Appendix I

Hydrology and flooding methodology

Hydrologic and hydraulic modelling

Catchment areas represented in the hydrologic and hydraulic DRAINS model are shown in **Figure I-1**. The model consists of 57 sub-catchments, overland flow paths and existing cross drainage structures. Overland flow paths and catchment definition was based on detailed survey and elevation contours at two metre intervals (NSW DFSI, 2018), and catchment imperviousness was estimated from aerial imagery captured in 2018.

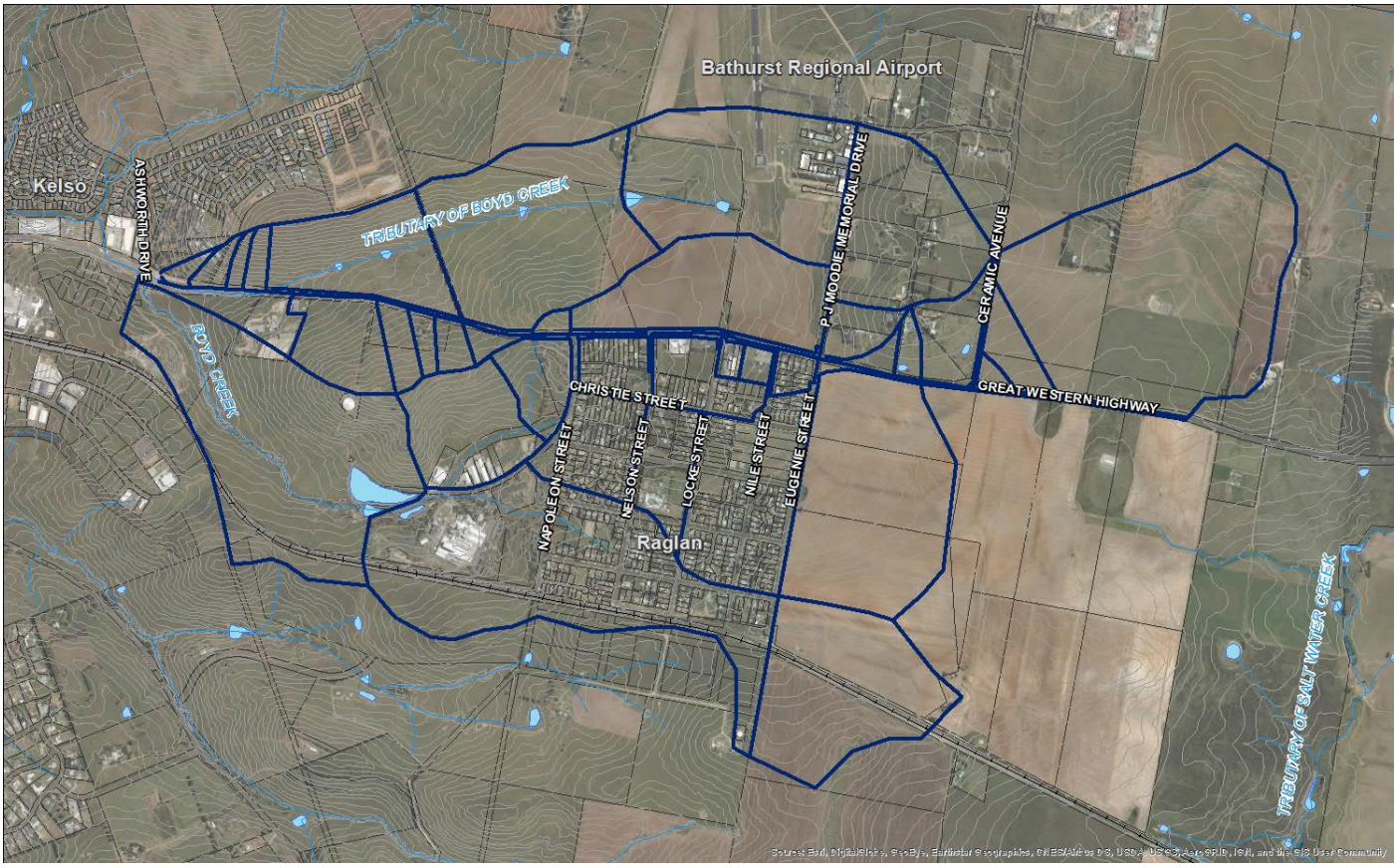

Figure I-1 DRAINS model catchment areas

The existing cross drainage structures under the highway were represented in the model based on the size and invert details obtained from TfNSW's detailed drainage survey. Bathurst Regional Council's existing trunk drainage on the southern side of the highway near Nelson Street was also represented in the model. The trunk drainage pipe layout and sizes were based on details provided by Bathurst Regional Council. Where available, pipe invert levels were sourced from TfNSW's survey. Where survey data did not exist invert levels were estimated assuming a minimum pipe cover of 0.45 metres and minimum grade of 0.5 per cent.

