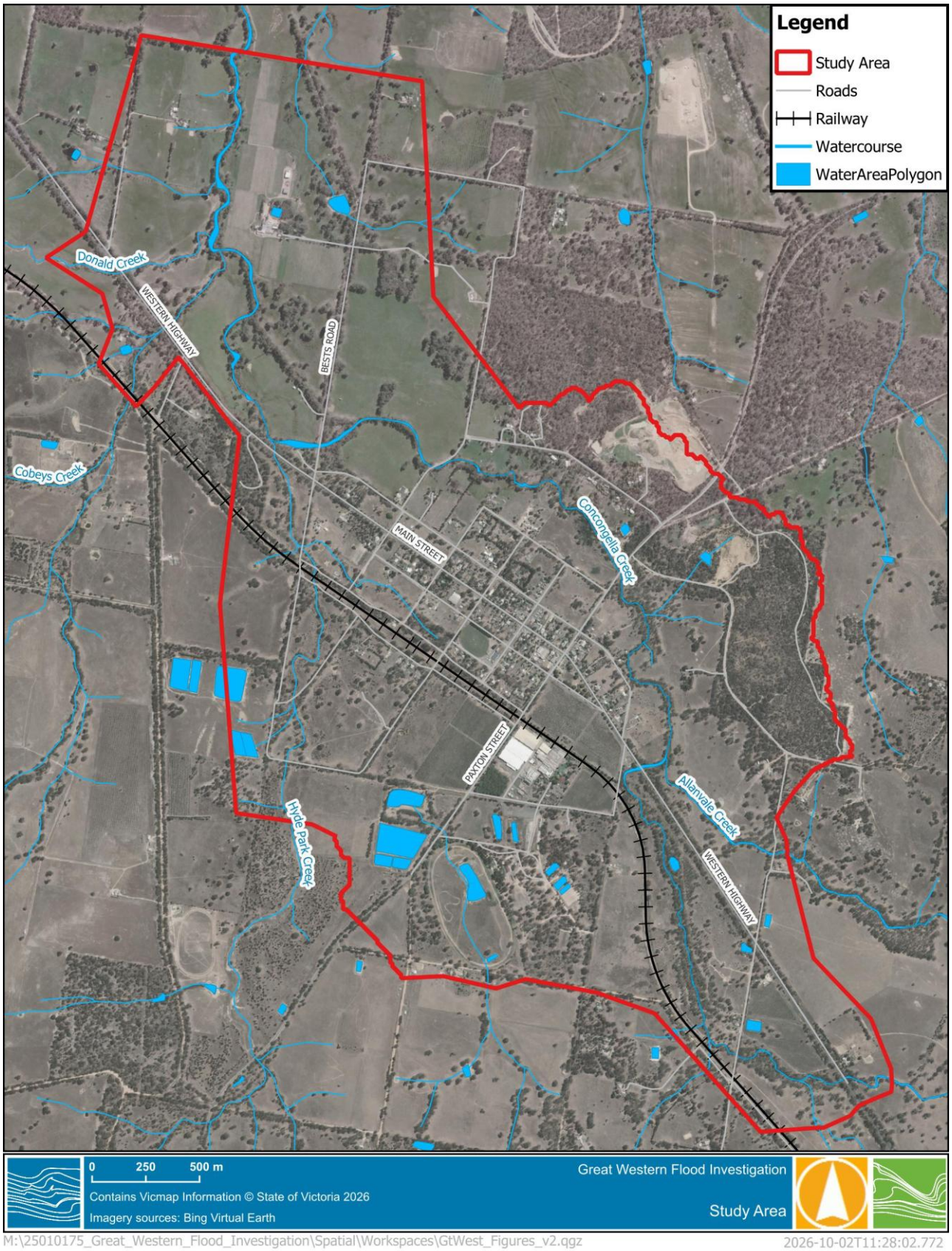


Figure 1-1 Study area

The study has produced reliable flood intelligence for use in emergency management situations, assessed the current flood impact/exposure in terms of annual average damages caused by flooding in Great Western, investigated structural and non-structural mitigation options, investigated and made recommendations for establishing a flood warning system for the town.

This report is one of the series documenting the outcomes of the Great Western Flood Investigation. Each reporting stage is shown below:

- R01 – Data Review Report
- R02 – Model Development and Calibration Report
- **R03 – Design Modelling Report – This Report**
- R04 – Flood Intelligence Report & Floodplain Management Plan
- R05 – Summary Report

The report details the final design hydrology and hydraulic modelling for the township. The report describes the sensitivity testing parameters and methodologies undertaken for the input parameters for the design methodologies. All design event flood mappings are included in this report.

1.2 Objectives and Outputs

The Great Western Flood Investigation outputs are required to meet several floodplain management objectives as highlighted in the project brief prepared by NGSC. The objectives of the investigation are described below:

- Review the available data and identify where additional data is to be obtained to complete the study to the required degree of accuracy.
- Develop best-practice hydrological and hydraulic models for the study area, including Council's stormwater network.
- Determine flood information for a range of flood modelling scenarios.
- Develop flood intelligence and response documentation for inclusion in NGSC Municipal Flood Emergency Plan (MFEP).
- Analyse options for structural and non-structural flood mitigation to alleviate flooding.
- Analyse the deficiencies in the existing stormwater system.
- Deliver draft mapping updates (Land Subject to Inundation Overlay (LSIO) & Flood Overlay (FO)) and explanatory reports to be used to amend the planning scheme.
- Provide a complete and concise document outlining the study methodology and deliverables.
- Providing flood data in an appropriate format to the Victorian Government and the Wimmera CMA and produce mapping suitable for DEECA's FloodZoom, all to Australian Height Datum (AHD).
- Make recommendations, and where possible, develop a flood-warning system.

1.3 Study Area

Great Western is in the Wimmera region of western Victoria, located 16.1 km northwest of Ararat and 12.7 km southeast of Stawell. It is on the banks of Concongella Creek and Hyde Park Creek, with their confluence downstream of the township. The first European settlers of Great Western consisted of sheep graziers in mid 1800s, before the discovery of gold and then the later development of viticulture, which remains as Great Western's primary economic drivers in the region today.

The upstream Concongella Creek catchment is south of Great Western and Hyde Park flows to the west, into Concongella Creek 1.7 km downstream, northwest of the township. Allanvale Creek located east of town, also joins into Concongella Creek upstream of Great Western, to the south east.

The catchment within and upstream of the study area is predominately agricultural, including extensive viticulture and farming activities. There are also bushland reserves and a quarry which are included in the study area.

The study area is focused on the township of Great Western and included the following key structures:

- Main waterway road crossings, formal or informal, at the following roads:
  - Western Highway
  - Paxton Road
  - Bests Road
- Road crossings at other locations than main waterways
- Underground pits and pipe drainage network within the township
- Railway located track southwest of the township and associated hydraulic structures
- Great Western Racecourse Dam.

2 DESIGN HYDROLOGY

2.1 Overview

The Great Western Flood Investigation has adopted a hydrologic/hydraulic modelling approach with the hydrology modelling completed using RORB software and hydraulic calculations completed within TUFLOW.

Design hydrology was undertaken using both Flood Frequency Analysis (FFA) and RORB modelling. The following sections of this report outline the methodology undertaken.

2.2 Flood Frequency Analysis

A flood frequency analysis (FFA) was completed for the Concongella Creek at Stawell streamflow gauge (Gauge ID: 415237). This analysis considered all available complete calendar years of data, from 1976 to 2024. Maximum daily flows lower than 1.0 m^3/s were censored (using the Multiple Grubbs Beck test). The analysis was completed in the RMC Best Fit software package as recommended by ARR2019.

The FFA distribution used for this study was the Log Pearson III distribution with Bayesian Inference providing the best fit to the observed data. The annual series of max flows utilised in the analysis, along with expected flood quantities from the results, are shown in Figure 2-1. The annual series is shown numerically in Table 2-1, with the censored values below 1 m^3/s are highlighted.

A graph of the Log Pearson III distribution and the observed values is shown in Figure 2-2. The adopted FFA quantiles are shown in Table 2-2.

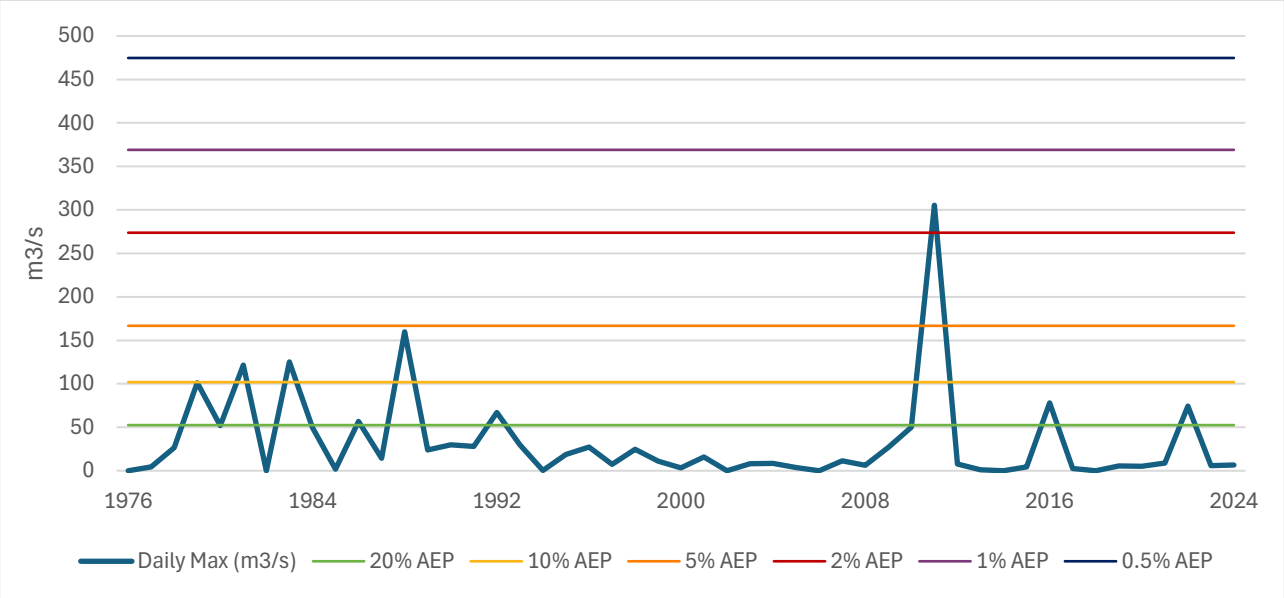


Figure 2-1 Daily flow with expected flood quantiles

Table 2-1 Adopted Annual Flow Series (Ordered by Flow Magnitude)

Year	Flow (m^3/s)	Year	Flow (m^3/s)	Year	Flow (m^3/s)	Year	Flow (m^3/s)
2011	305.4	1993	29.8	2004	8.4	2017	2.5
1988	159.9	1991	27.8	2003	8.1	1985	2.0
1983	125.2	1996	27.1	2012	7.7	2013	1.1

Year	Flow (m^3/s)	Year	Flow (m^3/s)	Year	Flow (m^3/s)	Year	Flow (m^3/s)
1981	121.4	2009	27.0	1997	7.3	1994	0.4
1979	101.3	1978	26.6	2024	6.8	1982	0
2016	78.1	1998	24.6	2008	6.1	1976	0
2022	74.2	1989	23.9	2023	6.0	2002	0
1992	67.2	1995	18.7	2019	5.7	2006	0
1986	56.6	2001	15.8	2020	5.0	2014	0
1980	52.0	1987	14.2	2015	4.6	2018	0
2010	50.1	2007	11.4	1977	4.5		
1984	49.9	1999	10.9	2005	3.5		
1990	30.0	2021	9.0	2000	3.2		

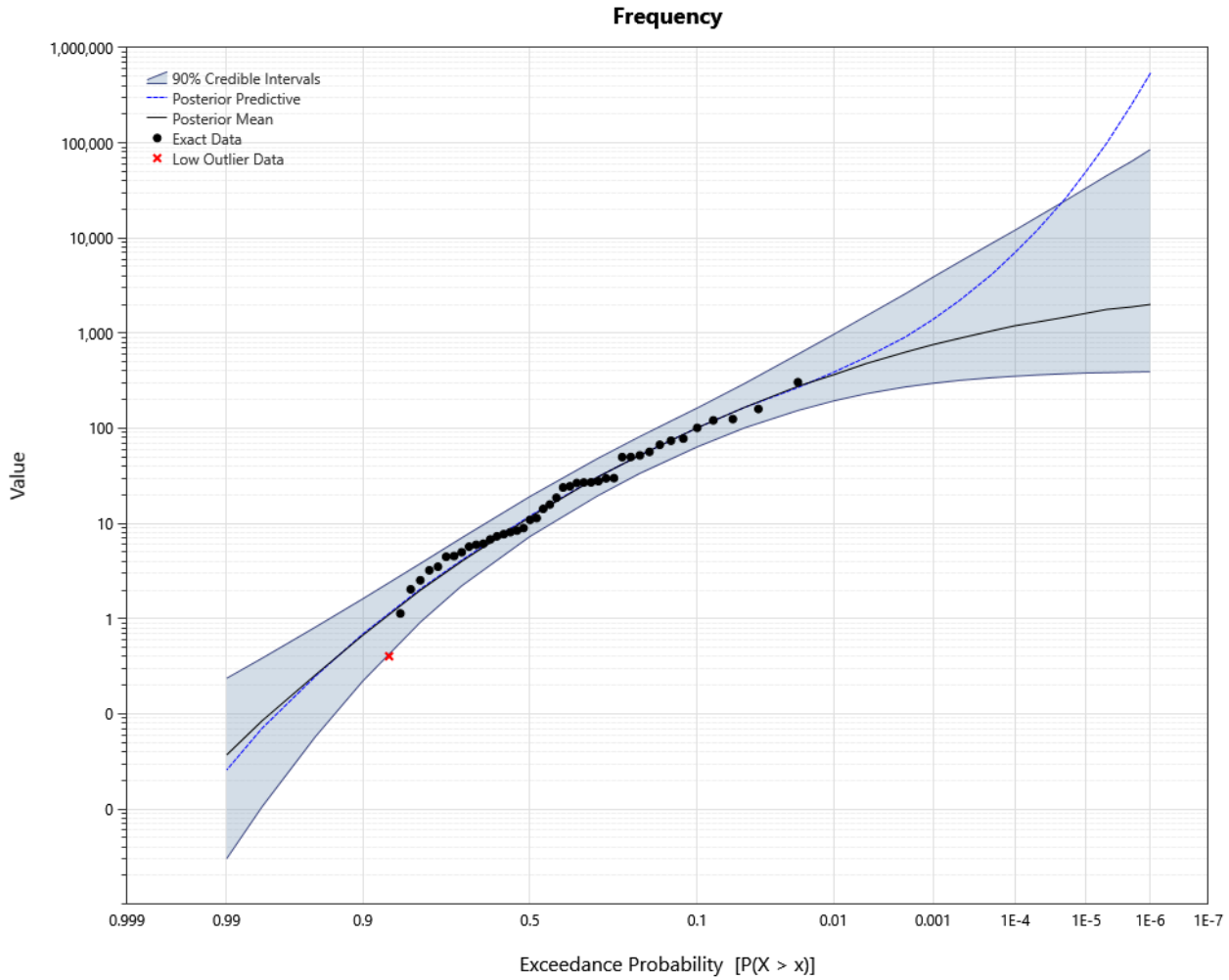


Figure 2-2 FFA: Log Pearson III with Bayesian Inference

Table 2-2 Adopted FFA Quantiles for Concongella Creek at Stawell (Guge ID: 415237)

AEP (%)	Peak Design Flow (m^3/s)		
	Log Pearson III	LP3 5% Limit	LP3 95% Limit
20%	52.5	33.7	82.0
10%	101.9	63.9	163.6
5%	166.7	101.2	295.8
2%	273.7	154.2	600.1
1%	369.0	194.2	968.8
0.5%	474.6	230.9	1,514.7
0.2%	627.2	272.6	2,599.7
0.1%	750.2	297.8	3,883.5
0.05%	877.8	319.5	5,589.7

Table 2-3 Approximate AEP of the 4 Largest Recorded Flows

Year	Flow (m^3/s)	Approximate AEP
2011	305.4	Between 2% to 5%
1988	159.9	Between 5% to 10%
2016	78.1	Between 10% to 20%
2022	74.2	Between 10% to 20%

2.3 RORB

2.3.1 Overview

The RORB model developed during the Western Highway Duplication Project[1] was adopted for the current study. Several minor updates were undertaken for the model with updated fraction impervious values on land use and adding additional print points, which were used as hydraulic model inflows along the modelled waterways. These details can be found in the Model Development and Calibration Report[2] (Water Technology 2026). RORB inflows were extracted at 9 locations for the hydraulic model, and these locations are listed in Table 2-4. Additional to the in-channel flows, direct rainfall was added to the subcatchment at Great Western using excess rainfall produced using ARR plugin on QGIS.

Table 2-4 Model Inflow Locations

Inflow	Number of inflow locations
Concongella Creek	3x
Allanvale Creek	2x
Inflow from Racecourse	1x

[1] Western Highway Duplication Project (2017) – Water Technology
[2] Great Western Flood Investigation Model Development and Calibration Report (2026) – Water Technology

Inflow	Number of inflow locations
Hyde Park Creek	1x
Cobeys Creek	1x
Robinsons Creek	1x

Hydrologic model parameters were adopted from the Western Highway Duplication Project[1] and were validated against community observations in a joint model validation approach. The joint model validation consisted of producing streamflow hydrographs in RORB, running the TUFLOW model with the hydrographs as inflow boundaries, and comparing the results to community observations.

For the design modelling, the design peak flows were generated using an Ensemble simulation in time series format. An analysis of these peak flows was then undertaken to determine the corresponding critical duration and temporal pattern at model key locations, as outlined in ARR2019. The analysis consists of taking the median peak flows from all ten temporal patterns, and the maximum of the modelled duration, to be the critical duration for the corresponding inflow location. Of the 9 inflow locations, critical durations of four locations that transverses through the township were analysed for each modelled design events.

In accordance with the Australian Rainfall and Runoff 2019 (ARR2019) Guideline v4.2[3], all baseline design flows were modelled using shared socioeconomical pathway (SSP) 3-7.0 Year 2030, the present day condition. Figure 2-3 details the SSP projection pathways across future years.

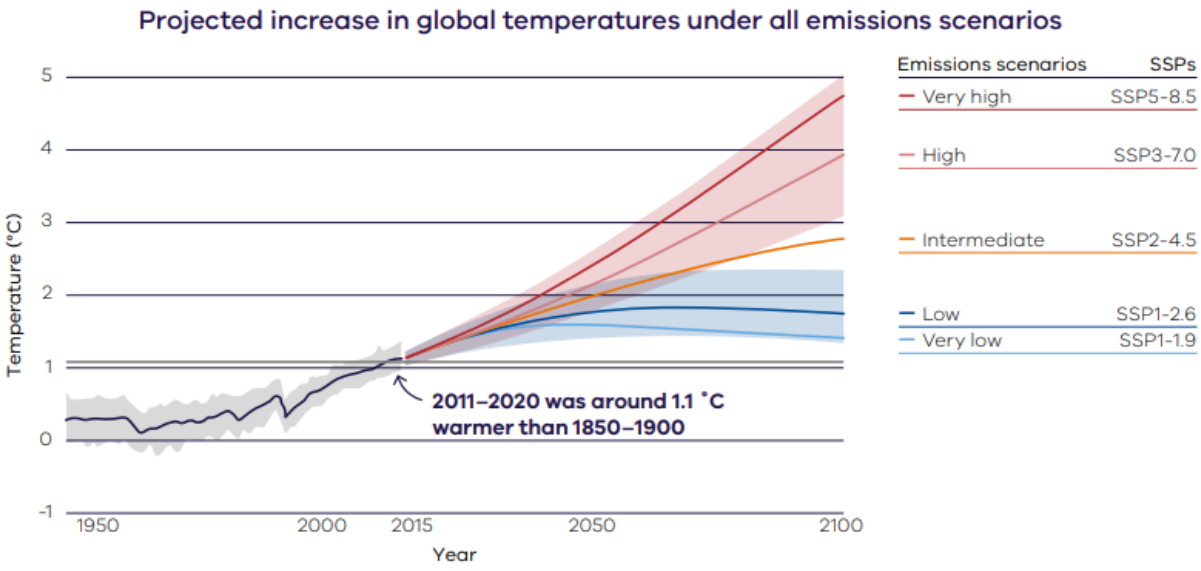


Figure 2-3 Project Climate Change Pathways

2.3.2 Design routing parameters

The routing parameter used for the design modelling are summarised in Table 2-5. Thse values were adopted from Western Highway Duplication Project[1].

[3] Victoria Climate Science Report 2024

Table 2-5 RORB model parameters summary

Interstation	Kc	m
Intersection Area 1	2.21	0.8
Intersection Area 2	3.09	
Intersection Area 3	4.17	
Intersection Area 4	2.53	
Intersection Area 5	3.41	
Concongella Creek	18.64	

2.3.3 Design rainfall

2.3.3.1 Intensity-Frequency-Duration (IFD) design rainfall depths

The design rainfall depths were downloaded via Bureau of Meteorology (BoM)[4] website using the centroid of the catchment, upstream of the study area, to produce an IFD table with one design rainfall depth for each design event and duration for the entire catchment.

Table 2-5 shows the design rainfall depths for each design event and duration.

Table 2-6 IFD design rainfall depth (mm)

Duration	63.20 %	50%	20%	10%	5%	2%	1%	1 in 200	1 in 500	1 in 1000	1 in 2000
15 min	10	11	15	19	23	28	33	37	43	47	52
20 min	11	13	17	21	25	32	37	42	48	54	59
25 min	12	14	19	23	28	35	40	46	53	59	65
30 min	13	15	20	25	30	37	43	49	56	63	69
45 min	15	17	23	29	34	42	49	56	64	72	79
1 hour	16	18	26	31	37	46	53	60	70	78	86
1.5 hour	18	21	29	35	42	51	59	67	77	86	95
2 hour	20	23	31	38	45	55	63	71	83	92	102
3 hour	22	25	35	42	49	60	69	78	90	100	111
4.5 hour	26	29	39	47	55	67	76	86	99	110	122
6 hour	28	31	43	51	60	72	82	92	107	118	130
9 hour	32	36	49	59	68	82	93	104	120	133	147
12 hour	35	40	54	64	74	89	101	113	131	144	160
18 hour	40	45	61	73	85	101	114	129	149	165	183

[4] Intensity-Frequency-Duration: Design Rainfalls: Water Information: Bureau of Meteorology

Duration	63.20 %	50%	20%	10%	5%	2%	1%	1 in 200	1 in 500	1 in 1000	1 in 2000
24 hour	44	49	67	80	93	111	127	143	165	184	202
30 hour	47	53	72	86	100	120	136	155	179	200	221
36 hour	49	56	76	91	106	128	145	165	193	215	238
48 hour	53	60	83	99	117	140	160	182	212	238	265
72 hour	58	65	91	110	129	156	178	204	240	271	304
96 hour	61	69	96	116	136	165	190	217	256	289	326

2.3.3.2 Temporal Patterns

Design storm temporal patterns were downloaded from the ARR Data Hub[5] and were used to simulate the distribution of burst rainfall depth during each storm event modelled. As the catchment size is greater than 75 km^2, a combination of point based and areal based temporal patterns were used.

Point temporal patterns were used to represent storm events up to 12-hours and areal based temporal patterns were used to represent storm events greater than 12-hours up to 168-hours.

2.3.3.3 Spatial Patterns

As the catchment area was larger 20km^2, non-uniform spatial variation pattern was applied with reference to catchment and subarea location across all design events simulated from 1-minute to 168-hours.

2.3.3.4 Pre-burst Rainfall

The catchment is in loss Region 3, as described in the Victorian Specific information in ARR2019[6]. As such, a 75% percentile pre-burst should be adopted in the design modelling. However, a median pre-burst was adopted instead due to over-estimation of pre-burst value if 75% percentile was used.

2.3.4 Design losses

The storm losses 5 mm for initial losses (IL) and 1 mm/hr for continuing losses (CL) were adopted from the Western Highway Duplication Project[1]. These values were used for the January 2011 flood event calibration, and produced a peak 1% AEP flow at the Concongella Creek at Stawell gauge location which matched the FFA, detailed in Section 2.2. Adopting these losses did not result in a close match between the RORB model results and those in the FFA. It is found that the losses were too low for the smaller events and too high for the larger events. Therefore, an adaptive design loss approach was used for modelling the design events to match the peak flow volume produced by FFA for each corresponding design event. Losses were increased for events smaller than a 1% AEP, while for design events larger than 1% AEP the design losses were kept at 5 mm for IL and 1 mm/hr for CL. Using losses lower than these for events larger than a 1% AEP was not considered

[5] https://data.arr-software.org/
[6] http://www.arrlossregionmap.com.s3-website-ap-southeast-2.amazonaws.com/

realistic and it is likely the rating curve at the Concongella Creek at Stawell streamflow gauge becomes less accurate.

A sensitivity test was conducted using constant and adaptive losses, and the resulted peak design flows are presented in Table 2-7. The final losses adopted for modelling the design events were adjusted with SSP3-7.0 2030 climate change factor, as listed in Table 2-8. The adopted peak flows are listed in Table 2-9.

Table 2-7 Design peak flows comparison between FFA, constant losses and adaptive losses

Peak Flow (m3/s) / AEP (%)	Log-Pearson III (FFA)	Constant Losses (IL=5, CL=1)	Adaptive Losses	
20% AEP	52.5	146.3	IL=17.0, CL=3.40	51.4
10% AEP	101.9	187.9	IL=13.5, CL=2.70	106.4
5% AEP	166.7	234.6	IL=11.0, CL=2.20	167.8
2% AEP	273.7	308.1	IL=7.3, CL=1.45	276.8
1% AEP	369.0	362.2	IL=5.0, CL=1.0	362.2
0.5% AEP	474.6	419.8		477.7
0.2% AEP	627.2	501.7		571.9
0.1% AEP	750.2	567.4		652.7
0.05% AEP	877.8	638.5		731.7

Table 2-8 ARR Data Hub climate change factor for SSP3-7.0 2030

Parameter	Climate Change Factors
Initial Losses	x1.04
Continuing Losses	x1.08

Table 2-9 Design losses for baseline and SSP3-7.0 2030 design events

AEP (%)	Initial Losses (mm)		Continuing Losses (mm/hr)	
	Baseline (2016)	SSP3-7.0 Year 2030	Baseline (2016)	SSP3-7.0 Year 2030
20%	17.0	17.7	3.4	3.67
10%	13.5	14.0	2.7	2.92
5%	11	11.4	2.2	2.38
2%	7.3	7.6	1.45	1.57
1%	5	5.2	1	1.08
0.5%				
0.2%				
0.1%				
0.05%				

2.4 Excess Rainfall

Additional to the waterway flows, direct rainfall was added to the at Great Western township using excess rainfall produced using ARR plugin on QGIS. Rain-on-Grid (RoG) approach was used to directly apply rainfall to the township. This approach allowed a better understanding of overland flow and drainage paths through the township, as well as better account for the land use losses within the subcatchment.

2.5 Critical Durations

The RORB model was run for the 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2%, 0.1%, 0.05% AEP events, and the Probable Maximum Flood (PMF) event. Table 2-10 summarises the critical durations and temporal patterns for each design event. There are multiple key locations in the model, each design event has multiple critical durations.

Based on the RORB results, hydraulic model inputs were prepared for all the durations and associated median peak flow generating temporal pattern, for each design event, to capture the critical duration at the key locations. For the design events where the same critical duration was observed at two key locations, only one temporal pattern was selected for the design event based on the pattern which resulted in the higher downstream peak flow at the Concongella Creek outflow.

Table 2-10 Adopted critical durations, temporal patterns, and design peak flows from ensemble simulation

Design Event (AEP)	Concongella Creek		Allanvale Creek		Inflow from Racecourse		Hyde Park Creek		Great Western Township (excess rainfall)	
20%	12 hr TP 10	15.4 m^3/s	9 hr TP 2	10.6 m^3/s	2 hr TP 4	6.6 m^3/s	4.5 hr TP 4	5.5 m^3/s	1 hr TP 6	3.6 m^3/s
10%	9 hr TP 16	35.2 m^3/s	9 hr TP 19	23.6 m^3/s	1.5 hr TP 18	10.8 m^3/s	9 hr TP 18	10.0 m^3/s	1 hr TP 5	4.3 m^3/s
5%	6 hr TP 16	51.0 m^3/s	6 hr TP 18	35.8 m^3/s	1.5 hr TP 19	15.0 m^3/s	3 hr TP 17	14.9 m^3/s	1 hr TP 6	8.0 m^3/s
2%	6 hr TP 22	80.3 m^3/s	6 hr TP 27	54.6 m^3/s	1 hr TP 28	18.1 m^3/s	3 hr TP 30	22.7 m^3/s	1 hr TP 5	9.7 m^3/s
1%	6 hr TP 27	101.5 m^3/s	6 hr TP 27	69.2 m^3/s	1 hr TP 28	22.4 m^3/s	2 hr TP 27	29.1 m^3/s	1 hr TP 3	7.5 m^3/s
0.5%	6 hr TP 22	115.6 m^3/s	6 hr TP 27	79.1 m^3/s	1 hr TP 28	25.1 m^3/s	2 hr TP 24	33.0 m^3/s	1 hr TP 3	8.5 m^3/s
0.2%	6 hr TP 22	134.7 m^3/s	6 hr TP 27	92.9 m^3/s	1 hr TP 28	28.9 m^3/s	2 hr TP 24	38.5 m^3/s	1 hr TP 3	9.8 m^3/s
0.1%	6 hr TP 22	149.4 m^3/s	6 hr TP 27	103.4 m^3/s	1 hr TP 28	31.8 m^3/s	2 hr TP 24	42.7 m^3/s	1 hr TP 3	10.9 m^3/s

Design Event (AEP)	Concongella Creek		Allanvale Creek		Inflow from Racecourse		Hyde Park Creek		Great Western Township (excess rainfall)	
0.05%	6 hr TP 22	165.1 m^3/s	6 hr TP 27	114.5 m^3/s	1 hr TP 28	34.9 m^3/s	2 hr TP 24	47.0 m^3/s	1 hr TP 3	12.1 m^3/s

2.6 Design flows

The modelled design flows for each design events, as well as the peak flows produced using FFA, are presented in Table 2-11.

Table 2-11 Design flow for FFA, baseline, and present day

AEP (%)	Peak Design Flow (m^3/s)		
	Log Pearson III	Baseline (2016)	SSP3-7.0 Year 2030
20%	52.5	51.4	63.0
10%	101.9	106.4	130.3
5%	166.7	167.8	197.3
2%	273.7	276.8	318.0
1%	369.0	362.2	415.6
0.5%	474.6	419.8	477.7
0.2%	627.2	501.7	571.9
0.1%	750.2	567.4	652.8
0.05%	877.8	638.5	731.7

2.7 Climate Change Analysis

As part of the climate change analysis, the hydrology inputs were scaled for SSP3-7.0 to year 2100. The scaled factors for design losses and pre-burst are presented in Table 2-12 and Table 2-13.

The same critical durations and temporal patterns were used for all design events across both present day and future climate change modelling. The design peak flow for the future climate change scenario is presented in Table 2-14.

Table 2-12 Climate change factor for losses

Parameter	Climate Change Factors	Adopted losses for 2100
Initial Losses	x1.12	5.6 mm
Continuing Losses	x1.27	1.27 mm/hr

Table 2-13 Climate change factor for pre-burst

Pre-burst durations	Climate Change Factors
<1 hour	x1.66
1.5 Hours	x1.59
2 Hours	x1.55
3 Hours	x1.50
4.5 Hours	x1.45
6 Hours	x1.42
9 Hours	x1.39
12 Hours	x1.37
18 Hours	x1.34
>24 Hours	x1.32

Table 2-14 Design flow for future SSP3-7.0 year 2100

AEP (%)	Peak Design Flow (m^3/s)	Increase compared to year 2030	
20%	87.6	24.6 m^3/s	39.0%
10%	183.5	53.2 m^3/s	40.8%
5%	259.1	61.8 m^3/s	31.3%
2%	401.7	83.7 m^3/s	26.3%
1%	509.7	94.1 m^3/s	22.6%
0.5%	588.9	111.2 m^3/s	23.3%
0.2%	700.0	128.1 m^3/s	22.4%
0.1%	785.8	133.0 m^3/s	20.4%
0.05%	882.6	150.9 m^3/s	20.6%

2.8 Probable Maximum Flood

The Probable Maximum Precipitation (PMP) was interpolated between depths estimated by the Generalised Short Duration Method (GDSM). The rainfall depths were modelled utilising the 'rare' temporal patterns obtained from the ARR DataHub and distributed spatially in line with the 0.05% AEP event.

An initial loss of 0 mm and a continuing loss of 0 mm/hr was applied. All ten temporal patterns were simulated in ensemble for the PMF. The same critical duration and associated temporal pattern for 0.05% AEP was used to simulate the PMF event (2hr TP24 and 6hr TP27).

3 DESIGN HYDRAULIC

3.1 Overview

As identified in Table 2-10, the design hydrographs of the selected critical durations and temporal patterns for each design event were extracted from RORB and QGIS ARR plugin, and used as source inflows and excess rainfall respectively, to the TUFLOW model. These distributed inflows were applied to the upstream of Conongella Creek, Allanvale Creek, inflow from Racecourse, and Hyde Park Creek, as in-channel flow, and across the entire subcatchment covering the township using excess rainfall.

Table 3-1 summaries the key model parameters/inputs adopted for the TUFLOW modelling. Further details on the TUFLOW model inputs are described in detail in the Model Development and Calibration Report[2].

Table 3-1 Key TUFLOW parameters summary

Parameter	
Model Build	2026.0.1-iSP-w64
Grid Cell Size	3 m with 3x Subgrid Sampling Frequency (~1 m)
Solution Scheme	GPU HPC
Inflow Boundary	■ 2d_sa source-area boundaries for in-channel flow ■ 2d_rf rainfall boundary for excess rainfall
Outflow Boundary	Height-Flow slope of 0.25%
Hydraulic Roughness	Manning's 'n' varies with land use
1d Elements	Culverts and pipes linked to 2D domain

3.2 Design Flood Modelling

Design flood modelling for the 20%, 10%, 5%, 1%, 0.5%, 0.2%, 0.1%, 0.05% AEP and PMF events were completed using the calibrated hydraulic model. Flood modelling outputs were applied for flood emergency improvement and planning, and flood maps will be used as guidance for future land use development.

The final flood maps for each design events were created by maximising all runs for each AEP event, including the critical durations and the associated temporal patterns as summarised in Table 2-10. Then, the maxed grids were filtered with a cut-off depths of >0.02 m and puddles >200 m^2.

