Table 2.17 Stony Creek afflux results (preferred option)

Cross section number	Stream	Location	Operation afflux (m)				Rehabilitation afflux (m)			
			5 yr	20 yr	100 yr	PMF	5 yr	20 yr	100 yr	PMF
822.50	Stony Creek	US of Berrima Road	0.00	0.01	0.01	0.59	0.00	0.01	0.01	0.59
741.17	Stony Creek	DS of Berrima Road	0.01	0.01	0.01	0.63	0.01	0.01	0.01	0.63
690.45	Stony Creek	DS of Berrima Road	0.01	0.01	0.01	0.64	0.01	0.01	0.01	0.64
622.8	Stony Creek	DS old Berrima Rail	0.01	0.01	0.01	0.95	0.01	0.01	0.01	0.95
577.44	Stony Creek	DS Berrima Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
561.66	Stony Creek	US Existing Rail Bridge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
547.77	Stony Creek	DS Existing Rail Bridge	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
497.77	Stony Creek	DS Existing Rail Bridge	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
585.31	NW tributary	US of Berrima Road	0.00	0.50	0.71	3.82	0.00	0.50	0.71	3.82
480.85	NW tributary	DS Berrima Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
337.3	NW tributary	DS Existing Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

US – upstream; DS – downstream; Hwy - Highway

Table 2.18 Peak flood velocities downstream of new infrastructure (preferred option)

Cross-section	Stream	Proposed structure	Cross-section distance downstream from infrastructure (m)	5 year ARI velocities (m/s)			20 year ARI velocities (m/s)			100 year ARI velocities (m/s)			PMF velocities (m/s)		
				Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff
421.49	Drainage depression alongside Hume Highway (tributary of Oldbury Creek)	4 x 1.8m x 0.9m RCBC	3	1.04	1.74	0.70	1.13	1.89	0.76	1.20	2.03	0.83	3.44	2.74	-0.70
			38	1.29	1.33	0.04	1.38	1.37	-0.01	1.45	1.51	0.06	2.93	2.82	-0.11
787.13	Overland flow path (flowing to tributary of Oldbury Creek)	1.4m dia pipe	22	0.57	0.51	-0.06	0.75	0.59	-0.16	0.80	0.67	-0.13	1.32	0.72	-0.60
113.72	Tributary of Oldbury Creek	2 x 1.4m dia pipes	0	0.71	3.08	2.37	0.78	3.77	2.99	0.86	5.49	4.63	1.52	7.29	5.77
			2	0.71	1.71	1.00	0.78	1.86	1.08	0.86	2.04	1.18	1.52	3.56	2.04
7907.82	Tributary of Oldbury Creek	5 x 2m x 1.2m RCBC	0	0.88	1.93	1.13	1.00	2.19	1.19	1.1	2.41	1.31	1.94	5.36	3.42
			2	0.88	0.95	0.07	1.00	1.06	0.06	1.1	1.11	0.01	1.94	2.16	0.22
			14	1.06	1.05	-0.01	1.21	1.18	-0.03	1.35	1.29	-0.06	2.63	2.29	-0.34
7081.2	Oldbury Creek	5 x 2m x 2m RCBC	0	1.86	1.2	-0.66	1.88	1.33	-0.55	1.91	1.48	-0.43	1.32	5.79	4.47
			82	0.87	0.87	0.00	0.96	0.95	-0.01	1.06	1.05	-0.01	1.55	1.86	0.31
246.32	Tributary of Oldbury Creek	3 x 0.75m dia pipe	32	0.81	0.74	-0.70	0.83	0.73	-0.1	0.92	0.82	-0.10	1.69	1.54	-0.15
561.66	Stony Creek	9 x 3.6m x 3m RCBC	26	0.14	0.14	0.00	0.21	0.21	0.00	0.28	0.28	0.00	1.39	1.39	0.00
480.85	NW Tributary of Stony Creek	7 x 2m x 1.5m RCBC	54	0.39	0.39	0.00	0.47	0.47	0.00	0.57	0.57	0.00	0.98	0.99	0.01

Ex – Existing; Op – Operation; Diff – Difference

2.4 Alternate option impact assessment

2.4.1 Flood extent

Figure 2.14 presents a comparison of the 100 year ARI flood extent for the existing and operation scenarios. Figures comparing the 5 and 20 year ARI and PMF flood extents for the existing and operation scenarios are presented in Appendix E.

