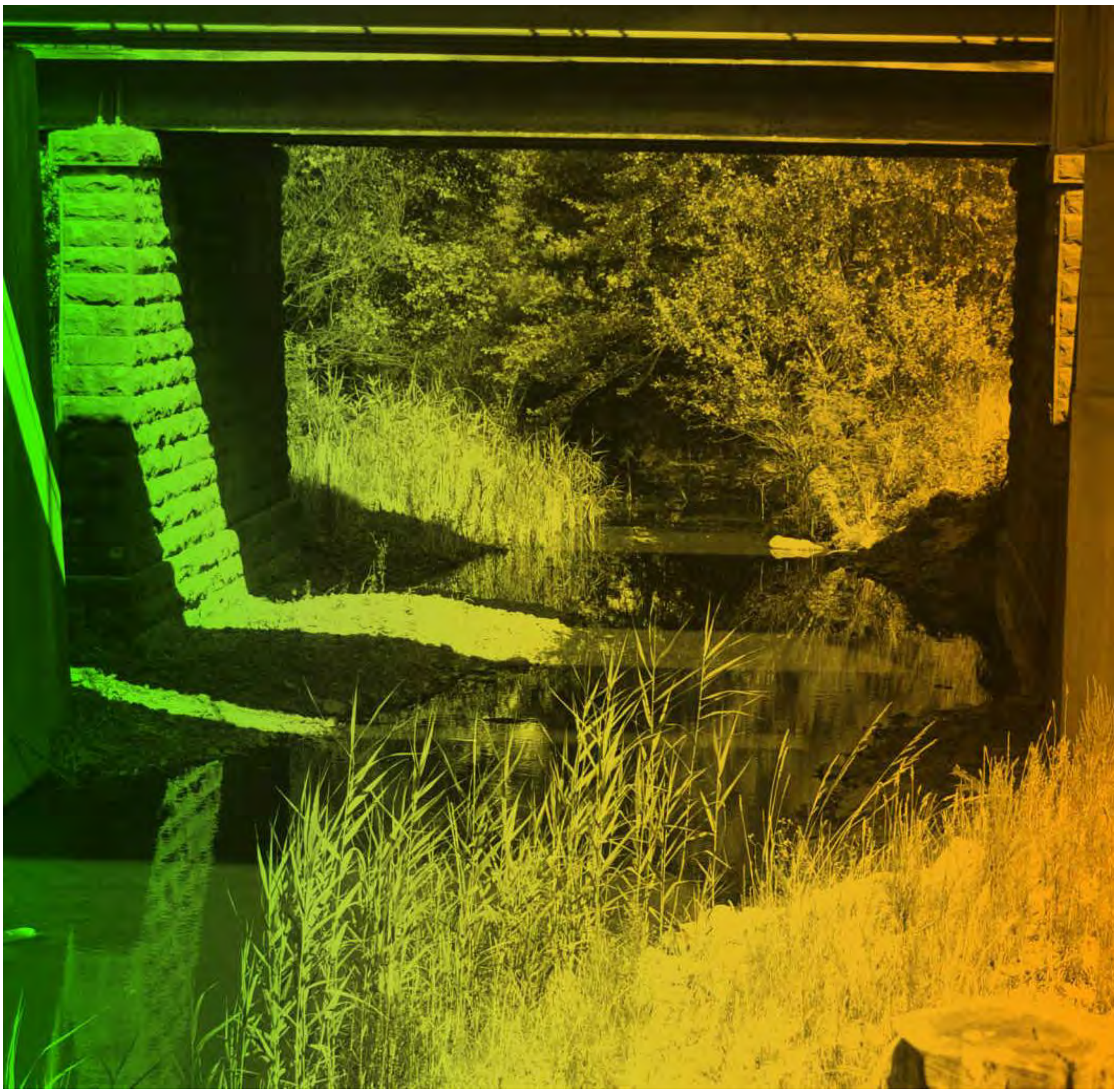
Kilmore Wallan Bypass
VicRoads
25 October 2012

Kilmore-Wallan Bypass Hydrological and Hydraulic Study



Kilmore-Wallan Bypass Hydrological and Hydraulic Study

Prepared for

VicRoads

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1.0 Introduction

1.1 Background

The communities of Wallan and Kilmore are approximately 50km north of Melbourne located on the Northern Highway. Due to the rapid growth in these townships and consequential increase in living density, a bypass has been proposed to redirect through traffic and assist in traffic movements within the townships.

VicRoads is investigating five possible alignments through the study area, all of which would connect to the Northern Highway and Hume Freeway.

1.2 Objectives

The five alignment alternatives all have varying levels of interaction with Dry Creek or Broadhurst Creek. As such it is the purpose of this report to determine the hydraulic structures required to conform to the standards of VicRoads and the Goulburn Broken Catchment Authority.

2.0 Alignment Options

The five alignment options currently proposed for the Kilmore bypass include:

- Alignment 1 – Quinns Road Option - southern connection from Northern Highway To Hume Freeway
- Alignment 2 – O'Gradys Road Option - western alignment relative to Dry Creek
- Alignment 3 – Dry Creek Option - eastern alignment relative to Dry Creek
- Alignment 4 – Sunday Creek Option - northern connection from Northern Highway to Hume Freeway
- Alignment 5 –Western Option – western connection bypassing to the west of Kilmore connecting the Hume Freeway via the Wondong Interchange

The impact of each of these alignments on the flow characteristics of Dry, Broadhurst and Sunday Creeks is assessed in this report.

3.0 Dry, Broadhurst and Kilmore Creeks - Hydrological Analysis

3.1 Overview

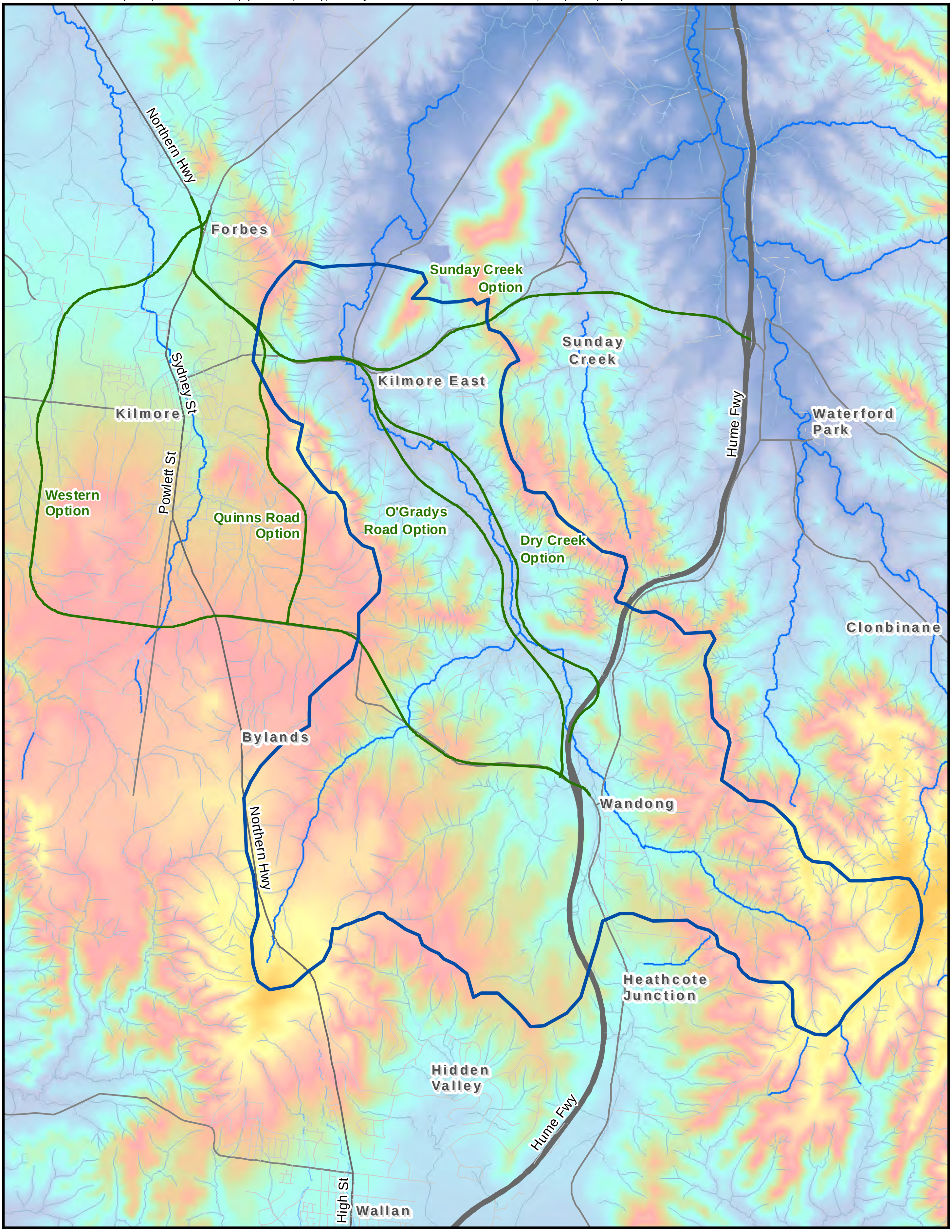
The hydrological modelling section of this study refers to the modelling of overland flows of Dry, Kilmore and Broadhurst Creeks. This analysis was undertaken using RORB (Refer Glossary), with support from the MapInfo RORB tool known as MiRORB for Dry and Broadhurst Creeks. In absence of VicRoads standards and procedures for hydrological modelling, Melbourne Water (MW) Technical Specifications were applied where appropriate. Flow rates for Kilmore Creek have been determined using industry based hydrological calculations as the flow is only required at two locations.

An estimation of peak discharges for the average recurrence intervals (ARI) of 100, 50 and 20 years were derived from the hydrologic models. These discharges were then utilised in the hydraulic modelling of Dry, Broadhurst, and Kilmore Creeks in HEC-RAS(Refer Glossary).

3.2 Catchment Boundary

The catchment boundary was defined through the visual analysis of topographic data, obtained through the Department of Sustainability and Environment (DSE). This topographic data consisted of 10 metre contours, which were converted into a Digital Elevation Model (DEM) using inverse distance weighting interpolation.

Figure 1 shows the catchment boundary overlayed upon the generated DEM.



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LEGEND

Catchment

Proposed Bypass Alignment (Centre Line)

Height (mAHD)
High : 581
Low : 220

Data sources:
Base Data: (c) 2011 DSE
Alignment: (c) VicRoads

FIGURE 1
CATCHMENT BOUNDARY

Vicroads

Kilmore-Wallan Bypass

Figure
1

3.3 Sub Catchment Boundaries

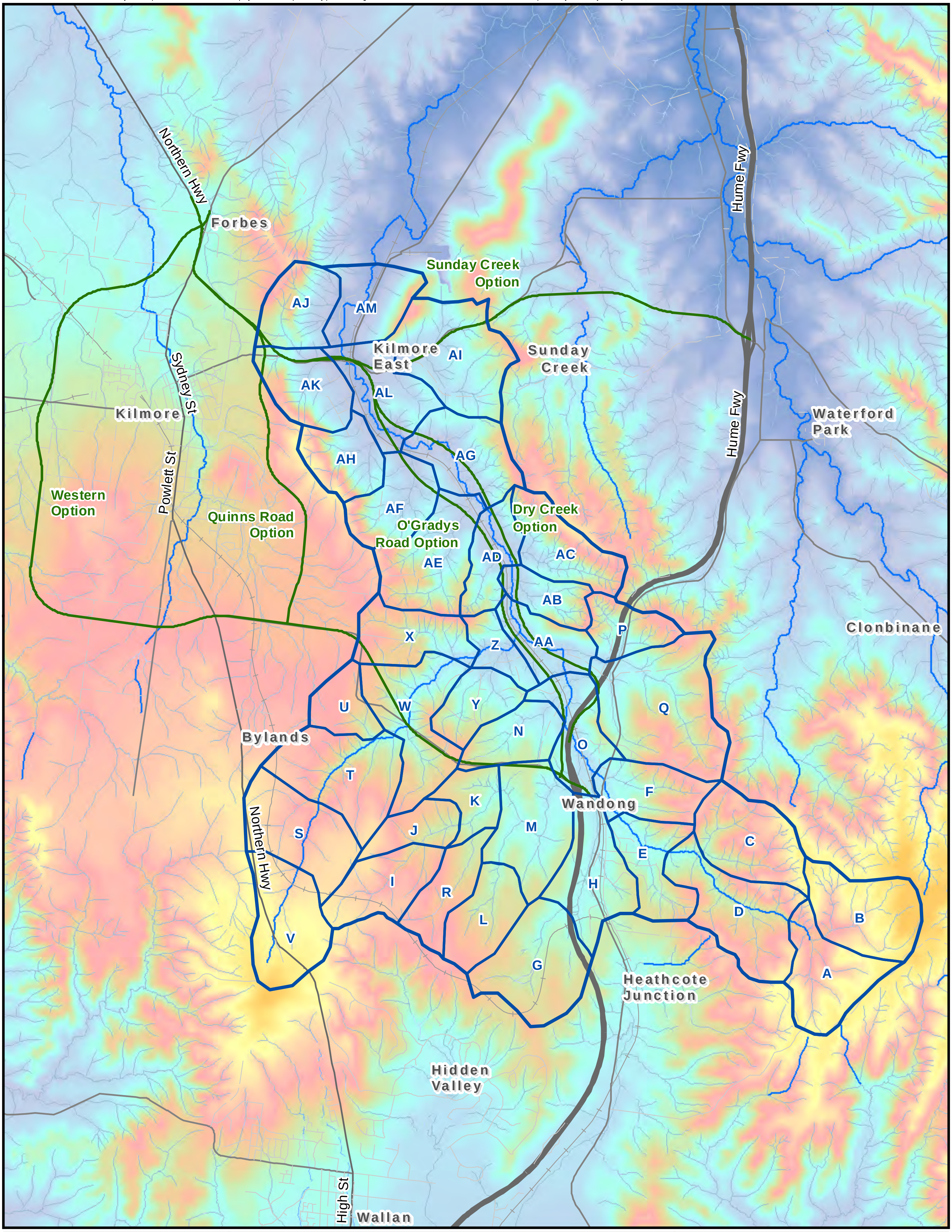
The overall catchment area was further divided into sub-catchments, which were once again identified through inspection of the DEM. These sub-catchments, whilst primarily considering the topography, were also defined to give hydrographs for flows crossing the proposed alignments.