Flood hazard mapping was prepared in line with ARR2019 and the Australian Disaster Resilience Guideline 7-3 Flood Hazard[7]. The hazard classifications are based on the peak depth, velocity and product of depth and velocity. The classifications are shown Figure 3-1.

All design flood mappings zoomed into the township are presented in Section 4. Full study area mapping can be found in the Appendices.

[7] Australian Disaster Resilience Guideline 7-3 Flood Hazard, 2017, Australian Institute Disaster Resilience

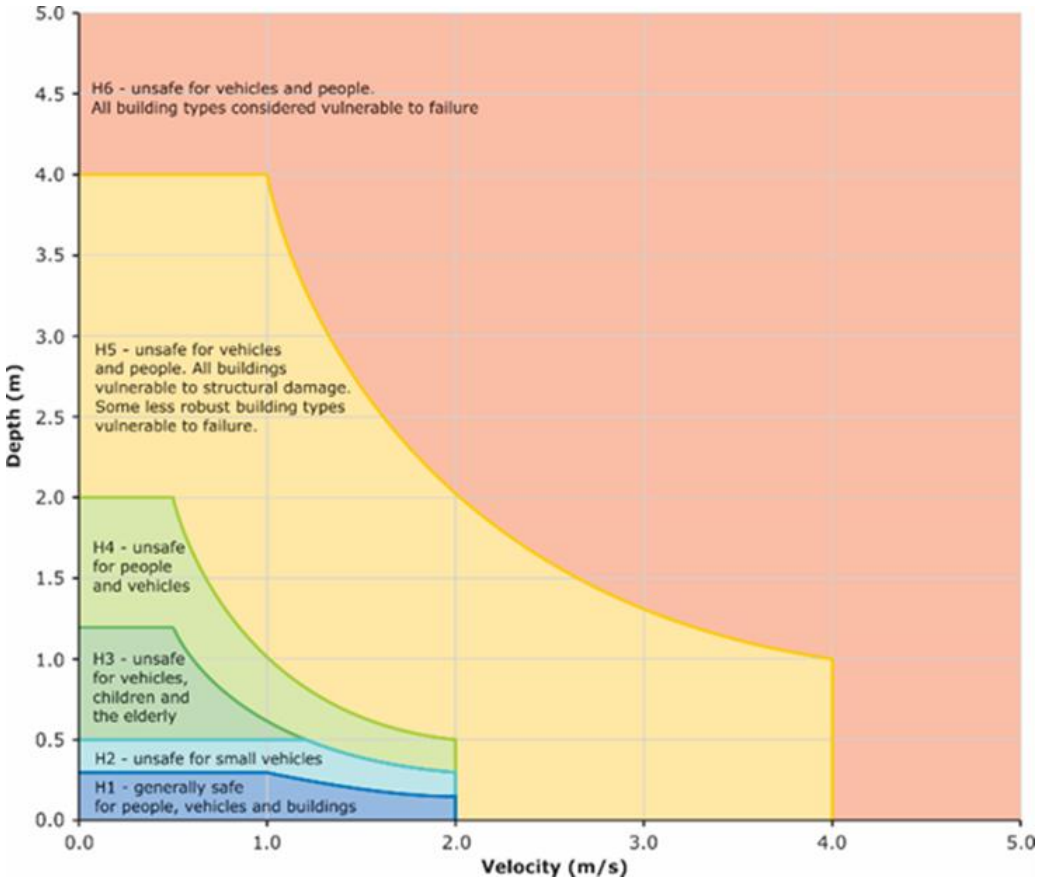


Figure 3-1 Flood hazard classifications

3.3 Sensitivity Analysis

3.3.1 Overview

Sensitivity testing of flood models consists of altering an input or parameter, and comparing results to the base case. This is undertaken to reveal the sensitivity of the model results to the test input or parameter.

Sensitivity testing of model was undertaken for the following parameters:

- Infiltration losses.
- Land-use Roughness (TUFLOW – hydraulic model).
- Structural Blockage including Open Drain, Pit, Culvert and Bridge (TUFLOW – hydraulic model).

The above scenarios were tested independently for the 1% AEP event at present day (SSP3-7.0 2030).

3.3.2 Design losses

A design losses sensitivity testing was undertaken given the adopted losses for this study were lower than the values recommended from the ARR DataHub. Sensitivity testing was undertaken lowering the initial loss to 20 mm and continuing loss to 2 mm/hr. These values are listed in . These losses have been adopted across numerous flood investigations across western Victoria including the previous Great Western Duplication assessment[1].

Lowering the losses reduced the 1% AEP peak flow approximately 100 m^3/s lower than the value produced using the design losses of 5 mm (IL) and 1 mm/hr (CL). The peak flow determined was significantly lower than the peak flow generated by FFA and that recorded for the January 2011 flood event.

Table 3-2 Available losses values

	IL (mm)	CL (mm/hr)
ARR DataHub	25	4.6
Adopted Design Losses	5	1

Table 3-3 Modelled peak flows for various losses

Scenario	Losses	1% AEP Peak Flow (m^3/s)
Design losses	IL=5, CL=1	362.2
Sensitivity test	IL=20, CL=2	260.0

3.3.3 Land-use Roughness Coefficients

Sensitivity to the adopted roughness values was tested by applying a 20% increased and reduction to land use roughness Manning's n values. The roughness values in the hydraulic model were multiplied by 0.8 and 1.2 for the low and high test respectively.

Figure 3-2 and Figure 3-3 show the difference in water level within Great Western for each roughness test.

The largest flood level changes were observed along the overland flow path across Stephenson Street next to Concongella Creek, and downstream of the creek at Bests Road. Flood levels across the township and Main Street remained largely unchanged. This indicated where the hydraulic model is most sensitive to roughness parameters in and around the waterways.

Flood levels in the waterway have increased up to 0.03 m in the township in the high roughness value test scenario; and a reduction of 0.02 m at the township in the low roughness value test scenario.

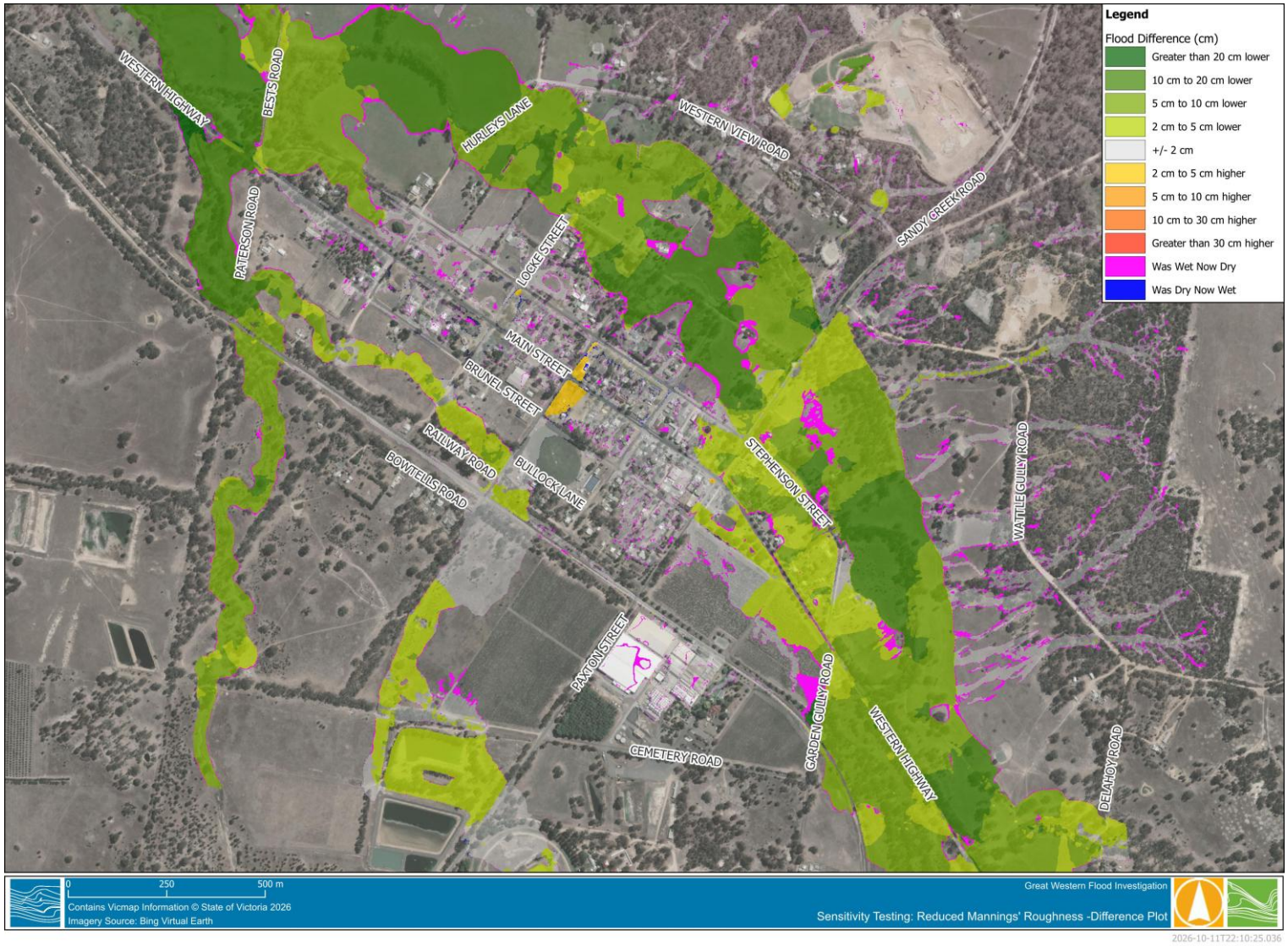


Figure 3-2 1% AEP SSP3-7.0 Year 2030 Difference Plot – Reduced Mannings' Roughness

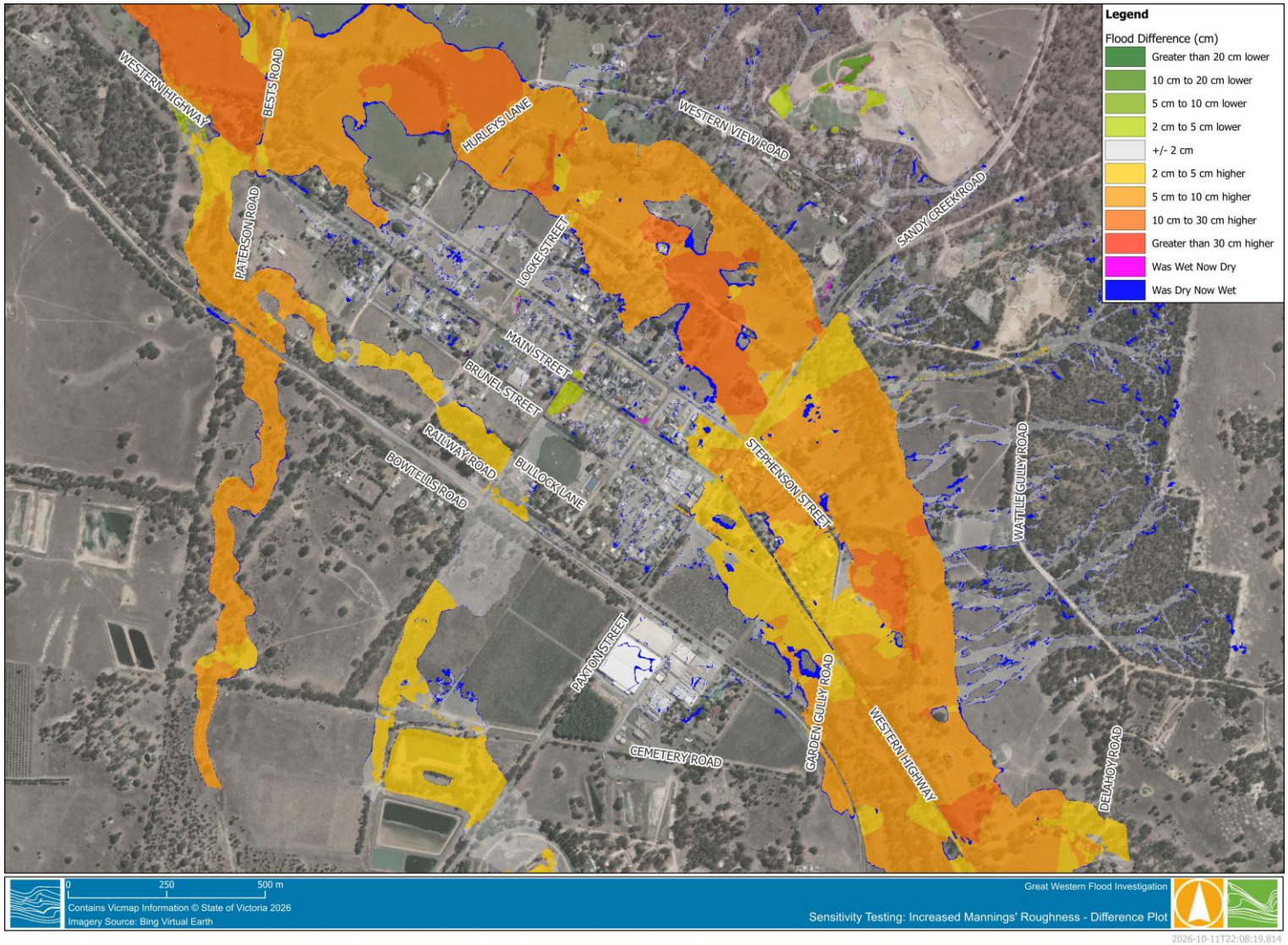


Figure 3-3 1% AEP SSP3-7.0 Year 2030 Difference Plot – Increased Mannings' Roughness

3.3.4 Structural Blockage

The Melbourne Water Blockage Assessment[8] was conducted for the structural blockage sensitivity testing. The assessment consisted of the following assessment criteria:

- Debris Availability - refers to the presence and quantity of particular types of debris within the source area. The critical types of debris are related to the geometry of the various hydraulic structures located within the catchment and more than one type of debris may need to be considered.
- Debris Mobility - refers to the ease with which the available debris is initially mobilised, then transported across overland flow paths into streams and then towards structures.
- Debris Transportability - refers to the ease with which the mobilised debris is transported down a stream or along a drainage channel to the structure.

These criteria were assessed based on site visits and aerial imagery and the selected criteria are presented in Table 3-4. The assessment resulted in a *Medium* level debris potential (DP_{Medium}).

The ratio of the is used in Table 3.6 to quantify the likelihood of this material bridging the openings and triggering a blockage.

The likelihood of material bridging the openings and triggering a blockage ($L_{10)}$ was assessed using the ratio of the width of the controlling openings of structures (W, e.g. grate clear spacing, kerb inlet height, diameter or width of the culvert or bridge pier spacings) to the length of the longest 10% of debris that could arrive at the site. The likelihood was estimated to be $W \geq L_{10} \leq 3^* L_{10}$.

The percentage of blockage factor to apply is listed in Table 3-5.

Table 3-4 Selected assessment criteria for Great Western

	Potential	
Debris Availability	Medium	■ State forest areas with clear understory, grazing land with stands of trees ■ Arid areas, where loose vegetation and exposed loose soils occur and vegetation is sparse. ■ Urban areas that are well maintained with limited debris present in the source area.
Debris Mobility	Medium	■ Low rainfall intensities and large, flat source areas. ■ Receiving streams that frequently overtop their banks. ■ Main debris source areas close to streams
Debris Transportability	Medium	■ Flat bed slopes (< 1%) ■ Stream velocity (1m < V < 2.5m/sec) ■ Narrow streams relative to horizontal debris dimension (W<L) ■ Streams meander with frequent constrictions/snag points. ■ High temporal variability in maximum stream flows

[8] Project 11: Blockage Of Hydraulic Structures Stage 2 Report February 2013 Engineers Australia

Table 3-5 Percentage of blockage factor to apply

AEP	At Site Debris Potential	Blockage Factor ($W \geq L_{10} \leq 3*L_{10}$)
1%	Medium	10%

Given the recommended blockage factor using Melbourne Water's Blockage Assessment was quite small, at 10%, it was decided to increase this value to 50% for the sensitivity test to allow a clear assessment on the impacts of structural blockage.

Blockage factors were applied to all culverts and pipes as follows:

- 50% blockage applied to all culverts
- 50% blockage applied to all pits connected to the underground pipe network in the township

Figure 3-4 shows the difference in water level in Great Western when 50% blockage of 1D network is applied. The results show an increased in flood level along the Main Street, particularly at 31, 77 and 78 Main Street, The increase was as high as 0.1 m at 77 and 78, and 0.3 m at 31 Main Street.

Flood level and extents were also increased in general with more water unable to be discharged into the township pipe network into Concongella Creek. This is because the pipes and culverts are at capacity in the 1% AEP design event. The flat terrain of the township is also a major factor contributing towards the pooling of water on the street and properties.

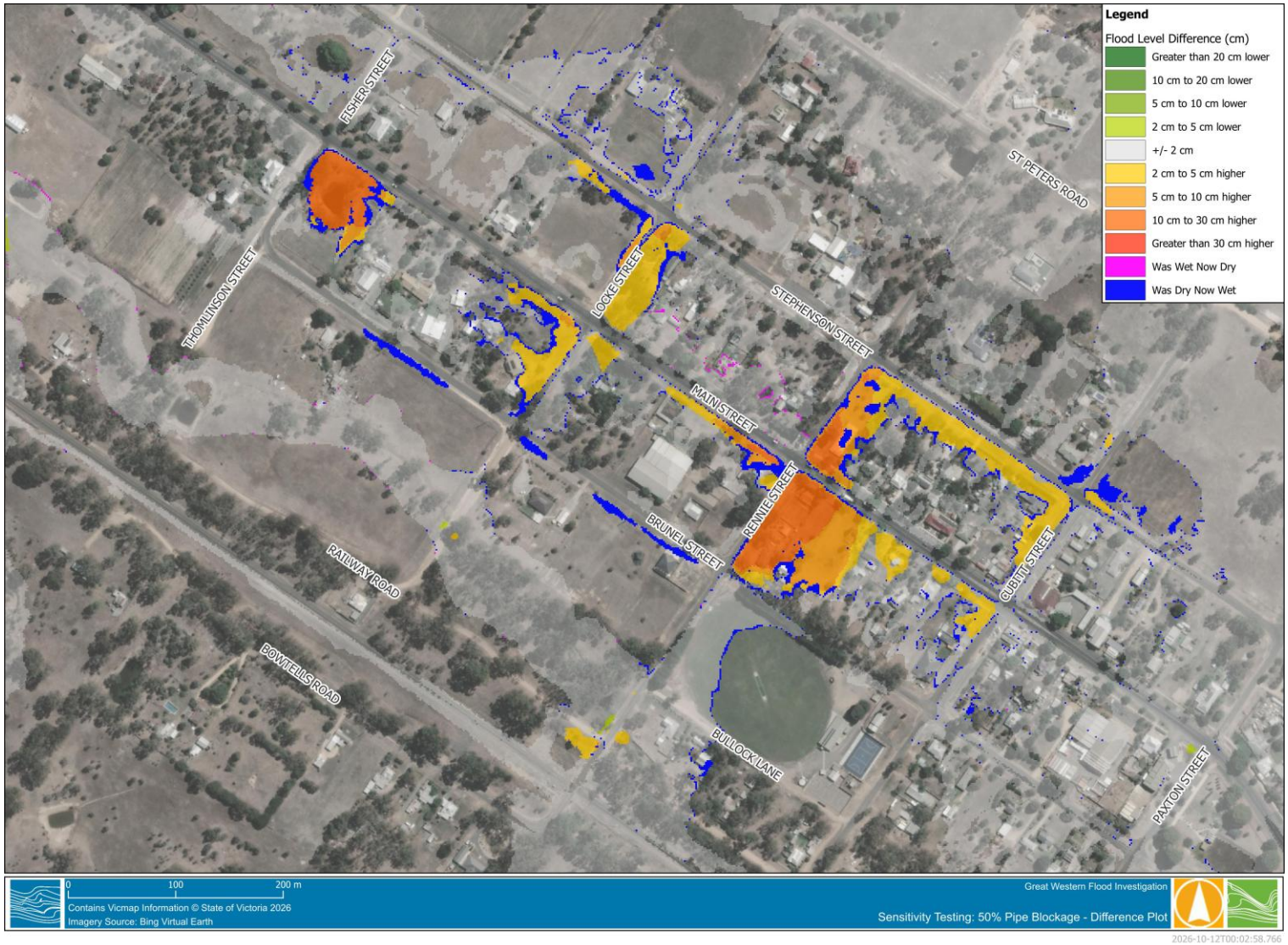


Figure 3-4 1% AEP SSP3-7.0 Year 2030 Difference Plot – 50% Blockage on Pipe Capacity

4 SUMMARY

Design modelling and sensitivity testing of the hydrologic and hydraulic models developed as part of the Great Western Flood Study has been completed and detailed in this report. Design flood mapping was provided along with this report.

The models have been simulated for the 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2%, 0.1%, 0.05% AEP and PMF events. The design events were simulated with project climate change increased rainfall intensity under SSP3-7.0 for the year 2030 and 2100.

For the 1% AEP event, the modelling shows a limited sensitivity to roughness coefficient overall of Great Western and Concongella Creek. On the other hand, the township, particularly around the Main Street, is sensitive towards structural blockage.

The flood mapping was produced in line with industry standards and the current Australian Rainfall and Runoff guidelines. The mapping is fit for the purposes of informing land use planning in Great Western through the development of draft overlays for a future planning scheme amendment. As part of this study, model outputs will be used to assess average annual flood damages for the township, and the models will be utilised to assess potential structural mitigation options. Flood intelligence products were be developed to inform emergency management planning and response, including updated content for the Municipal Flood Emergency Management Plan.

5 DESIGN EVENT MAPPING

5.1 Overview

The following sections outline the design flood mapping for each model scenario.