Figure 2.15 presents a comparison of the 100 year ARI flood extent for the existing and rehabilitation scenarios. Figures comparing the 5 and 20 year ARI and PMF flood extents for the existing and rehabilitation scenarios are presented in Appendix F.

Comparison of the 100 year ARI flood extents shows that changes in flood extent during operation of the rail infrastructure will occur:

- upstream of where the rail line crosses Oldbury Creek south west of Berrima Cement works;
- just upstream of the Hume Highway on a tributary of Oldbury Creek; and
- in the vicinity of the rail loop.

The changes in flood extent all occur on land owned by Hume Coal or Boral. The increased flood extent upstream of the Hume Highway is minor.

The flooded land area for the 100 year ARI event for each scenario is as follows, indicating that the flood extent increases by around 9% during operation but reverts to close to existing conditions following rehabilitation:

- Existing: 127.2 ha
- Operation: 138.3 ha
- Rehabilitation: 127.3 ha

The increase in flood levels up to the PMF to the south west of Berrima Cement works has no impact on the works or the pit.

As for the preferred option, the high order flood event behaviour will change within the rail loop in the area containing the colony of Paddy’s River Box trees; however, the dominant flow regime in the area of the trees will not change.

As shown in Figure 2.15, once the rail infrastructure is removed during rehabilitation, the flood extent in these areas will return to existing conditions, apart from just upstream of the Hume Highway where the minor increase in flood extent will remain due to remnant features in the rehabilitation landform.

2.4.2 Flood levels

Afflux results for Oldbury Creek are presented in Table 2.19. Results are presented for the cross-sections shown in red on Figure 2.9. Afflux results for Stony Creek are presented in Table 2.20. Results are presented for the cross-sections shown in red on Figure 2.11. The cross-sections target key areas of interest including privately owned land, locations where existing roads cross streams and locations where new infrastructure is proposed to cross streams.

Afflux results are presented for the operation and rehabilitation cases. The results are the difference between the flood levels under the operational or rehabilitation and existing cases. In some areas negative afflux values are predicted where the rail line results in minor diversion of flows or downstream of the rail embankment where the rail line has a positive afflux impact on the upstream side of the embankment and a negative afflux impact downstream.