The XPRAFTS model parameters adopted in the model are shown in **Table I-1**. The initial and continuing losses for pervious areas were selected based on the latest recommendations in the *NSW Floodplain Risk Management Guide* (OEH 2019).

Table I-1 Adopted XPRAFTS hydrologic model parameters

XPRAFTS Parameters	Value
Impervious area initial loss (mm)	1
Impervious area continuing loss (mm/hr)	0

XPRAFTS Parameters	Value
Pervious area initial loss (mm)	8
Pervious area continuing loss (mm/hr)	0.8
Manning's 'n' (Urban pervious areas)	0.025
Manning's 'n' (Rural pervious areas)	0.04
Bx	1

The model was run for flood events ranging from the one exceedance per year (EY) up to the one per cent AEP, for storm durations ranging from five minutes to three hours and for the ensembles of 10 temporal patterns as per the ARR hydraulic procedures. The highest median of the duration ensembles was adopted as the critical flow at each pipe and flow path as per ARR recommendations. Critical storm durations were found to range from five minutes up to 1.5 hours.

The estimated probable maximum flood (PMF) discharges, probable maximum precipitation depths and temporal patterns were adopted from the Bureau of Meteorology's Generalised Short Duration Method (GSDM). An initial loss of zero millimetres and continuing loss of one millimetre per hour was adopted as per general guidance in Book 8 Chapter 6 of ARR (2019).

The DRAINS model events and results have been reviewed to assess the existing flow patterns and culvert capacities.

Design flow validation

Validation of the DRAINS model discharges was completed by comparing the flow downstream of the five 1350 millimetre RCP culverts with results from the regional flood frequency estimation (RFFE) model (ARR, 2019) and an existing XPRAFTS model developed by Bathurst Regional Council. The contributing catchment area to this unnamed tributary is about 1.7 square kilometres of predominantly rural lands with an overall imperviousness of less than 10 per cent. The comparison of DRAINS model peak flow and the RFFE model and Bathurst Regional Council model is shown in **Table I-2**.

Table I-2 DRAINS model validation against RFFE model – tributary downstream of 5 x 1350 RCPs

Design Event AEP	DRAINS Model (m^3/s)	RFFE Model (m^3/s)			Council XP-RAFTS model (m3/s)
		Lower bound	Discharge	Upper bound	
10%	8.48	1.81	4.32	10.3	Not available
1%	14.75	5.40	13.7	34.9	7.05

The comparison in **Table I-2** shows the DRAINS model estimate for the one per cent AEP is comparable with the RFFE model discharge. While the DRAINS model result is closer to the RFFE upper bound for the 10 per cent AEP. The DRAINS model one per cent AEP flow is about double the estimate from Bathurst Regional Council's XPRAFTS model. The Bathurst Regional Council XPRAFTS result is close to the RFFE model lower bound and therefore more likely to be an underestimation. Based on the comparison against the RFFE results, the DRAINS model is considered to provide a reasonable estimate for larger infrequent floods and potentially a more conservative estimate for smaller more frequent floods.

Existing environment

Details of the existing trunk drainage system (including the layout, number and size of pipes) were provided by Bathurst Regional Council. The layout of the existing drainage pipes and overland flow paths are shown in **Figure I-2**. Key locations where DRAINS modelling results are compared are also shown on **Figure I-2** and described in **Table I-3**.