5.2 20% AEP SSP3-7.0 Year 2030



Figure 5-1 Zoomed into Township – 20% AEP SSP3-7.0 Year 2030 Flood Depth

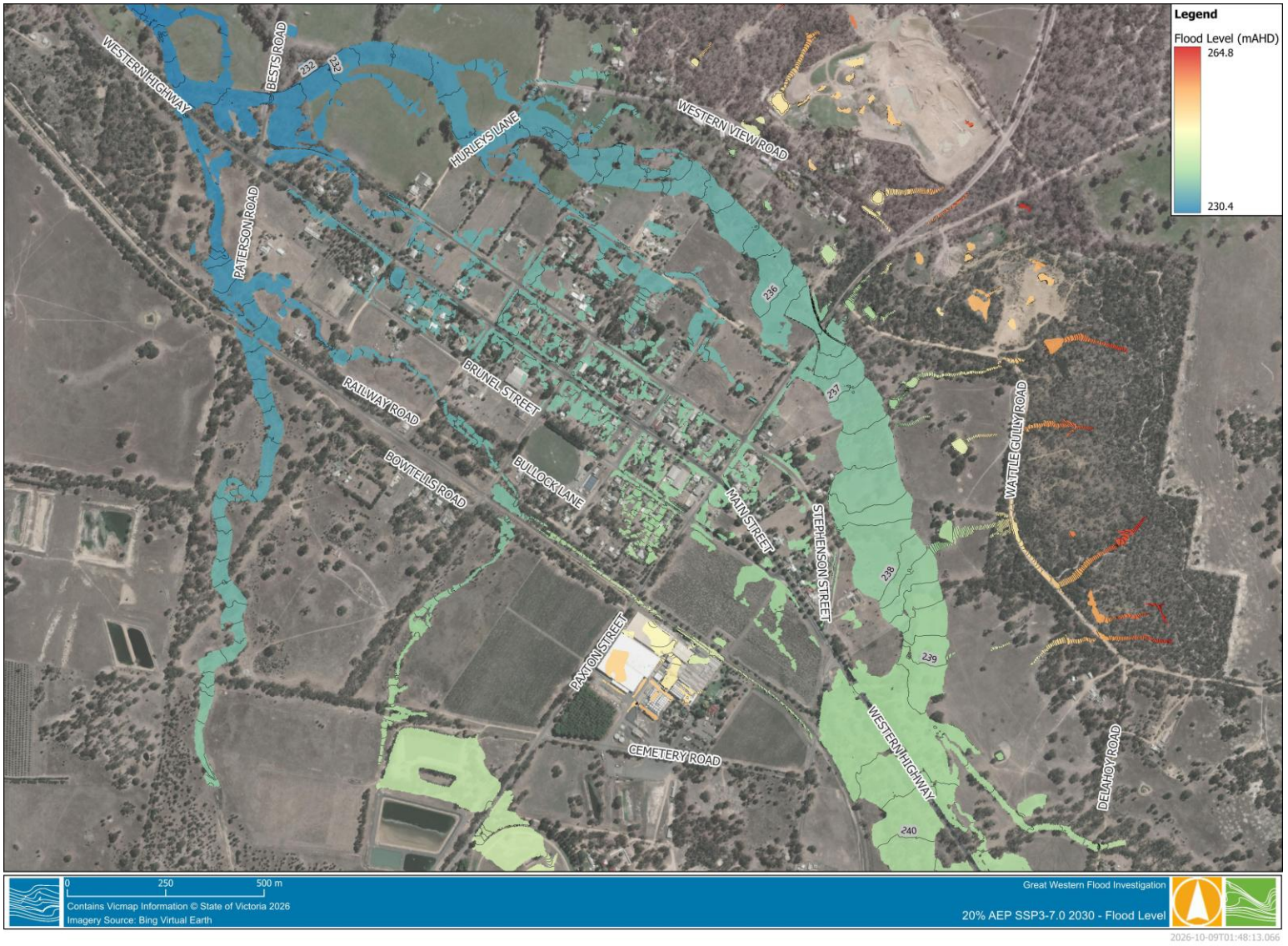


Figure 5-2 Zoomed into Township – 20% AEP SSP3-7.0 Year 2030 Flood Level



Figure 5-3 Zoomed into Township – 20% AEP SSP3-7.0 Year 2030 Flood Velocity

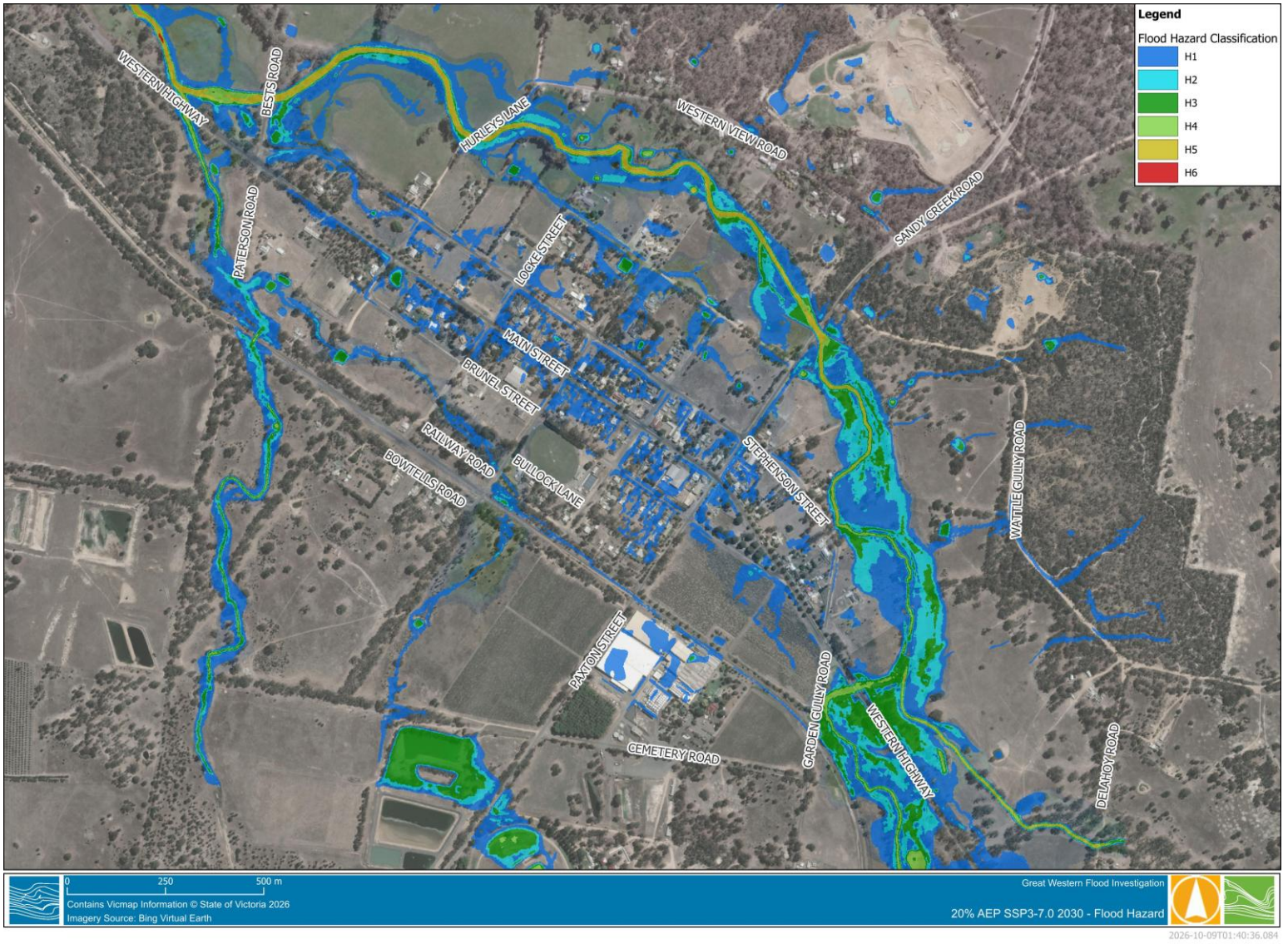


Figure 5-4 Zoomed into Township – 20% AEP SSP3-7.0 Year 2030 Flood Hazard

5.3 10% AEP SSP3-7.0 Year 2030

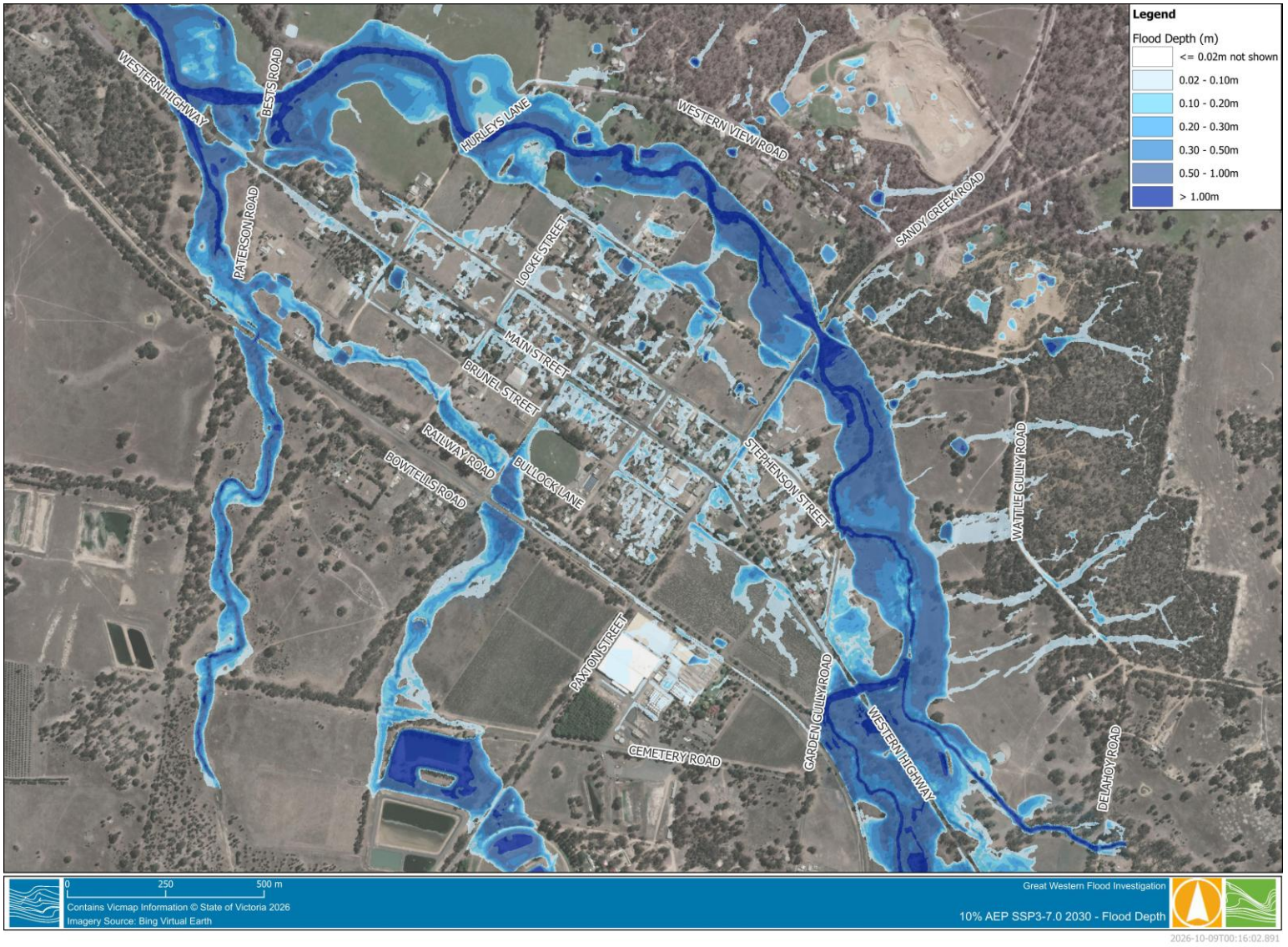


Figure 5-5 Zoomed into Township – 10% AEP SSP3-7.0 Year 2030 Flood Depth

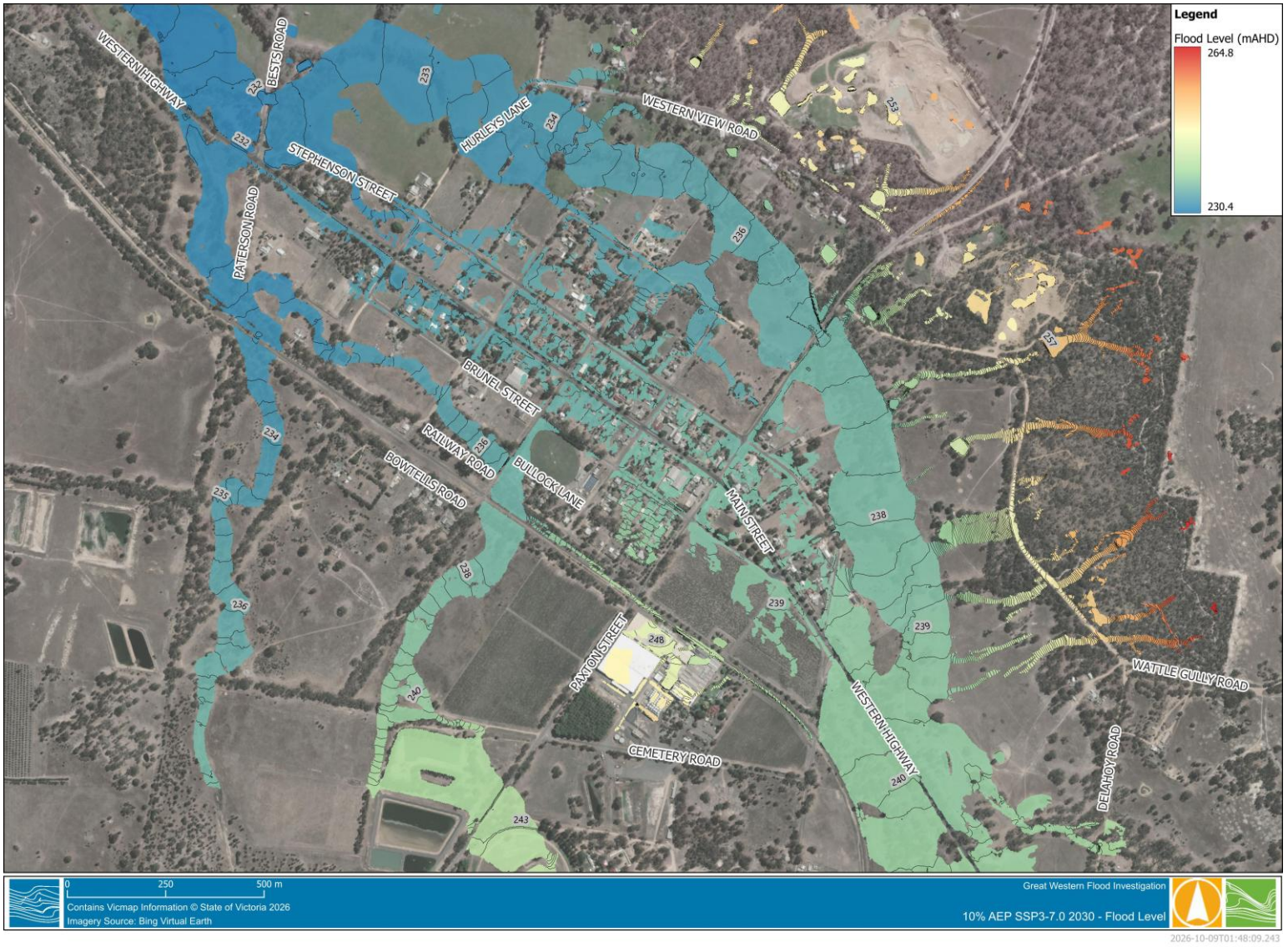


Figure 5-6 Zoomed into Township – 10% AEP SSP3-7.0 Year 2030 Flood Level



Figure 5-7 Zoomed into Township – 10% AEP SSP3-7.0 Year 2030 Flood Velocity

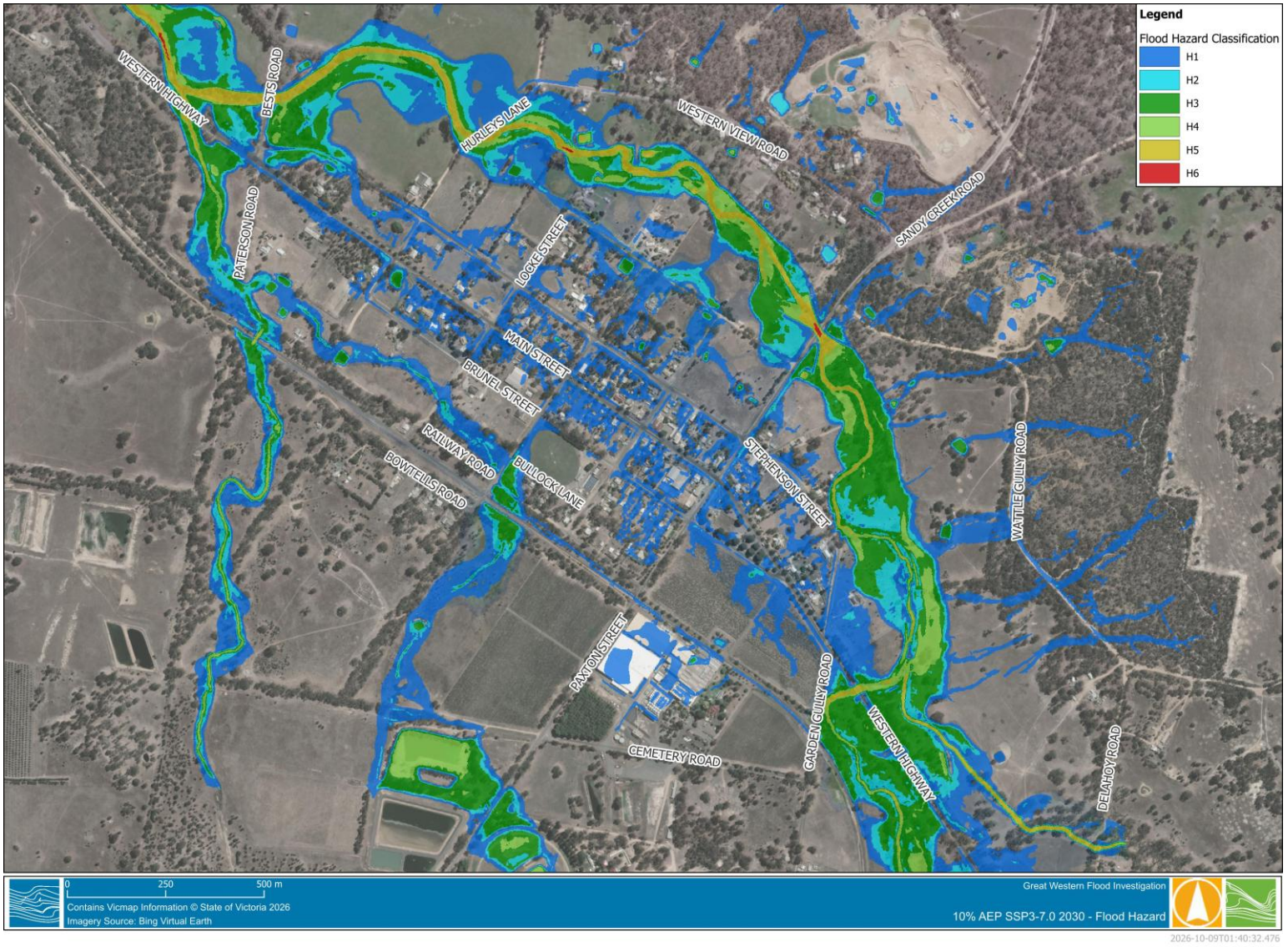


Figure 5-8 Zoomed into Township – 10% AEP SSP3-7.0 Year 2030 Flood Hazard

5.4 5% AEP SSP3-7.0 Year 2030

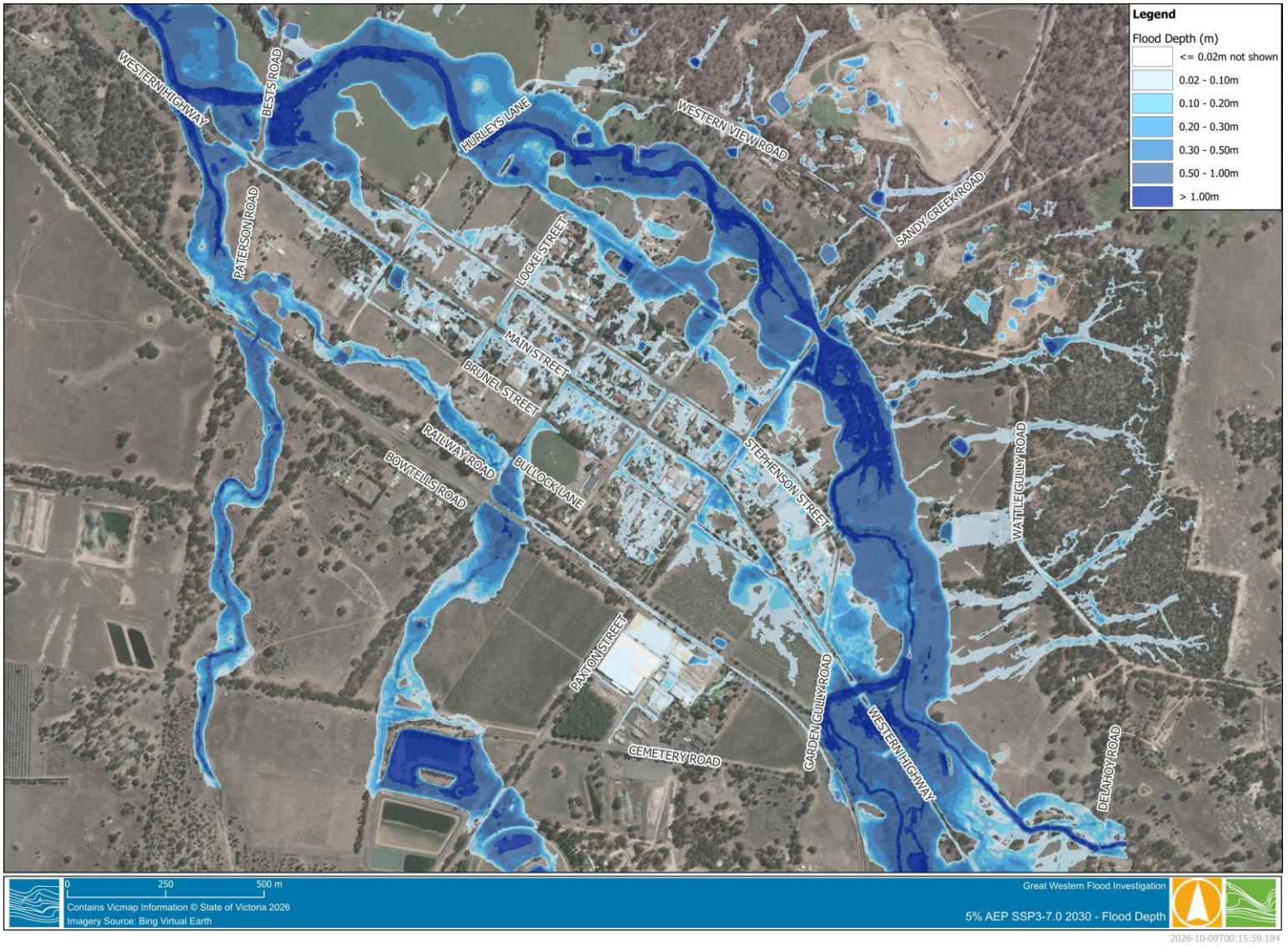


Figure 5-9 Zoomed into Township – 5% AEP SSP3-7.0 Year 2030 Flood Depth

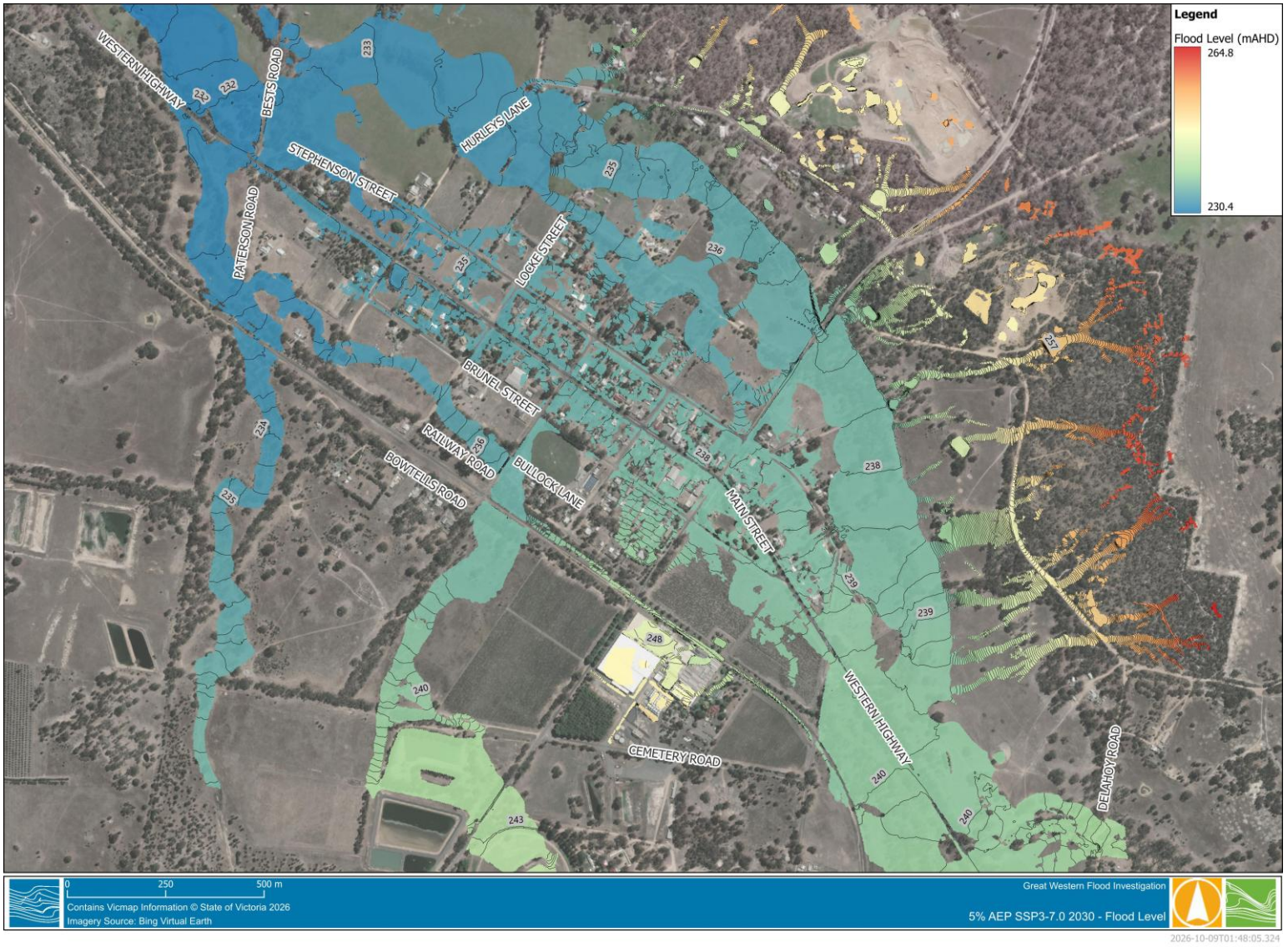


Figure 5-10 Zoomed into Township – 5% AEP SSP3-7.0 Year 2030 Flood Level



Figure 5-11 Zoomed into Township – 5% AEP SSP3-7.0 Year 2030 Flood Velocity

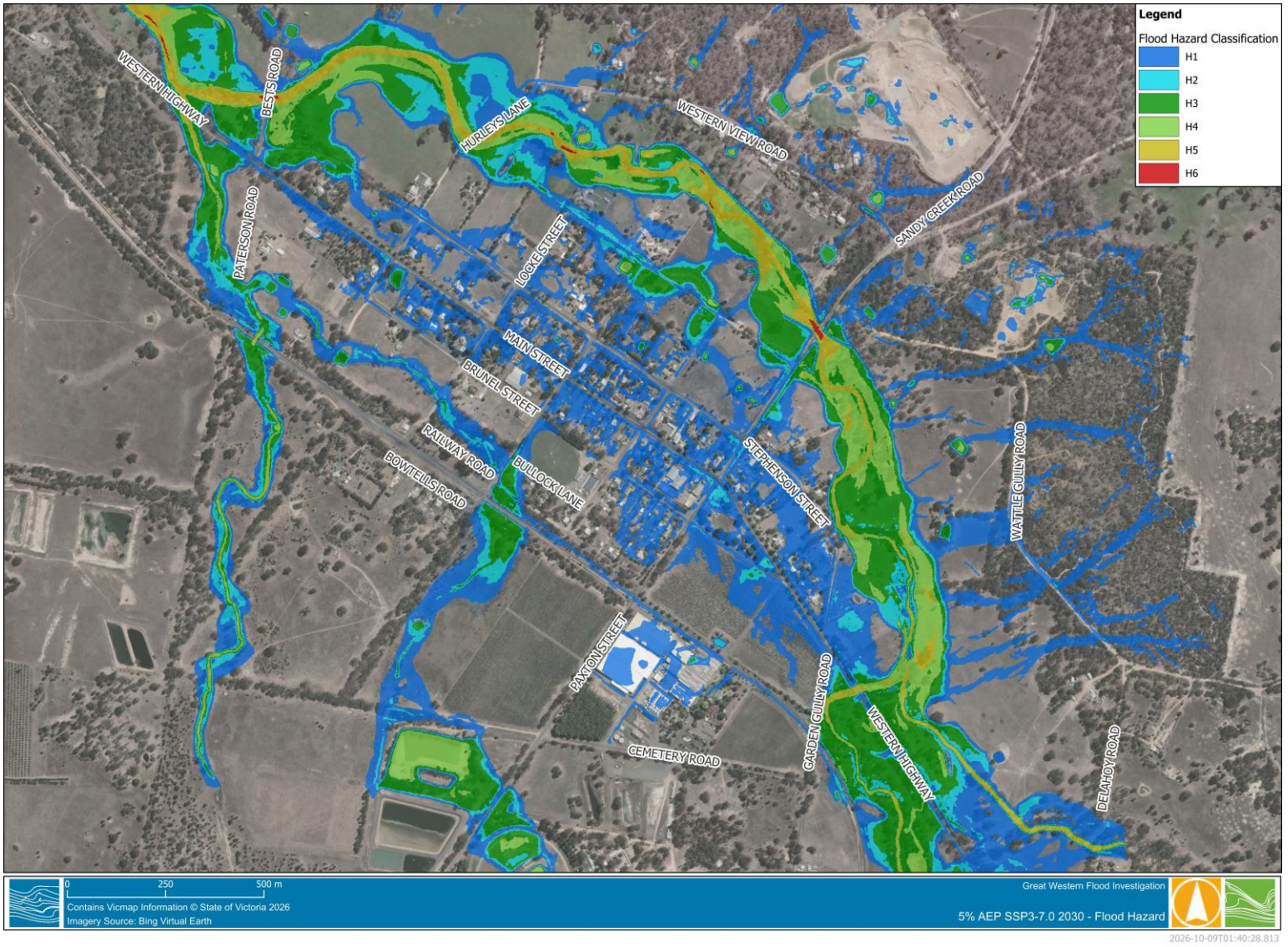


Figure 5-12 Zoomed into Township – 5% AEP SSP3-7.0 Year 2030 Flood Hazard

5.5 2% AEP SSP3-7.0 Year 2030

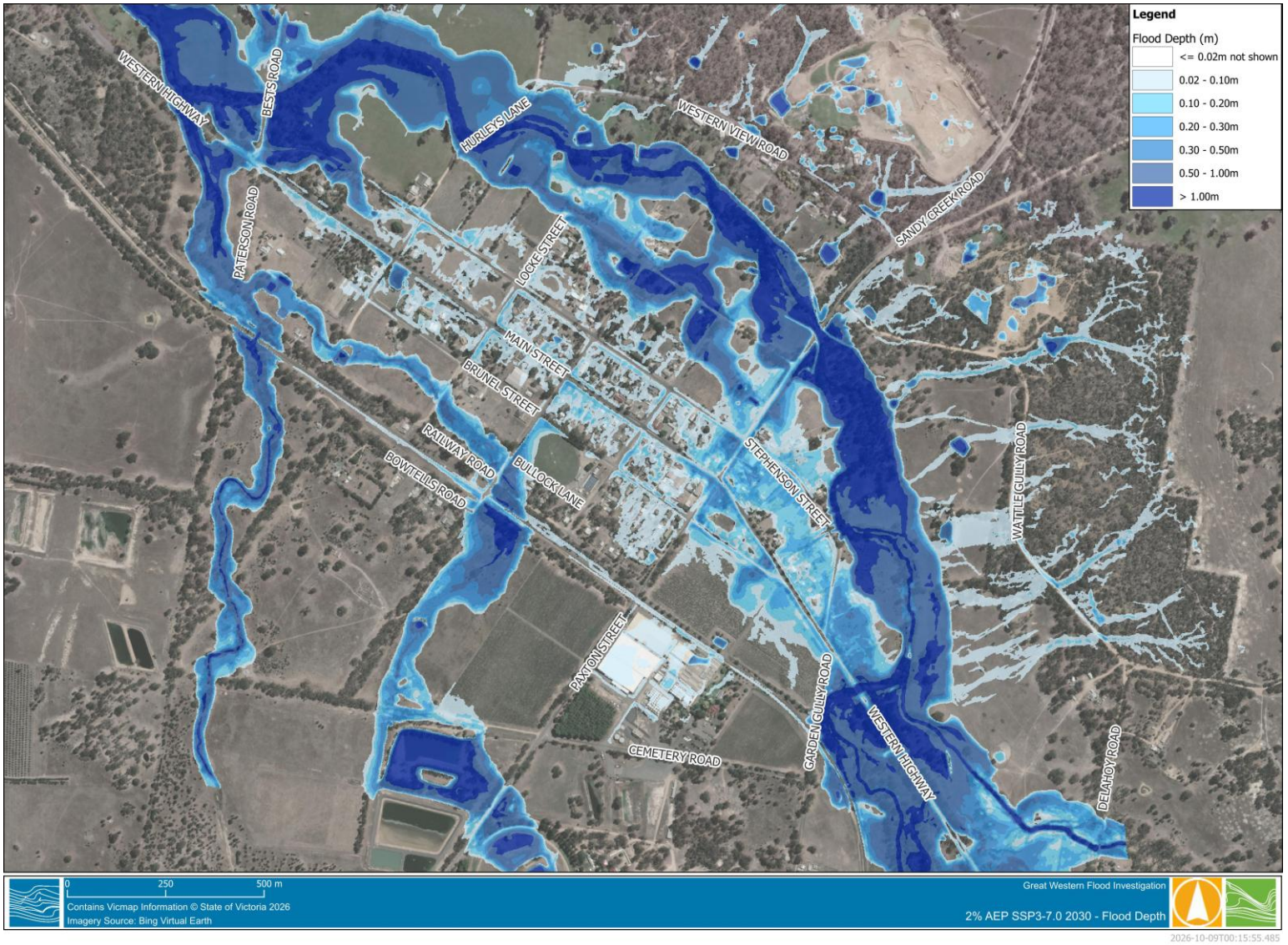


Figure 5-13 Zoomed into Township – 2% AEP SSP3-7.0 Year 2030 Flood Depth

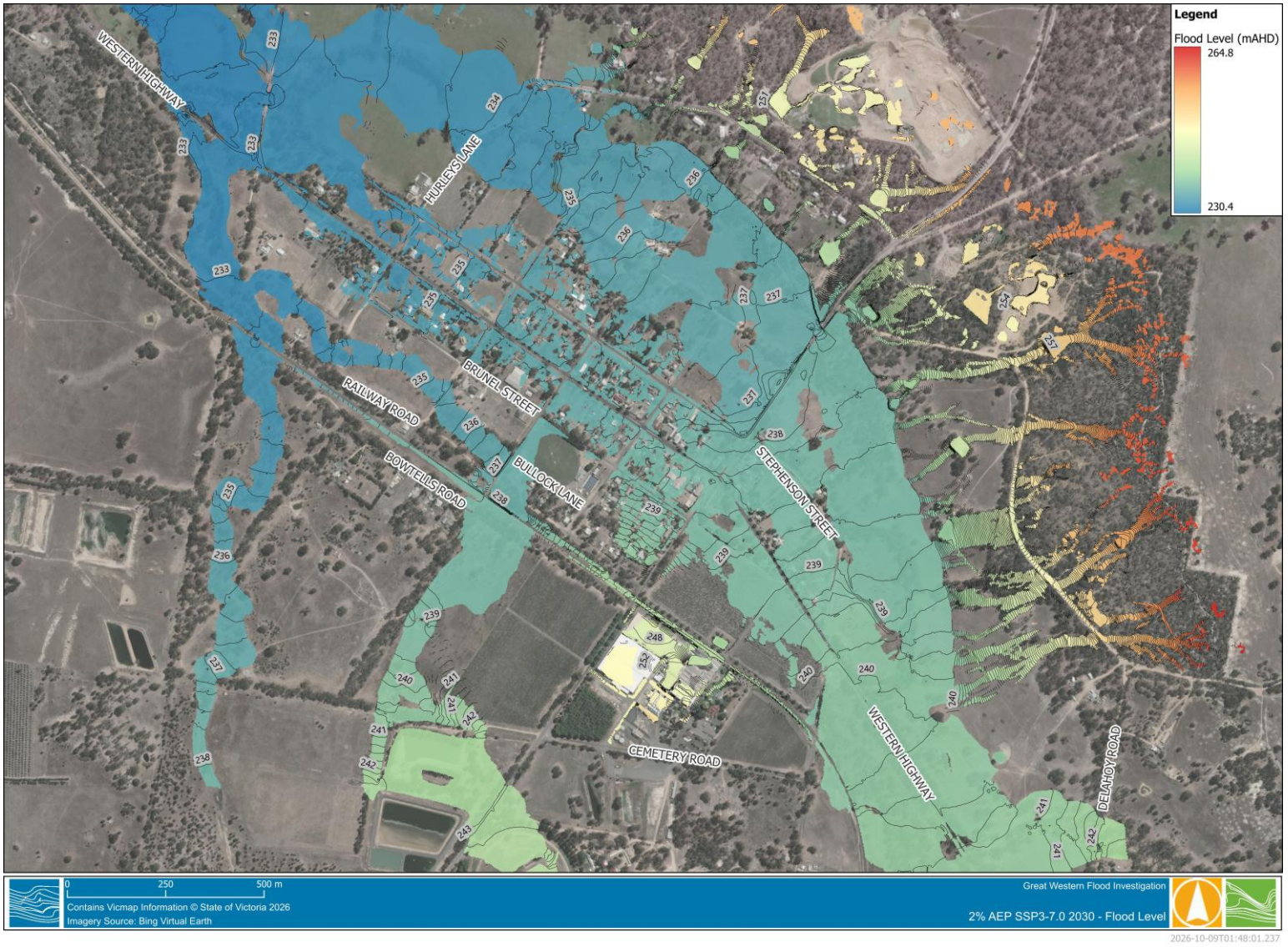