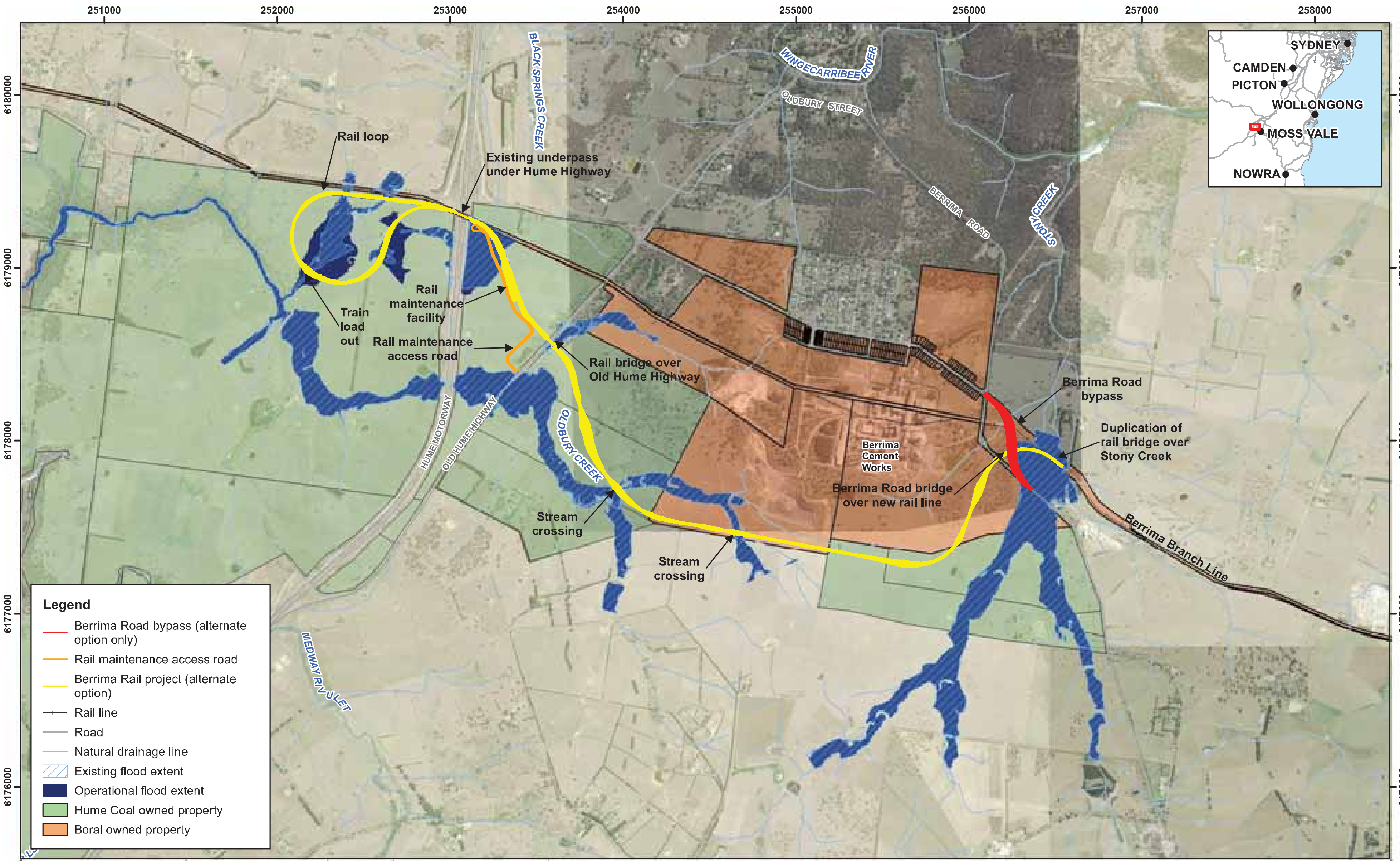
Tables 2.19 and 2.20 show generally minor afflux impacts. Comparison to the acceptability criteria for flooding events up to 100 year ARI for the operation and rehabilitation scenarios indicates the following:

- Buildings – there are no buildings located within the flood extents
- Public roads/rail – predicted afflux will generally be less than 100 mm. The afflux at Oldbury Creek cross-section 421.49, which is just downstream of the bridge, exceeds the proposed acceptable limit, however this impact is localised and the water level is lower than the Old Hume Highway road level in all modelled events.
- Private properties – most land located along the Berrima Rail alignment is owned by Hume Coal or Boral. Predicted afflux at private properties downstream is within the acceptability criteria (less than 250 mm).

2.4.3 Flood velocities

Peak velocities downstream of new infrastructure crossing streams in the project area (see Table 2.15) are presented in Table 2.21.

Changes in peak velocity downstream of the new infrastructure are generally within the range +/- 0.8 m/s. Higher velocity changes are predicted at culvert outlets on Oldbury Creek at cross section 7081.2 and on the Oldbury Creek Tributary at cross section 113.72; however, the table shows that these velocity changes reduce downstream of the culvert outlets and the velocity changes can therefore be managed locally at the outlets. The velocity increases at these locations exceed the acceptability criterion, but these exceedances are local to the culvert outlets and can be managed through appropriate energy dissipating structures. At detailed design opportunities to reduce pipe and/or channel grades at the inlet and outlet of the structures should be investigated to reduce the high velocities at these locations.



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Coordinate system: GDA 1994 MGA Zone 56

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Figure 2.14

100 year ARI flood extent - Operation (alternate option)