Figure 2 shows the sub-catchment boundaries and its naming convention. Values corresponding to area and fraction impervious can be seen in Table 1.

Table 1 Sub-Catchment Summary

Sub-Catchment	Fraction Impervious Value	Area (km^2)
A	0.1	1.956
B	0.1	2.037
C	0.1	2.059
D	0.1	2.516
E	0.2	1.515
F	0.1	1.504
G	0.1	1.868
H	0.2	2.445
I	0.1	1.587
J	0.1	0.928
K	0.1	0.837
L	0.1	1.575
M	0.1	2.075
N	0.1	1.237
O	0.1	1.665
P	0.1	1.071
Q	0.1	2.477
R	0.1	1.212
S	0.1	2.191
T	0.1	2.526
U	0.1	1.567
V	0.1	2.18
W	0.1	1.851
X	0.1	1.456
Y	0.2	1.141
Z	0.1	0.75

Sub-Catchment	Fraction Impervious Value	Area (km^2)
AA	0.1	1.226
AB	0.1	0.911
AC	0.1	1.653
AD	0.1	1.157
AE	0.1	2.245
AF	0.1	1.527
AG	0.1	1.903
AH	0.1	1.307
AI	0.1	2.736
AJ	0.1	1.44
AK	0.2	1.582
AL	0.1	1.739
AM	0.1	1.521
	Total	**65.173**



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LEGEND

Sub-catchment

Proposed Bypass Options

Height (mAHD)
High : 581
Low : 220

Data sources:
Base Data: (c) 2011 DSE
Alignment: (c) VicRoads

FIGURE 2
SUB-CATCHMENT BOUNDARIES

Vicroads

Kilmore-Wallan Bypass

Figure
2

3.4 Fraction Impervious Values

Due to the rural nature of the study area, relatively low Fraction Impervious (FI) values were used in the hydrologic models. Using a cadastral layer, developed areas were identified within each sub-catchment and FI values were then assigned according to the level of development. In general, a FI value of 0.2 was assigned to sub-catchments with a developed area greater than its open space area. Otherwise a default FI value of 0.1 was applied. Table 1 summarises the FI values assigned to each sub-catchment as well as its respective areas.

Based on observations made during the site inspection, it was established that all private dams would likely be full during a peak storm event. As such, a conservative approach was adopted where the total runoff from all sub-catchments was assumed to contribute to the respective waterways.

3.5 Rainfall Data

Intensity Frequency Duration (IFD) factors, shown below in Table 2, were generated from the Bureau of Meteorology (BOM) website (www. bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml).

Table 2 IFD Factors for Kilmore

ARI	Intensity (mm/hr)		
	1hr	12hr	72hr
2 Year (Current)	19.41	4.14	1.14
50 Year (Current)	39.53	7.34	2.37
2 Year (2100)	25.62	5.46	1.50
50 Year (2100)	52.18	9.69	3.23
G = 0.29	F_2 = 4.31	F_{50} = 15.00	

Design rainfall intensities for desired storm events were extrapolated from the above values based on algebraic procedures described in “Australian Rainfall and Runoff”, which were then used in the hydrologic models. The factors at the bottom of the table were used to account for geographical variances.

Both rainfall data sets were used in RORB calculations; however, hand calculations and resultant calibrations were based only upon the current IFD data, which is further discussed in Section 3.6. The G, F2 and F50 are statistical parameters to relate rainfall distribution to geographical locations within Australia.

3.6 Model Calibration

The RORB model was calibrated to stream flow gauge data where it was available. However, flow data is often unavailable for small creek systems; and where this was the case, the model was calibrated to an estimated flow calculated using the Rational Method.

Two specific points in the model were chosen for the calibration process. These two points, shown as Point 1 and Point 2 in Figure 3, corresponded to the convergence of the upper sub-catchments and the lower sub-catchments respectively.

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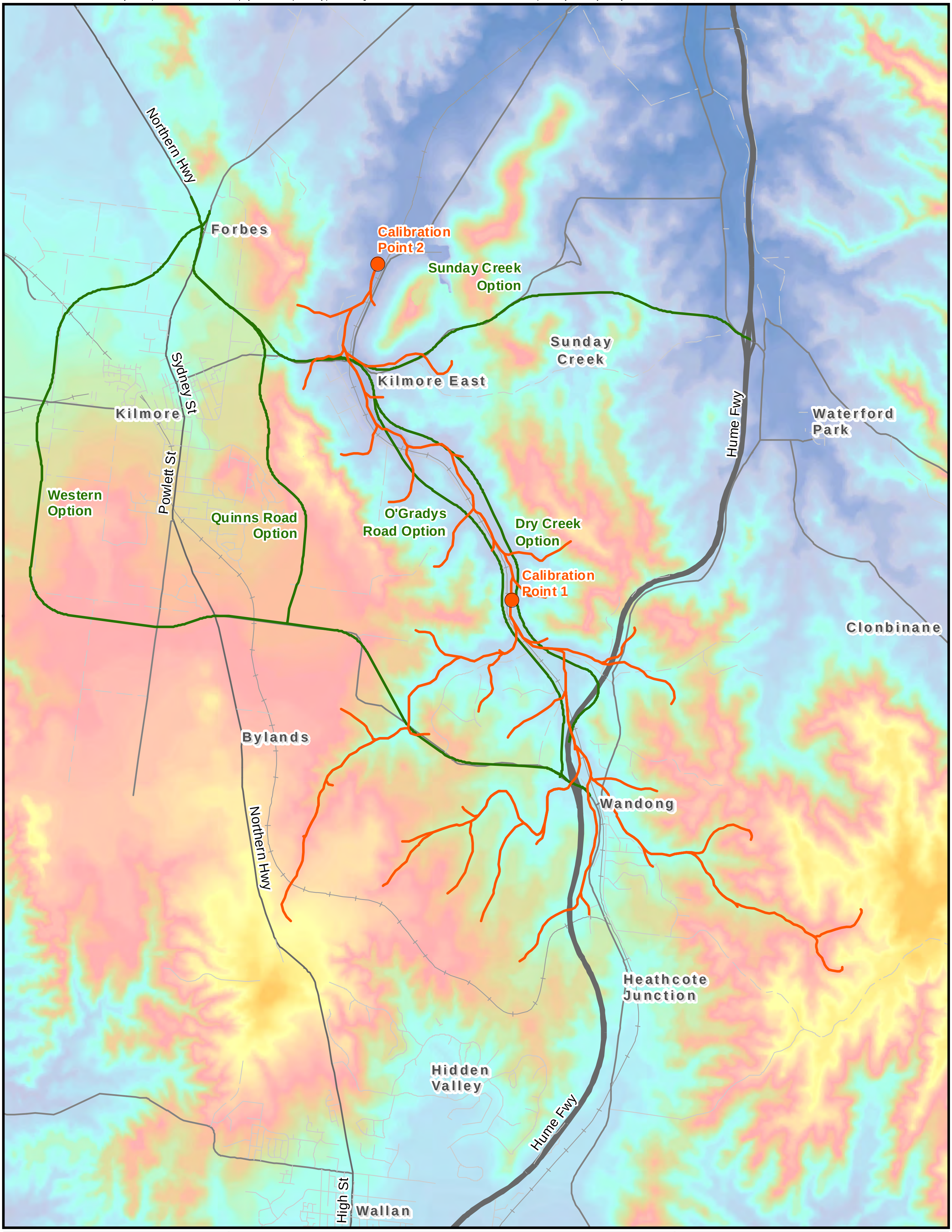

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LEGEND

- Calibration Point
- Reach
- Proposed Bypass Options

Height (mAHD)
High : 581
Low : 220

Data sources:
Base Data: (c) 2011 DSE
Alignment: (c) VicRoads

FIGURE 3
CALIBRATION POINTS AND REACHES

Vicroads

Kilmore-Wallan Bypass

Figure
3

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3.6.1 The Rational Method

The Rational Method was applied to the two calibration points in order to derive an initial estimate of flow rates, which were used to calibrate the RORB model. The variables required for the Rational Method and the calculated results are summarised in Table 3.

The time of concentration (t_c) value for Point 1 (the midpoint) was calculated using an approximate average of the Bransby Williams and Modified Friends equations, which are defined in the glossary at the end of this report. These are empirical methods which take into consideration catchment characteristics such as areas, slopes, and length of flow paths. Time of concentration is an important variable in defining the critical storm intensity used to determine the peak flow rate. The peak flow rate was then applied to the HEC-RAS model of Dry Creek to calculate the flow velocity within the downstream section of the creek. Travel time in the creek was then added to the midpoint's t_c (Point1) to estimate a t_c at Point 2. This gave a more accurate estimation of the t_c at Point 2 (the base) compared to values derived from the Bransby Williams and Modified Friends equations alone. Additionally, as the calibration areas consist of multiple sub-catchments, the FI values were calculated based on an area weighted average.

Table 3 Rational Method Calculations

	Point 1 (Midpoint)	**Point 2 (Base)**
Area	41.89	65.37
Fraction Impervious	0.112	0.110
Adopted t_c (min)	210	300
Runoff Coefficient C_{10}	0.239	0.238
100 Year ARI Rural Frequency Factor	1.3	
Runoff Coefficient C_{100}	0.311	0.309
100 year Intensity for t_c (mm/hr)	21.15	16.80
Peak Flow Q100 (m^3/s)	**76.6**	**94.4**

3.6.2 Calibration Process

As hydraulic structures would be assessed for the 100 year ARI storm event, it was established that calibration of the RORB model should be conducted with 100 year ARI values. Table 4 below summarises the calibration process.

Table 4 k_c Calibration Summary

Calibration Points	**Rational Method Q_{100} (m^3/s)**	**Rational Method t_c (min)**	**RORB Q_{100} k_c=14.99 (m^3/s)**	**RORB peak storm duration (hr)**	**RORB Q_{100} k_c=15.01 (m^3/s)**	**RORB peak storm duration (hr)**	**RORB Q_{100} k_c=15.03 (m^3/s)**	**RORB peak storm duration (hr)**
Point 1 (Mid)	76.6	210	80.3	12	**80.2**	**12**	80.1	12
Point 2 (Base)	94.4	300	90.8	24	**90.8**	**24**	90.7	24

Values for k_c were adjusted to achieve the best calibration to the calculated flow rates. A k_c value of 15.01 was adopted as the resultant flow rates for Points 1 and 2 were ±3.6 m^3/s from the rational method target. The RORB input parameters that were used in this investigation were:

Table 5 RORB Input Parameters

Parameter	Value
k_c	15.01
Initial Loss	15mm
100 Year Run of Coefficient	0.6
50 Year Run of Coefficient	0.55
20 Year Run of Coefficient	0.45

3.7 Results

Resulting flow rates have been presented at points along Dry and Broadhurst Creeks in Table 6 below. These values were applied to the hydraulic models in HEC-RAS to represent the current flood characteristics. Figure 4 illustrates the corresponding nodes where these flow rates apply to.