Figure 5-14 Zoomed into Township – 2% AEP SSP3-7.0 Year 2030 Flood level



Figure 5-15 Zoomed into Township – 2% AEP SSP3-7.0 Year 2030 Flood Velocity

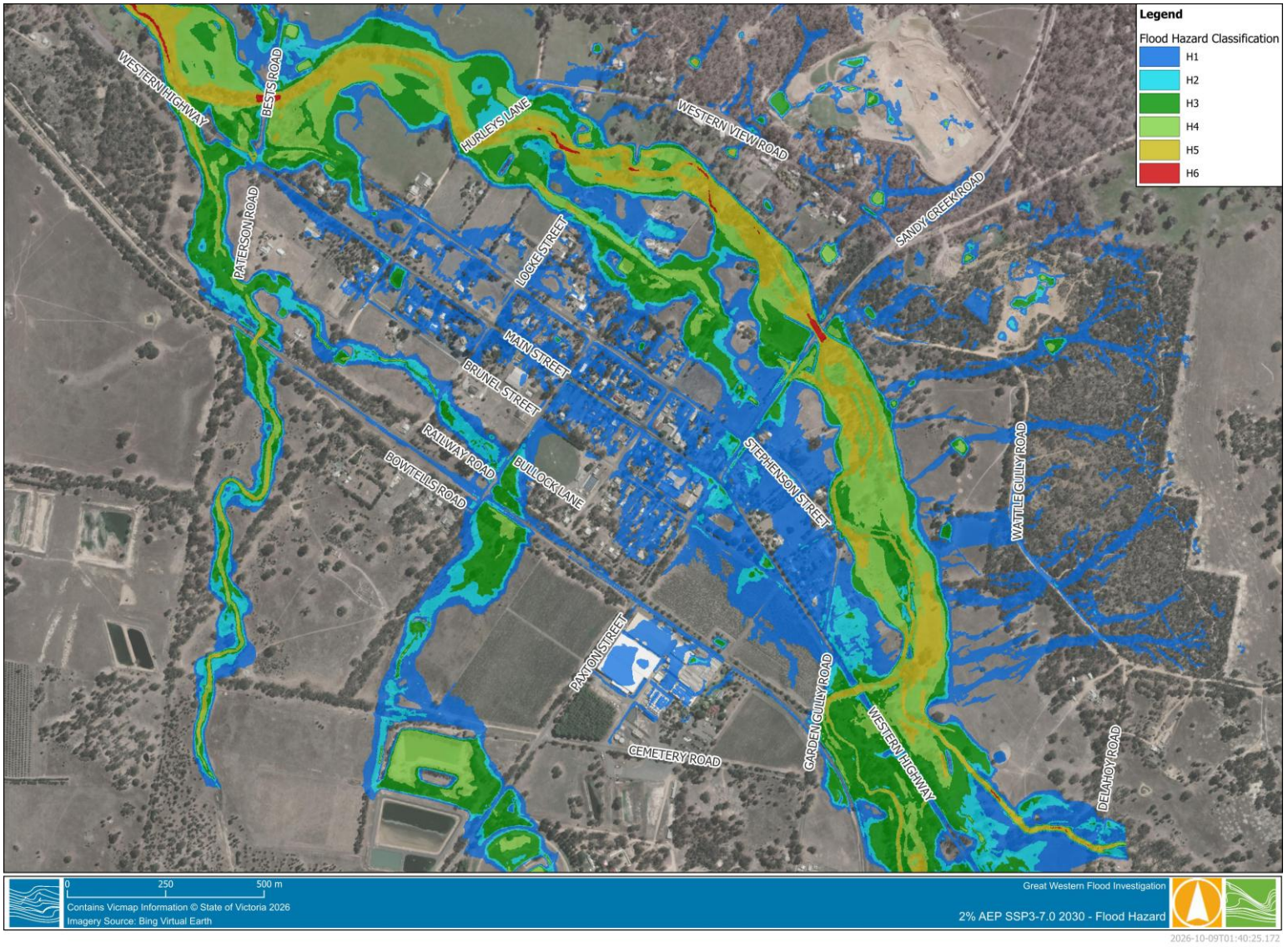


Figure 5-16 Zoomed into Township – 2% AEP SSP3-7.0 Year 2030 Flood Hazard

5.6 1% AEP SSP3-7.0 Year 2030

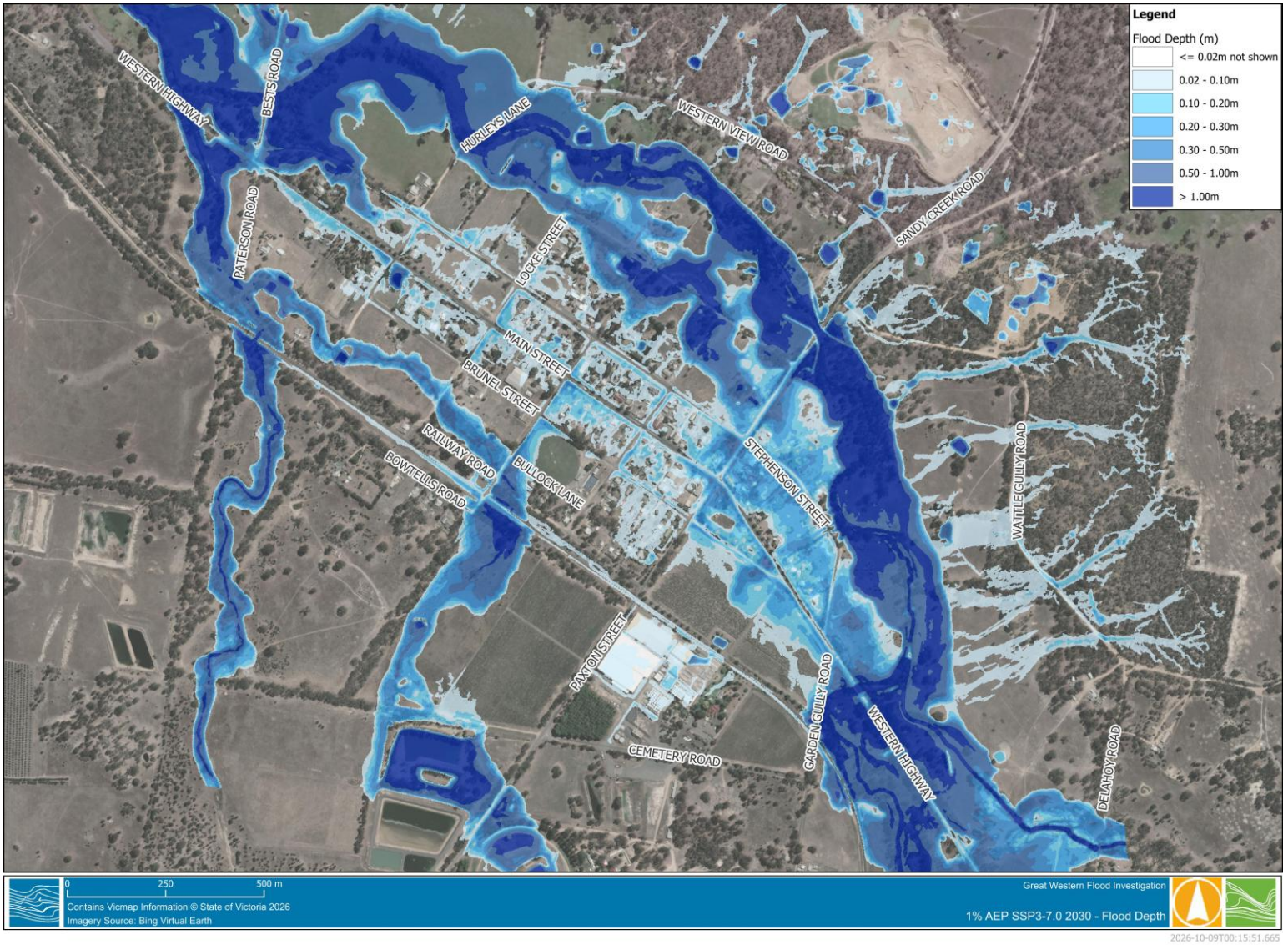


Figure 5-17 Zoomed into Township – 1% AEP SSP3-7.0 Year 2030 Flood Depth

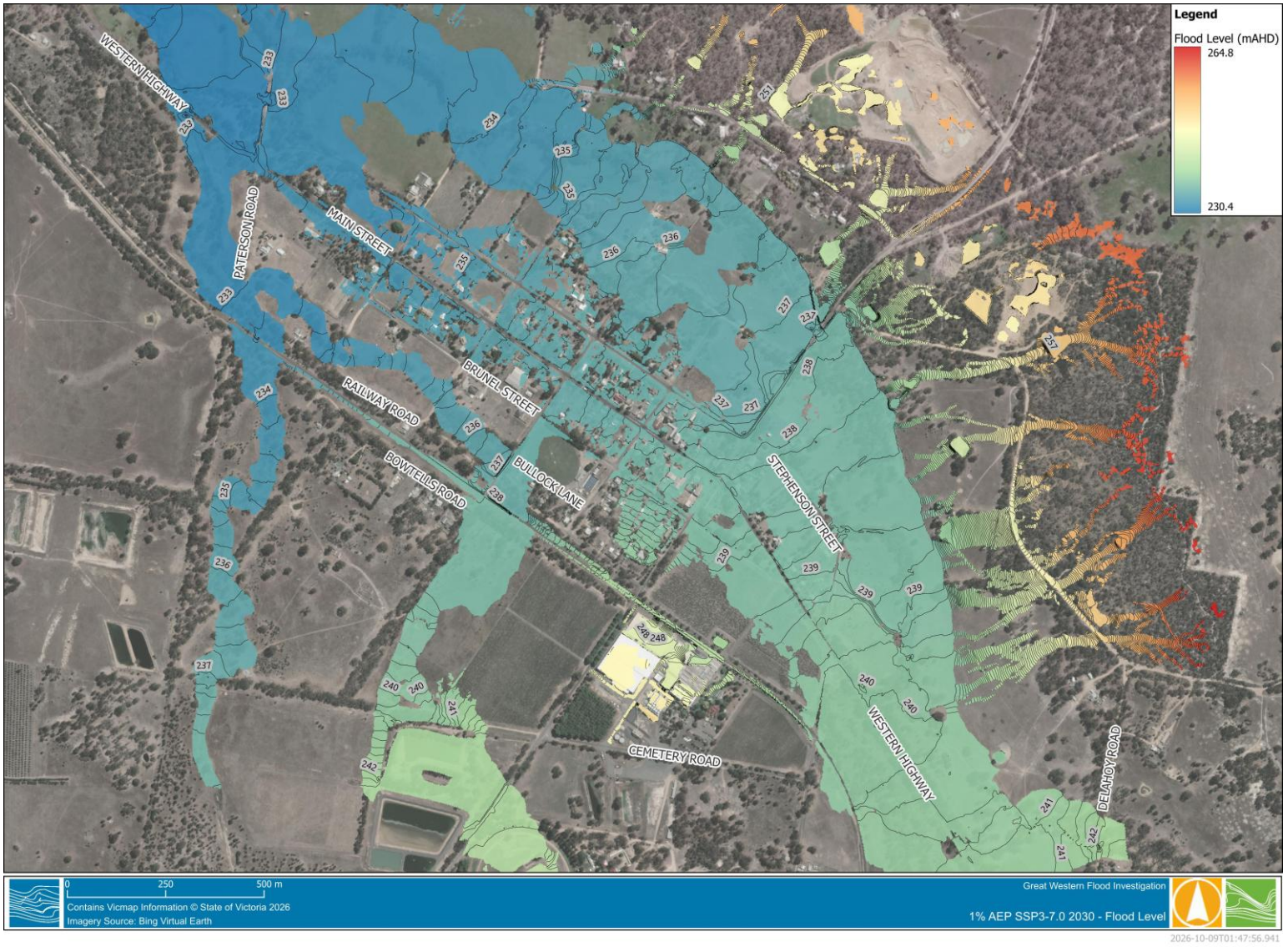


Figure 5-18 Zoomed into Township – 1% AEP SSP3-7.0 Year 2030 Flood Level



Figure 5-19 Zoomed into Township – 1% AEP SSP3-7.0 Year 2030 Flood Velocity

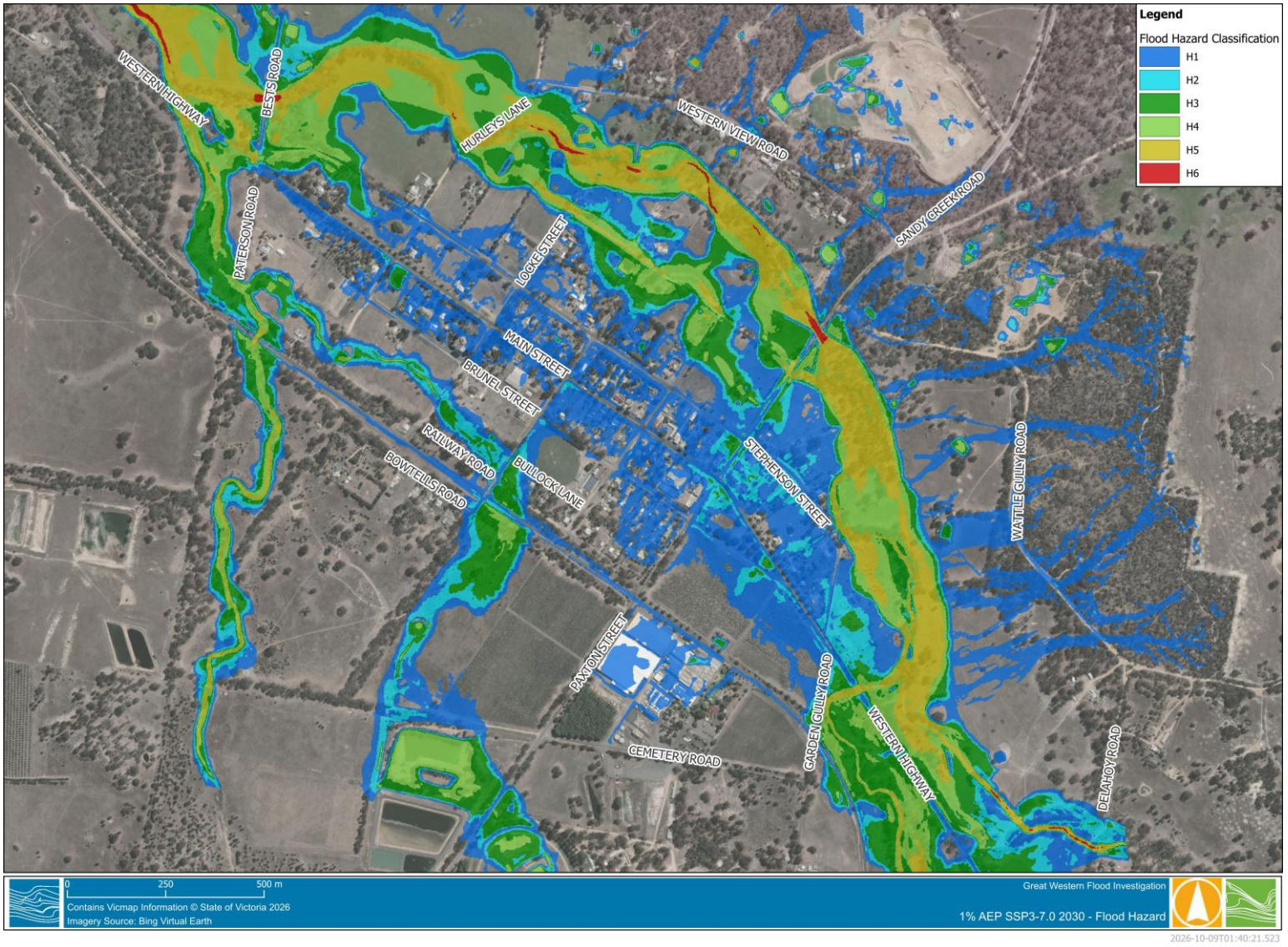


Figure 5-20 Zoomed into Township – 1% AEP SSP3-7.0 Year 2030 Flood Hazard

5.7 0.5% AEP SSP3-7.0 Year 2030

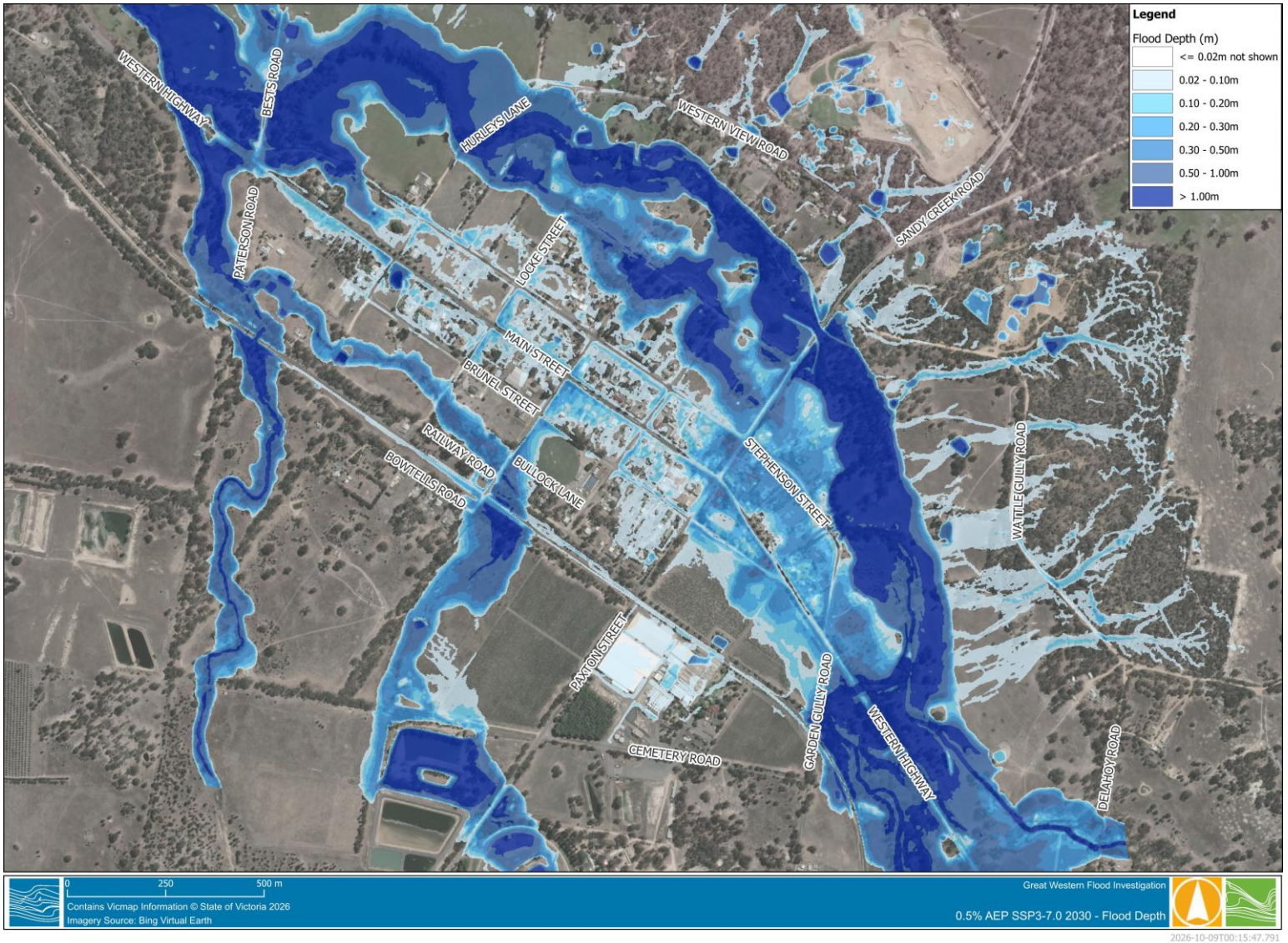


Figure 5-21 Zoomed into Township – 0.5% AEP SSP3-7.0 Year 2030 Flood Depth

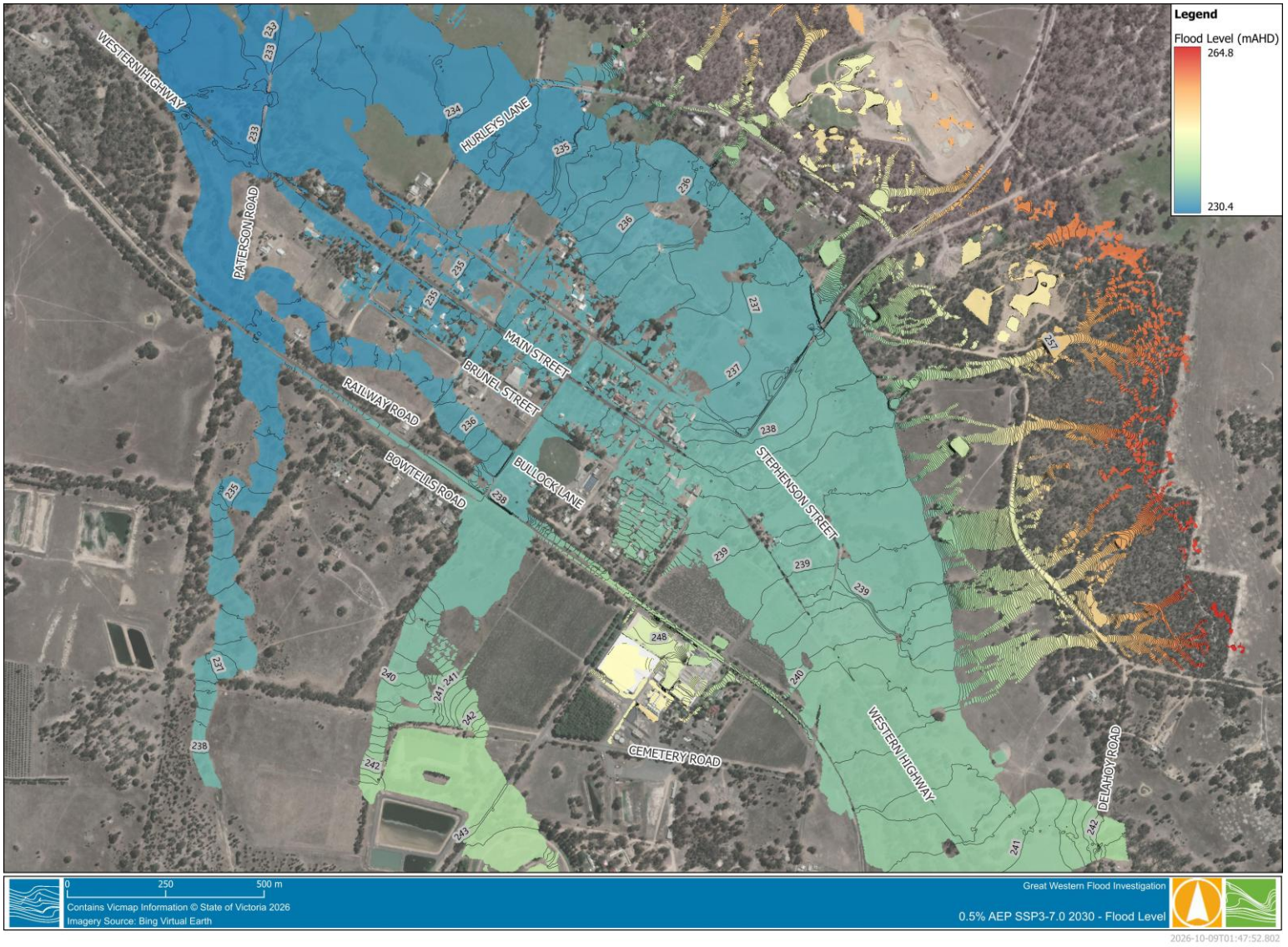


Figure 5-22 Zoomed into Township – 0.5% AEP SSP3-7.0 Year 2030 Flood Level



Figure 5-23 Zoomed into Township – 0.5% AEP SSP3-7.0 Year 2030 Flood Velocity

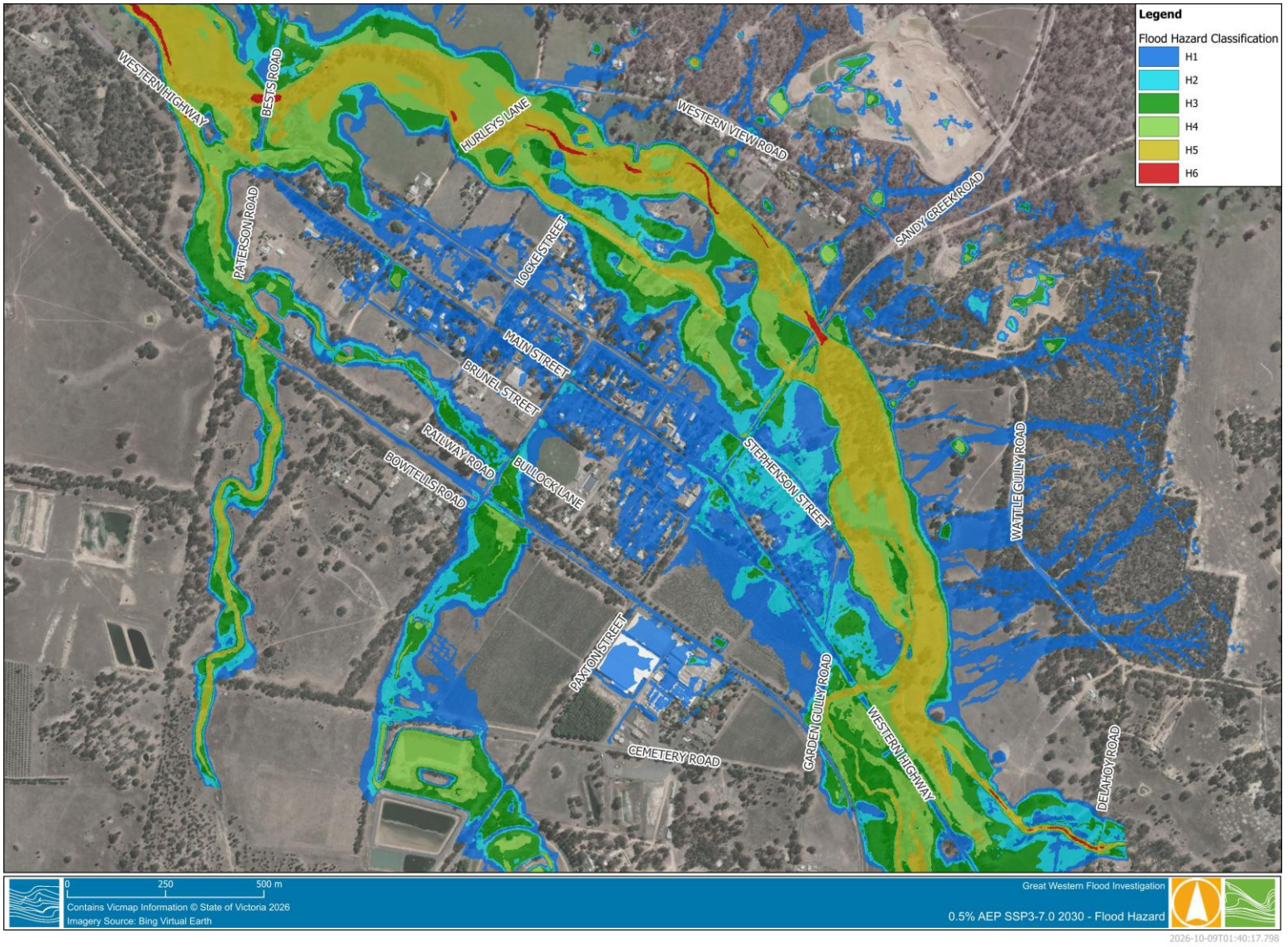


Figure 5-24 Zoomed into Township – 0.5% AEP SSP3-7.0 Year 2030 Flood Hazard

5.8 0.2% AEP SSP3-7.0 Year 2030

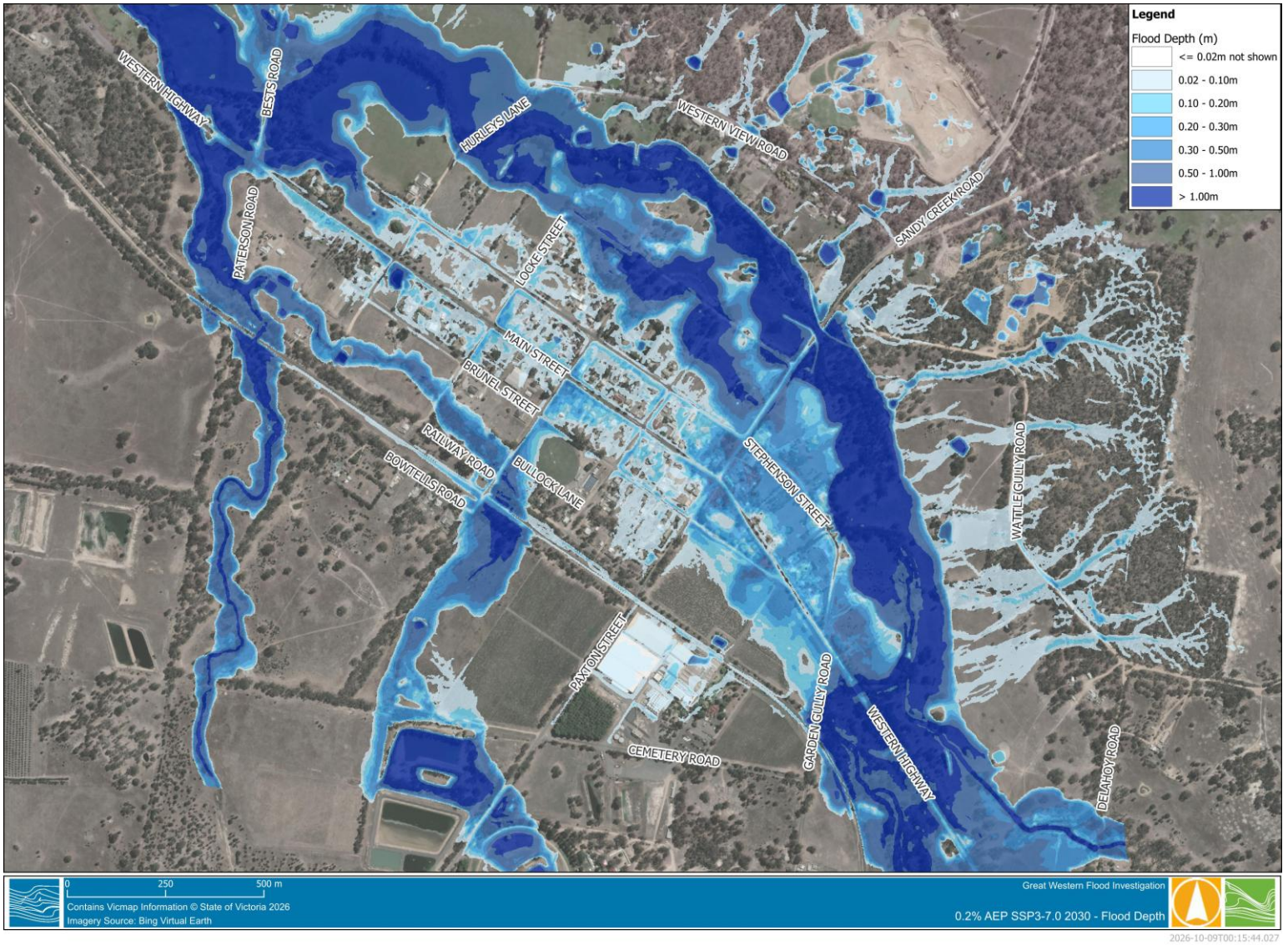


Figure 5-25 Zoomed into Township – 0.2% AEP SSP3-7.0 Year 2030 Flood Depth

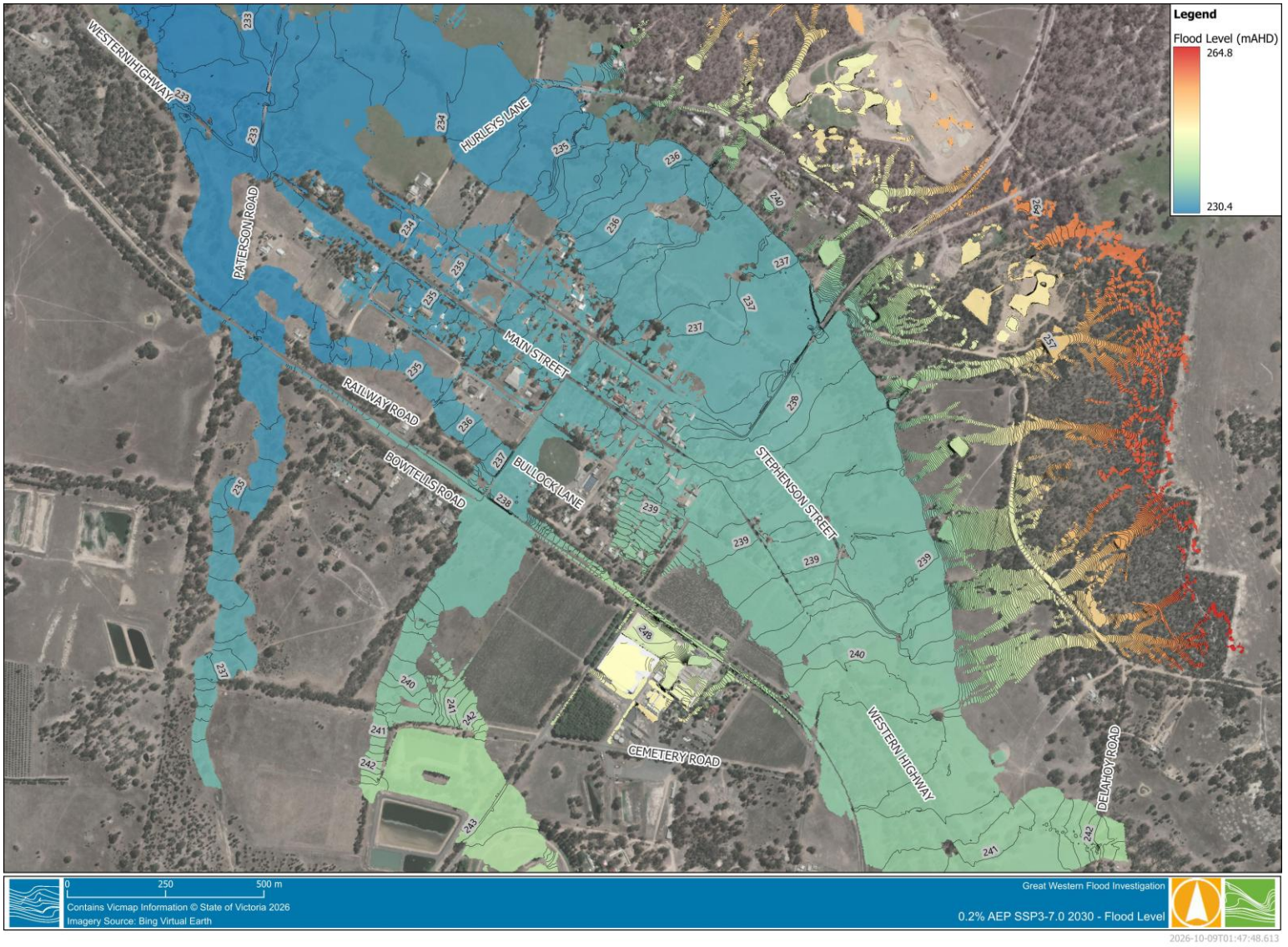


Figure 5-26 Zoomed into Township – 0.2% AEP SSP3-7.0 Year 2030 Flood Level



Figure 5-27 Zoomed into Township – 0.2% AEP SSP3-7.0 Year 2030 Flood Velocity