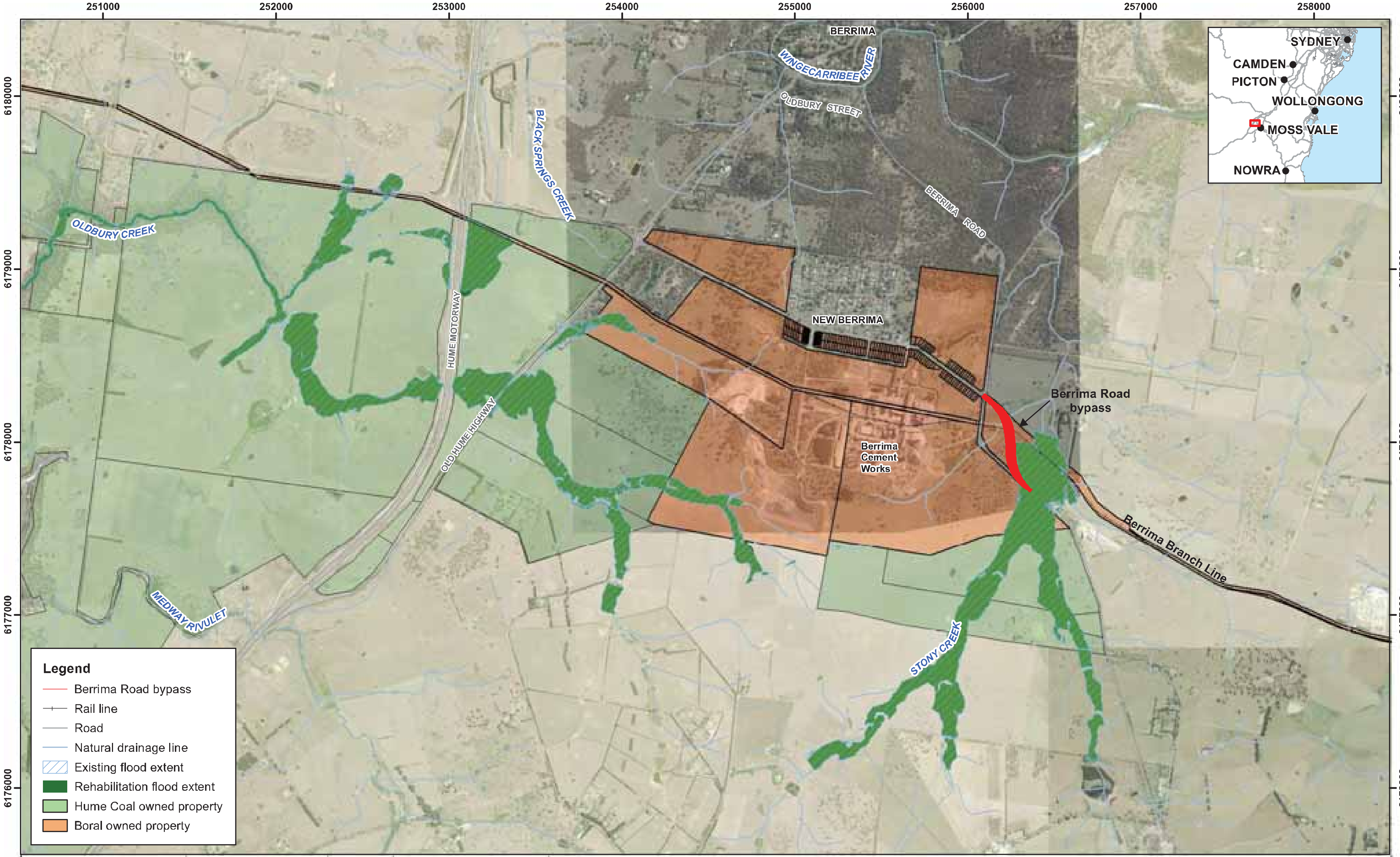

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Figure 2.15

100 year ARI flood extent - Rehabilitation (alternate option)

Table 2.19 Oldbury Creek afflux results (alternate option)