Table 6 RORB Results

		Current Conditions		
Point No.	**Chainage**	**Q_{20} (m^3/s)**	**Q_{50} (m^3/s)**	**Q_{100} (m^3/s)**
1	D12000	5.9	8.4	10.5
2	D9900	26.6	39.3	48.9
3	D8100	43.4	64.0	80.2
4	D6300	45.6	68.0	85.3
5	D4200	45.4	67.3	84.8
6	D1800	48.9	72.2	88.5
7	B700	12.6	18.3	22.9

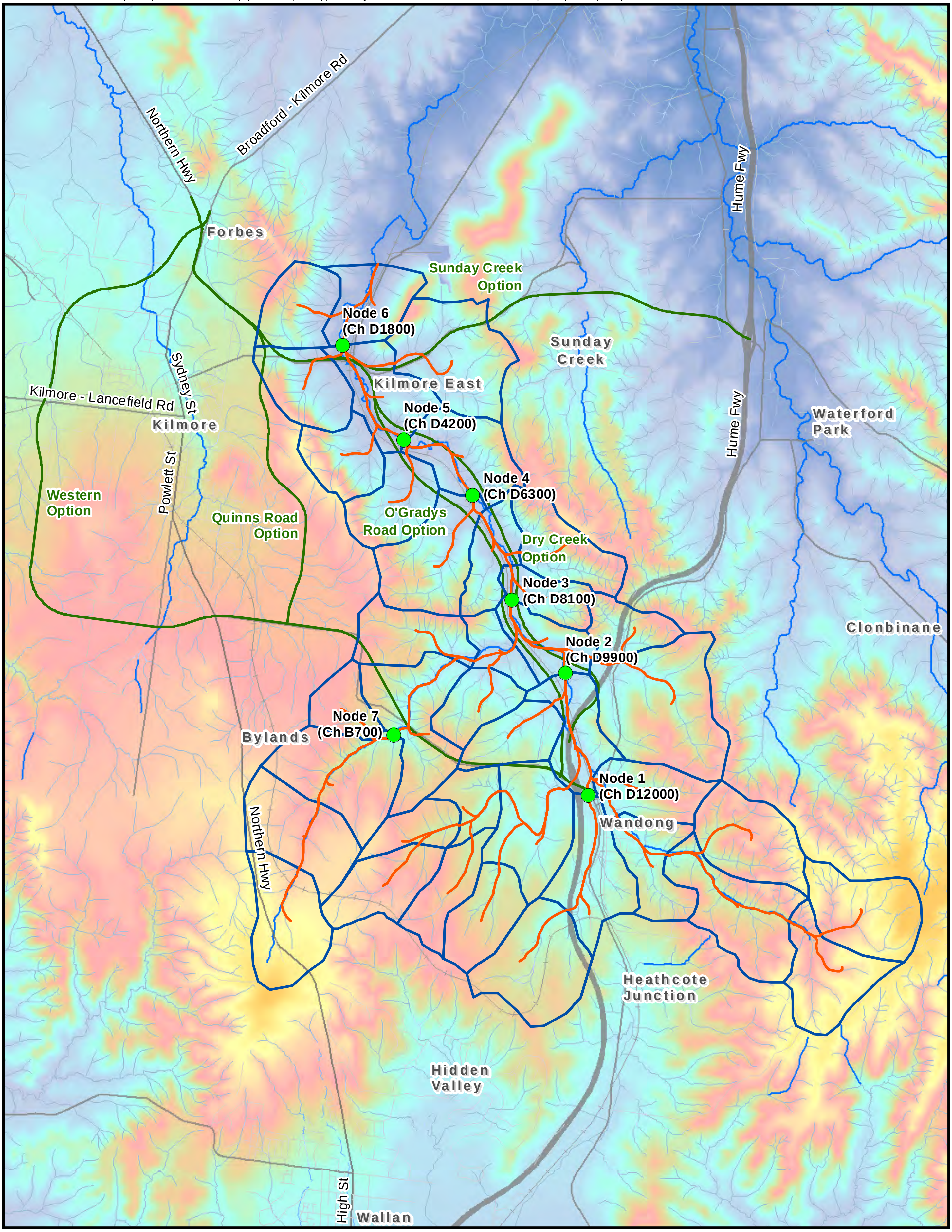
Please Note: Chainage prefix D denotes Dry Creek and B denotes Broadhurst Creek.

3.8 Kilmore Creek

Rational Method was used to determine the 100 year ARI peak flow within Kilmore Creek where it crosses the proposed Western Option alignment. The main parameters and 100 year ARI flow estimates for Kilmore Creek at the southern and northern crossing of the Western Option are provided in Table 7 below.

Table 7 Kilmore Creek 100 year flow rate

	Southern Crossing	**Northern Crossing**
Area (km2)	3.5	25.1
Fraction Impervious	0.11	0.4
Adopted t_c (min)	73.29	250
Runoff Coefficient C_{10}	0.24	0.45
100 Year ARI Rural Frequency Factor	1.3	1.3
Runoff Coefficient C_{100}	0.31	0.58
100 year Intensity for t_c (mm/hr)	44.28	19.2
Peak Flow Q100 (m^3/s)	**13.26**	**78.9**



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LEGEND

- Result Node
- Proposed Bypass Options
- Reach
- Sub-catchment

Height (mAHD)
High : 581
Low : 220

Data sources:
Base Data: (c) 2011 DSE
Alignment: (c) VicRoads

FIGURE 4
RESULT NODE LOCATIONS

Vicroads

Kilmore-Wallan Bypass

Figure
4

4.0 Local Catchments - Hydrological Analysis

4.1 Overview

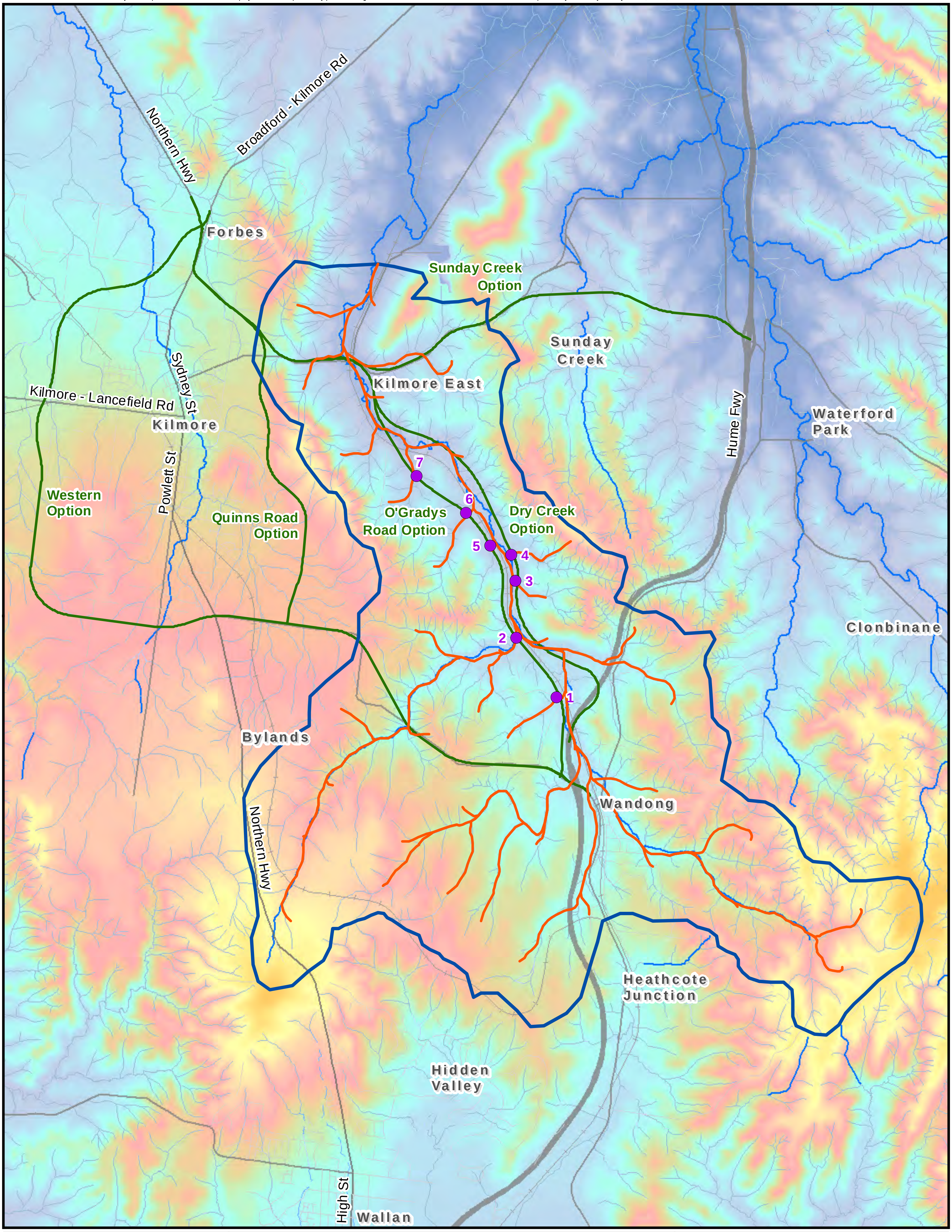
The Rational Method was used to generate flow rates for subareas that were impeded from draining into the main waterways by a proposed bypass alignment. As these are minor reaches, calculations have been performed by hand. The locations of such crossings are indicated in Figure 5.

The methodology used is consistent with that discussed in Section 3.6.1, where the Rational Method was used for calibration purposes.

4.2 Results

Table 8 Rational Method Calculations for Minor Reaches

Minor Reach Crossing No.	Rational Method t_c (min)	Current Conditions Rational Method Q_{100} (m^3/s)
1	52	6.2
2	185	25.2
3	28	5.3
4	40	10.4
5	26	4.1
6	55	8.3
7	30	6.8



PROJECT ID 60242832 CREATED BY TCH LAST MODIFIED TCH 25 OCT 2012 AECOM www.aecom.com N DATUM GDA 1994, PROJECTION MGA ZONE 55 0 0.5 1 2 Kilometres 1:80,000 when printed at A4	**LEGEND** Minor Reach Crossing Proposed Bypass Alignment (Centre Line) Reach Catchment Height (mAHD) High : 581 Low : 220 Data sources: Base Data: (c) 2011 DSE Alignment: (c) VicRoads	**FIGURE 5** **MINOR REACH CROSSINGS** **Vicroads** *Kilmore-Wallan Bypass* Figure 5

5.0 Dry Creek - Hydraulic Analysis

5.1 Overview

The hydraulic component of this study refers to the modelling of the Dry and Broadhurst channels and their respective flood plains. The intention of this modelling is to generate flood extents along the reach through the consideration of channel geometry and existing hydraulic controls.

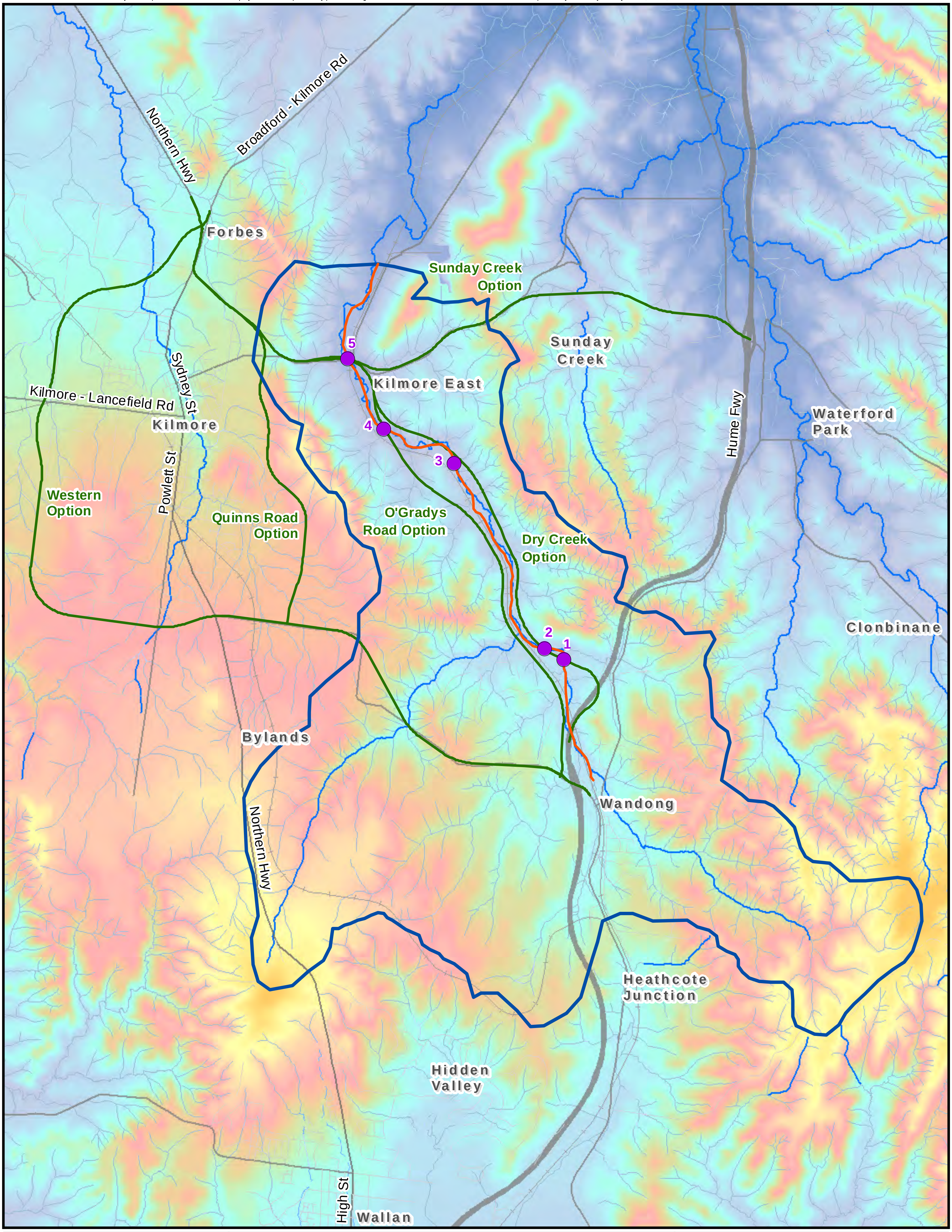
HEC-RAS was used in conjunction with 12D to create two, one dimensional flow models for Dry, Sunday and Broadhurst Creeks. Flow rates from the RORB model, discussed in Section 3.0, were then entered into HEC-RAS at their respective cross sections to produce peak steady state water surface levels. Tributary reaches have not been modelled in this manner due to insufficient details in the topographic data needed to accurately define the waterways.