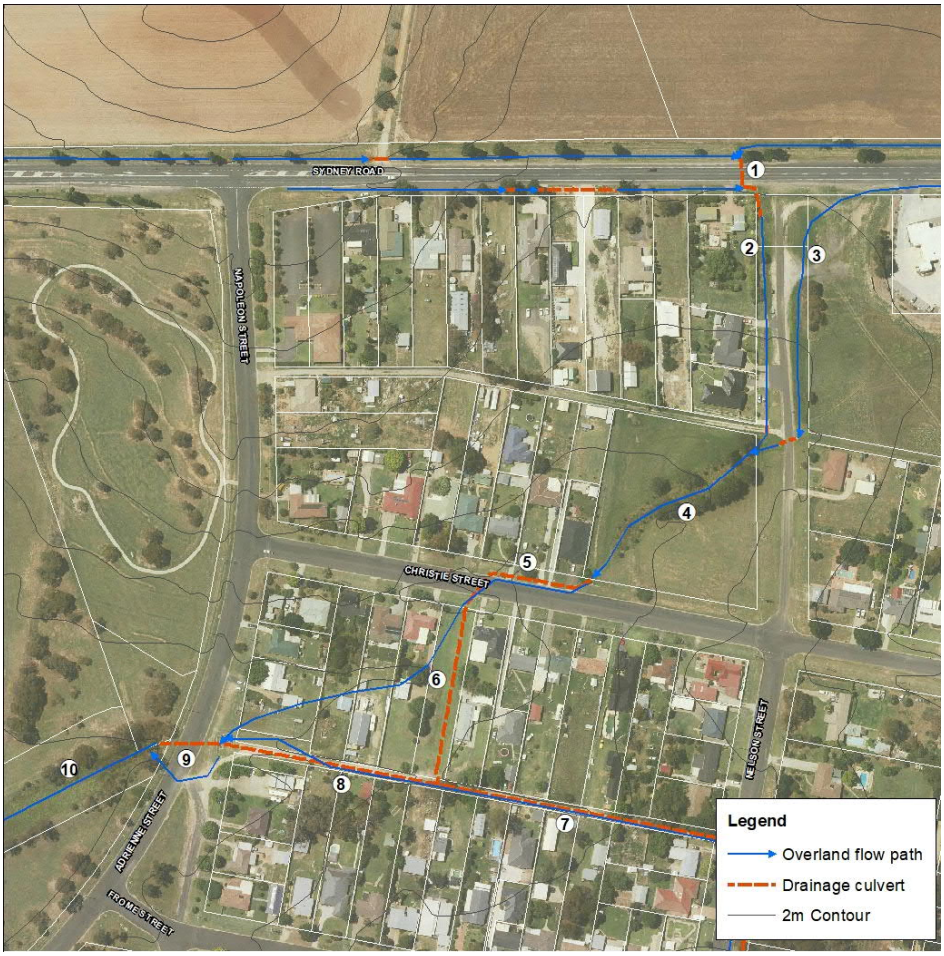

Figure I-2 Existing overland flow paths and drainage culverts near Nelson Street

Table I-3 Description of key comparison locations

ID Number (from Figure I-2)	Location description	
	Pipe size (mm)	Overland flow path
1	2 x 600 RCP	Great Western Highway sag
2	-	Open channel on the western side of Nelson Street
3	-	Open channel on the eastern side of Nelson Street
4	-	Open space at the intersection of Christie Street and Nelson Street
5	2 x 825 RCP	Christie Street sag
6	1 x 1200 RCP	Through private properties from Christie Street to Adrienne Street
7	1 x 1350 RCP	Drainage easement from Nelson Street to Adrienne Street (east)
8	1 x 1800 RCP	Drainage easement from Nelson Street to Adrienne Street (west)

ID Number (from Figure I-2)	Location description	
	Pipe size (mm)	Overland flow path
9	2 x 1500 RCP	Adrienne Street sag
10	-	Main channel of Boyd Creek

Hydrologic and hydraulic modelling results

Existing culvert capacities

Table I-4 summarises existing culverts, their contributing catchment areas and the flow distributions at each structure in the 10 per cent and one per cent AEP storm events. These results assume the culverts are free from blockage and provide an estimate of the existing culverts maximum potential capacity.