Cross section number	Stream	Location	Operation afflux (m)				Rehabilitation afflux (m)			
			5 yr	20 yr	100 yr	PMF	5 yr	20 yr	100 yr	PMF
246.32	Tributary 2b	DS Medway Road	0.01	0.00	0.00	-0.02	0.02	0.03	0.03	0.05
306.77	Catchment tributary 2	DS Medway Road	0.00	0.02	0.03	0.53	0.00	0.00	0.00	0.00
347.57	Tributary 2b	US Medway Road	-0.02	-0.01	0.00	0.01	0.01	0.00	0.00	0.01
350	Branch	Rural land	-0.13	-0.16	-0.20	-0.62	0.00	0.00	0.00	0.00
372.91	Catchment tributary 2	US Medway Road	0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
417.29	Oldbury Creek	Rural land	-0.07	-0.16	-0.21	-1.93	0.00	0.00	0.00	0.00
533.14	Branch	Rural land	-0.17	-0.19	-0.23	-0.62	0.00	0.00	0.00	0.00
543.84	Tributary T1	Old Hume Hwy	-0.05	-0.06	-0.07	0.93	0.04	0.06	0.06	0.00
606.67	Tributary T1	Rural land and Old Hume Hwy	0.03	0.05	0.06	0.69	0.00	0.00	0.00	0.00
647.53	Oldbury Creek	Rural land	0.04	-0.02	-0.10	-0.80	0.00	0.00	0.00	0.00
750	Branch	Rural land	-0.18	-0.22	-0.25	-0.67	0.00	0.00	0.00	0.00
773.14	Tributary T1	Rural land	-0.04	-0.04	-0.04	-0.10	0.01	0.01	0.01	0.03
1073.16	Tributary T1	Rural land	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
1194.89	Tributary 2	DS Hume Hwy	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.00
1260	Tributary 2	US Hume Hwy	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00
2741.84	Oldbury Creek	Private land	0.00	-0.13	-0.20	-0.04	0.00	0.00	0.00	0.00
2819.73	Oldbury Creek	Private land	0.09	0.01	-0.04	-0.31	0.04	0.00	0.00	0.00
2928.8	Oldbury Creek	Private land	0.05	0.00	-0.04	-0.18	0.02	0.00	0.00	0.00
3007.9	Oldbury Creek	Private land	-0.31	-0.41	-0.45	-0.73	0.00	0.00	0.00	0.00
4120.53	Oldbury Creek	Embankment DS inline storage	0.04	0.07	0.08	-0.02	0.04	0.07	0.09	0.06
4288.37	Oldbury Creek	Embankment DS inline storage	-0.14	-0.22	-0.26	-0.16	0.39	0.37	0.34	0.10
4390.64	Oldbury Creek	Embankment US inline storage	0.01	0.01	0.02	0.02	0.00	0.00	0.00	0.00
4611.83	Oldbury Creek	US inline storage	0.02	0.00	0.02	-0.01	0.00	0.00	0.00	0.00
4641.08	Oldbury Creek	US inline storage	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.01
5624.5	Oldbury Creek	DS Hume Hwy	-0.04	-0.06	0.07	0.10	0.00	0.02	0.00	0.04
5691.94	Oldbury Creek	US Hume Hwy	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00
5980	Oldbury Creek	DS Old Hume Hwy	-0.02	-0.01	0.01	0.00	0.06	0.08	0.07	0.00
6024.59	Oldbury Creek	US Old Hume Hwy	-0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
7081.2	Oldbury Creek	DS 5 x 2000 mm x 2000 mm RCBC on Oldbury Creek	0.03	0.02	0.01	0.00	0.05	0.04	0.02	0.00
7142.77	Oldbury Creek	Hume Coal Land	0.02	0.01	0.01	2.80	0.00	0.00	0.00	0.00
7401.61	Oldbury Creek	Hume Coal Land	0.01	0.00	0.01	1.32	0.00	0.00	0.00	0.00
7696.2	Oldbury Creek	Private land (Boral)	0.01	0.02	0.01	0.05	0.00	0.00	0.00	0.00
7907.82	Oldbury Creek	Private land (Boral)	0.01	0.02	0.02	0.03	0.07	0.10	0.14	0.26
7999.53	Oldbury Creek	US 5 x 2000 mm x 1200 mm RCBC on Oldbury Creek Private Land	0.00	-0.01	0.00	2.04	0.15	0.18	0.23	0.47
8234.11	Oldbury Creek	Private Land	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00
421.49	Oldbury Creek	DS Culvert under design rail bridge	0.10	0.11	0.12	0.28	0.00	0.00	0.01	0.19
392.69	Tributary 2	US 2 x 1400 mm pipe under rail loop	0.00	0.62	1.78	4.09	0.03	0.04	0.05	0.15
855.9	Tributary 2	US 1400 mm diameter pipe under rail loop	3.42	3.88	4.74	5.89	0.00	0.00	0.00	0.00
787.17	Oldbury Creek	DS Culvert under rail loop	0.01	0.03	0.04	0.30	0.03	0.03	0.02	0.30
254.46	Tributary 2	US 2 x 1400 mm diameter pipe on tributary of Oldbury Creek	1.32	1.9	3.02	4.81	0.14	0.16	0.17	0.02
113.72	Oldbury Creek Tributary 2	DS Culvert under rail loop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