The hydraulic models were used to determine flood extents and flow characteristics for the existing conditions. Structures associated with the proposed alignments were then incorporated into the models to determine the associated impacts on water surface levels. The location of major structures are provided in Figure 6 and detailed further in Appendix A.

Water surface levels derived from HEC-RAS were imported into GIS, and used to create flood maps by intersecting the flood profiles with digital terrain data.

5.2 Results

The flood inundation maps for the 100, 50, and 20 year ARI events are provided in Figure 7, Figure 8 and Figure 9. In most locations there was no significant difference between the 100 and 20 year ARI flood extents due to the well-defined waterway and the steep nature of the surrounding terrain.



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LEGEND

- Major Reach Crossing
- Major Reach
- Proposed Bypass Alignment (Centre Line)
- Catchment

Height (mAHD)
High : 581
Low : 220

Data sources:
Base Data: (c) 2011 DSE
Alignment: (c) VicRoads

FIGURE 6
MAJOR REACH CROSSINGS

Vicroads

Kilmore-Wallan Bypass

Figure
6

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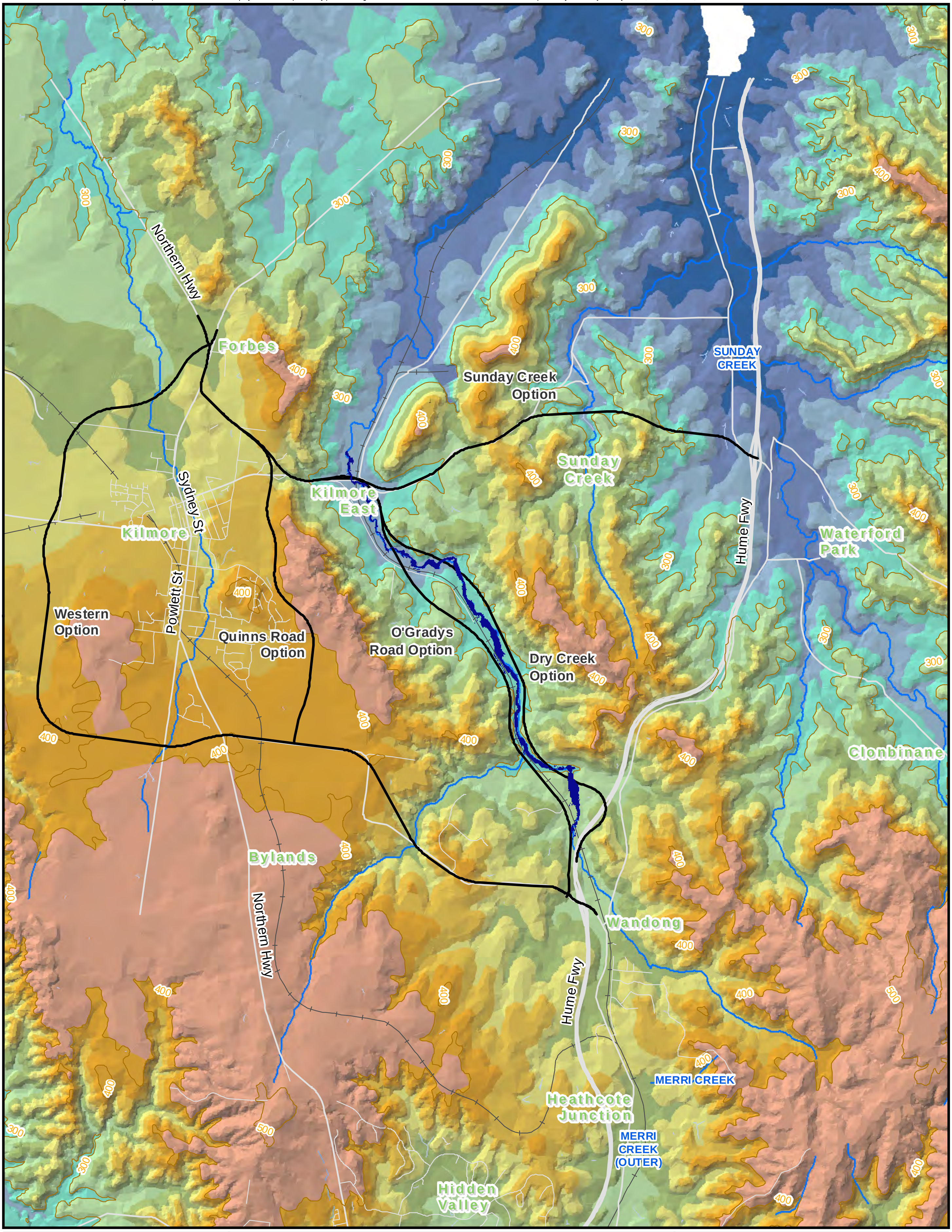

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0 650 1,300 2,600 Metres

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LEGEND

- Flood Extent
- Proposed Bypass Options
- Contour

Elevation (mAHD)
- 220 - 240
- 240 - 260
- 260 - 280
- 280 - 300
- 300 - 320
- 320 - 340
- 340 - 360
- 360 - 380
- 380 - 400
- 400 - 560

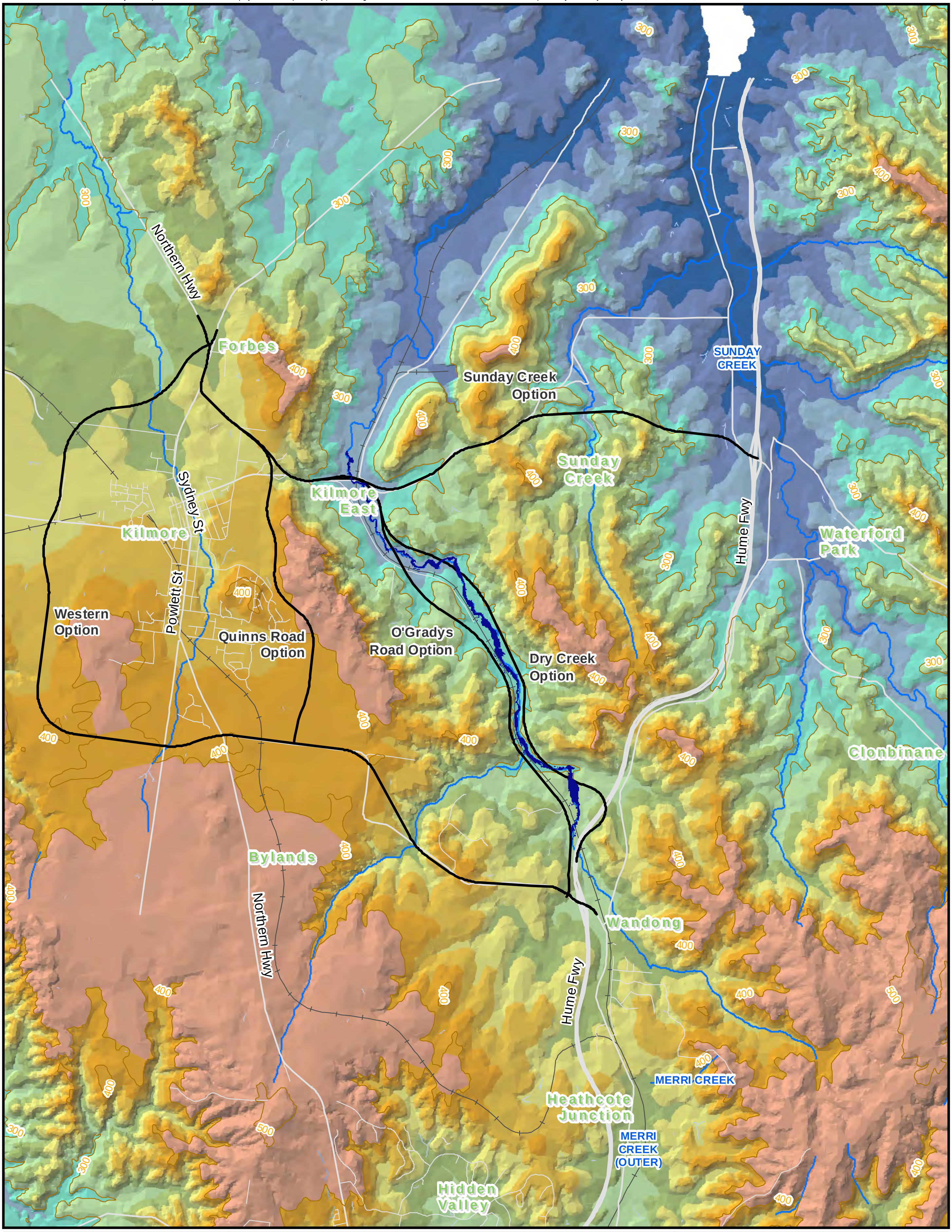
FIGURE 7
100 YEAR ARI FLOOD EXTENT

Vicroads

Kilmore-Wallan Bypass

Data sources:
Base Data: (c) 2011 DSE
Alignment: (c) VicRoads

Figure
7



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LEGEND

- Flood Extent
- Proposed Bypass Options
- Contour

Elevation (mAHD)

- 220 - 240
- 240 - 260
- 260 - 280
- 280 - 300
- 300 - 320
- 320 - 340
- 340 - 360
- 360 - 380
- 380 - 400
- 400 - 560

FIGURE 8
50 YEAR ARI FLOOD EXTENT

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Data sources:
Base Data: (c) 2011 DSE
Alignment: (c) VicRoads

Figure
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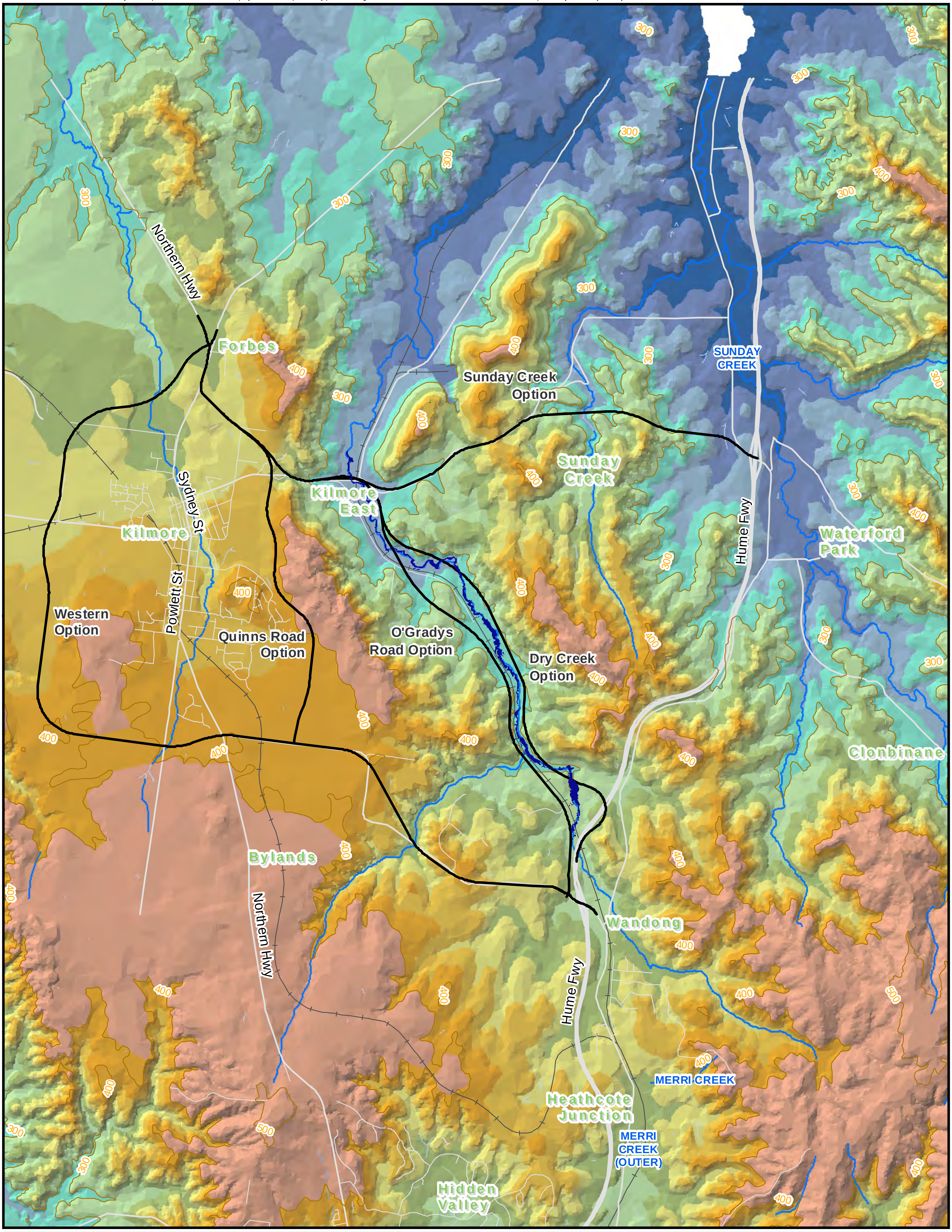

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LEGEND

- Flood Extent
- Proposed Bypass Options
- Contour

Elevation (mAHD)

- 220 - 240
- 240 - 260
- 260 - 280
- 280 - 300
- 300 - 320
- 320 - 340
- 340 - 360
- 360 - 380
- 380 - 400
- 400 - 560

FIGURE 9
20 YEAR ARI FLOOD EXTENT

Vicroads

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Data sources:
Base Data: (c) 2011 DSE
Alignment: (c) VicRoads

Figure
9

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6.0 Hydraulic Design

6.1 Performance Criteria

Through AECOM's contact with the Goulburn Broken CMA, the following design criteria were suggested by the CMA:

- Hydraulic components to be designed for 100year ARI event peak flows.
- For bridges, peak water surface level to remain under the road surface by 600mm.
- For culverts, peak water surface level to remain under the road surface by 300mm.
- Minimum earth cover of 600mm for any culvert.
- Change in flood levels to have no adverse impact on built areas. See Table 9.