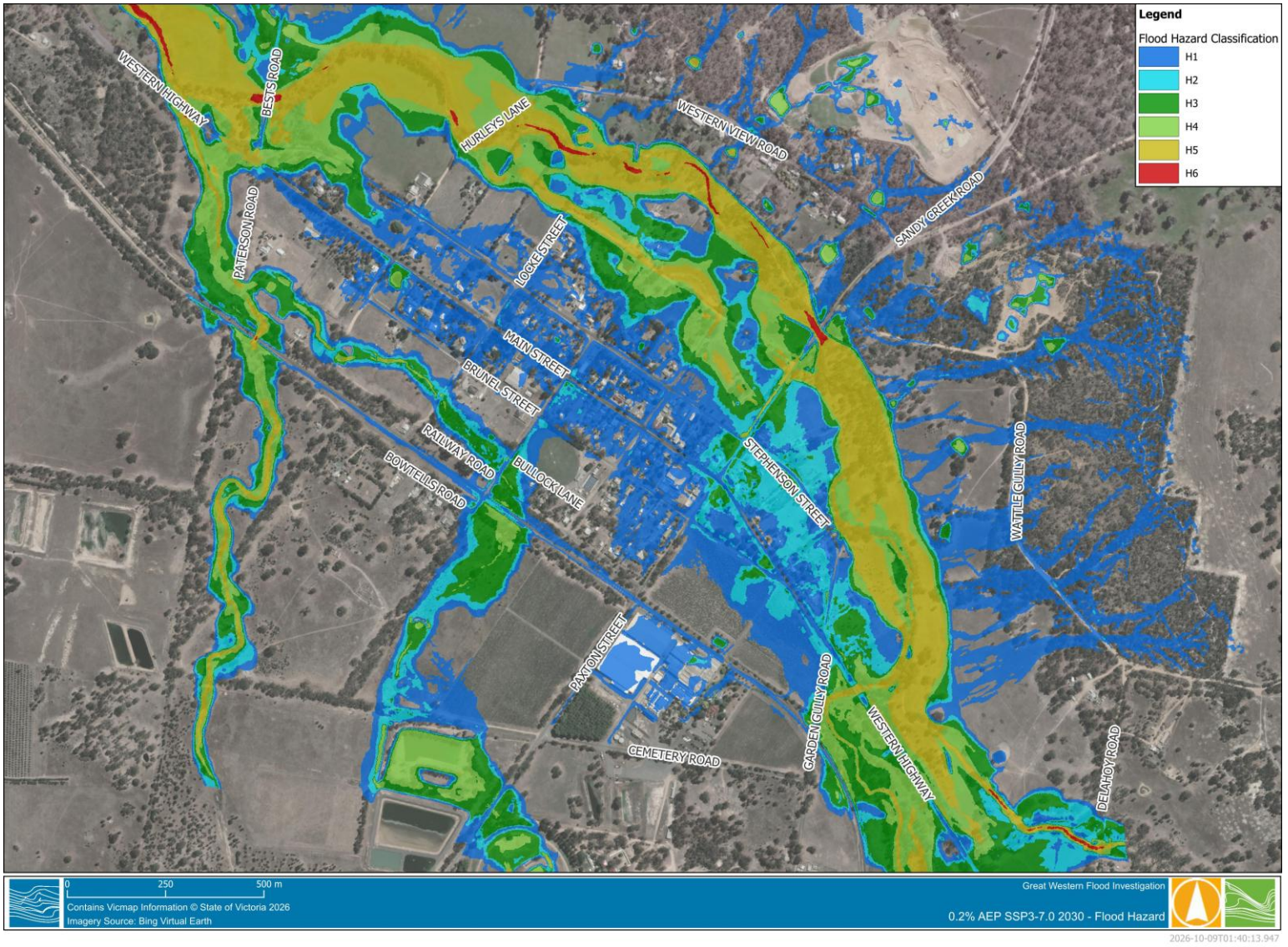


Figure 5-28 Zoomed into Township – 0.2% AEP SSP3-7.0 Year 2030 Flood Hazard

5.9 0.1% AEP SSP3-7.0 Year 2030

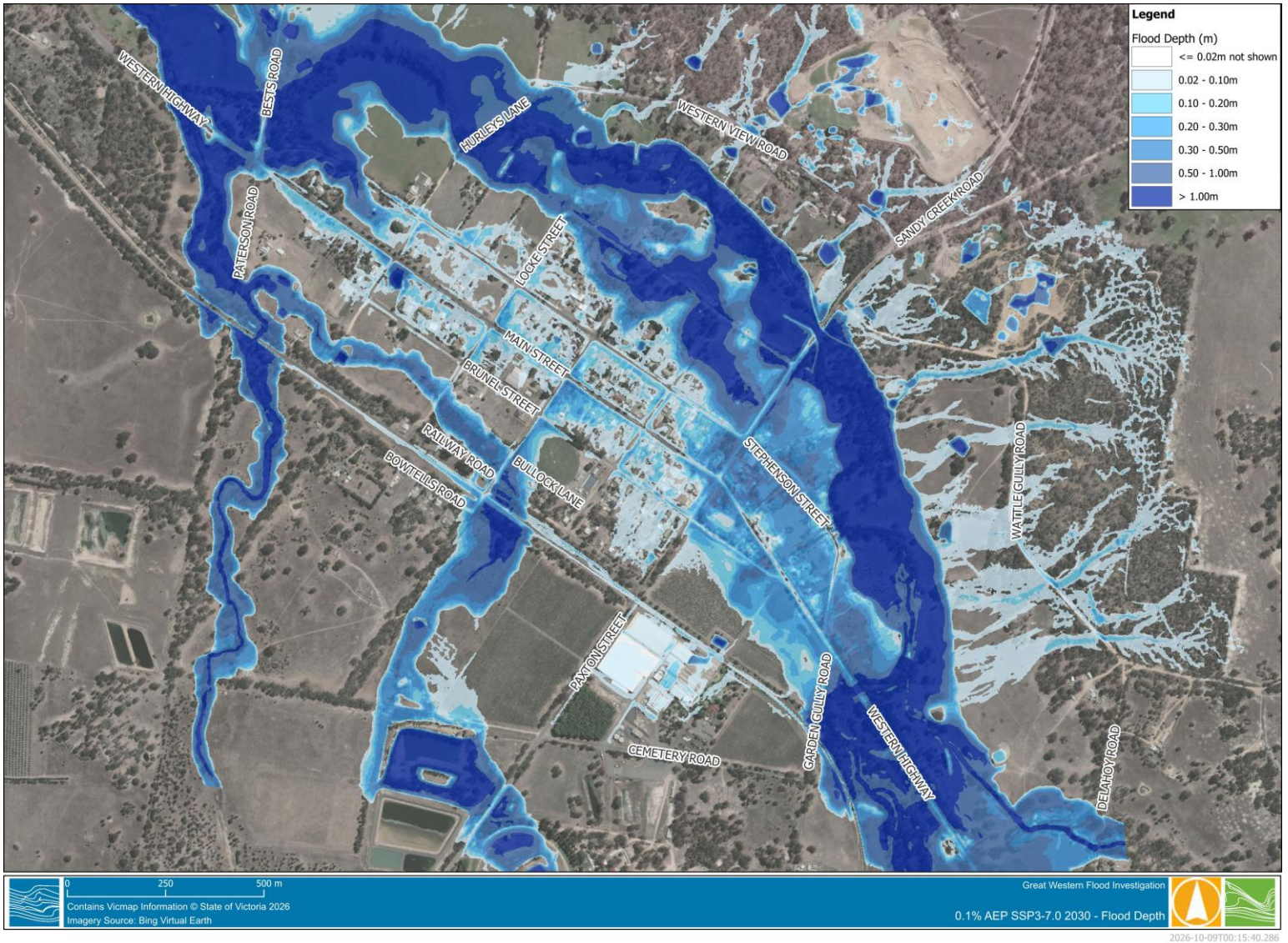


Figure 5-29 Zoomed into Township – 0.1% AEP SSP3-7.0 Year 2030 Flood Depth

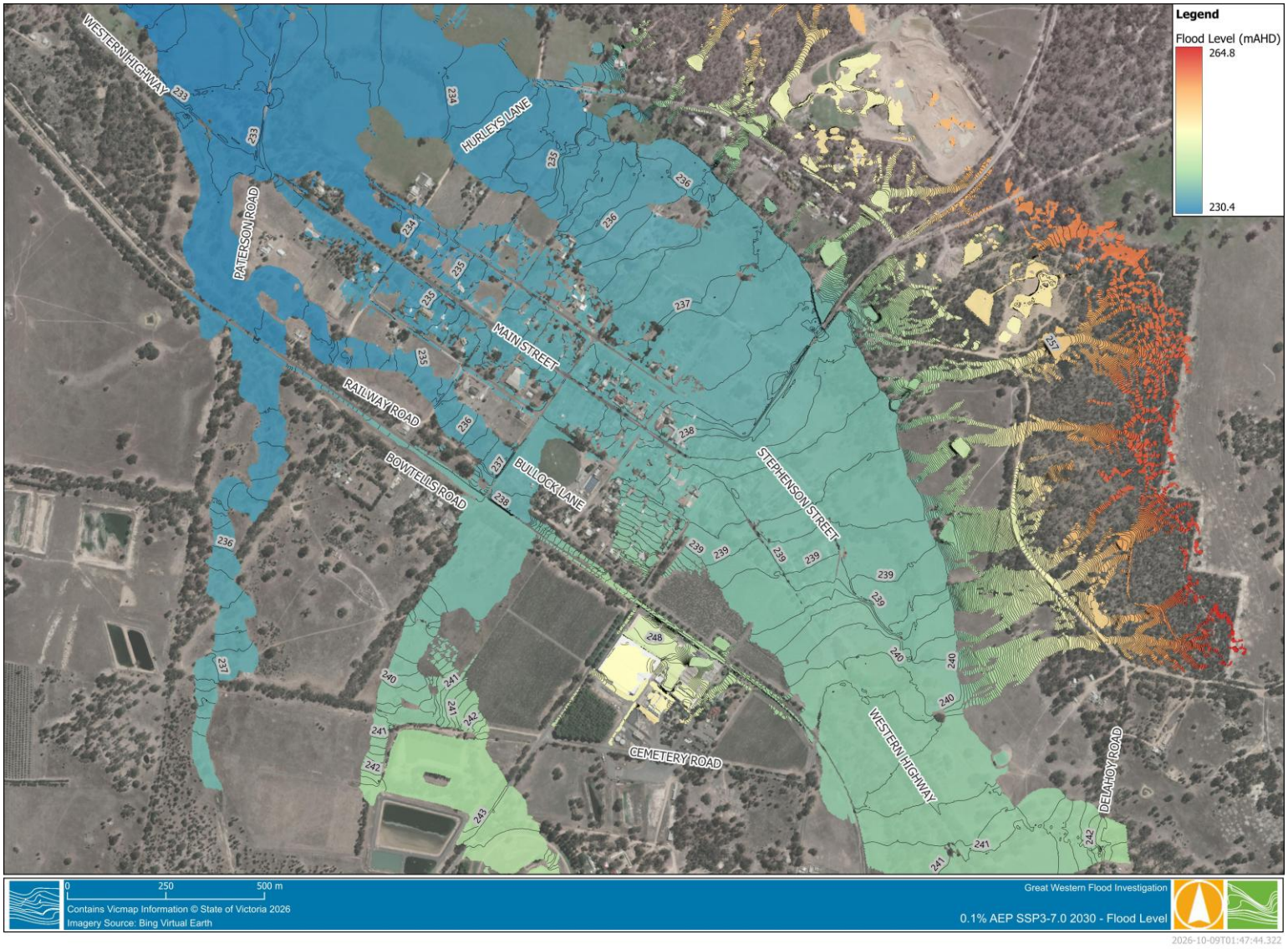


Figure 5-30 Zoomed into Township – 0.1% AEP SSP3-7.0 Year 2030 Flood Level



Figure 5-31 Zoomed into Township – 0.1% AEP SSP3-7.0 Year 2030 Flood Velocity

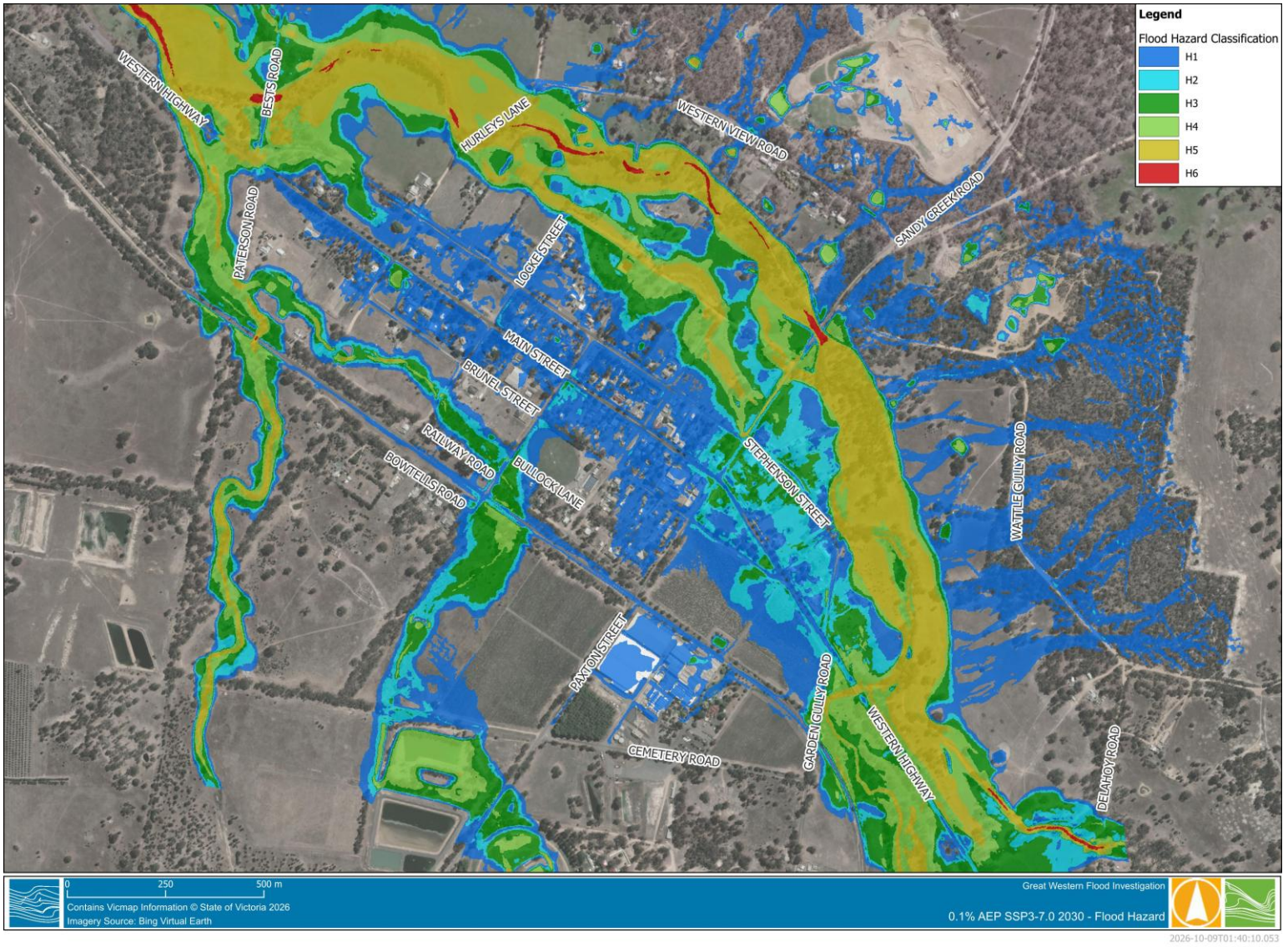


Figure 5-32 Zoomed into Township – 0.1% AEP SSP3-7.0 Year 2030 Flood Hazard

5.10 0.05% AEP SSP3-7.0 Year 2030

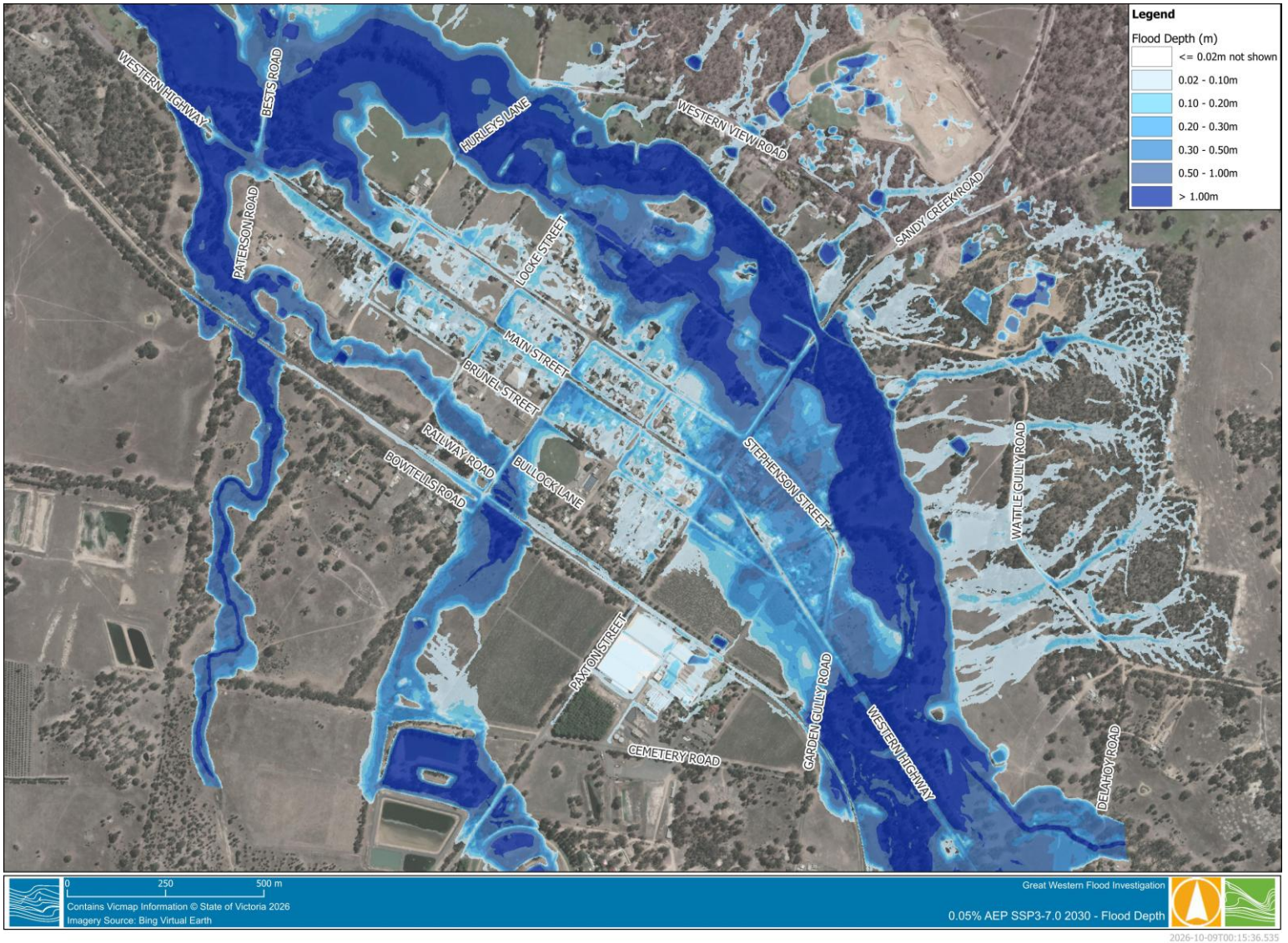


Figure 5-33 Zoomed into Township – 0.05% AEP SSP3-7.0 Year 2030 Flood Depth

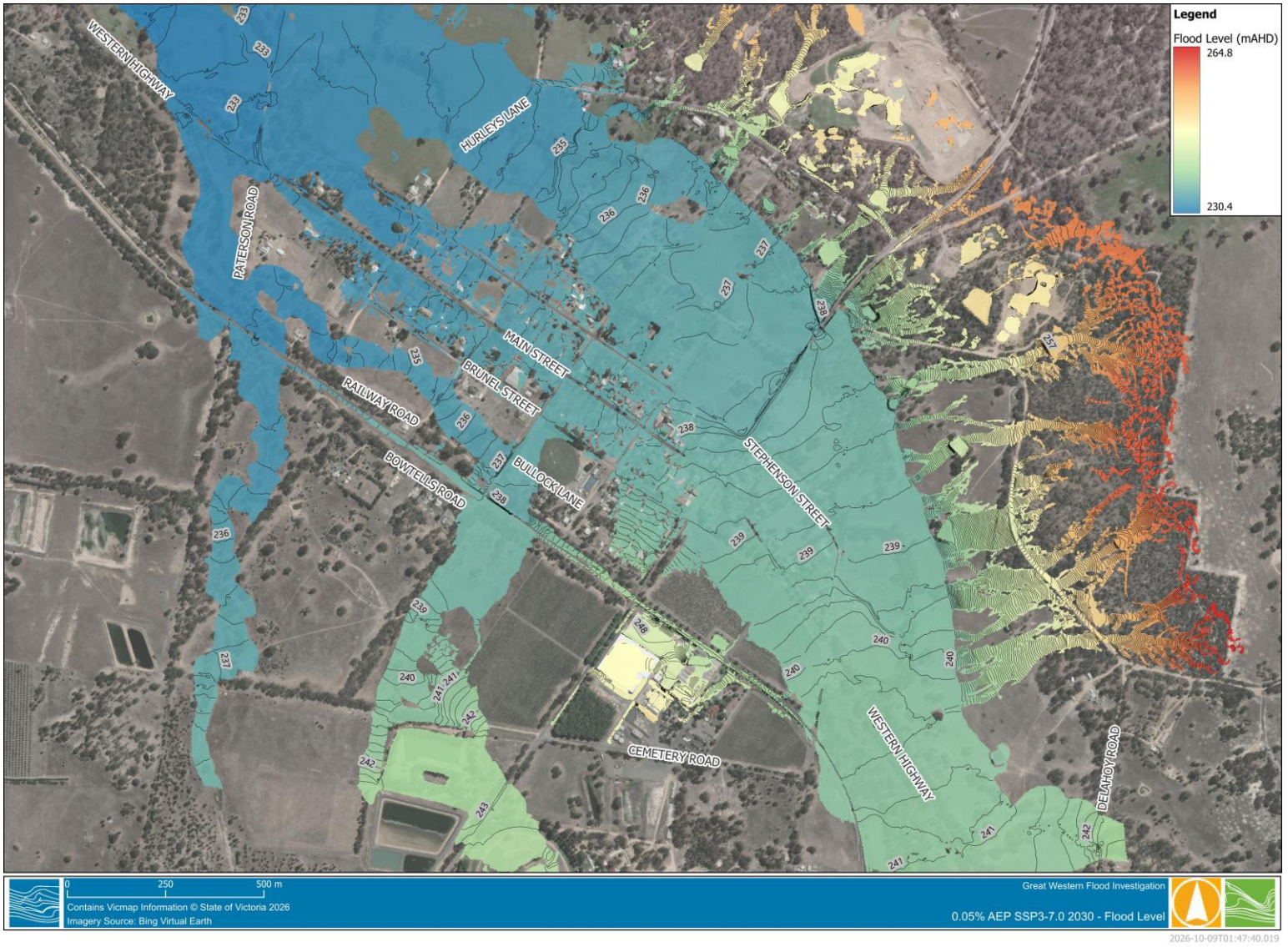


Figure 5-34 Zoomed into Township – 0.05% AEP SSP3-7.0 Year 2030 Flood Level



Figure 5-35 Zoomed into Township – 0.05% AEP SSP3-7.0 Year 2030 Flood Velocity

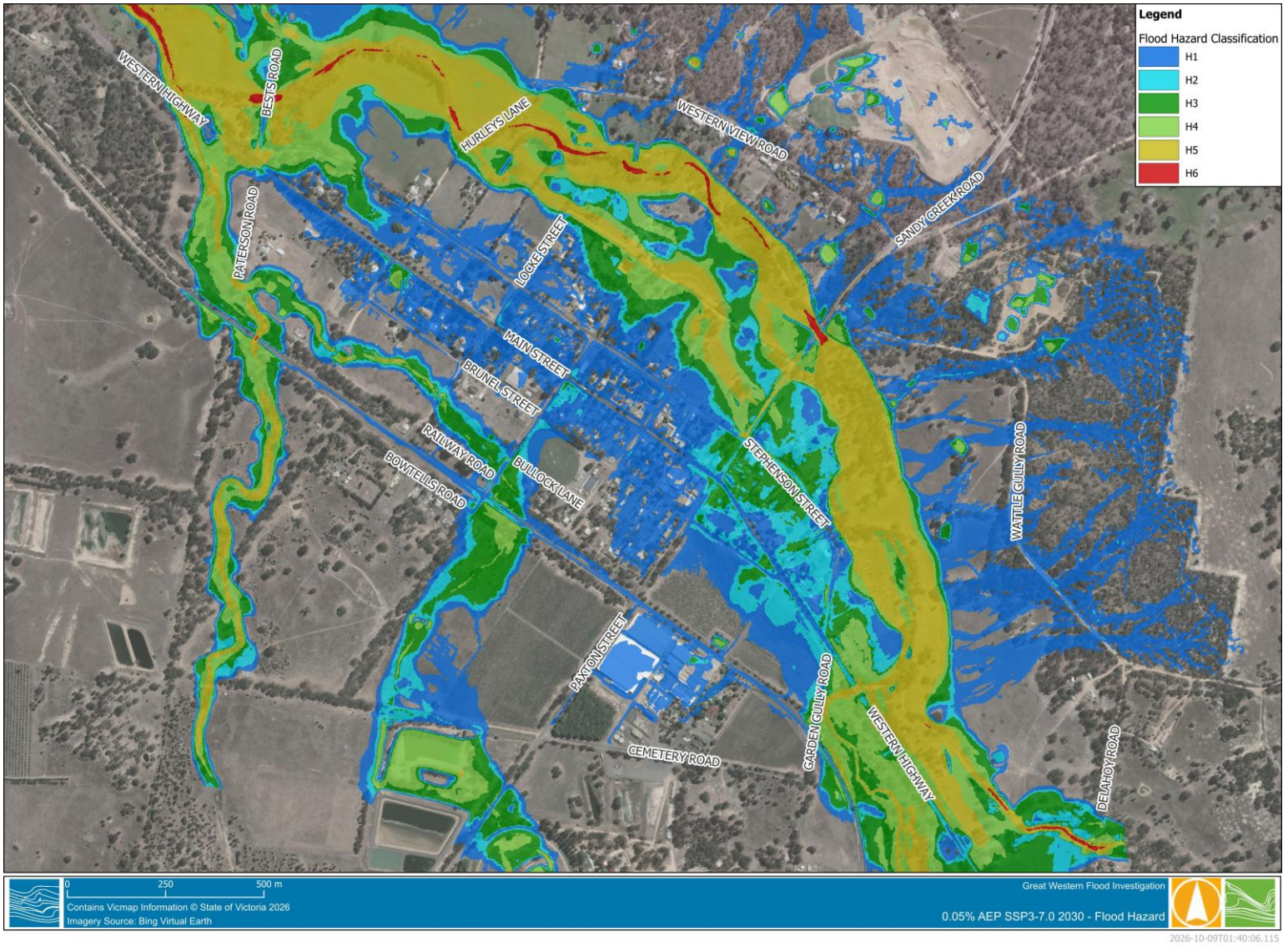


Figure 5-36 Zoomed into Township – 0.05% AEP SSP3-7.0 Year 2030 Flood Hazard

5.11 Probable Maximum Flood

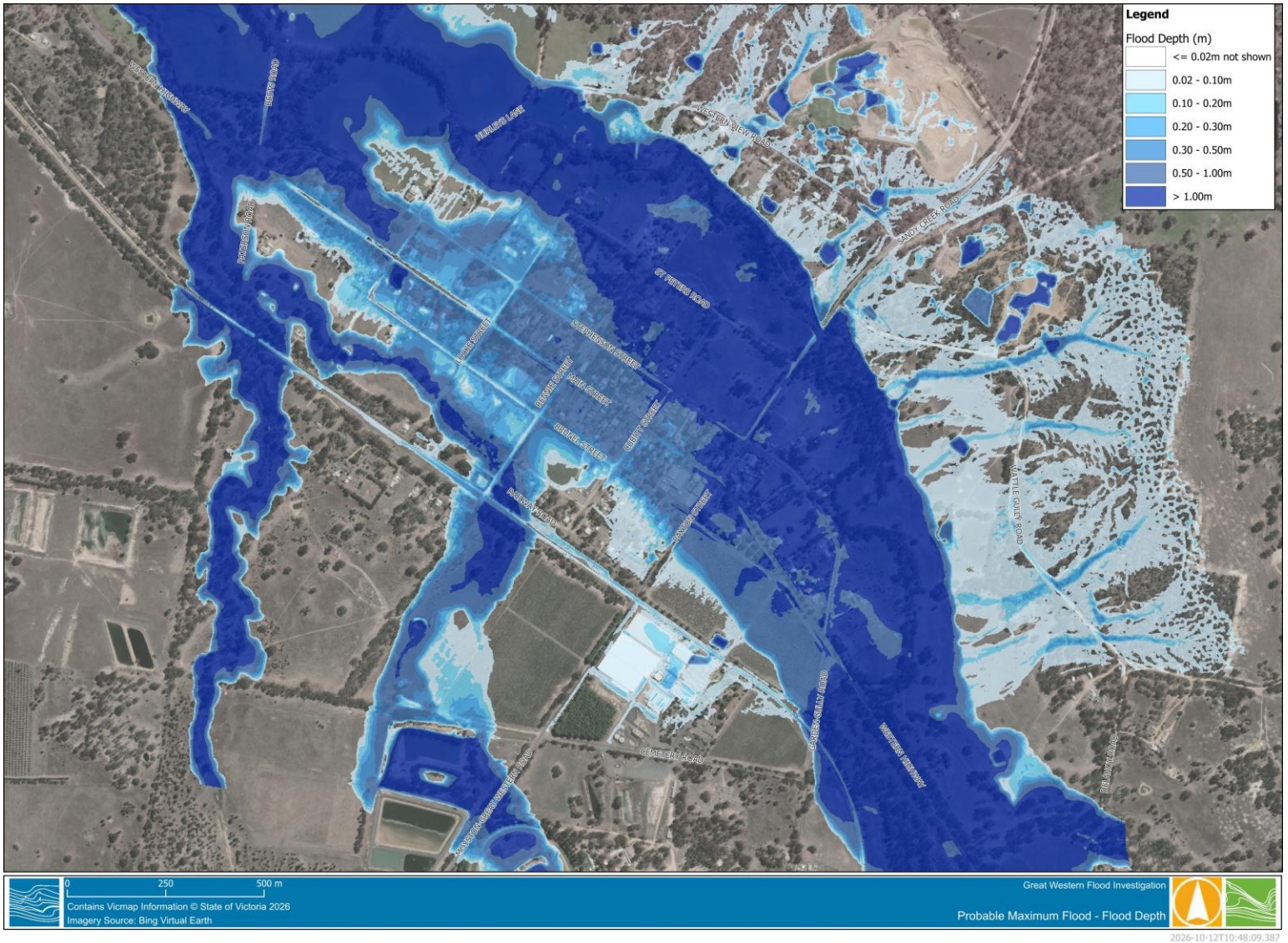


Figure 5-37 Zoomed into Township – PMF Flood Depth

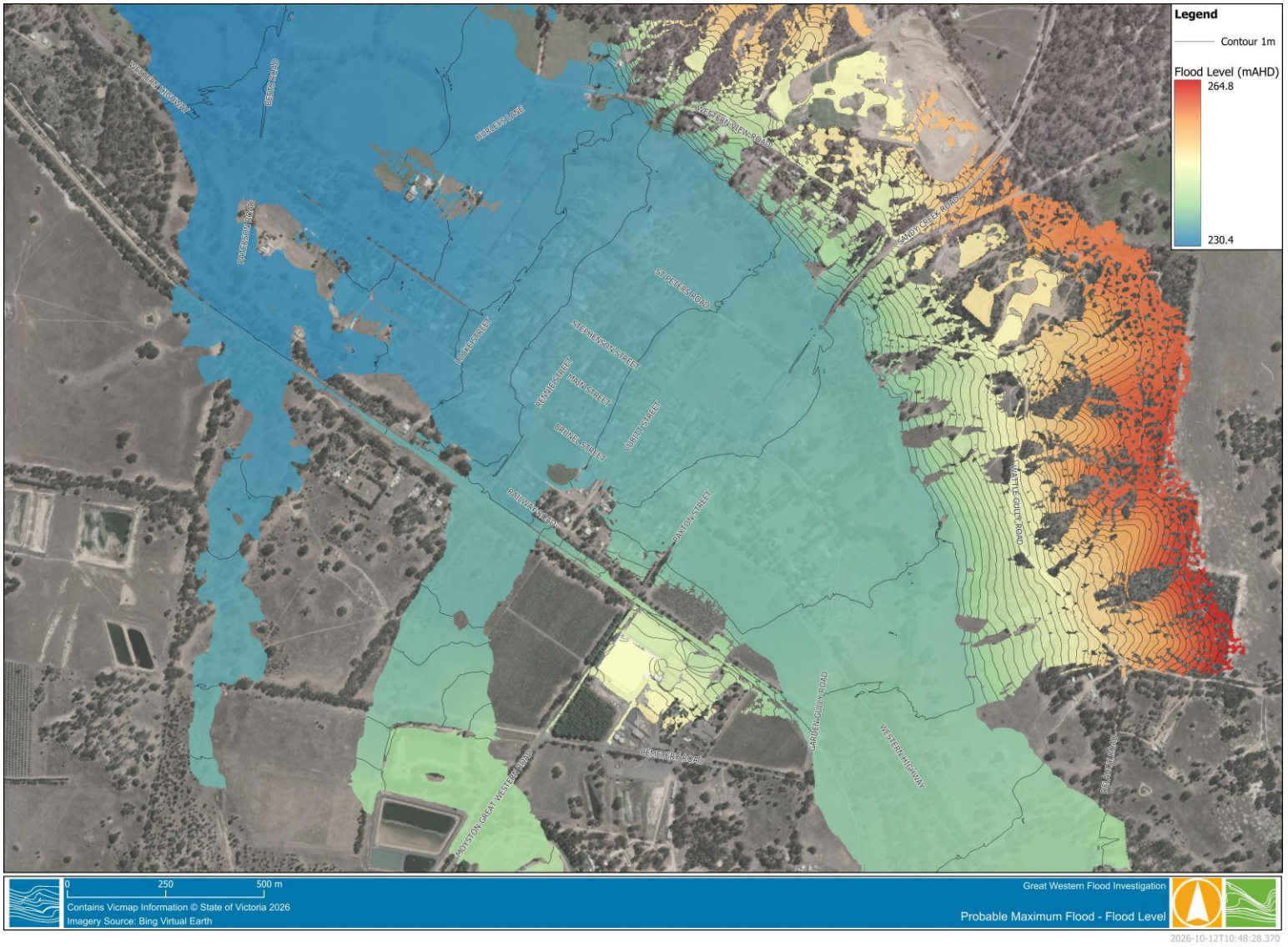


Figure 5-38 Zoomed into Township – PMF Flood Level



Figure 5-39 Zoomed into Township – PMF Flood Velocity

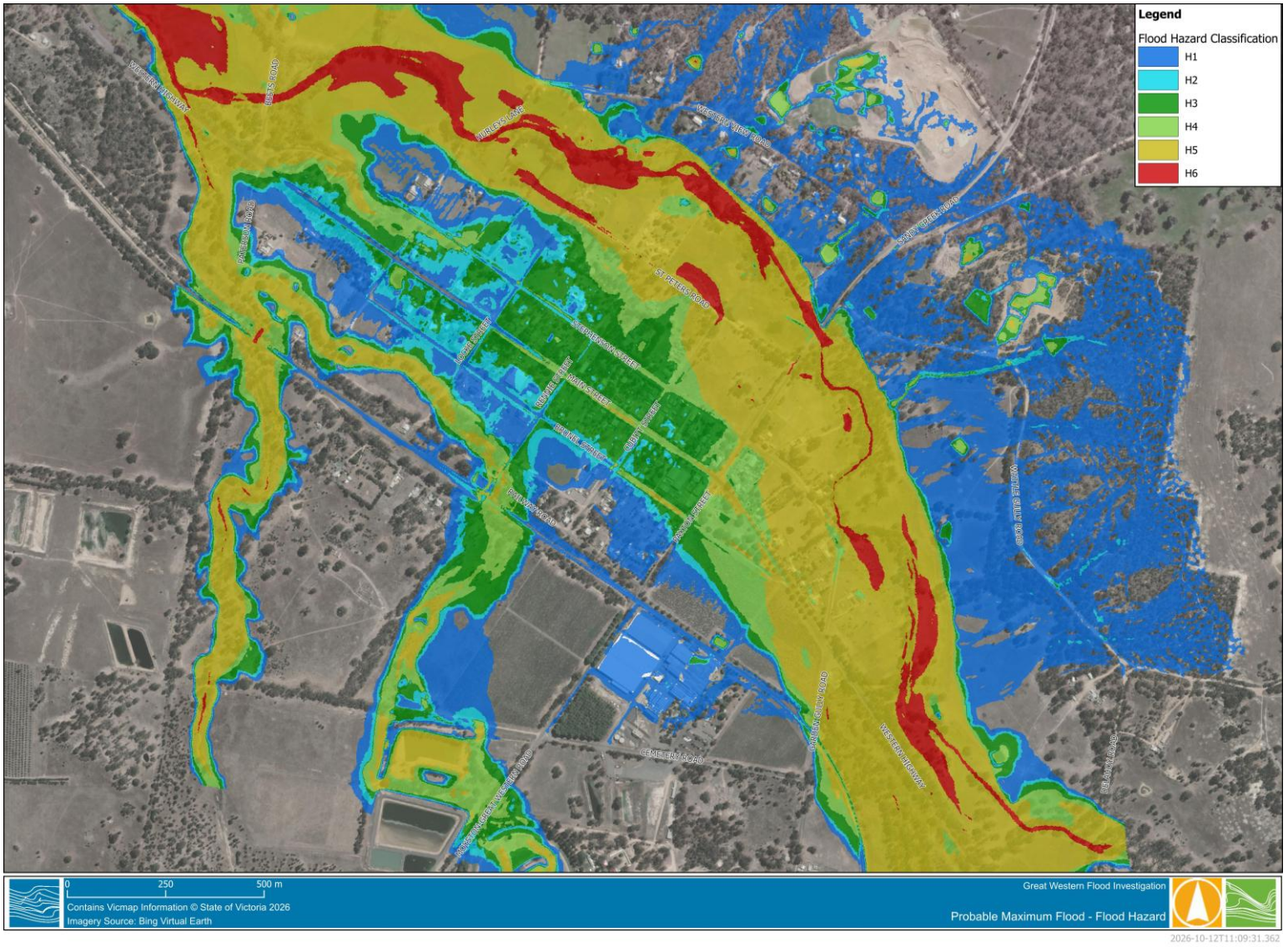


Figure 5-40 Zoomed into Township – PMF Flood Hazard

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APPENDIX A
FLOOD MAPPINGS FOR FUTURE SSP3-7.0 2100