Table I-4 Existing culverts and flow distributions

Chainage	Number of culverts and size	Crossing	Contributing catchment area (ha)	10% AEP (m^3/s)		1% AEP (m^3/s)	
				Culvert flow	Bypass / overflow	Culvert flow	Bypass / overflow
51487	1 x 450 RCP	Great Western Highway	5.97	0.27	0.45	0.27	1.52
51625	1 x 450 RCP	Property access	6.37	0.30	0.34	0.31	0.50
51650	2 x 450 RCP	Great Western Highway	11.64	0.61	0.36	0.73	1.13
51820	1 x 450 RCP	Ceramic Avenue	9.47	0.27	0.51	0.27	1.25
52142	1 x 450 RCP	Great Western Highway	2.33	0.26	0	0.32	0.18
52420	1 x 450 RCP	Great Western Highway	3.57	0.19	0.15	0.21	0.31
52440	2 x 450 RCP	PJ Moodie Memorial Drive	5.44	0.33	0.08	0.48	0.26
52450	1 x 450 RCP	PJ Moodie Memorial Drive	5.66	0.38	0.31	0.41	1.01
52610	1 x 300	Great Western Highway at Nile Street	2.91	0.13	0.51	0.13	1.22
52840	2 x 300	Great Western Highway at Locke Street	3.46	0.18	1.09	0.18	2.24
52860	3 x 450 RCP	Property access	18.18	0.85	0.46	0.97	1.20
53157	2 x 600 / 1 x 900 RCP	Great Western Highway at Nelson Street	51.03	1.33	1.71	1.35	4.01
53373	1 x 450 RCP	Property access	0.16	0.04	0	0.07	0

Chainage	Number of culverts and size	Crossing	Contributing catchment area (ha)	10% AEP (m^3/s)		1% AEP (m^3/s)	
				Culvert flow	Bypass / overflow	Culvert flow	Bypass / overflow
53620	1 x 450 RCP	Great Western Highway	1.23	0.17	0	0.31	0
53890	1 x 450 RCP	Great Western Highway	1.88	0.22	0	0.33	0.11
53900	1 x 300 RCP	Property access	Not assessed. Culvert would need to be removed for highway duplication.				
54000	1 x 450 RCP	Great Western Highway	2.79	0.35	0	0.40	0.36
54125	1 x 450 RCP	Great Western Highway	2.17	0.24	0.07	0.29	0.56
54205	1 x 450 RCP	Property access	Not assessed. Culvert would need to be removed for the proposal.				
54250	1 x 450 RCP	Great Western Highway	4.09	0.34	0.25	0.40	1.14
54610	1 x 450 RCP	Property access	13.08	0.36	1.29	0.44	3.31
54695	5 x 1350 RCP	Great Western Highway	168.61	8.48	0	14.8	0
54800	1 x 525 RCP	Great Western Highway	2.08	0.23	0.11	0.37	0.27
54870	1 x 525 RCP	Great Western Highway	1.44	0.23	0.11	0.40	0.32
55025	1 x 600 RCP	Great Western Highway	2.19	0.21	0.21	0.34	0.57
55145	1 x 525 RCP	Great Western Highway	1.49	0.21	0.21	0.35	0.62

The DRAINS model results indicate the majority of existing culverts are undersized with bypass (overflows) occurring at most culverts in the 10 per cent and one per cent AEP flood events. Therefore, most culverts would require upgrade or expanding to achieve the one per cent AEP cross drainage capacity and flood immunity design criteria.

The modelling results also indicate that with existing drainage flooding occurs over the highway near Nelson Street in less than the 10 per cent AEP event. The peak flood depth over the road crown is estimated at 0.07 metres and 0.1 metres in the 10 per cent and one per cent AEP events respectively.

The existing five cell 1350 millimetre diameter RCPs that carry the unnamed tributary of Boyd Creek under the highway are considered to have one per cent AEP capacity. There is a relatively small volume of overflow (less than five litres per second) from the culverts in the one per cent AEP event that would flow west north of the highway.

Downstream flows

The locations where runoff is discharged from the highway corridor into downstream overland flow paths or creeks, and the existing peak flow rates in the 10 per cent and one per cent AEP events are shown in **Table I-5**.

Table I-5 Existing downstream peak discharges (m^3/s)

Location	1 EY	10% AEP	1% AEP
Outlet of culvert 200 m east of eastern limit of works	2.02	5.08	8.91
CH 53120 – Nelson Street eastern side	0.24	1.12	2.27
CH 53140 – Nelson Street western side	1.45	3.02	5.36
CH 53620 – 160 m west of Napoleon Street	0.08	0.21	0.38
CH 53900 – at Future Road about 100 metres east of the Bathurst Sheds entrance	0.12	0.29	0.47
CH 55160 – Table drain on northern side of highway at western limit of works	0.04	0.21	0.62
CH 55020 – Unnamed tributary of Boyd Creek at western limit of works	3.96	9.92	17.30
Culverts at Ashworth Drive intersection 300 m west of western limit of works	14.24	31.00	59.32

Flooding at Nelson Street

Table I-6 summarises the existing critical flow rates (pipe flow and overland flow) for the 10 percent and one percent AEP events at each key location identified in **Figure I-2**.