Table 9 Section 4.1.2 of Flood Plain Management in Victoria (Water Resources Council Victoria, 1978)

Grade of Surrounding Flood Plain	Permissible Change in Flood Level
Flatter than 1 in 2000	50-150mm
Between 1 in 2000 and 1 in 200	100-250mm
Steeper than 1 in 200	200-300mm

Through topographical analysis of the flood plain and using the contour generated DEM, it was identified that the grade of flood plains at all major and minor crossings were steeper than 1 in 200. As a result, proposed hydraulic structures have been designed to maintain any change in flood levels to less than 300mm as well as not adversely impacting built areas.

6.2 Dry Creek Structures (Major Crossings)

There are five locations along Dry Creek where the proposed bypass alignments cross the existing waterway. These locations are indicated in Figure 6 and described in detail below. A summary of water surface levels for the existing and developed conditions have been provided in Appendix B.

6.2.1 Location 1

The Dry Creek Option crosses the waterway at this location, and will require 4 x 2400mm x 2100mm box culverts to ensure the increase in upstream water levels will be maintained below 300mm. The 100 year ARI flow in this section of the creek is approximately 49m^3/s with a flood level of approximately 299.8 AHD. The amount of afflux caused by the proposed culverts is dependent on the length of the culverts which will be influenced by the final skew on the road. The current proposed alignment crosses the waterway on a significant skew and it is recommended that if this alignment is adopted, the horizontal alignment be amended to reduce both the environmental impact of the crossing and the associated afflux.

6.2.2 Location 2

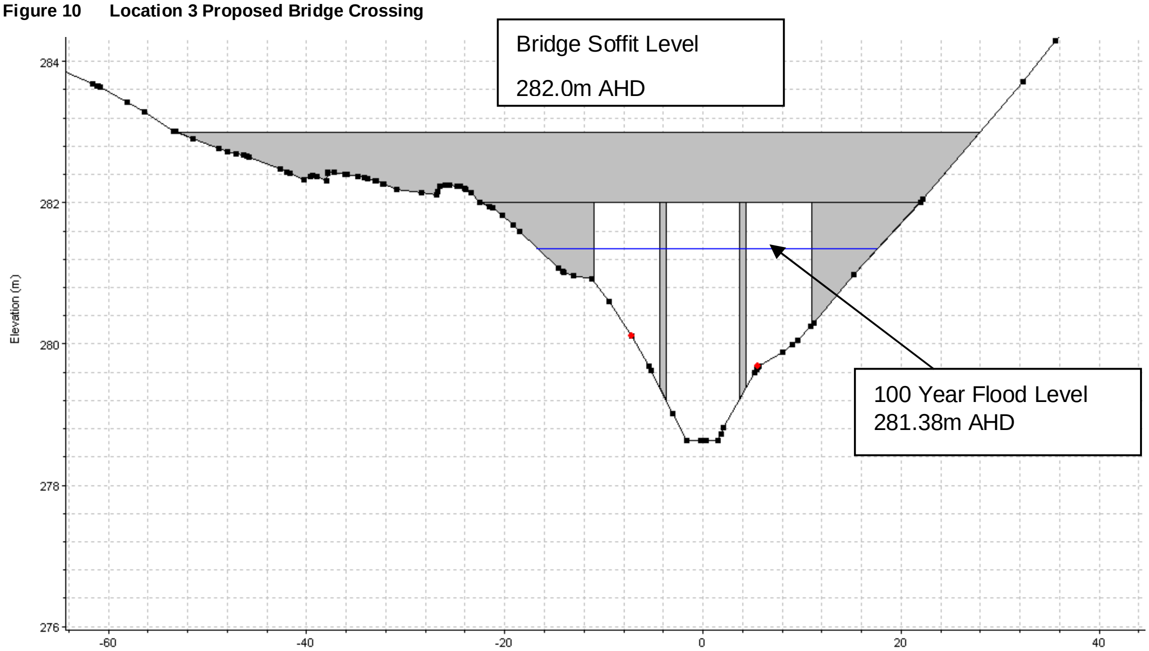
The Dry Creek Option crosses and shares a similar alignment with the waterway at this location, which will require a substantial bridge structure with a span of approximately 400m to ensure there is minimal impact to the waterway and that the increase in upstream water levels will be maintained below 300mm. The 100 year ARI flow in this section of the creek is approximately 49m^3/s. The flood levels range from approximately 298.3m AHD in the upstream portion of the structure to 296.2m AHD in the downstream portion. The span of the bridge is dependent on the road and creek geometries, as well as the need to reduce afflux. The 100 year ARI event exceeds the capacity of the incised watercourse, and portions of the banks will be inundated. Deck levels should be set to provide the necessary clearance from the 100 year water surface level. It is highly recommended that the proposed horizontal alignment of the road at this location be revised to minimise the length of encroachment into the existing waterway. This would in turn result in construction cost savings as well as minimal impact to the existing waterway.

6.2.3 Location 3

The Dry Creek Option crosses the waterway at this location. The 100 year ARI flow in this section of the Creek is approximately 85m^3/s and as a result, a bridge structure is recommended for this crossing. The span of the bridge is partially influenced by the creek geometry as well as the need to reduce afflux. The 100 year ARI event exceeds the capacity of the incised watercourse and a portion of the banks will be inundated. The deck elevation has been set to provide the necessary clearance from the 100 year water surface level and abutments have been recommended to reduce the overall span.

The suggested bridge configuration is shown in Figure 10 as a HEC-RAS output. The structure allows for a bridge length of 22m between abutments with two 700mm diameter piers. This structure will result in an afflux of approximately 135mm between the existing and developed conditions. Water levels will continue to remain within a well-defined waterway. If this alignment is chosen, the afflux will be largely retained within the road corridor, subject to its eventual width.

Figure 10 Location 3 Proposed Bridge Crossing



6.2.4 Location 4

The O'Grady's Road Option crosses Dry Creek at Location 4. A bridge structure will also be required at this location. The structure is largely dependent on the road geometry to cross the defined waterway. The total span of the bridge will be approximately 24m and an allowance has been made for two piers perpendicular to the flow to be used in the construction. The structure is indicated in the HEC-RAS schematic in Figure 11.

Figure 11 Location 4 Proposed Bridge Crossing

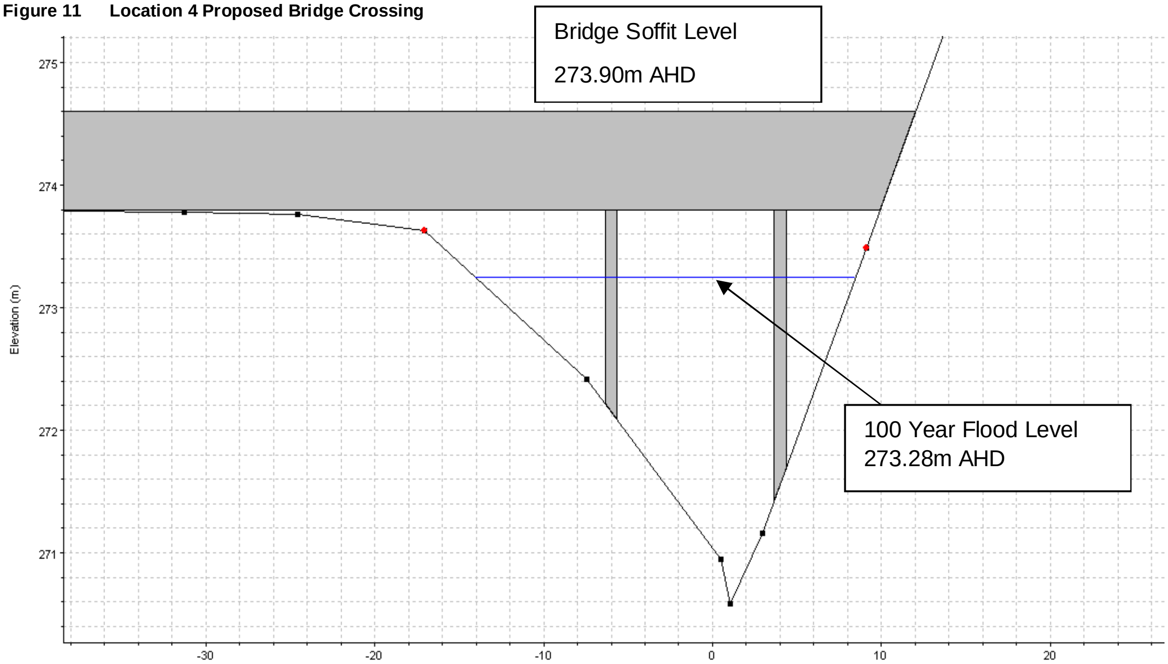
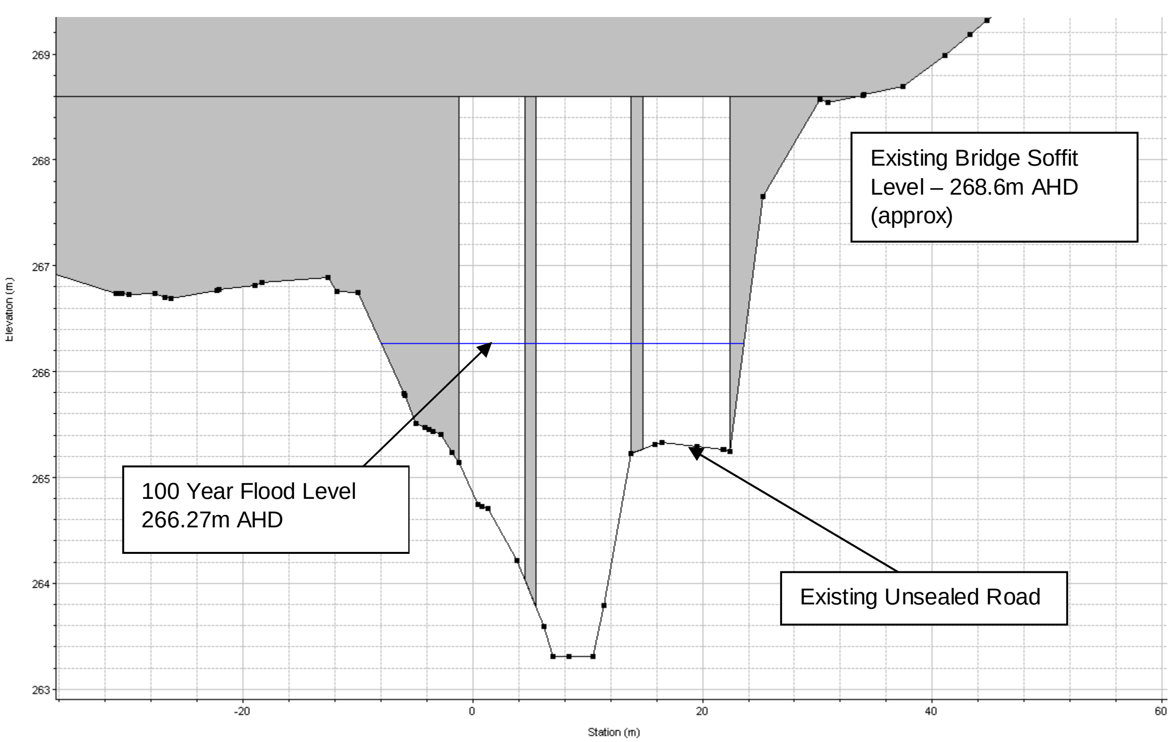