5.12 20% AEP SSP3-7.0 Year 2100



Figure 5-41 Zoomed into Township – 20% AEP SSP3-7.0 Year 2100 Flood Depth

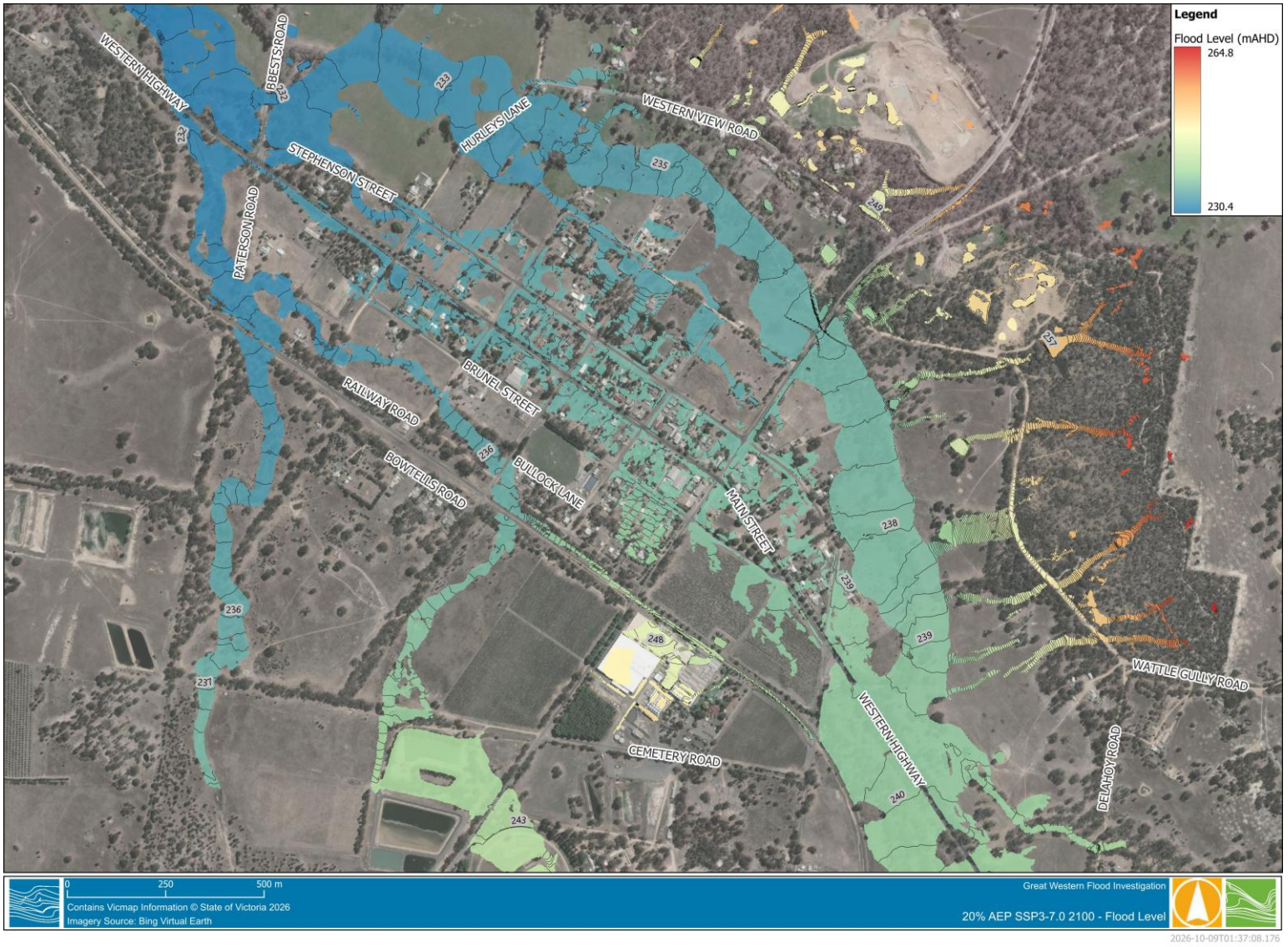


Figure 5-42 Zoomed into Township – 20% AEP SSP3-7.0 Year 2100 Flood Level



Figure 5-43 Zoomed into Township – 20% AEP SSP3-7.0 Year 2100 Flood Velocity

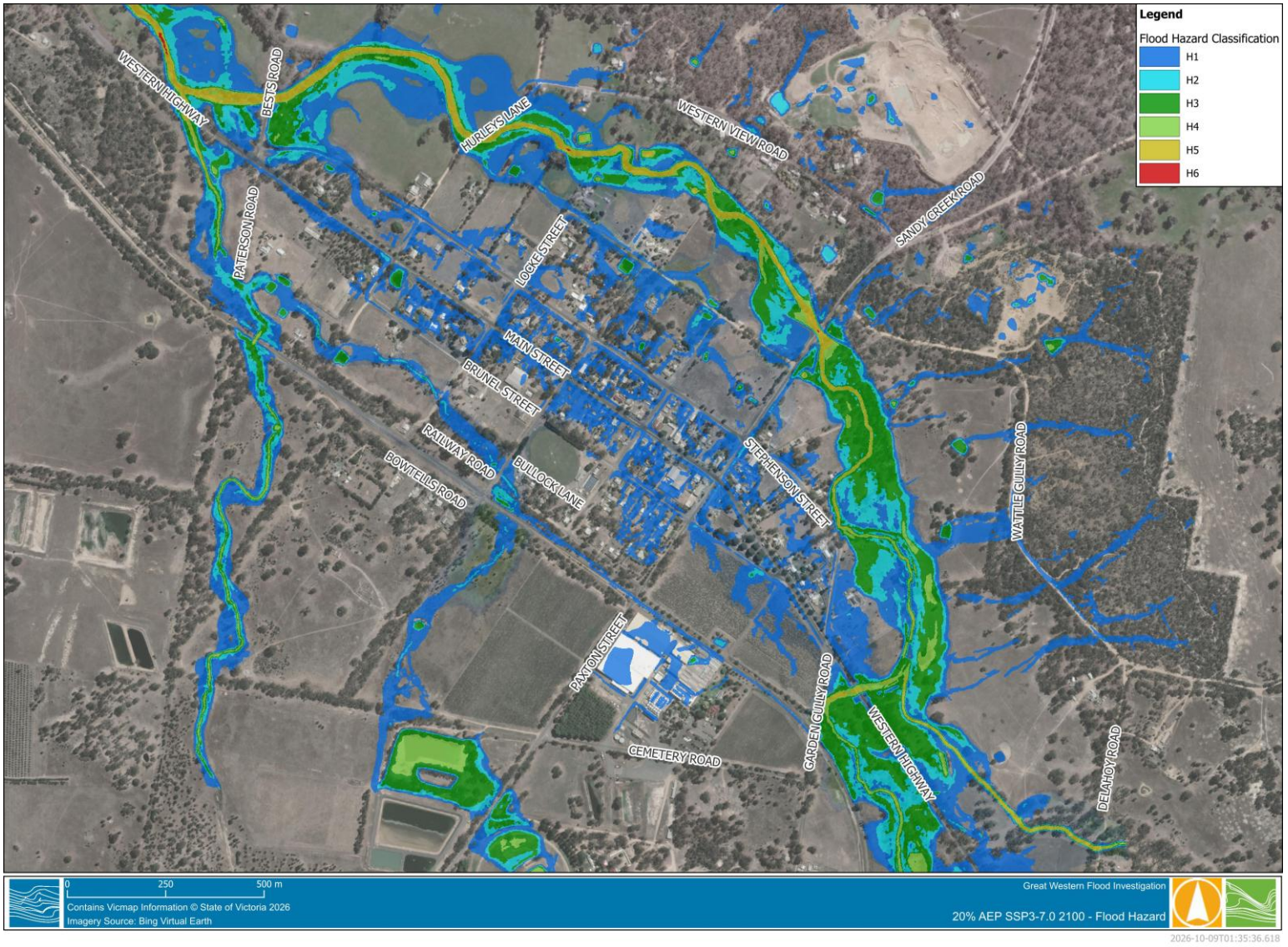


Figure 5-44 Zoomed into Township – 20% AEP SSP3-7.0 Year 2100 Flood Hazard

5.13 10% AEP SSP3-7.0 Year 2100

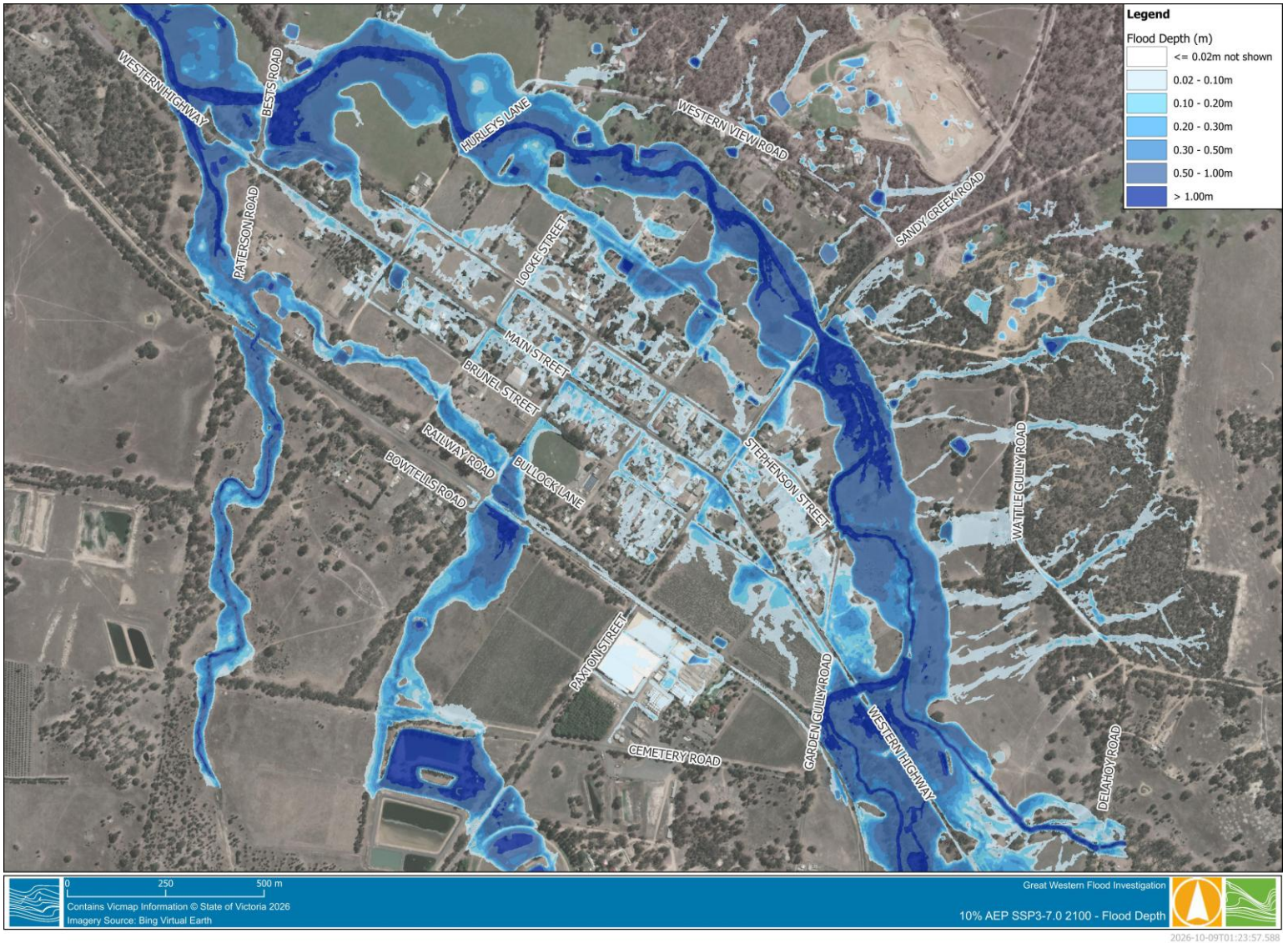


Figure 5-45 Zoomed into Township – 10% AEP SSP3-7.0 Year 2100 Flood Depth

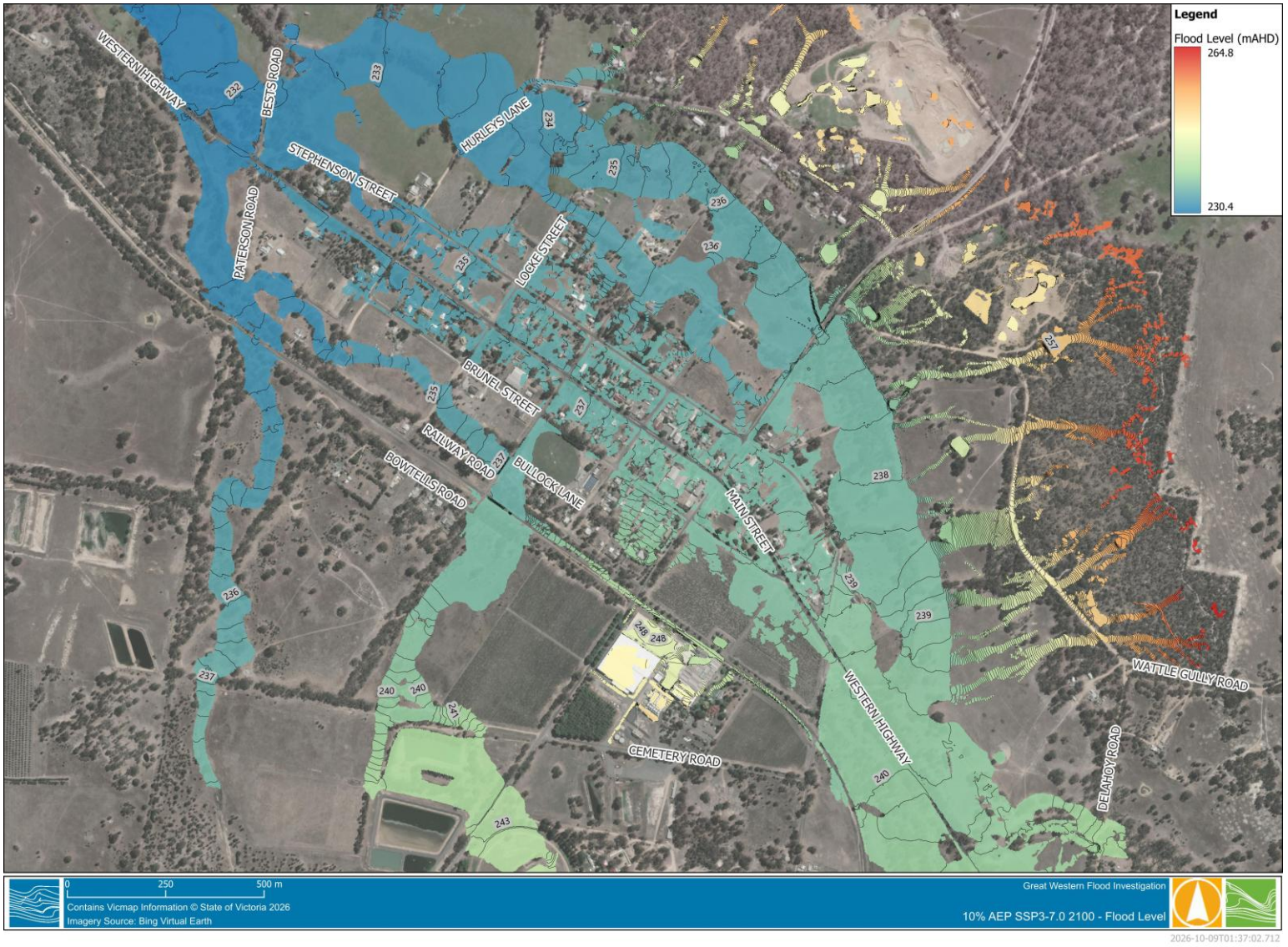


Figure 5-46 Zoomed into Township – 10% AEP SSP3-7.0 Year 2100 Flood Level



Figure 5-47 Zoomed into Township – 10% AEP SSP3-7.0 Year 2100 Flood Velocity

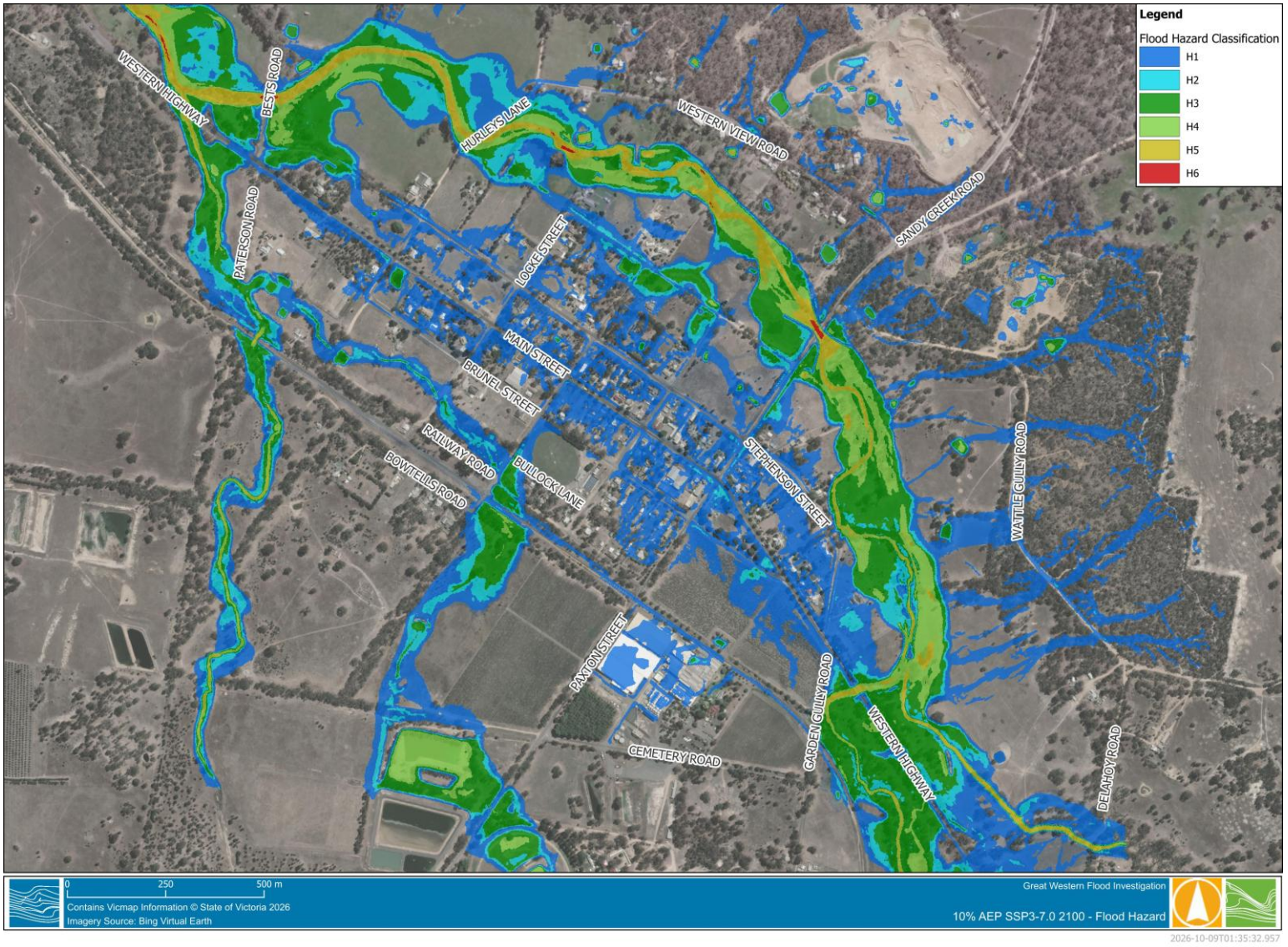


Figure 5-48 Zoomed into Township – 10% AEP SSP3-7.0 Year 2100 Flood Hazard

5.14 5% AEP SSP3-7.0 Year 2100

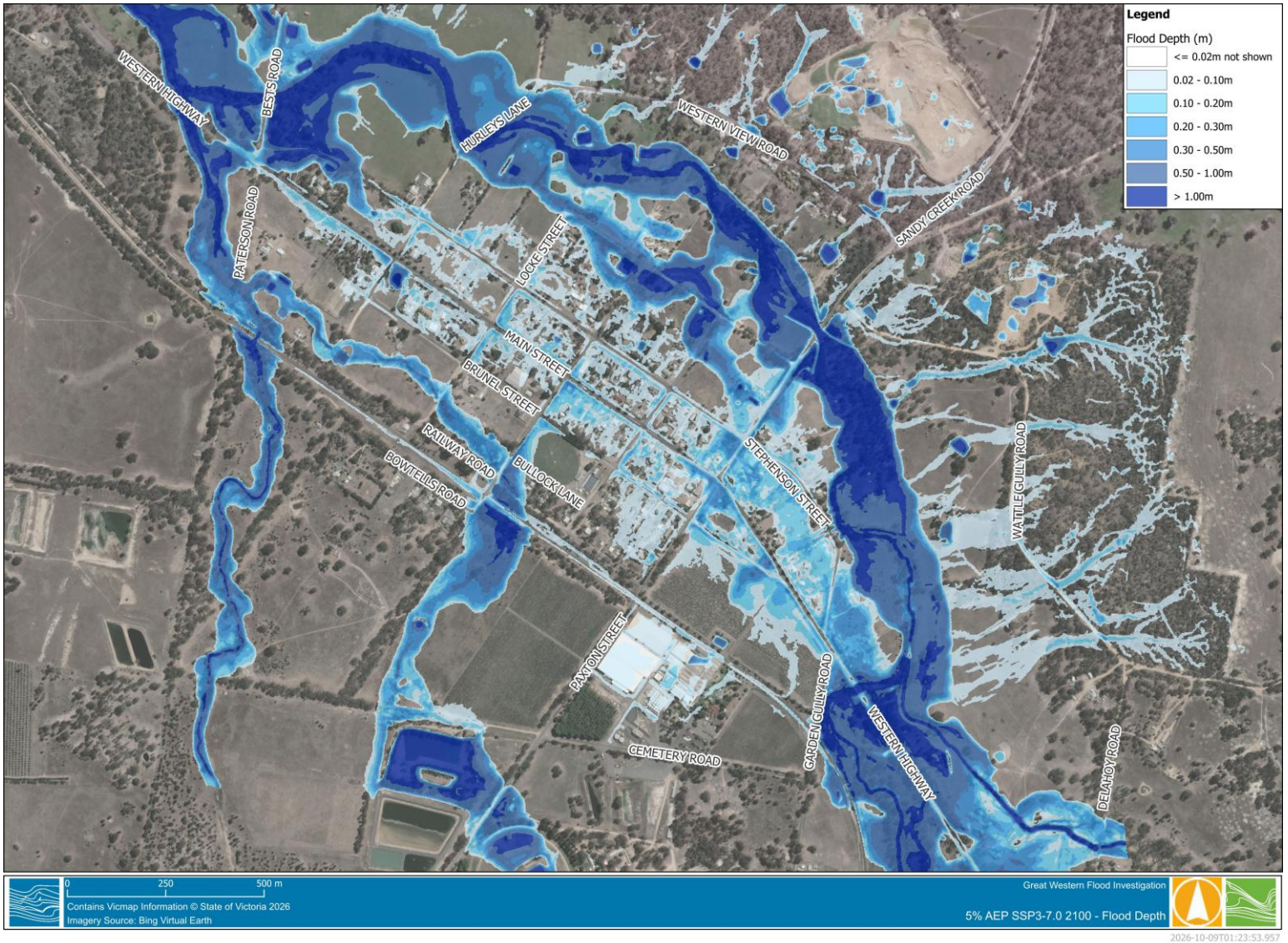


Figure 5-49 Zoomed into Township – 5% AEP SSP3-7.0 Year 2100 Flood Depth

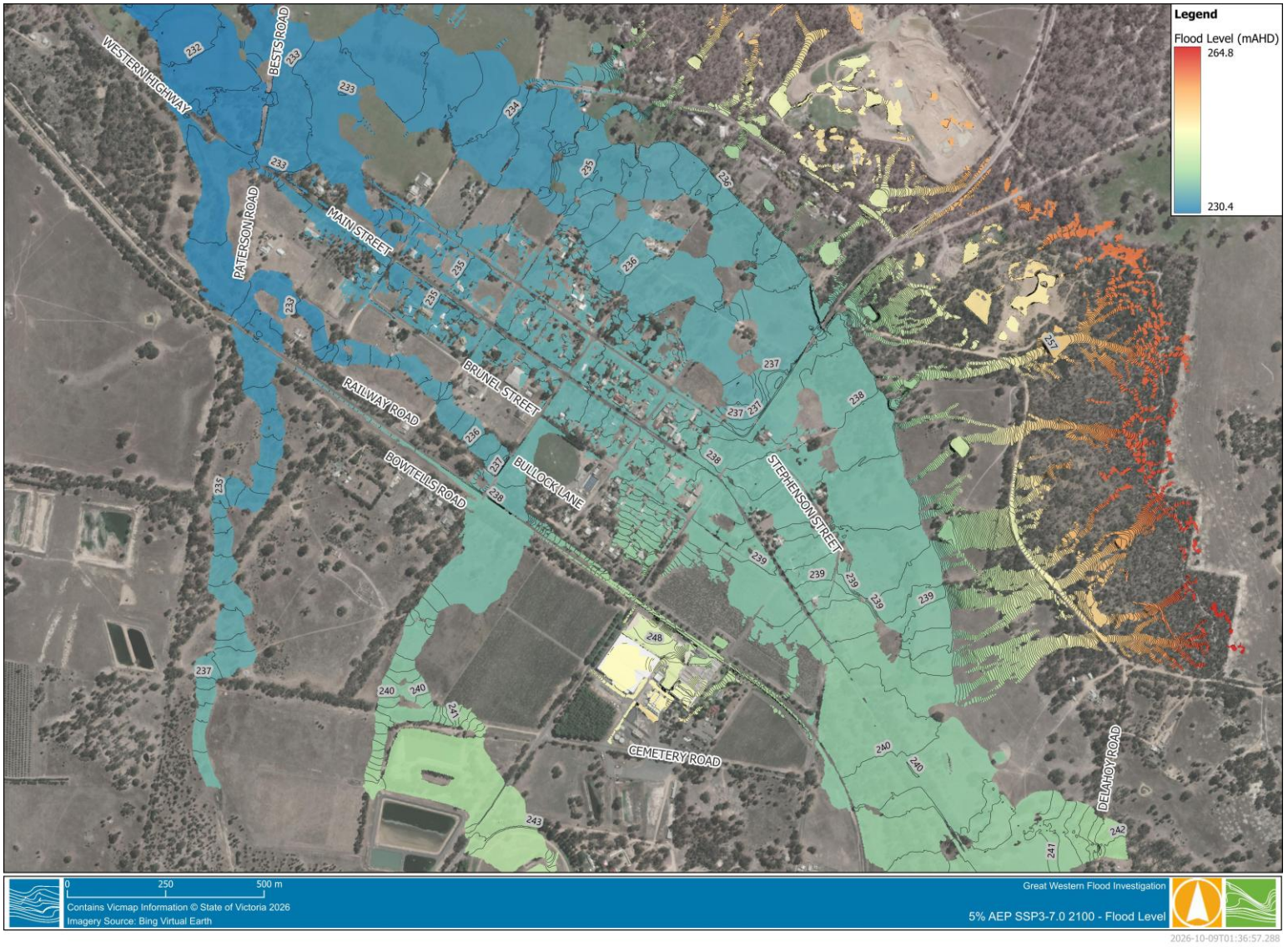


Figure 5-50 Zoomed into Township – 5% AEP SSP3-7.0 Year 2100 Flood Level



Figure 5-51 Zoomed into Township – 5% AEP SSP3-7.0 Year 2100 Flood Velocity

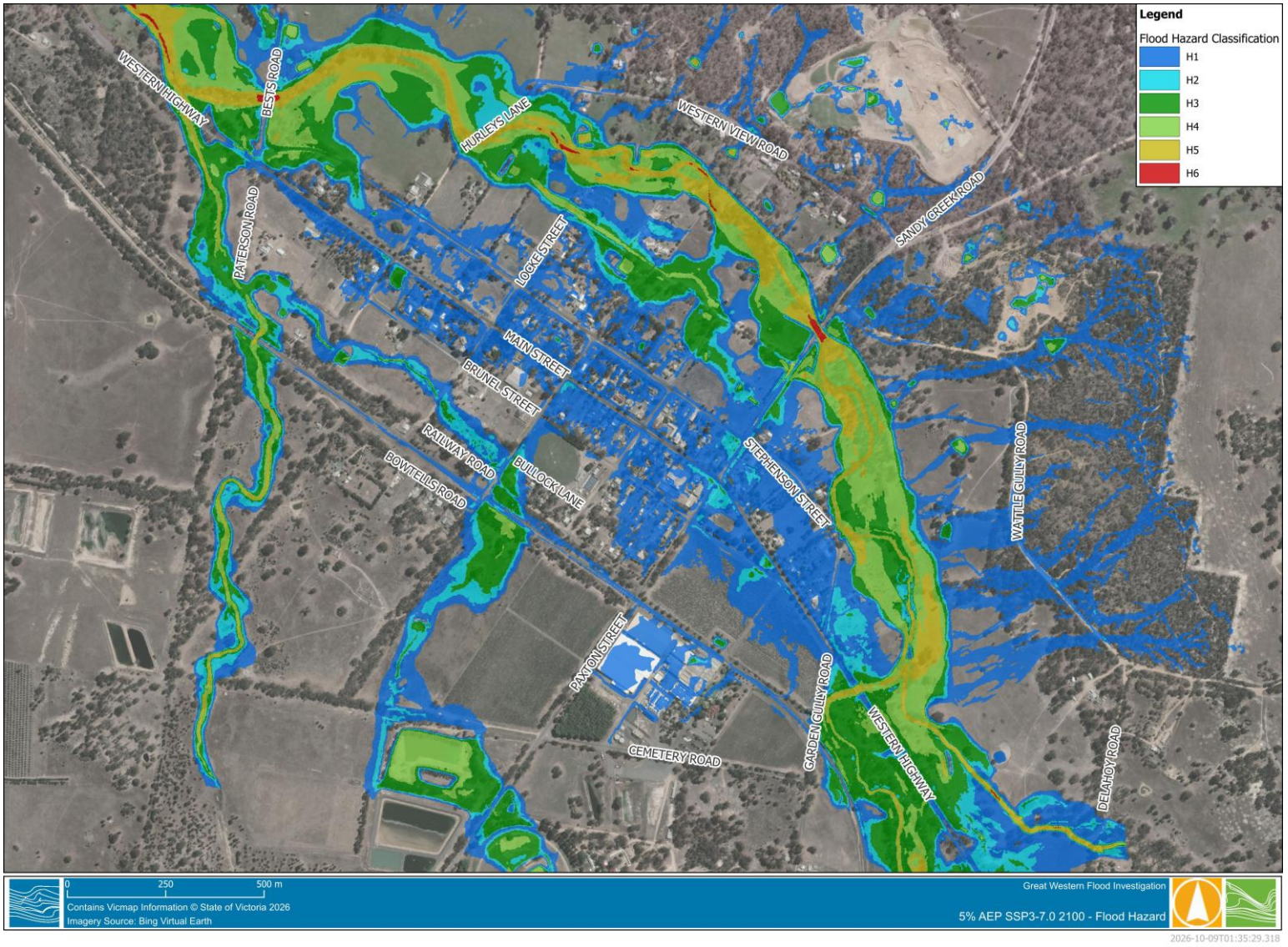


Figure 5-52 Zoomed into Township – 5% AEP SSP3-7.0 Year 2100 Flood Hazard

5.15 2% AEP SSP3-7.0 Year 2100

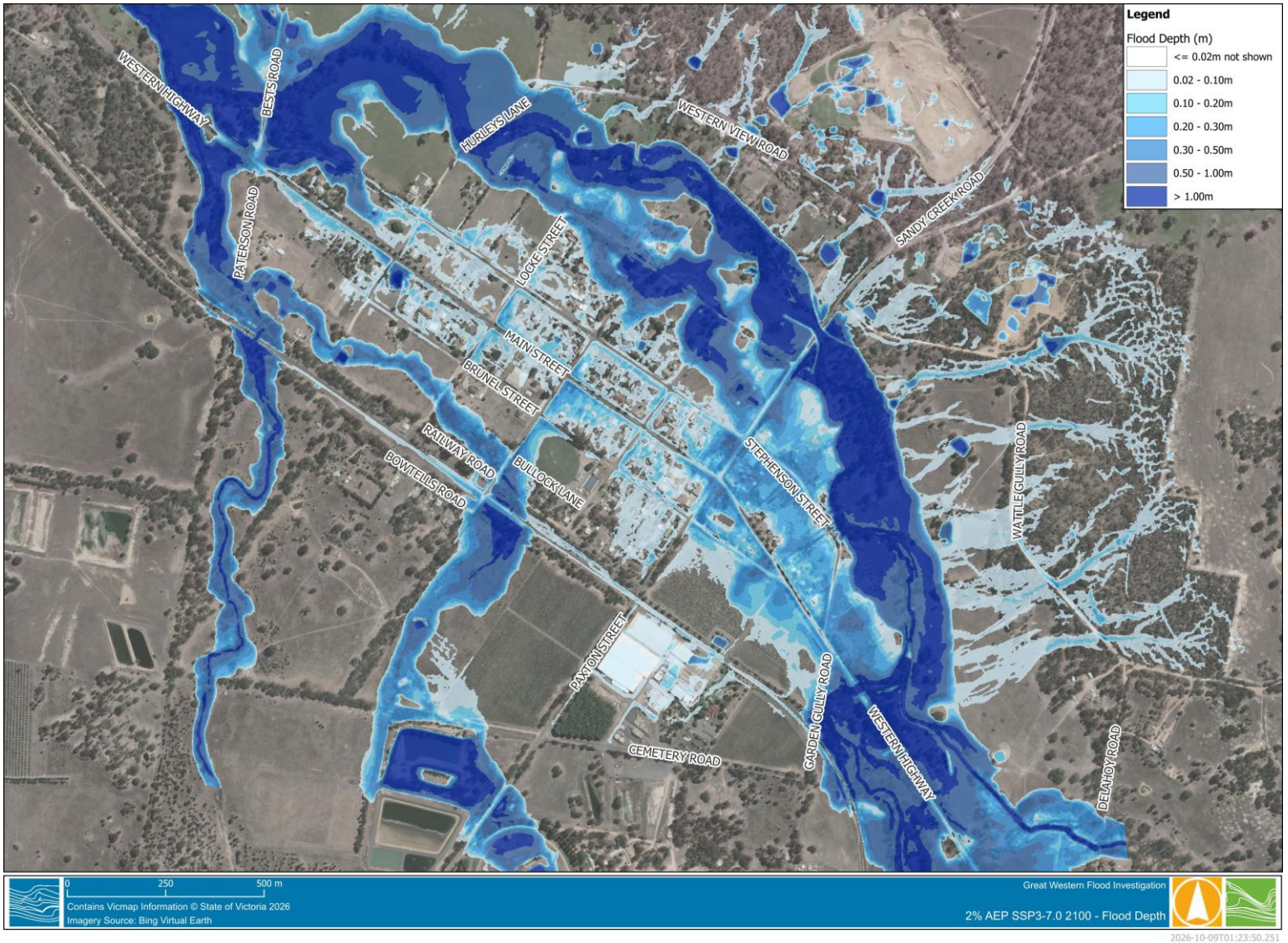


Figure 5-53 Zoomed into Township – 2% AEP SSP3-7.0 Year 2100 Flood Depth

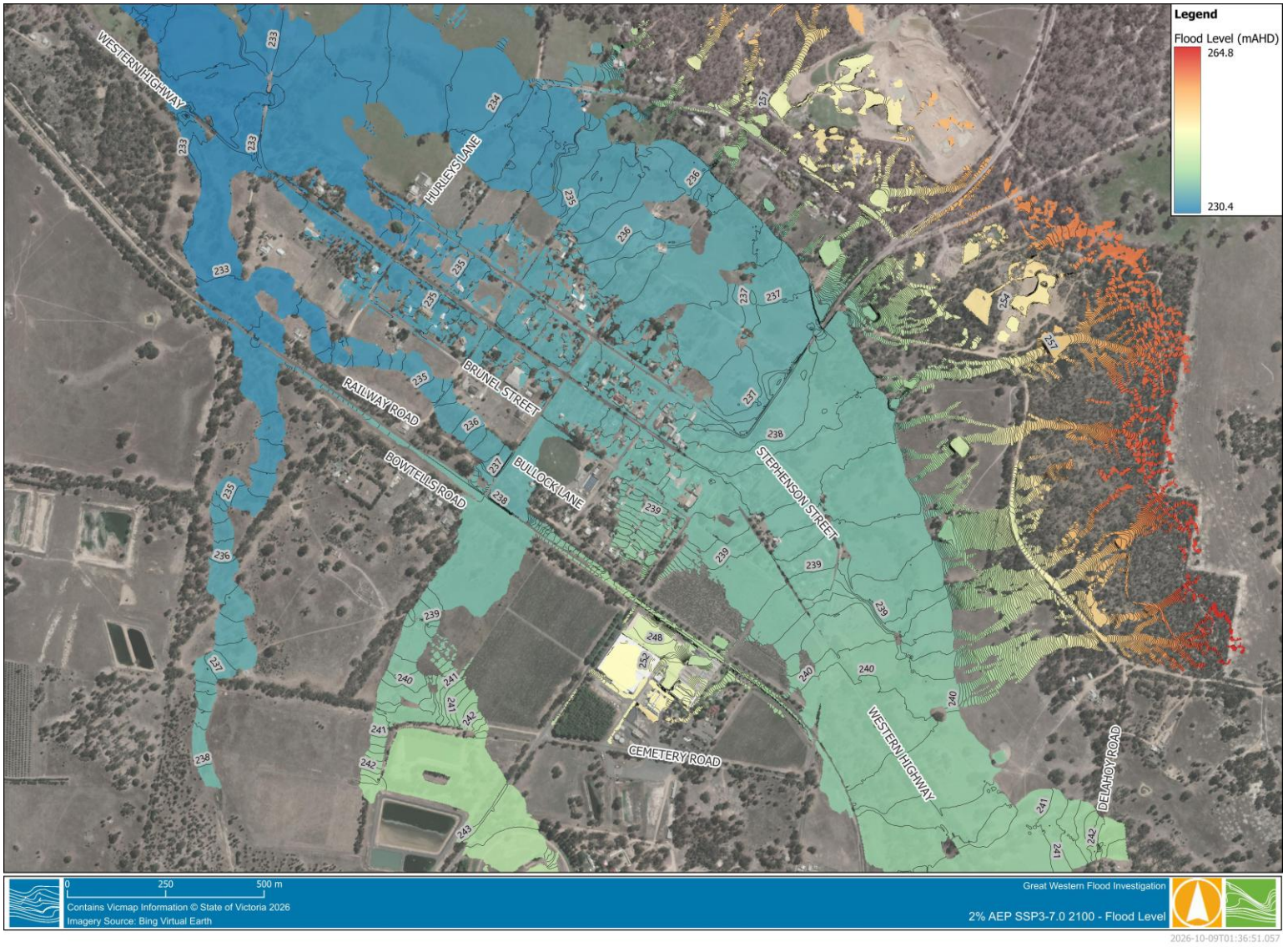


Figure 5-54 Zoomed into Township – 2% AEP SSP3-7.0 Year 2100 Flood Level



Figure 5-55 Zoomed into Township – 2% AEP SSP3-7.0 Year 2100 Flood Velocity