Table I-6 Existing peak discharges downstream of Nelson Street

ID Number	Location	10% AEP (m^3/s)		1% AEP (m^3/s)	
		Pipe flow	Overland flow	Pipe flow	Overland flow
1	Great Western Highway sag at Nelson Street	1.33	1.71	1.35	4.01
2	Nelson Street (west)	-	3.02	-	5.36
3	Nelson Street (east)	-	1.12	-	2.27
4	Open space	-	4.28	-	8.37
5	Christie Street sag	1.89	3.53	1.96	7.75
6	Christie Street to Adrienne Street	2.66	2.51	2.67	7.51
7	Christie Street to Adrienne Street (West)	5.83	1.85	5.94	9.41
8	Nelson Street to Adrienne Street (East)	8.77	0.98	9.00	7.71
9	Adrienne Street	10.92	0.00	13.94	7.09
10	Downstream channel	-	12.22	-	23.46

The results show Bathurst Regional Council's existing trunk drainage system has varying capacity ranging from one EY up to the 10 percent AEP. The twin 825 millimetre diameter pipes on the northern side of Christie Street have one EY capacity, while the twin 1500 millimetre diameter pipes under Adrienne Street have capacity for the 10 percent AEP event.

The overland flow path between Christie Street and Adrienne Street (location 6 on **Figure I-2**) has minor overland flows (less than 100 millimetre depth) in a 50 per cent AEP event and more significant flows (about 300 millimetre depth) in a 20 percent AEP event.

Operational impacts

Flooding at Nelson Street

The proposal would increase the paved area draining to the Nelson Street sag by about two hectares. The increase is equivalent to about a four per cent increase in imperviousness relative to the total catchment area (51.8 hectares) draining to the sag. Without flood mitigation this increase in paved area would have the potential to increase downstream runoff flow rates and volumes, causing adverse flood impacts to several private properties.

A flood detention basin is proposed on the northern side of the highway at Nelson Street (**Table I-7**) to ensure the proposal does not cause unreasonable increases to downstream inundation levels. Hydrologic and hydraulic modelling identified the required detention storage volume would be about 4,000 cubic metres.

The peak flows at key locations downstream of the highway at Nelson Street have been assessed for existing and proposed conditions and differences the are shown in **Table I-7**.

Table I-7 Operational phase flows downstream of Nelson Street (per cent change from existing)

ID	Location	10% AEP (m^3/s)		1% AEP (m^3/s)	
		Pipe flow	Overland flow	Pipe flow	Overland flow
1	Great Western Highway sag at Nelson Street	2.87 (116%)	0 (-100%)	4.65 (244%)	0 (-100%)
2	Nelson Street (West)	-	2.87 (-5%)	-	4.65 (-13%)
3	Nelson Street (East)	-	0 (-100%)	-	0 (-100%)
4	Open space	-	3.73 (-13%)	-	6.33 (-24%)
5	Christie Street sag	1.89 (0%)	3.18 (-10%)	1.96 (0%)	6.04 (-22%)
6	Christie Street to Adrienne Street	2.64 (-1%)	2.27 (-9%)	2.71 (2%)	5.72 (-24%)
7	Nelson Street to Adrienne Street (west)	5.83 (0%)	1.88 (2%)	5.93 (0%)	9.41 (0%)
8	Nelson Street to Adrienne Street (east)	8.79 (0%)	1.01 (2%)	8.98 (0%)	7.73 (0%)
9	Adrienne Street	10.58 (-3%)	0 (0%)	13.94 (0%)	6.12 (-14%)
10	Downstream channel	-	12.16 (0%)	-	22.78 (-3%)

Table I-7 shows there would be reductions, or no discernible change, in overland peak flow. The proposal would not cause any adverse flood impacts to existing properties or Council's existing trunk drainage downstream of the highway at Nelson Street. Between Christie Street and Adrienne Street where private properties would be sensitive to any potential increases in flooding, there would be a reduction in flood risk

with a nine per cent and 24 per cent reduction in overland peak flow in the 10 per cent AEP and one per cent AEP events respectively.