Figure 12 Location 5 Proposed Bridge Crossing



6.2.5 Location 5

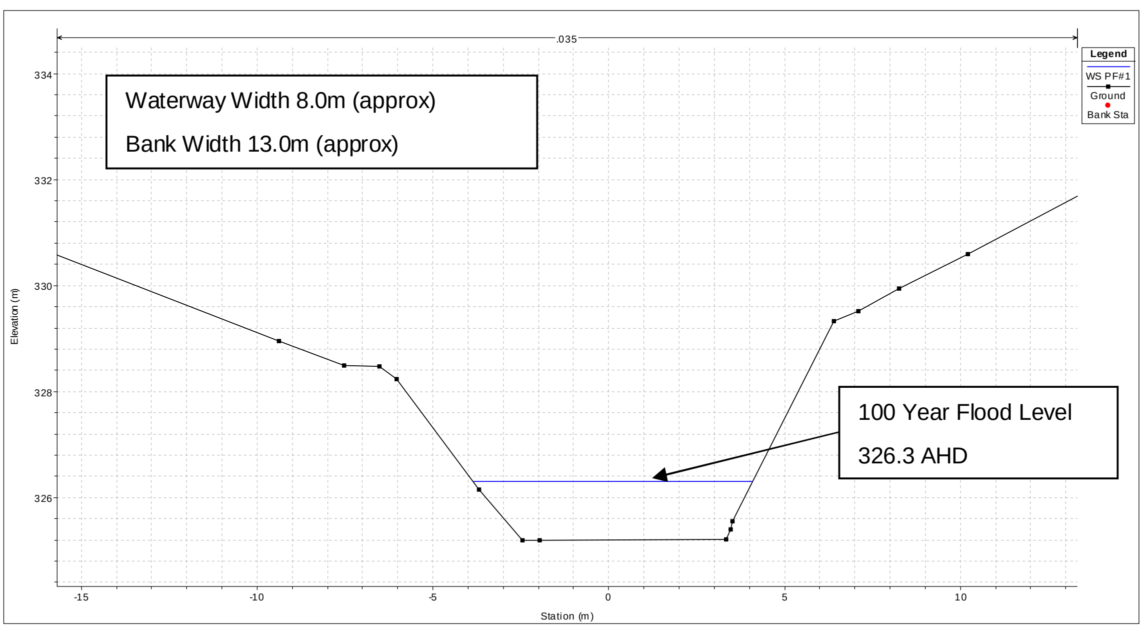
The O'Grady's Road, Dry Creek and Sunday Creek Options all cross Dry Creek at Location 5. The waterway crossing is complicated by the existing rail overpass. There is an existing narrow road that passes the side piers, however this is not wide enough to accommodate the proposed bypass. Furthermore, the existing flood level for the 100 year ARI event is approximately 266.3m AHD and the existing road would need to be raised by approximately 1.3m to provide the necessary freeboard. This would only leave approximately 2.0m clearance to the underside of the rail bridge. The existing rail bridge geometry is shown in Figure 12. A rail overpass with a clearance of 7.2m will be required to cross Dry Creek at this location to allow for double stacked containers as advised by VicRoads.

6.3 Broadhurst Creek Structures

There are existing 3.0m diameter pipes under the existing road crossing at Broadhurst Creek. It is intended that the culverts be removed and a new bridge provided for the crossing. Once the culverts are removed, the existing 100 year ARI event water level will be approximately 326.3m AHD based on the geometry of the waterway upstream and downstream of the culverts. The final water level may vary depending on the geometry and vegetation used within the reinstated section of the waterway.

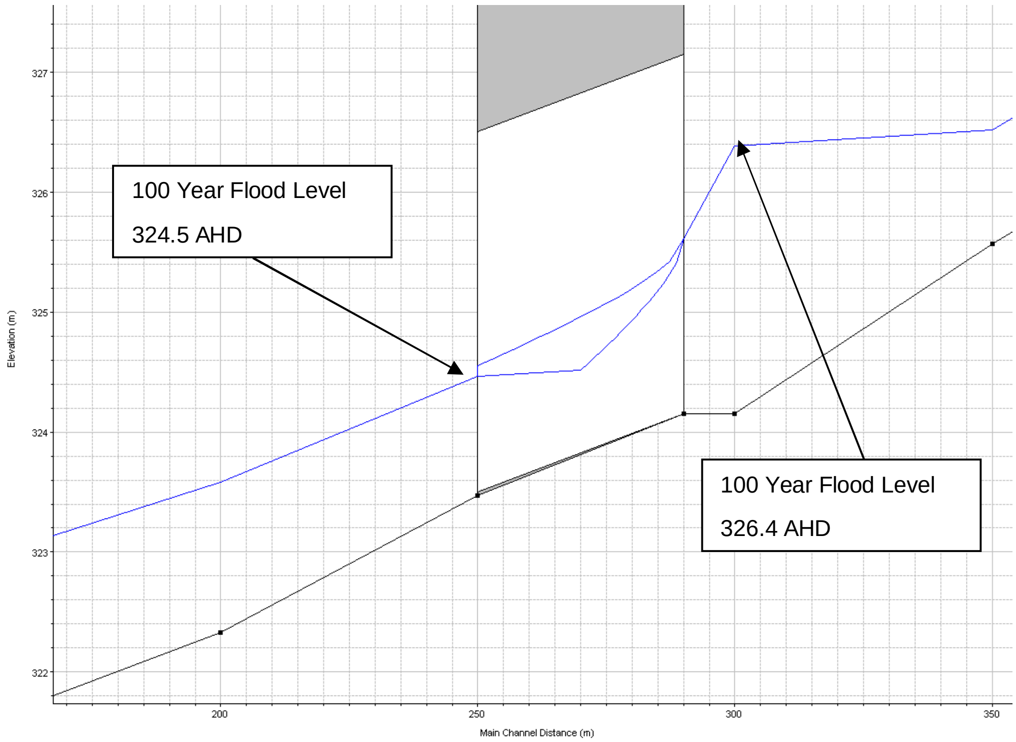
Figure 13 indicates the existing waterway cross section immediately upstream of the existing culverts. With Broadhurst Creek being a well-defined waterway, it would be recommended that the existing banks be maintained and the bridge abutments be placed without impeding the defined channel. As a result, the protection of the waterway will be the governing criteria in determining the bridge span rather than meeting hydraulic constraints.

Figure 13 Broadhurst Creek Cross Section



An alternative design may involve extending the existing culverts to accommodate the duplicated roadway. If this option is adopted, there will be no increase in the 100 year ARI flood level upstream of the culverts as the inlet capacity of the culverts is controlling the upstream water level and not the losses through the pipes. A long section through the culverts for both the existing and extended scenarios is provided in Figure 14.

Figure 14 100 Year flow profile for 20 and 40m long culverts



6.4 Kilmore Creek Structures

The western alignment option crosses Kilmore Creek at two locations, once to the south of the town, and once to the north. At both locations the waterway is well defined and the 100 year ARI flow in contained within the banks.

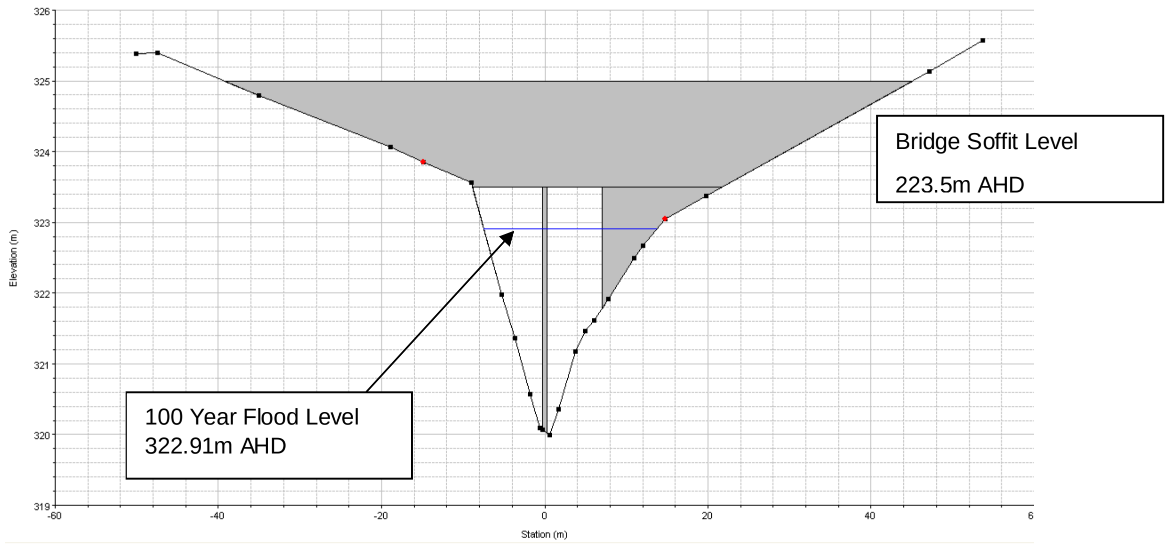
6.5 Southern Crossing

The 100 year flow rate at this section of the waterway is low enough to be conveyed by a set of culverts under the road. Hydraulic calculations indicate that 5 x 1200mm diameter pipes will be sufficient and result in approximately 150mm of afflux. The increased water surface level will continue to be contained within the defined waterway at this location.

6.6 Northern Crossing

The suggested bridge configuration is shown in Figure 15 and consists of a 16m span with a central pier. The bridge geometry has been configured to allow for the abutments to remain clear of the steeper section of the banks, but allows for the eastern abutment to encroach into the flow area to minimise the overall span.

Figure 15 Kilmore Creek, northern Structure



6.7 Minor Reach Structures

Minor reach crossings were identified in sub-catchments where a proposed alignment obstructed the existing drainage pattern. Consequently, eight minor reach crossings were identified and shown previously in Figure 5. Using flow rates derived from the Rational Method in Section 4.0, as well as tail water and flood levels in the minor reach channels found using Manning's equation, culverts were designed and analysed using the program HY-8.

Results from this process is summarised in Table 10 with crossing numbers corresponding to those shown in Figure 5.

Ultimately a dual carriageway design was assumed and a 40m wide road was used for the analysis process to define the likely culvert length.

Table 10 Minor Reach Structure Results

No.	Option Effected	Culvert Type	Q_{100} (m^3/s)	Head Water Level (m AHD)	Minimum Road Surface (m AHD)	Outlet Velocity (m/s)	Inverts	
							Inlet	Outlet
1	O'Grady's	5 No. 1200 RCP	6.2	305.16	306.07	3.76	304.27	303.66
2	O'Grady's	7 No. 2400 x 750 BC	25.2	297.75	298.05	2.45	296.65	295.63
3	Dry	5 No. 900 RCP	5.3	293.56	294.05	2.31	292.55	292.40
4	Dry	5 No. 1200 RCP	10.4	288.92	289.48	4.10	287.68	287.02
5	O'Grady's	4 No. 900 RCP	4.1	289.48	290.04	3.92	288.54	287.79
6	O'Grady's	4 No. 1200 RCP	8.3	287.56	288.12	3.77	286.32	285.82
7	O'Grady's	5 No. 1200 RCP	6.8	281.74	282.60	3.62	280.80	280.20

Culverts with outlet velocities between 2.5m/s and 3.5m/s shall have grass or gravel cover downstream whilst those greater than 3.5m/s shall have stones with diameters greater than 150mm. This is in accordance with Part 7.3 of the VicRoads Design Guidelines.

As no built structures have been affected by the change in flood levels, Table 11 demonstrates further compliance of these minor reach structures with the change in flood level criteria detailed in Table 9.

Table 11 Minor Reach Structure Compliance with Change in Flood Level Criteria

Crossing No.	Pre-Existing Flood Depth (m)	New Flood Depth (m)	Change in Flood Depth (m)	Comments
1	0.61	0.89	+0.28	
2	0.86	1.10	+0.24	
3	0.41	0.51 (1.01 from new invert)	+0.1	Upstream invert level lowered by 0.5m from original ground surface.
4	1.10	1.24	+0.14	
5	0.81	0.94	+0.13	
6	1.07	1.24	+0.17	
7	0.76	0.94	+0.18	

7.0 Options Assessment

The evaluation objectives indicate that the key surface water objective is to avoid or minimise impacts on water quality, hydrology and floodplain to the extent practicable.

The following criteria and measures have been developed to assess each of the options discussed in this report.

1. The length and number of proposed waterway crossings are minimised to reduce the impact on Dry Creek. Measure: relative length of waterway crossings.
2. Minimise the increase in water surface elevation as a result of the proposed crossings. *Measure*: The total increase in water surface elevation is minimised.

The above criteria have been assessed against a ratings table provided by VicRoads which rates the benefit or disbenefit of each option

Option	**Criteria**	**Measurement**	**Ranking**
Quinns	Length of proposed crossings	Bridge	Neutral
O'Grady's		Overpass, bridge and five minor crossings	Neutral
Dry Creek		Overpass, 3 bridges bridge and one major culvert	Moderately Poor
Sunday Creek		Overpass, Sunday Creek Crossing	Neutral
Western		One Bridge and 5 major pipes	Neutral
Quinns	Cumulative increase in water surface levels. Note: all individual increases are within the CMA criteria	0m	Neutral
O'Grady's		Approximately 1.0m	Neutral
Dry Creek		Approximately 0.9m	Neutral
Sunday Creek		0m	Neutral
Western		Approximately 0.2m	Neutral

8.0 Summary

Table 12 summarises the minimum requirements for major infrastructure for each of the proposed options. Based on the hydrological and hydraulic analysis undertaken, the Quinns Road option is likely to present the fewest hydraulic constraints. Of the two options that follow Dry Creek, the O'Gradys Road option is likely to result in the least amount of impact as it involves fewer crossings.

Whichever preferred option is adopted, minor alterations to the horizontal geometry are likely to minimise the impact on the waterways and result in cost savings. Reducing the skew of waterway crossings and ensuring road embankments do not encroach into the waterway shall be considered in further detail as the road geometry progresses.

Table 12 Major Infrastructure Summary

Alignment	Structures Required
Western Option	16m bridge
	5 x 1200 pipes
Quinns Road Option	Provide Bridge – 13m min width at base
O'Gradys Road Option	Rail Overpass
	24m bridge
	Multiple small culvert crossings
Dry Creek Option	Rail Overpass
	24m bridge
	22m bridge
	400m bridge
	4 No. 2400 x 2100 box culverts
Sunday Creek Option	Rail Overpass
	Sunday Creek Crossing

9.0 Glossary

12D – Is a terrain and surveying program which for purposes of this study, was used to define the HEC-RAS cross sections.