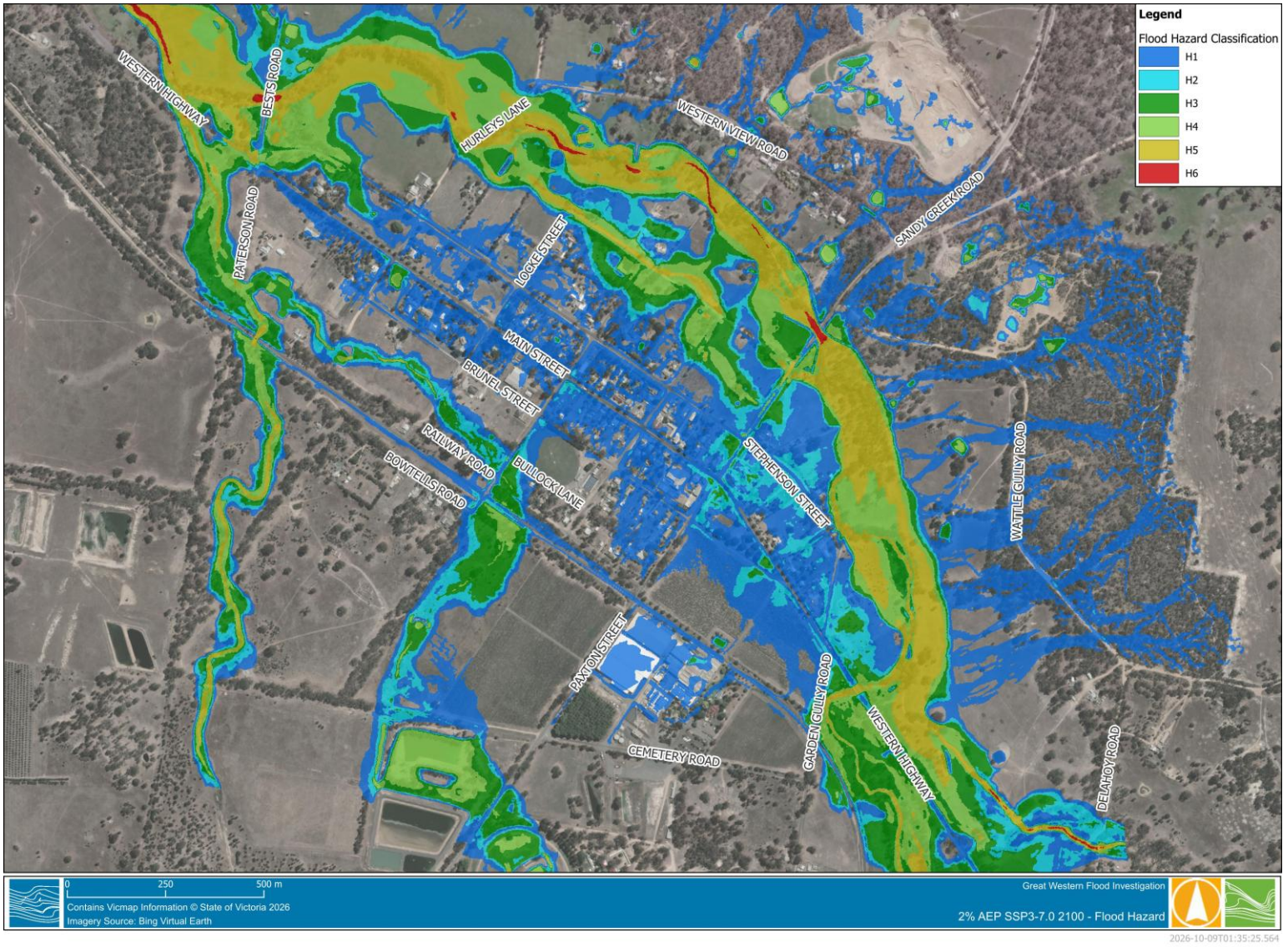


Figure 5-56 Zoomed into Township – 2% AEP SSP3-7.0 Year 2100 Flood Hazard

5.16 1% AEP SSP3-7.0 Year 2100

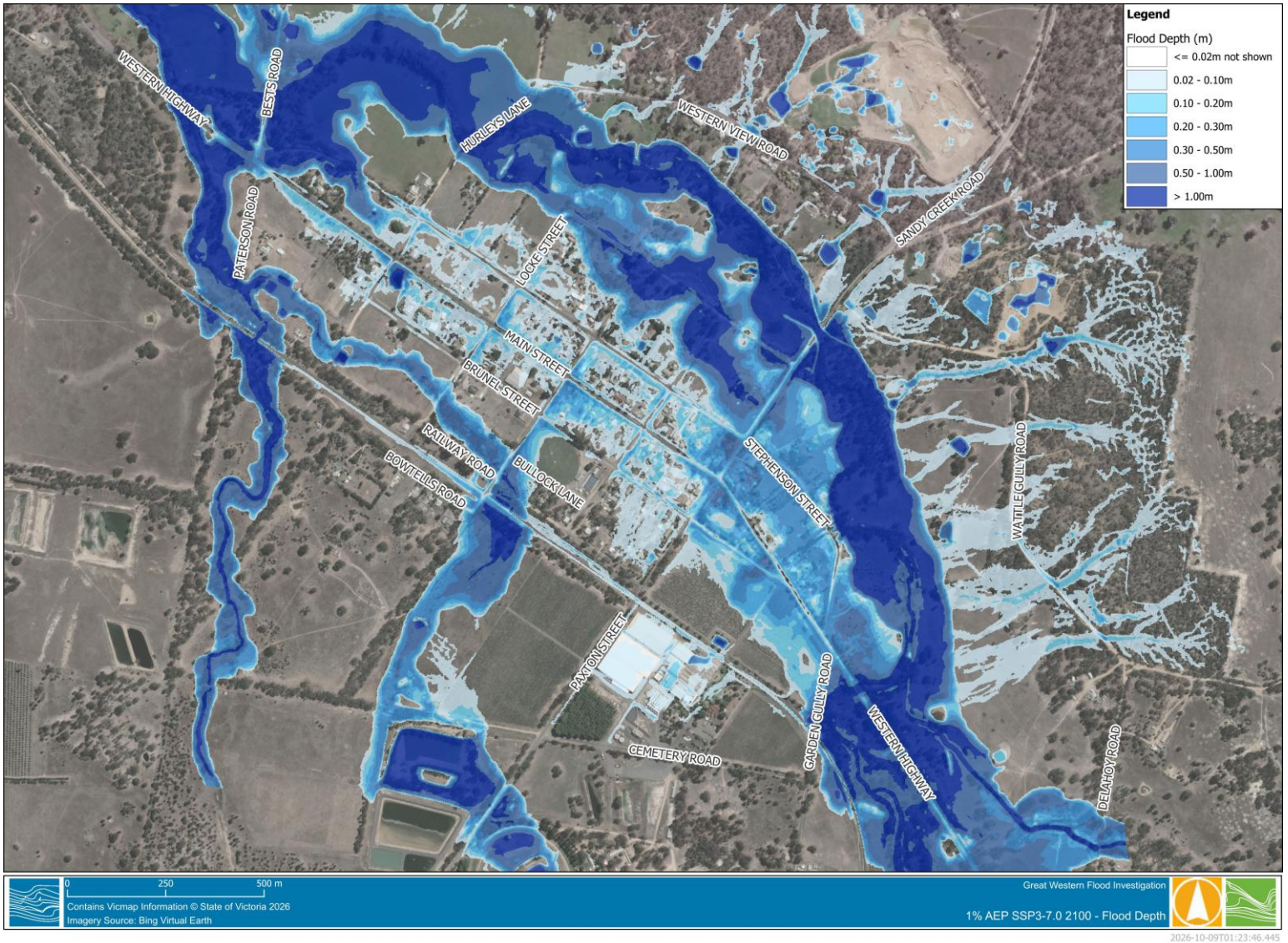


Figure 5-57 Zoomed into Township – 1% AEP SSP3-7.0 Year 2100 Flood Depth

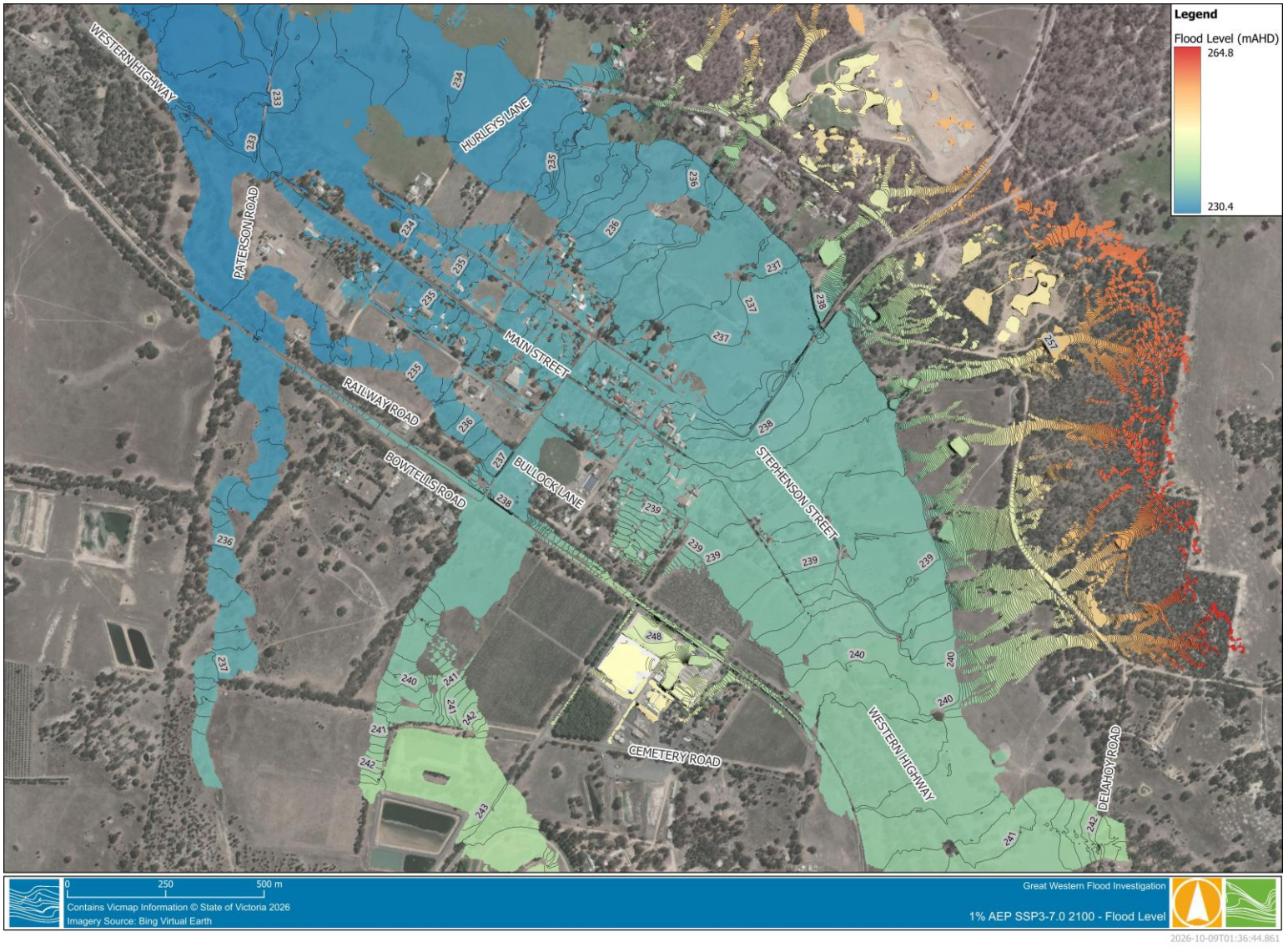


Figure 5-58 Zoomed into Township – 1% AEP SSP3-7.0 Year 2100 Flood Level



Figure 5-59 Zoomed into Township – 1% AEP SSP3-7.0 Year 2100 Flood Velocity

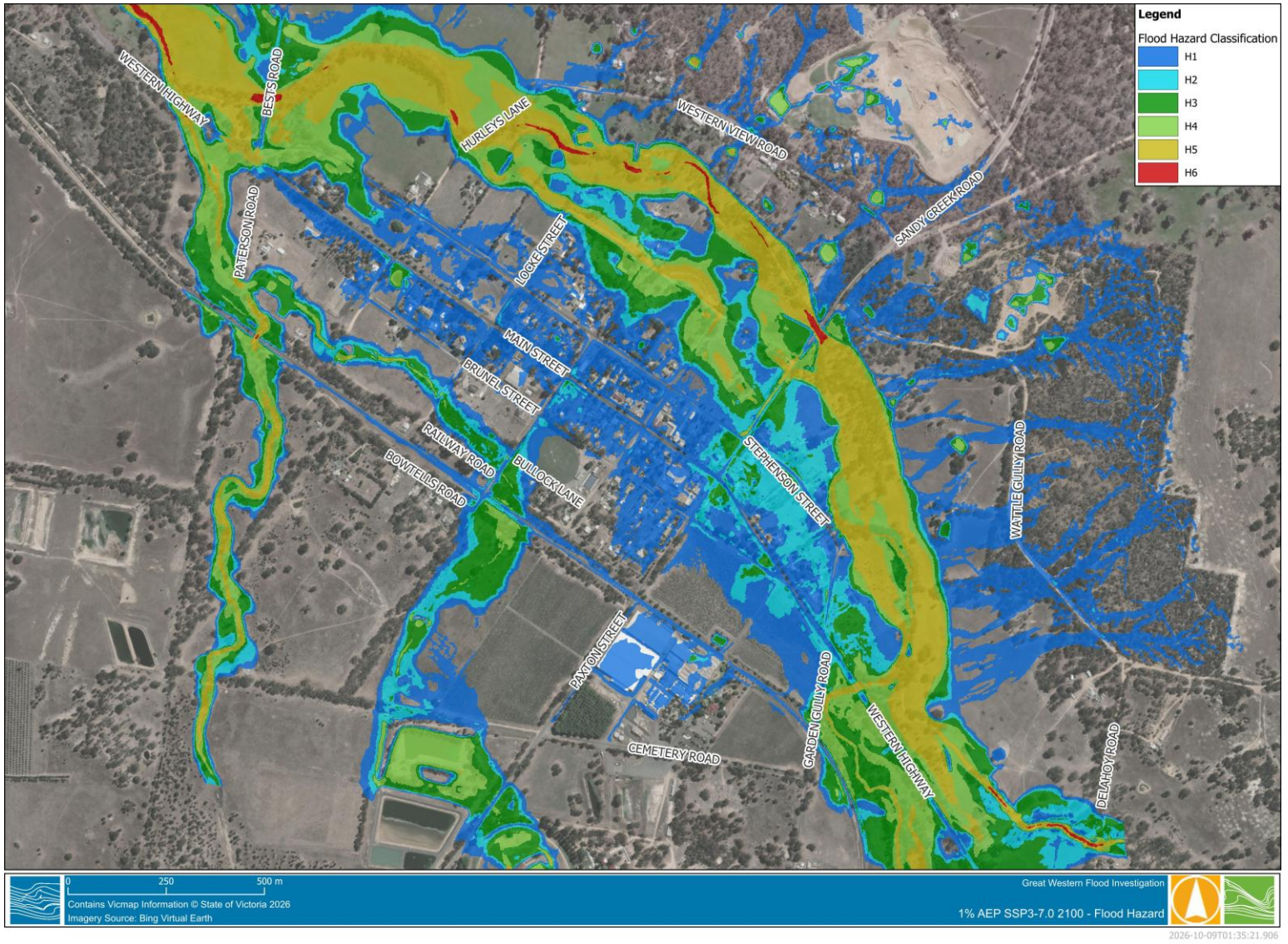


Figure 5-60 Zoomed into Township – 1% AEP SSP3-7.0 Year 2100 Flood Hazard

5.17 0.5% AEP SSP3-7.0 Year 2100

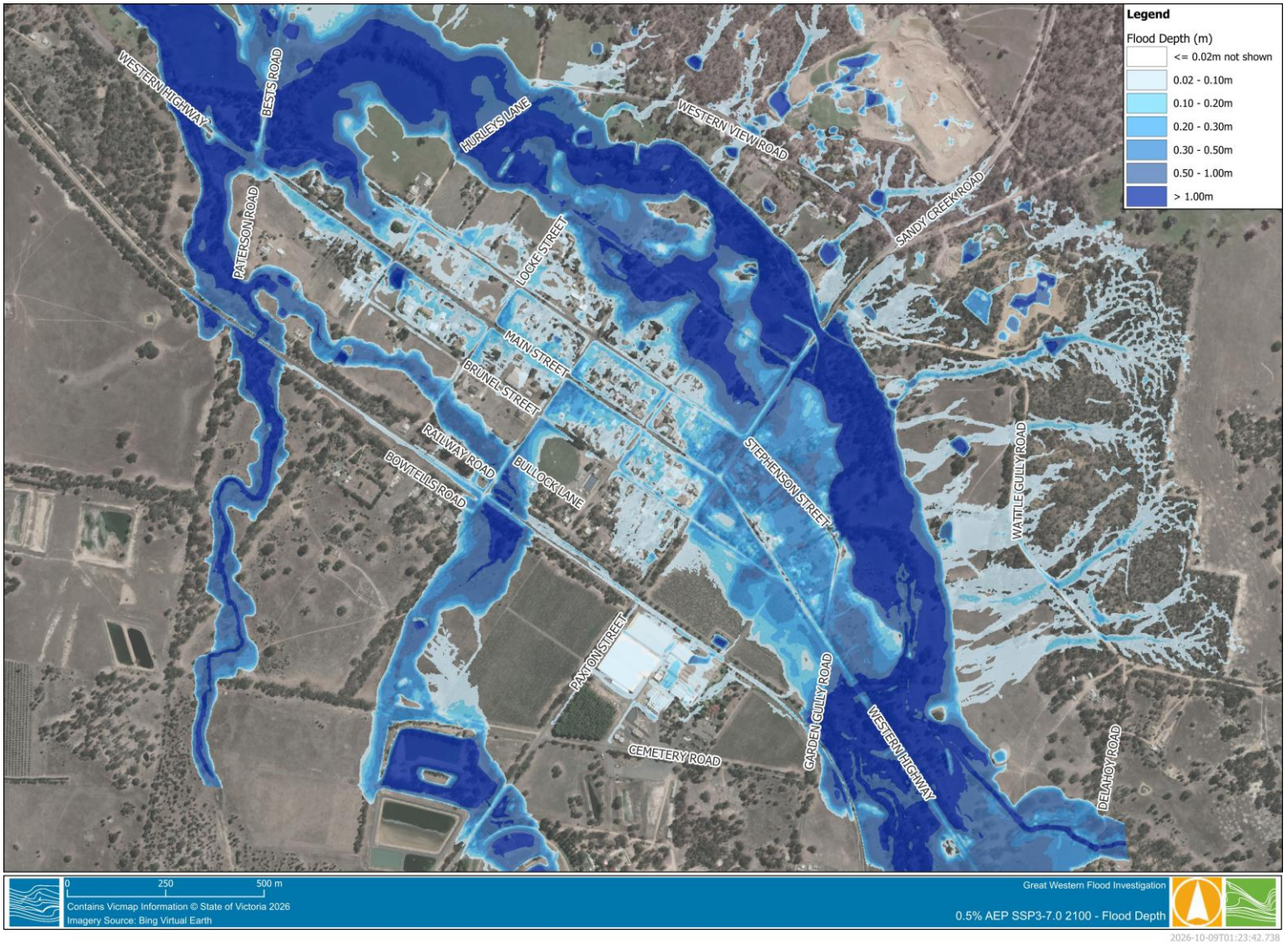


Figure 5-61 Zoomed into Township – 0.5% AEP SSP3-7.0 Year 2100 Flood Depth

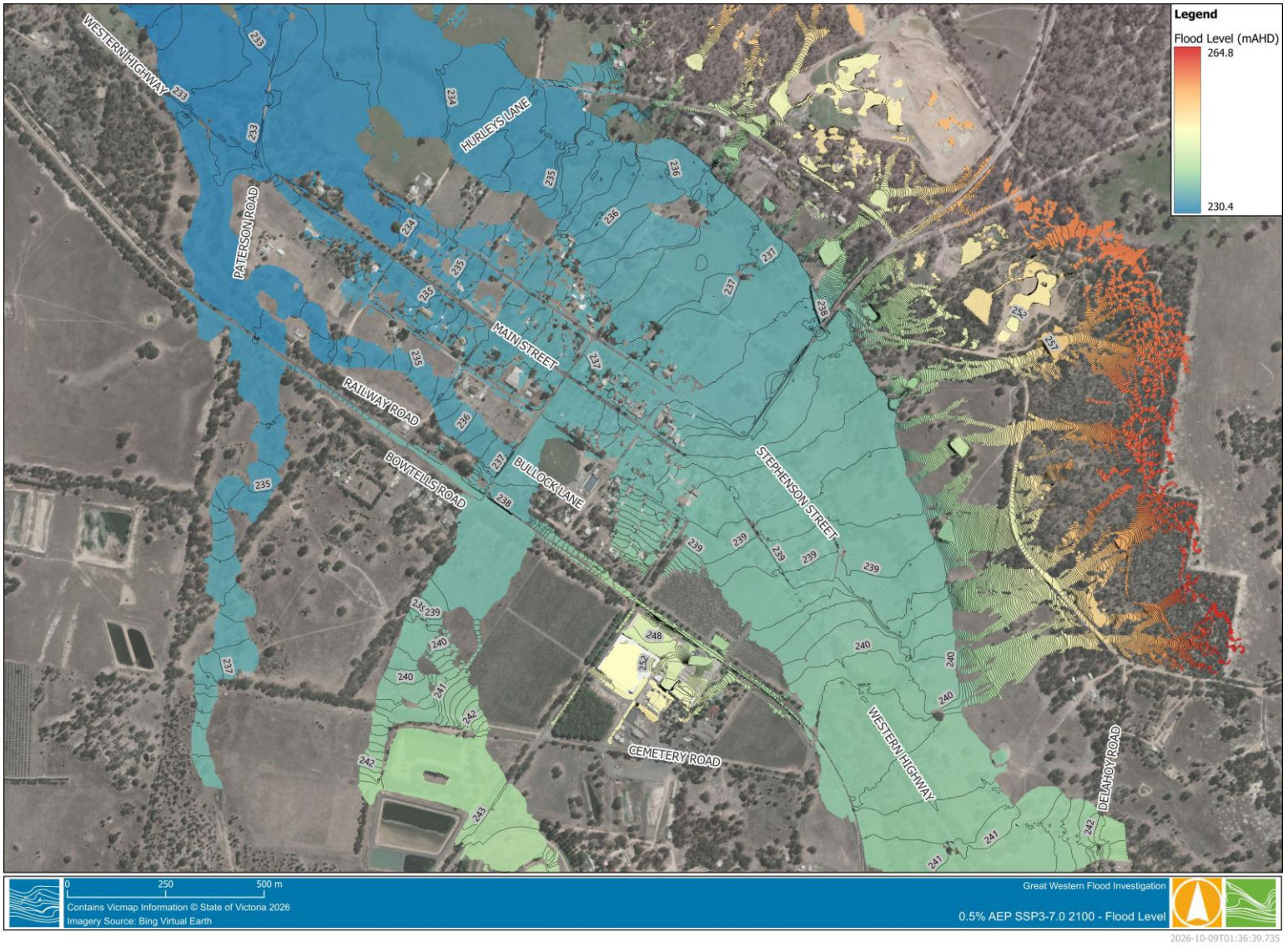


Figure 5-62 Zoomed into Township – 0.5% AEP SSP3-7.0 Year 2100 Flood Level



Figure 5-63 Zoomed into Township – 0.5% AEP SSP3-7.0 Year 2100 Flood Velocity

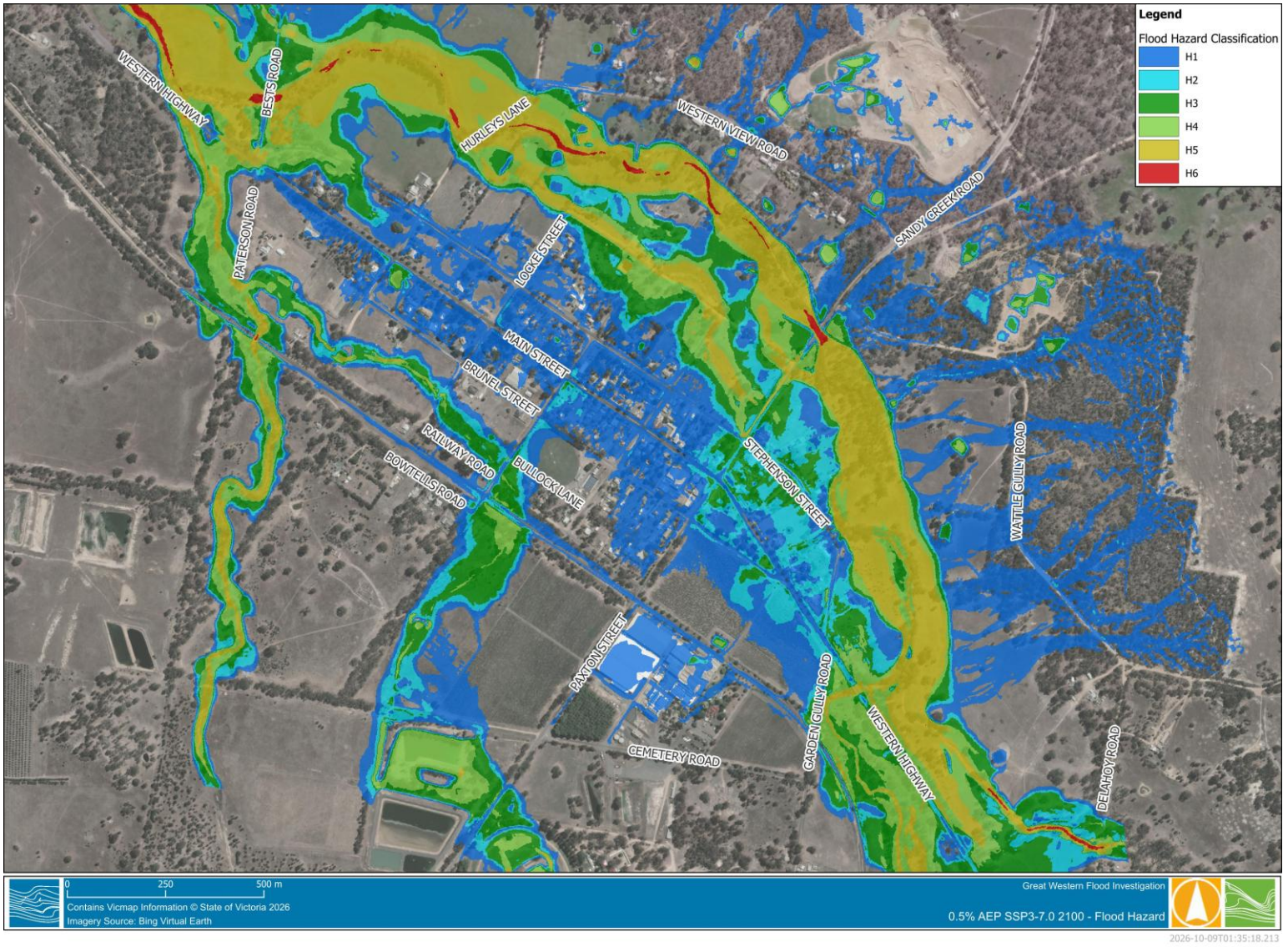


Figure 5-64 Zoomed into Township – 0.5% AEP SSP3-7.0 Year 2100 Flood Hazard

5.18 0.2% AEP SSP3-7.0 Year 2100

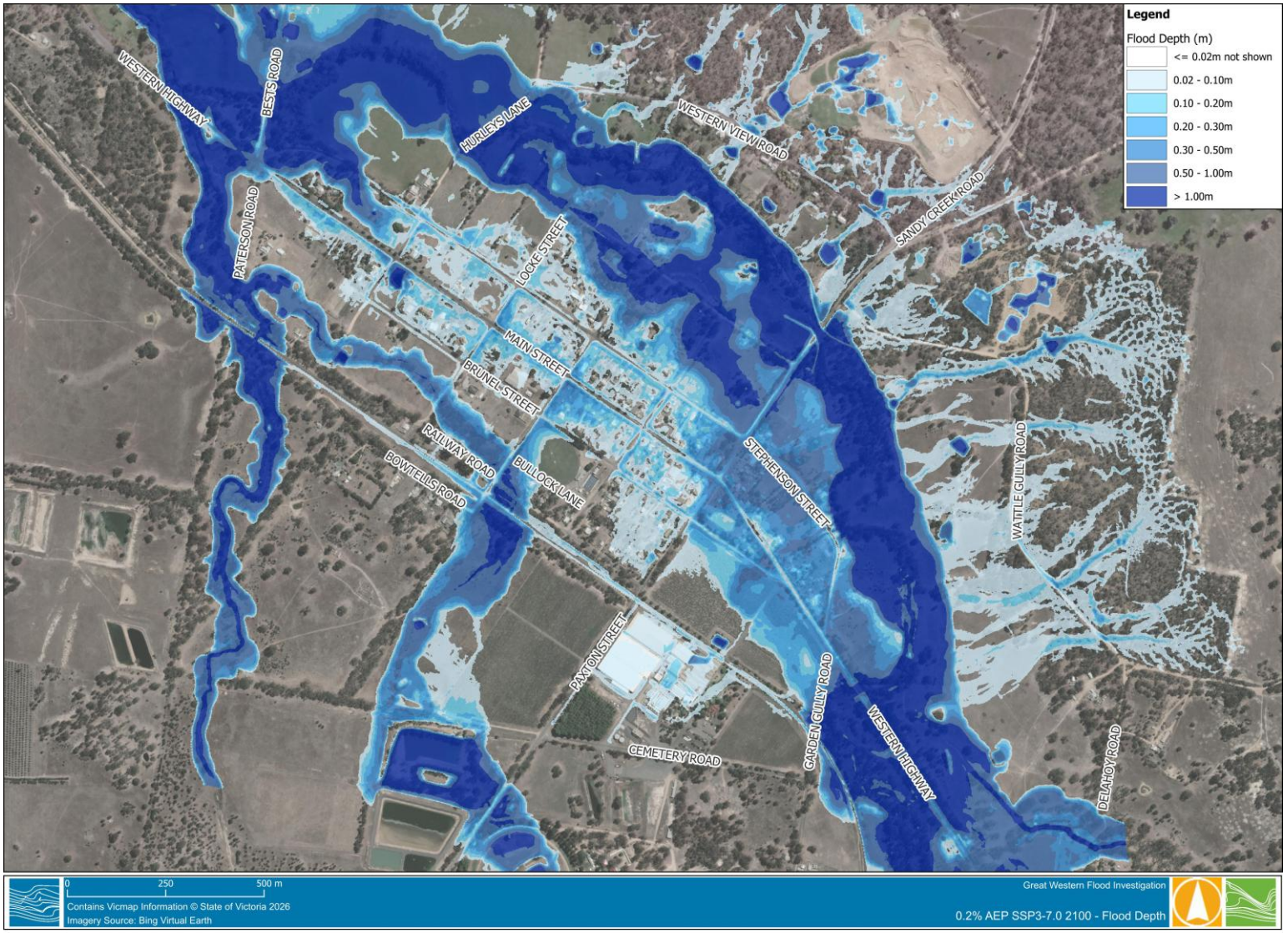


Figure 5-65 Zoomed into Township – 0.2% AEP SSP3-7.0 Year 2100 Flood Depth

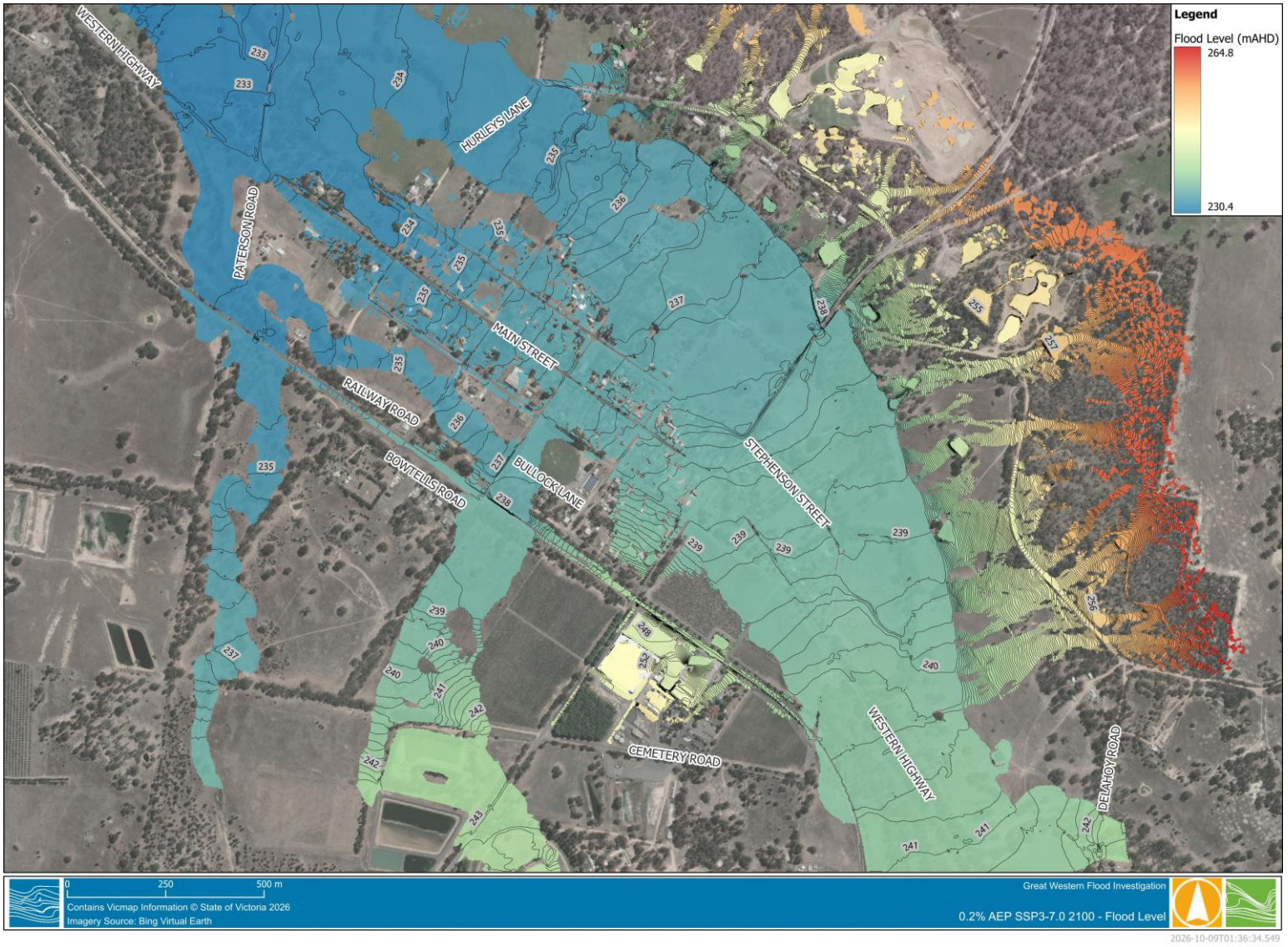


Figure 5-66 Zoomed into Township – 0.2% AEP SSP3-7.0 Year 2100 Flood Level

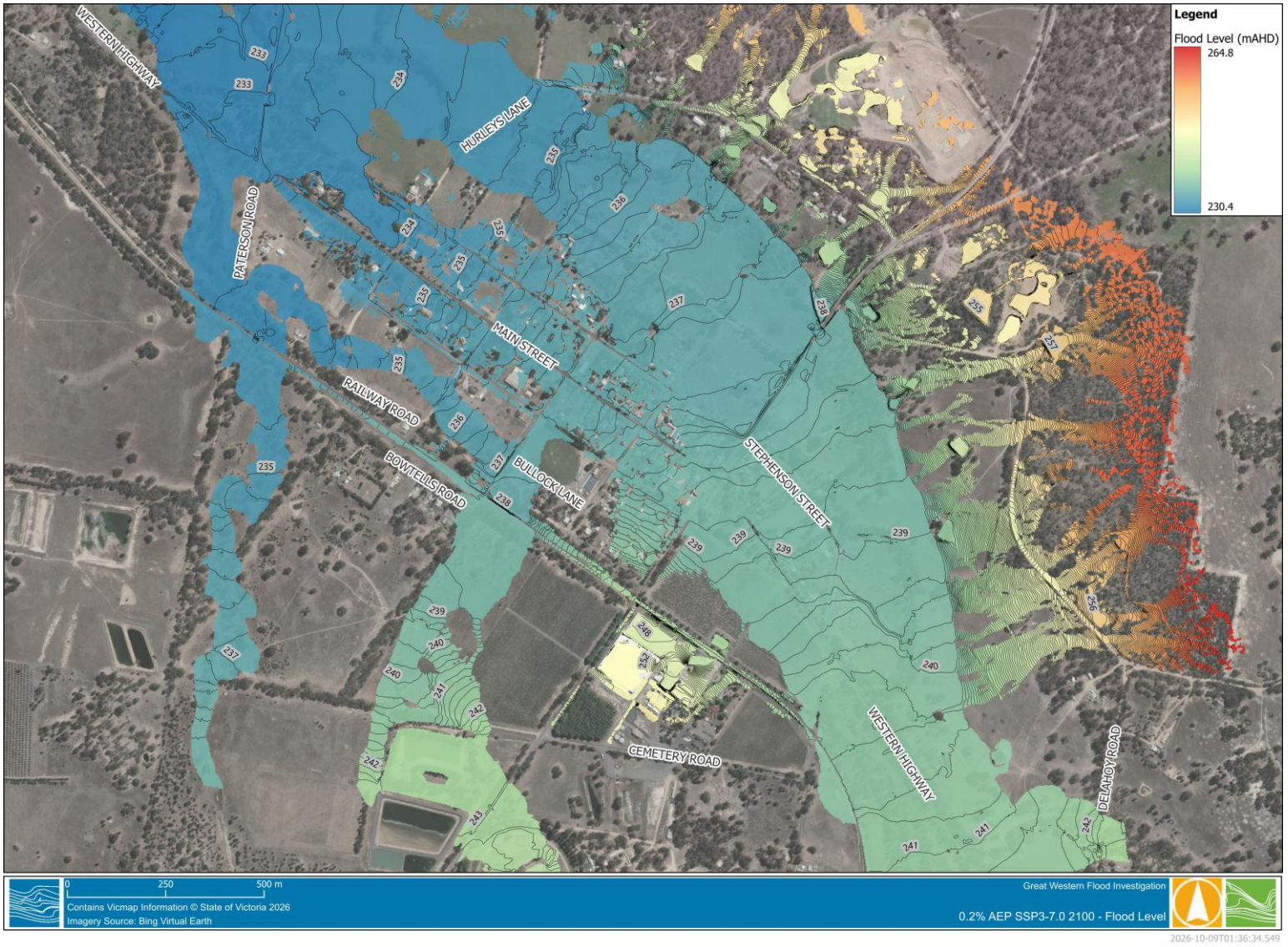


Figure 5-67 Zoomed into Township – 0.2% AEP SSP3-7.0 Year 2100 Flood Velocity

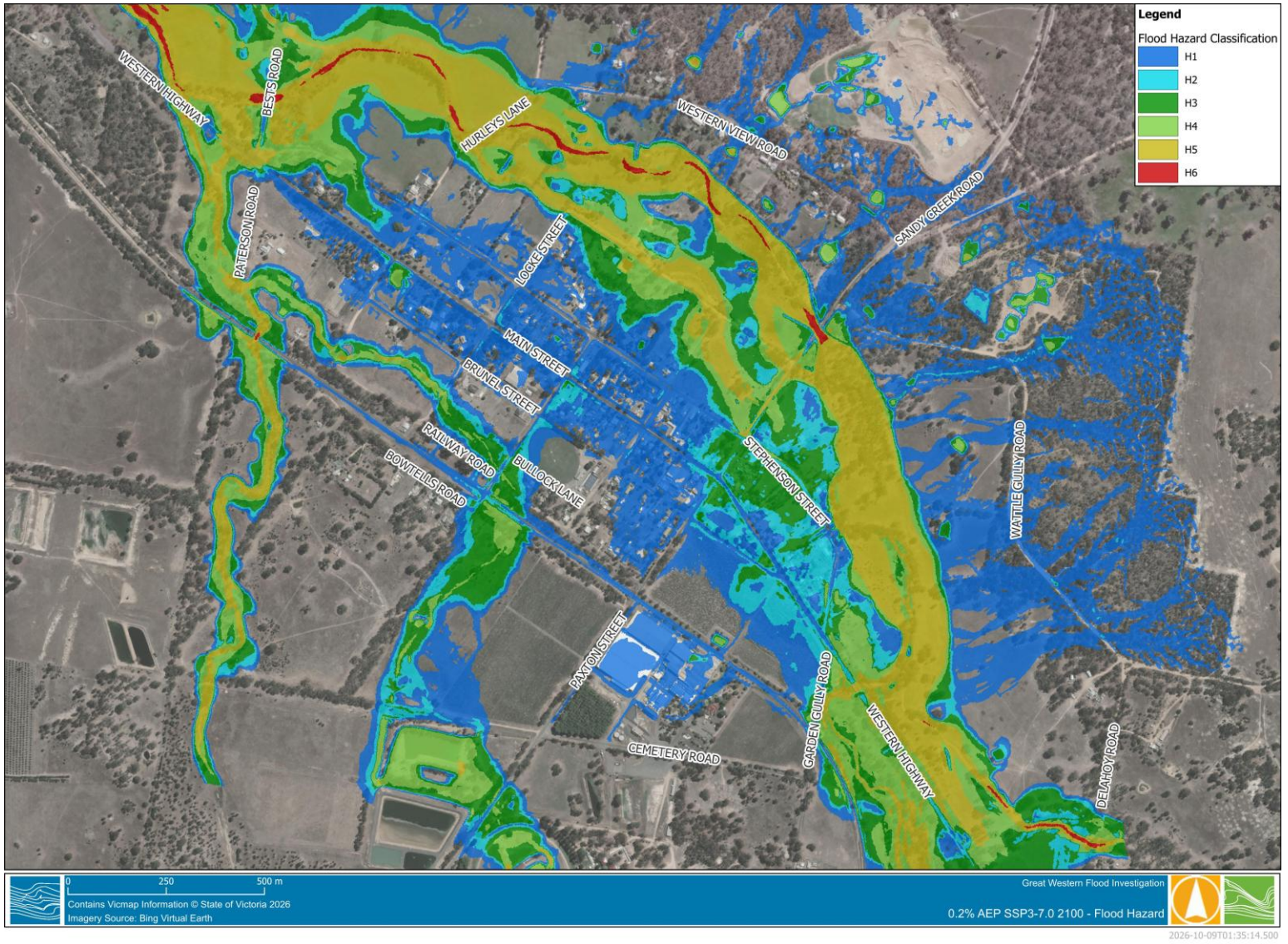


Figure 5-68 Zoomed into Township – 0.2% AEP SSP3-7.0 Year 2100 Flood Hazard

5.19 0.1% AEP SSP3-7.0 Year 2100

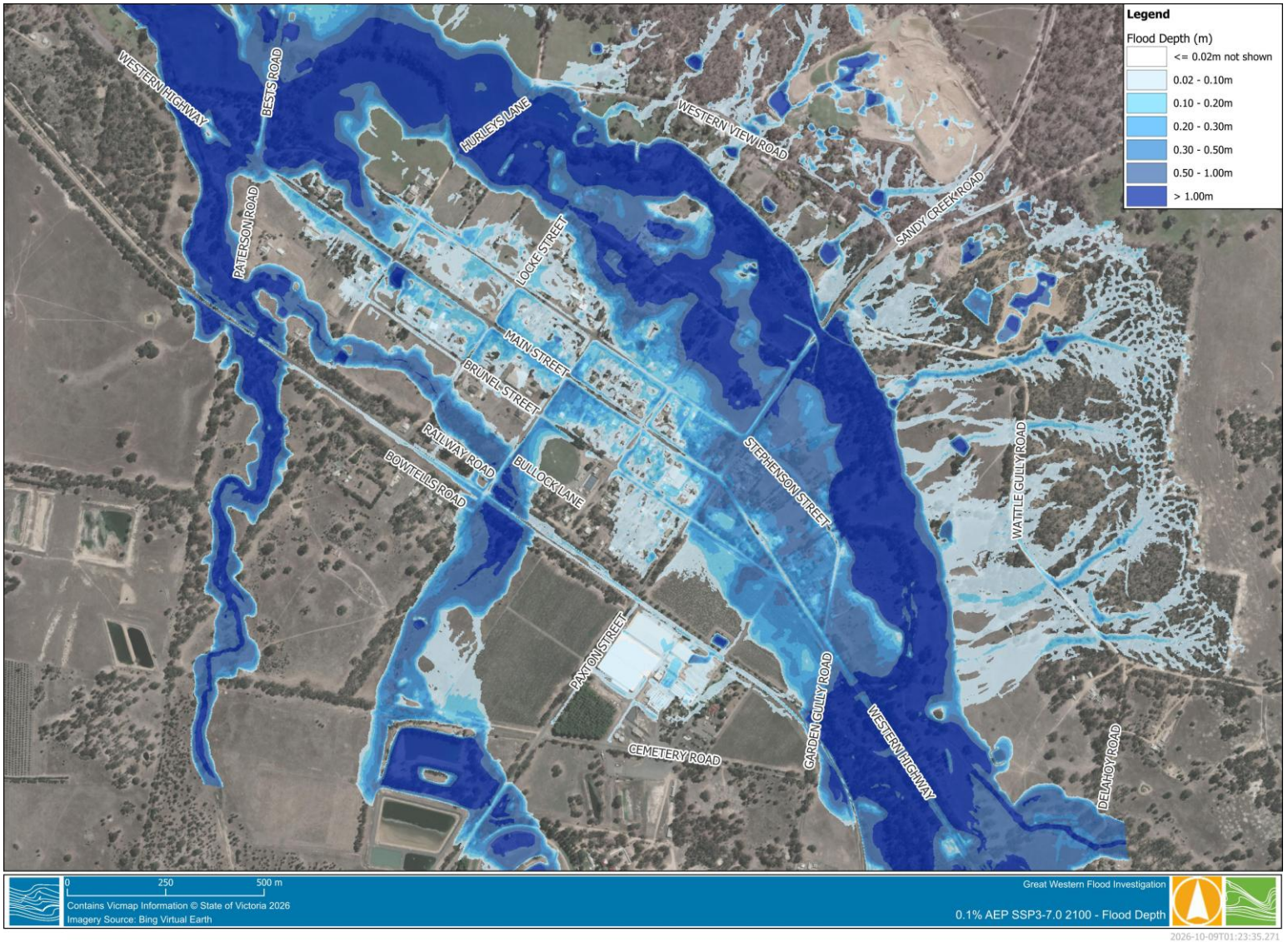


Figure 5-69 Zoomed into Township – 0.1% AEP SSP3-7.0 Year 2100 Flood Depth