Average Recurrence Interval (ARI) – A statistical estimate of the average period in years between the occurrence of a flood of a given size or larger (e.g. floods as big or larger than the 100 year ARI flood event will occur on average once every 100 years). The ARI of a flood event gives no indication of when a flood of that size will occur next.

Bransby Williams Equation – Is an equation prescribed by AR&R (2001) to calculate the time of concentration defined as:

$$t_c = \frac{58L}{A^{0.1}S_e^{0.2}}$$

Fraction Impervious (FI) – This value represents the fraction of area in a sub catchment where water cannot infiltrate the ground surface.

HEC-RAS – Is a hydraulic analysis program developed by the United States Department of Defense, used in the modelling the hydraulic effects of one-dimensional flow through a series of defined cross sections.

HY-8 – Is a hydraulic analysis program developed by the United States Department of Transportation, used in the modelling the effects of hydraulic controls such as culverts.

Intensity Frequency Duration (IFD) Factor – Are statistically determined rainfall characteristics relating to the intensity frequency and duration of rainfall events.

Modified Friends Equation – Is an equation prescribed by AR&R (2001) to calculate the time of concentration defined as:

$$t_c = \frac{8.5L}{Ch.A^{0.1}.S_e^{0.4}}$$

RORB – A general runoff and stream flow routing program used to calculate flood hydrographs from rainfall and other channel inputs.

Time of Concentration (t_c) – The time taken for water in the furthest most reach of a catchment or sub catchment to reach the outlet.

G – regional skewness parameter documented in Australian Rainfall and Runoff Volume 2

F_2 – Factor for 2 year rainfall intensities documented in distribution maps in Australian Rainfall and Runoff Volume 2

F_{50} – Factor for 50 year rainfall intensities documented in distribution maps in Australian Rainfall and Runoff Volume 2

Appendix A

Site Investigation Report

Appendix A Site Investigation Report

1.0 Introduction

1.1 Background

Approximately 55km north of Melbourne, the area of East Kilmore has been identified as a corridor for four alternative routes for the Kilmore Wallan Bypass.

Two of these options meander along and traverse Dry Creek and are the most hydraulically sensitive of the five, with a fourht route utilising the pre-existing crossing of Broadhurst Creek by Wandong Road. A fifth route crosses Kilmore Creek near Willowmavin Road and a site inspection of the nearby waterway was undertaken, however as the crossing are in an inaccessible section of the creek, photos have not been included in this report. As such this investigation will examine the ~6 km stretch of Dry Creek as well at the crossing of Broadhurst Creek to ensure accurate model inputs have been chosen.

There were four people present for the duration of the site investigation. They are as follows:

- Melanie Collett (AECOM)
- Sam Marginson (AECOM)
- James Baker (AECOM)
- Nicholas Collins (VicRoads)

1.2 Objectives

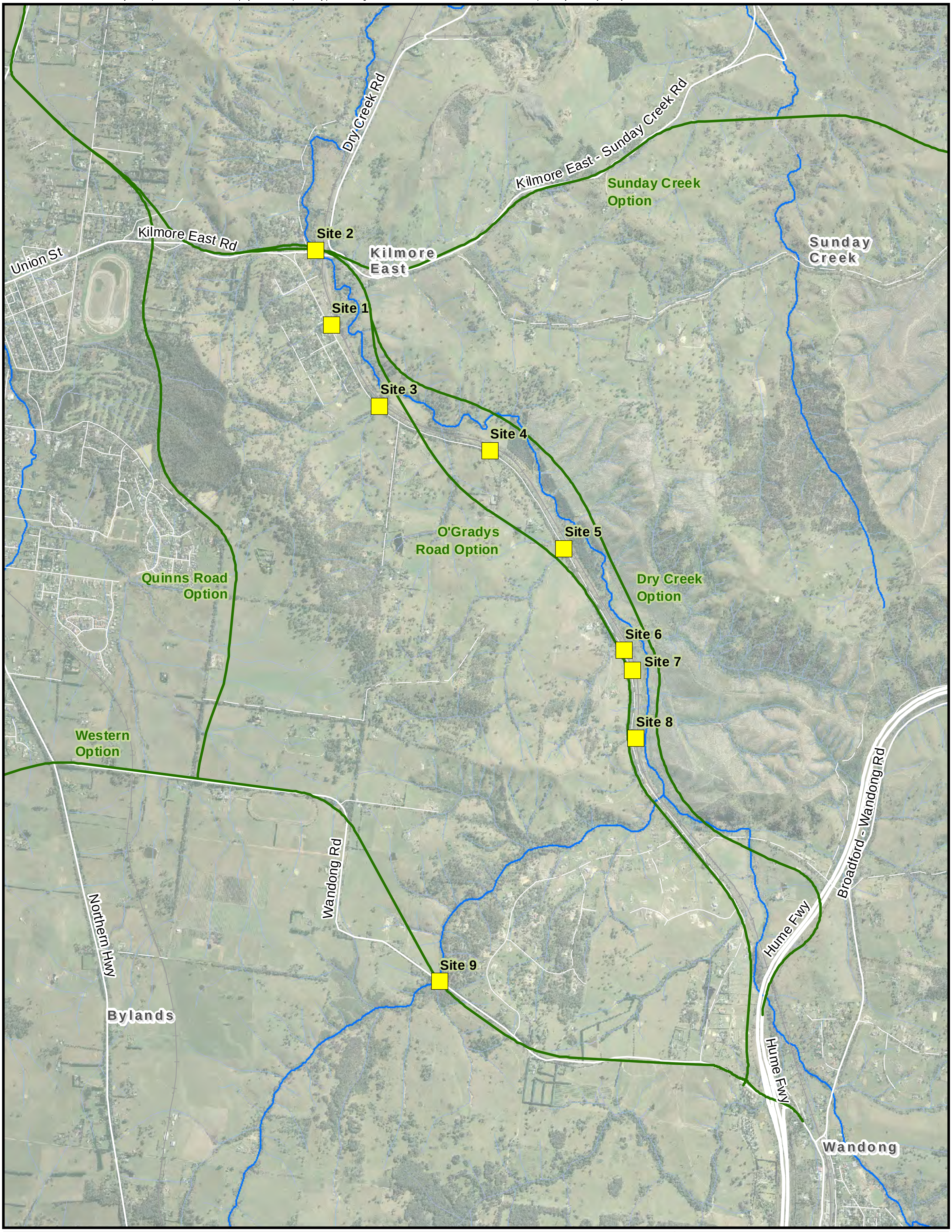
Objectives are to gather model inputs such as roughness factors and the dimensions of hydraulic controls through visual observations of structures and terrain.

2.0 Investigation Methodology

2.1 Overview

Prior to the investigation, nine inspection sites were identified during the desktop investigation. These sites were chosen because of either the presence of a hydraulic control or because of potential visibility of or access to Dry Creek. Sites can be seen marked up in Figure 16

To ensure the desktop investigation had not missed potential points meeting these two criteria, during travel between sites the rail track and creek were watched carefully, such that an unscheduled stop could be made.



PROJECT ID 60242832
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DATUM GDA 1994, PROJECTION MGA ZONE 55

0 0.25 0.5 1 Kilometres

1:40,000 when printed at A4

LEGEND

- Site Inspection Point
- Proposed Bypass Options

Data sources:
Base Data: (c) 2011 DSE
Aerial: (c) VicRoads
Alignment: (c) VicRoads

FIGURE 16
INVESTIGATION SITES

Vicroads

Kilmore-Wallan Bypass

Figure

16

3.0 Comments and Photos

Please refer to Figure 16 for the site numbering convention used in Table 13.

Table 13 Comments and Photos Ordered by Site Number

Site No.	Comment/Description	Photo
1	Rendezvous point at Kilmore East Station.	N/A
2	File Reference: DSC_0439.jpg Rail bridge looking upstream. Duplicated rail line has been aligned with original, expect for one support on the south end. See Figure 17.	
2	File Reference: DSC_0441.jpg Rail bridge looking upstream. Road segment of the underpass. Scattered debris around the footings on the supports suggests flooding. See Figure 17.	
2	File Reference: DSC_0442.jpg Rail bridge looking upstream. See Figure 17.	

Site No.	Comment/Description	Photo
2	File Reference: DSC_0443.jpg Flood debris.	
2	File Reference: DSC_0444.jpg Rail bridge looking downstream. Very dense vegetation and tall grass on embankments. See Figure 17.	
2	File Reference: DSC_0445.jpg Rail bridge looking downstream. The duplication support not present on the original bridge. Note gravel and rock lining on batter. See Figure 17.	

Site No.	Comment/Description	Photo
2	File Reference: DSC_0446.jpg Rail bridge looking downstream. Shows extended floodplain to the north. See Figure 17.	
2	File Reference: DSC_0448.jpg Upstream of rail bridge.	
2	File Reference: DSC_0449.jpg Upstream of rail bridge. A small gully west of the main creek.	
2	File Reference: DSC_0450.jpg Road bridge looking upstream. Very dense vegetation with little visible flow. See Figure 18.	

Site No.	Comment/Description	Photo
2	File Reference: DSC_0451.jpg Road bridge looking upstream. Exposed basalt amongst the vegetation. See Figure 18.	
3	File Reference: DSC_0453.jpg Road culvert looking north. Culvert is not a part of the main reach but is indicative of the type of structures one might expect on future developments.	
3	File Reference: DSC_0454.jpg Rail bridge looking east towards creek. Bridge not a part of main reach. Very wide flood plain.	

Site No.	Comment/Description	Photo
3	File Reference: DSC_0455.jpg Rail bridge looking east towards creek. Bridge not a part of main reach. Note very lush vegetation in defined channel.	
3	File Reference: DSC_0456.jpg East side of rail bridge. Extended flood plain looking north-east.	
3	File Reference: DSC_0457.jpg East side of rail bridge. Extended flood plain looking east.	

Site No.	Comment/Description	Photo
3	File Reference: DSC_0459.jpg East side of rail bridge. Extended flood plain looking south-east.	
4	Site not used. Creek was not visible.	N/A
5	File Reference: DSC_0460.jpg Rail bridge looking east. Bridge not a part of main reach. Very vegetated flood plain on east side of rail. Standing water under rail bridge.	
5	File Reference: DSC_0461.jpg Road bridge/culverts looking east. Culverts not a part of main reach. East side of rail is mostly farm land with cattle and horse’s present.	

Site No.	Comment/Description	Photo
6	File Reference: DSC_0462.jpg Level rail crossing looking east. Lots of trees lining creek bank. Farm land to west.	
7	Site not used. Unsafe to stop and creek not visible.	N/A
8	File Reference: DSC_0463.jpg Road culverts looking east. Culverts not a part of main reach. Standing water and dense vegetation. Farm land on this side is very tall marshy grass.	
8	File Reference: DSC_0464.jpg Rail bridge looking east. Bridge not a part of main reach. Flood plain consists mostly of trees.	

Site No.	Comment/Description	Photo
8	File Reference: DSC_0466.jpg Upstream of road looking west. Shows tall marshy grass and very steep hill to the north.	
8-9	Farm dams observed as full or near full.	N/A
9	File Reference: DSC_0470.jpg Road culverts looking north. Remains of what appears to be an attempted weir of foot crossing. Dimensions approx. 7000mm long and 500-700mm deep. Very high embankment with the road the stationary point of a very steep dip. See Figure 19.	
9	File Reference: DSC_0471.jpg Driveway bridge looking west. Water is audibly and visibly flowing across exposed and eroded basalt. See Figure 20.	

4.0 Sketches

These sketches were made on site and are annotated values estimated by visual inspection. Only structures of the main reach of Dry and Broadhurst Creeks were sketched.