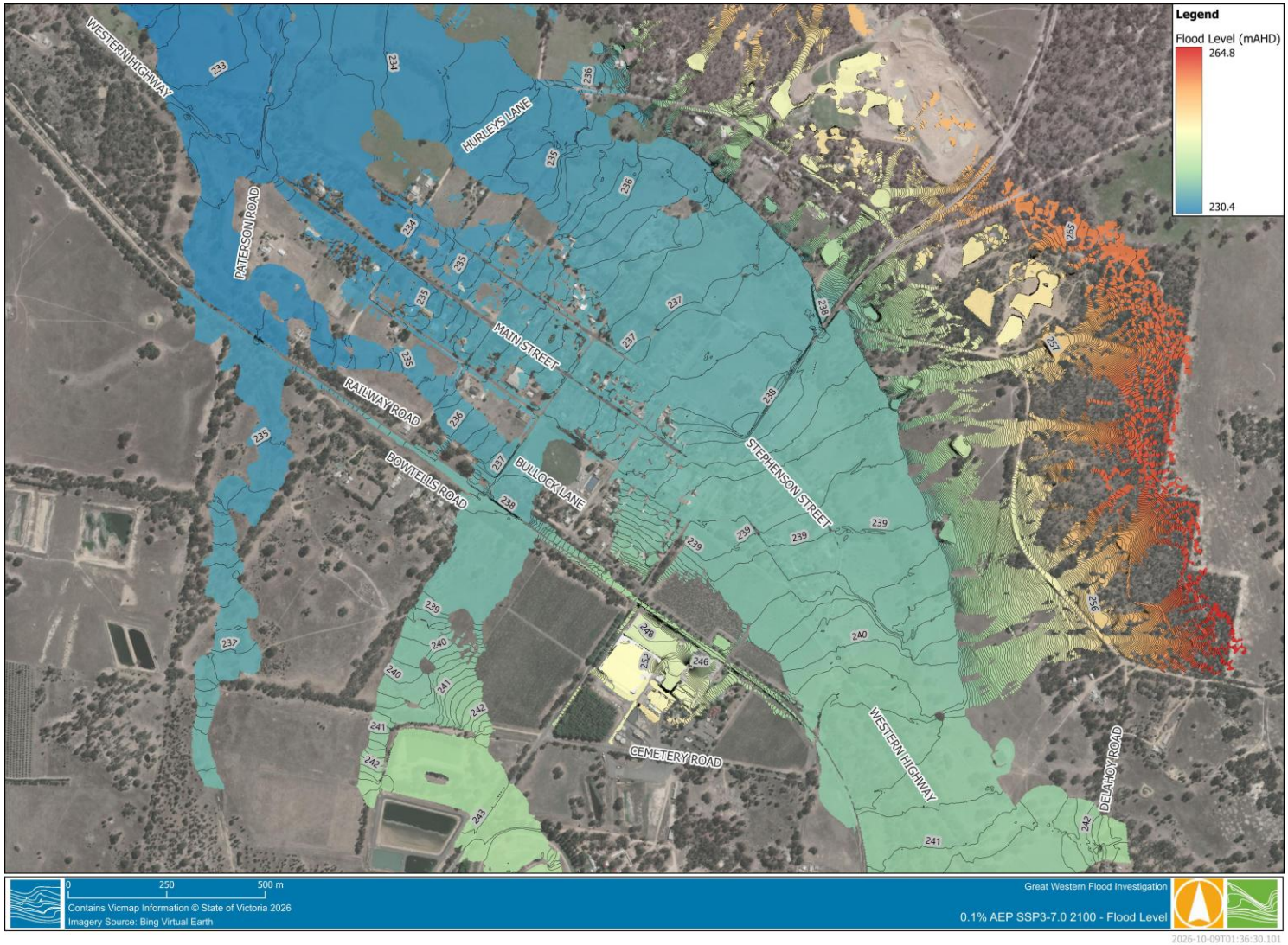


Figure 5-70 Zoomed into Township – 0.1% AEP SSP3-7.0 Year 2100 Flood Level



Figure 5-71 Zoomed into Township – 0.1% AEP SSP3-7.0 Year 2100 Flood Velocity

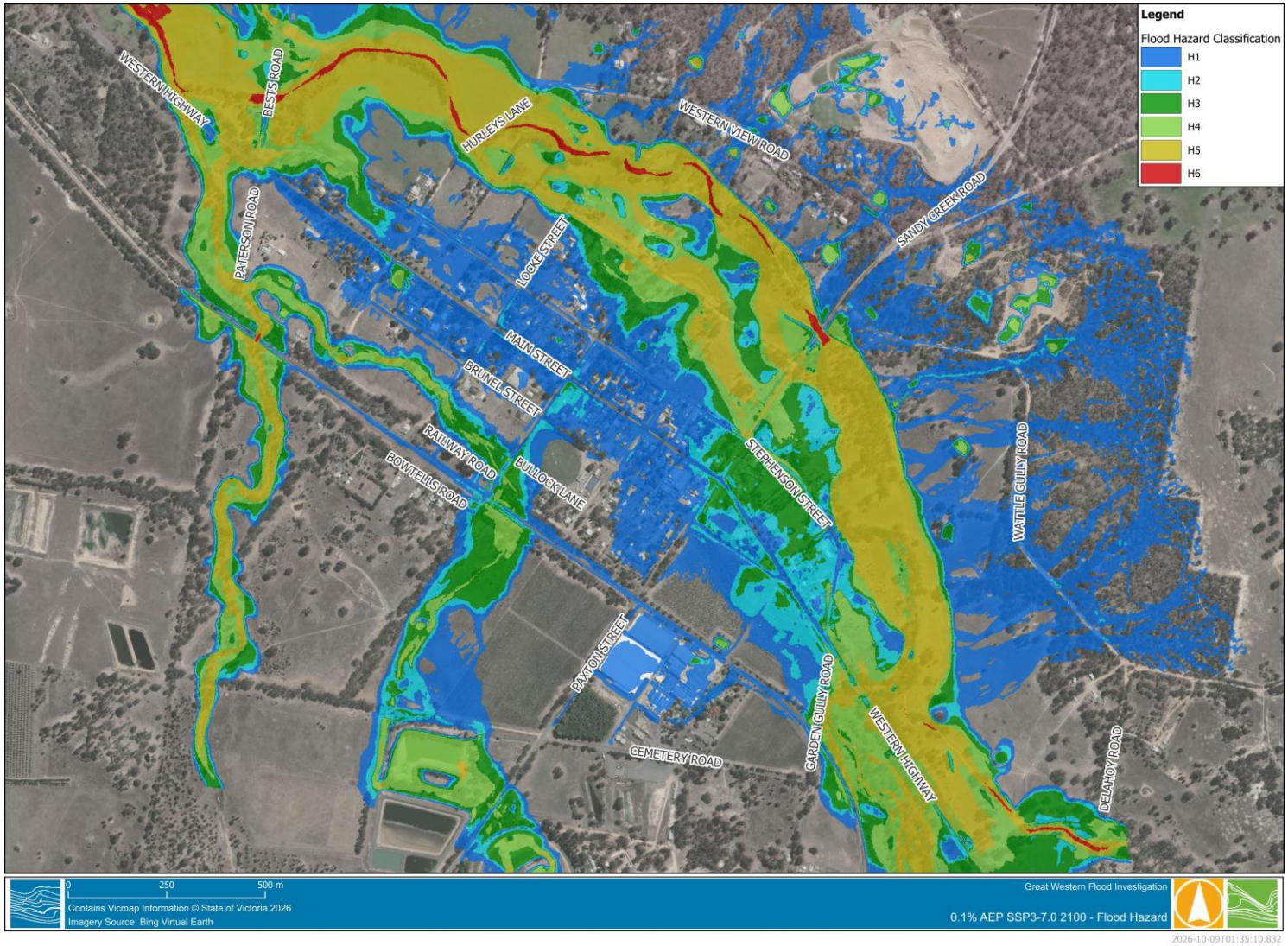


Figure 5-72 Zoomed into Township – 0.1% AEP SSP3-7.0 Year 2100 Flood Hazard

5.20 0.05% AEP SSP3-7.0 Year 2100

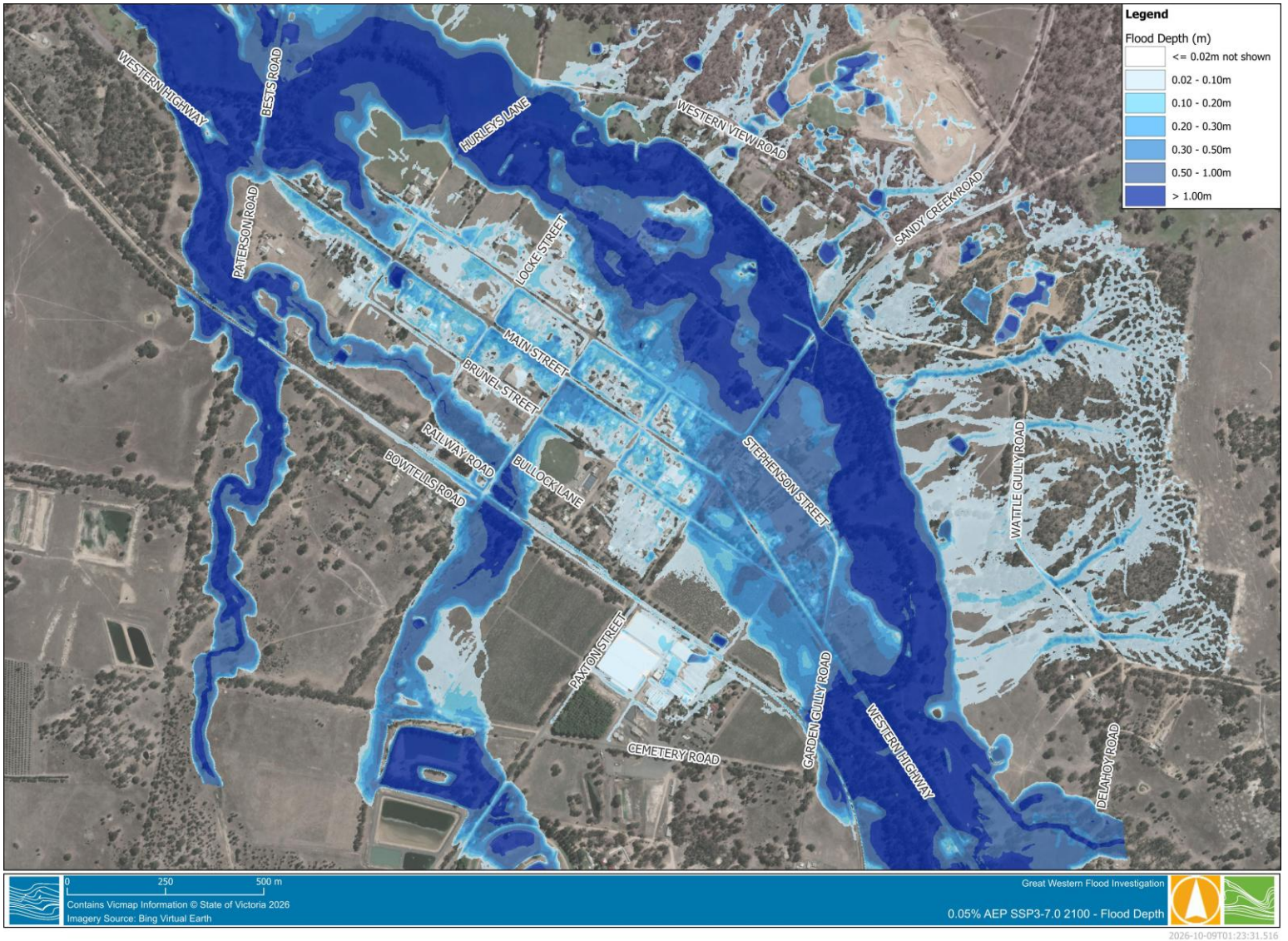


Figure 5-73 Zoomed into Township – 0.05% AEP SSP3-7.0 Year 2100 Flood Depth

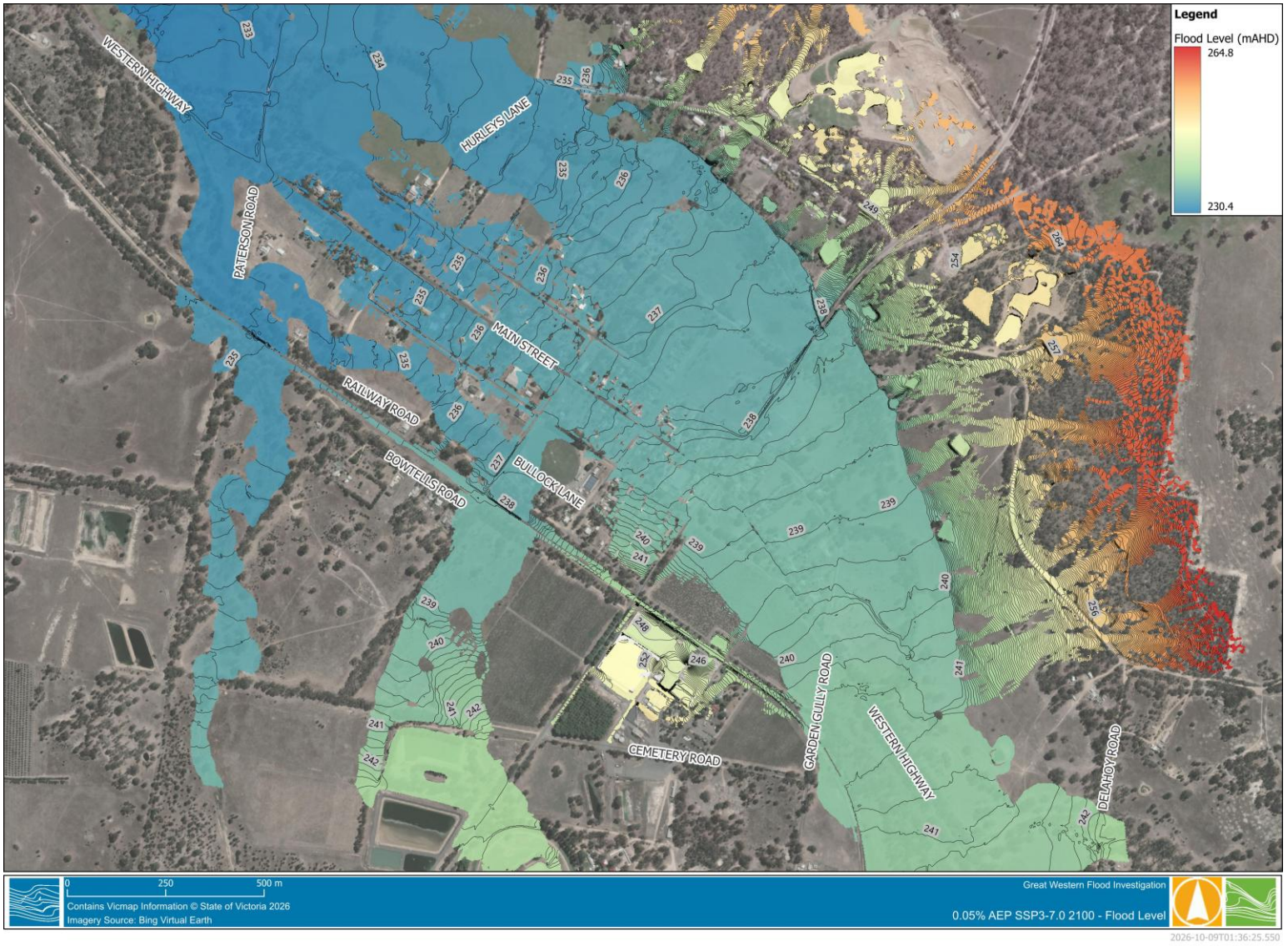


Figure 5-74 Zoomed into Township – 0.05% AEP SSP3-7.0 Year 2100 Flood Level



Figure 5-75 Zoomed into Township – 0.05% AEP SSP3-7.0 Year 2100 Flood Velocity

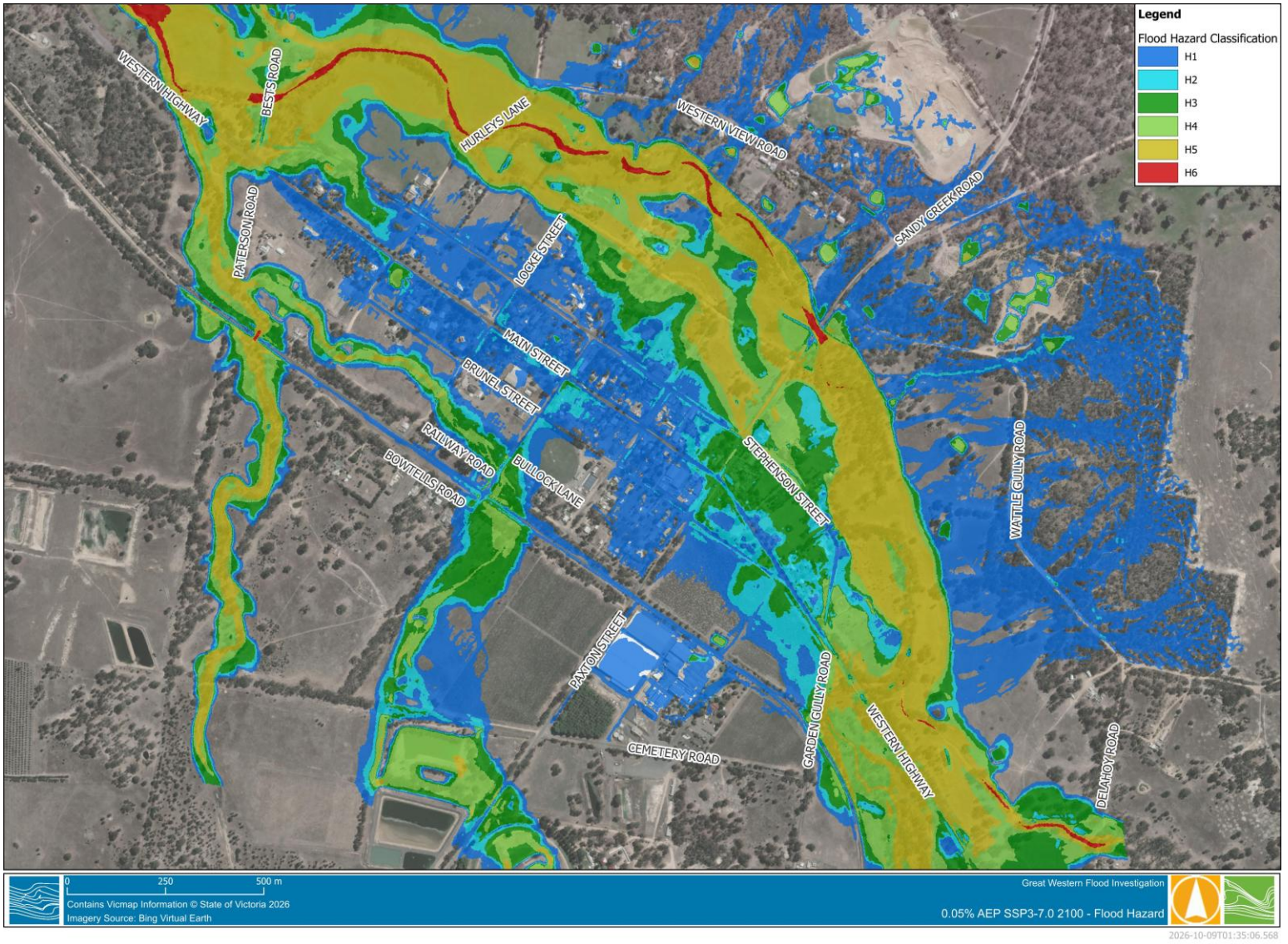


Figure 5-76 Zoomed into Township – 0.05% AEP SSP3-7.0 Year 2100 Flood Hazard

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APPENDIX B
FLOOD MAPPING SSP3-7.0 2030

Provided as attachment



WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

APPENDIX C
FLOOD MAPPING SSP3-7.0 2100

Provided as attachment



WATER TECHNOLOGY
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Fremantle WA 6160

Wangaratta
First Floor, 40 Rowan Street
Wangaratta VIC 3677

Wimmera
597 Joel South Road
Stawell VIC 3380

Darwin
5/5 Goyder Road
Parap NT 0820

Sydney
Suite 3, Level 1, 20 Wentworth Street
Parramatta NSW 2150

Adelaide
1/198 Greenhill Road
Eastwood SA 5063

New Zealand
7/3 Empire Street
Cambridge New Zealand 3434

Geelong
51 Little Fyans Street
Geelong VIC 3220

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Varsity Lakes QLD 4227

Sunshine Coast
Office #4 of the Regatta 1 Business Centre
2 Innovation Parkway
Birtinya QLD 4575

1300 198 413

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