Figure 17 Rail Bridge Site 2

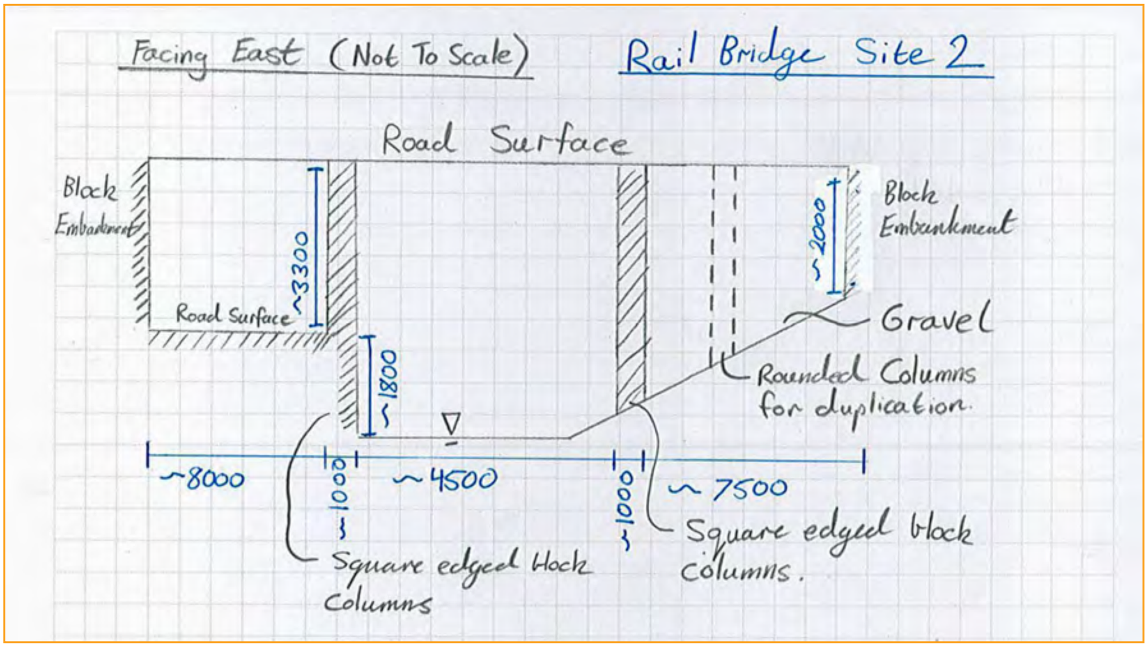


Figure 18 Road Bridge Site 2

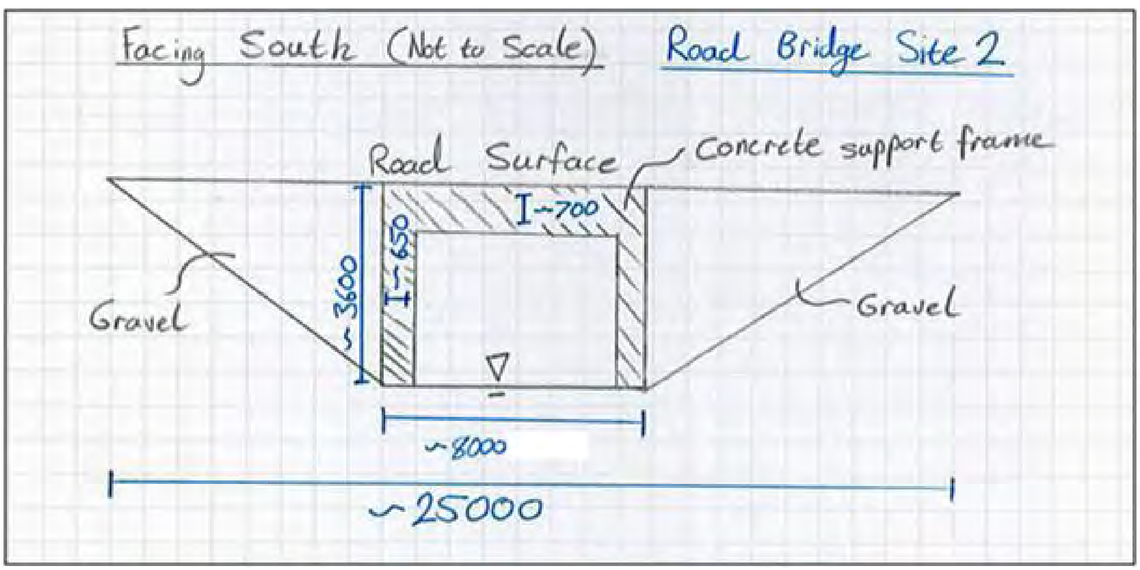


Figure 19 Road Bridge Site 9

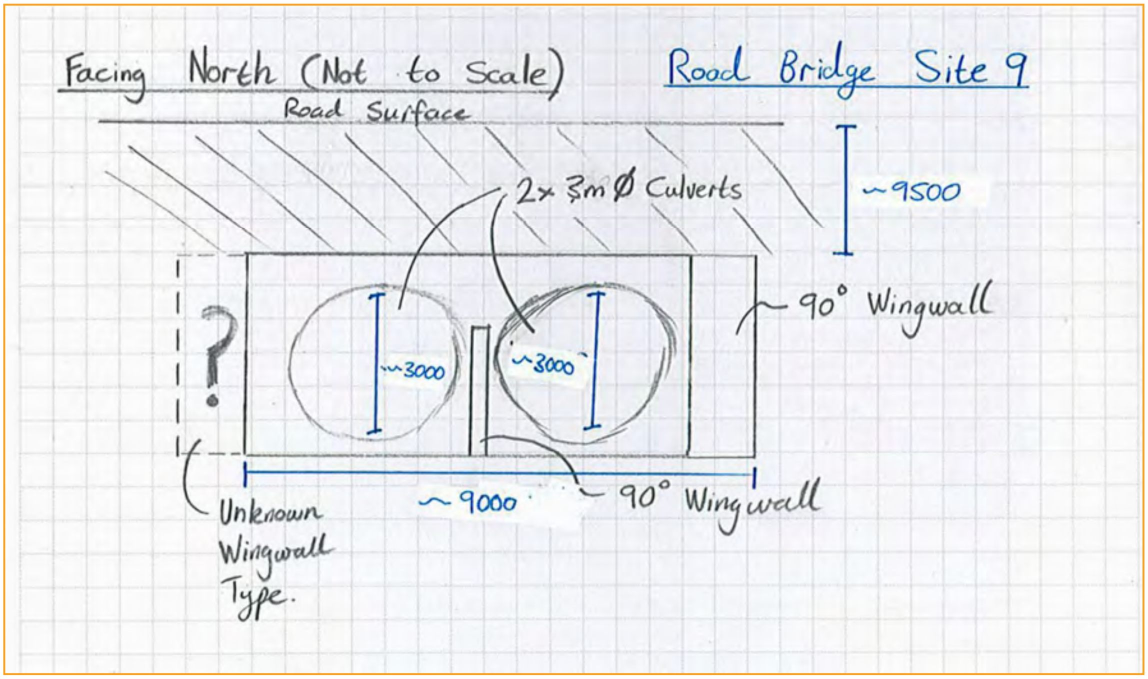
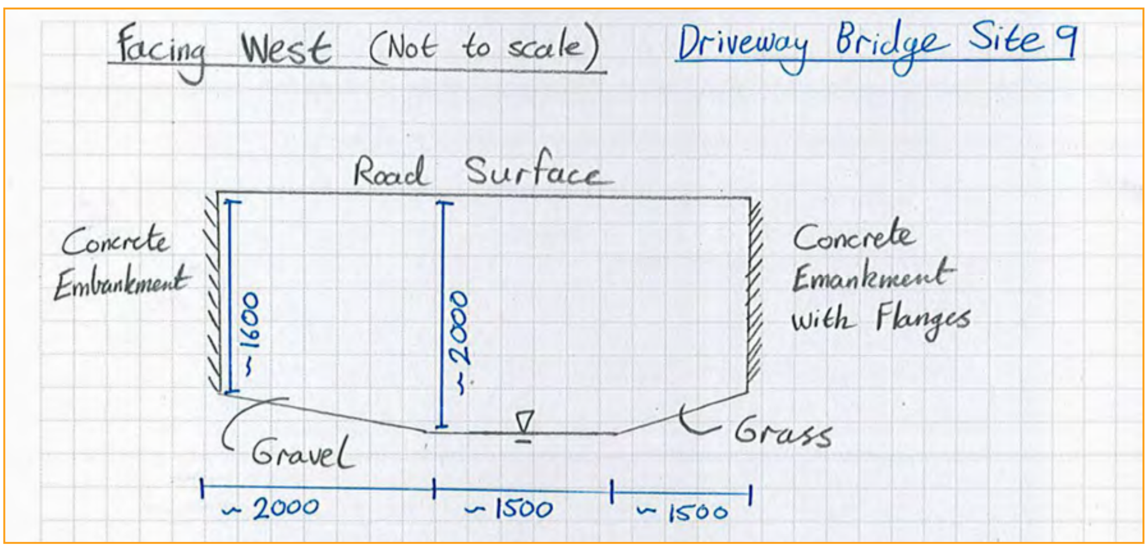


Figure 20 Driveway Bridge Site 9



Regards,

James Baker
Undergraduate Engineer
James.Baker2@aecom.com

Appendix B

Water Surface Level Tables

Dry Creek Water Surface Data

River Sta	Existing W.S. Elev (m)	Proposed W.S. Elev (m)	Afflux (m)	Crossing Location
10972.78	304.8	304.8	0.0	
10753.48	304.3	304.3	0.0	
10432.56	302.8	302.8	0.0	
10193.43	302.2	302.2	0.0	
10077.09	301.7	301.7	0.0	
9781.04	300.8	300.9	0.0	
9565.19	299.8	299.8	0.0	
				Location 1
9445	299.4	299.4	0.0	
9309.46	298.7	298.7	0.0	
9237.54	298.6	298.6	0.0	Location 2
9097.16	298.3	298.3	0.0	
8980.3	297.6	297.6	0.0	
8880.28	296.9	296.9	0.0	
8792.1	296.7	296.7	0.0	
8717.64	296.3	296.3	0.0	
8645.06	296.2	296.2	0.0	
8366.02	295.7	295.7	0.0	
8176.56	295.3	295.3	0.0	
7951.83	294.0	294.0	0.0	
7783.98	292.8	292.8	0.0	
7594.1	292.3	292.3	0.0	
7385.81	291.0	291.0	0.0	
7263.94	290.0	290.0	0.0	
6974.93	289.4	289.4	0.0	
6793.41	289.0	289.0	0.0	
6654.48	288.5	288.5	0.0	
6428.4	287.3	287.3	0.0	
6302.94	287.0	287.0	0.0	
5880.72	286.1	286.1	0.0	
5544.01	285.2	285.2	0.0	
5408.2	284.9	284.9	0.0	
5248.58	283.8	283.8	0.0	
4931.57	282.8	282.8	0.0	
4757.61	282.5	282.5	0.0	
4584.78	282.1	282.1	0.0	

River Sta	Existing W.S. Elev (m)	Proposed W.S. Elev (m)	Afflux (m)	Crossing Location
4541.94*	282.0	282.0	0.0	
4499.10*	281.8	281.9	0.1	
4456.27*	281.7	281.8	0.1	
4413.43*	281.6	281.7	0.1	
4370.59*	281.4	281.5	0.1	
				Location 3
4327.76	280.7	280.7	0.0	
4205.63	280.7	280.7	0.0	
3986.09	280.4	280.4	0.0	
3804.96	279.0	279.0	0.0	
3513.77	278.2	278.2	0.0	
3286.52	278.0	278.0	0.0	
3193.62	277.1	277.1	0.0	
2965.64	276.4	276.4	0.0	
2696.55	274.8	274.8	0.0	
2549.42	274.4	274.4	0.0	
2377.06	273.2	273.2	0.0	
				Location 4
2151.75	270.4	270.4	0.0	
1984.78	270.1	270.1	0.0	
1758.94	269.8	269.8	0.0	
1584.78	269.7	269.7	0.0	
1355.38	268.7	268.7	0.0	
1204.05	267.9	267.9	0.0	
1118.51	267.1	267.1	0.0	
818.5	266.5	266.5	0.0	
				Location 5
776.31	265.7	265.7	0.0	
675.1	265.2	265.2	0.0	
				Location 5
618.8	264.8	264.8	0.0	
365.13	264.4	264.4	0.0	
162.1	263.3	263.3	0.0	

Kilmore Creek Water Surface Data

River Sta	Existing W.S. Elev (m)	Proposed W.S. Elev (m)	Afflux m
1478.88	328.15	328.15	0.0
1455.95	328.14	328.14	0.0
1412.2	327.99	327.99	0.0
1379.41	327.81	327.81	0.0
1346.55	327.63	327.63	0.0
1296.99	327.01	327.01	0.0
1274.69	326.94	326.94	0.0
1233.68	326.7	326.7	0.0
1171.61	325.88	325.88	0.0
1131.66	326.11	326.11	0.0
1066.69	325.84	325.84	0.0
1015.32	325.29	325.29	0.0
966.14	325.08	325.08	0.0
918.86	324.83	324.82	0.0
867.41	324.05	324.07	0.0
823.21	323.9	323.92	0.0
780.56	323.31	323.23	0.1
739.22	323.32	323.09	0.2
Bridge			
709.37	322.86	322.86	0.0
677.94	322.69	322.69	0.0
639.64	322.37	322.37	0.0
603.55	322.36	322.36	0.0
560.86	322.13	322.13	0.0
521.44	321.9	321.9	0.0
478.24	321.88	321.88	0.0
436.86	321.72	321.72	0.0
391.77	321.49	321.49	0.0
352.86	321.2	321.2	0.0
323.18	321.07	321.07	0.0
284.33	320.84	320.84	0.0
225.02	320.15	320.15	0.0
171.18	319.54	319.54	0.0
126.67	319.33	319.33	0.0
81.15	319.2	319.2	0.0
38.24	319.02	319.02	0.0
2.36	318.51	318.51	0.0

Small Creek Water Surface Data

River Sta	Existing W.S. Elev (m)	Proposed W.S. Elev (m)	Afflux (m)
700	331.7	331.7	0.0
650	331.0	331.0	0.0
600	329.8	329.8	0.0
550	329.1	329.1	0.0
500	328.6	328.6	0.0
470			
450	327.8	327.8	0.0
400	326.5	326.5	0.0
350	326.4	326.4	0.0
Extended Culverts			
300	324.5	324.5	0.0
250	323.6	323.6	0.0
200	322.9	322.9	0.0
150	322.6	322.6	0.0
100	321.9	321.9	0.0
50	320.9	320.9	0.0