US – upstream; DS – downstream; Hwy - Highway

Table 2.20 Stony Creek afflux results (alternate option)

Cross section number	Stream	Location	Operation afflux (m)				Rehabilitation afflux (m)			
			5 yr	20 yr	100 yr	PMF	5 yr	20 yr	100 yr	PMF
713.52	Stony Creek	US of Berrrima Road	0.02	-0.03	0.06	0.15	0.02	-0.03	0.06	0.15
609.92	Stony Creek	US of Berrrima Road	0.02	-0.03	0.06	0.16	0.02	-0.03	0.06	0.16
560.83	Stony Creek	DS Berrima Road	0.02	-0.02	0.06	0.19	0.02	-0.02	0.06	0.19
454.13	Stony Creek	DS Berrima Road	0.02	-0.02	0.06	0.19	0.02	-0.02	0.06	0.19
395.75	Stony Creek	DS old Berrima Rail	0.02	0.00	0.07	0.28	0.02	0.00	0.07	0.28
351.49	Stony Creek	DS old Berrima Rail	-0.02	-0.04	0.01	-0.10	-0.02	-0.04	0.01	-0.10
335.12	Stony Creek	DS Existing Rail Bridge	-0.09	-0.89	-0.12	-0.10	-0.09	-0.89	-0.12	-0.10
284.57	Stony Creek	DS Existing Rail Bridge	0.00	0.07	0.05	0.06	0.00	0.07	0.05	0.06
227.5	Stony Creek	DS Existing Rail bridge	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01

US – upstream; DS – downstream; Hwy - Highway

Table 2.21 Peak flood velocities downstream of new infrastructure (alternate option)

Cross-section	Stream	Proposed structure	Cross-section distance downstream from infrastructure (m)	5 year ARI velocities (m/s)			20 year ARI velocities (m/s)			100 year ARI velocities (m/s)			PMF velocities (m/s)		
				Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff
421.49	Drainage depression alongside Hume Highway (tributary of Oldbury Creek)	4 x 1.8m x 0.9m RCBC	3	1.04	1.74	0.70	1.13	1.89	0.76	1.20	2.03	0.83	3.44	2.74	-0.70
			38	1.29	1.33	0.04	1.38	1.37	-0.01	1.45	1.51	0.06	2.93	2.82	-0.11
787.13	Overland flow path (flowing to tributary of Oldbury Creek)	1.4m dia pipe	22	0.57	0.51	-0.06	0.75	0.59	-0.16	0.80	0.67	-0.13	1.32	0.72	-0.60
113.72	Tributary of Oldbury Creek	2 x 1.4m dia pipes	0	0.71	3.08	2.37	0.78	3.77	2.99	0.86	5.49	4.63	1.52	7.29	5.77
			2	0.71	1.71	1.00	0.78	1.86	1.08	0.86	2.04	1.18	1.52	3.56	2.04
7907.82	Tributary of Oldbury Creek	5 x 2m x 1.2m RCBC	0	0.88	1.93	1.13	1.00	2.19	1.19	1.1	2.41	1.31	1.94	5.36	3.42
			2	0.88	0.95	0.07	1.00	1.06	0.06	1.1	1.11	0.01	1.94	2.16	0.22
			14	1.06	1.05	-0.01	1.21	1.18	-0.03	1.35	1.29	-0.06	2.63	2.29	-0.34
7081.2	Oldbury Creek	5 x 2m x 2m RCBC	0	1.86	1.2	-0.66	1.88	1.33	-0.55	1.91	1.48	-0.43	1.32	5.79	4.47
			82	0.87	0.87	0.00	0.96	0.95	-0.01	1.06	1.05	-0.01	1.55	1.86	0.31
351.59	Stony Creek	Duplication of bridge over Stony Creek	0	0.50	0.51	0.01	0.72	0.70	-0.02	0.90	0.87	-0.03	2.72	2.98	0.26

Ex – Existing; Op – Operation; Diff – Difference

2.5 Cumulative impacts

The cumulative impacts of the Hume Coal Project and Berrima Rail Project were assessed in the Oldbury Creek catchment where infrastructure from both projects is located. There is no difference between the preferred and alternate Berrima Rail Project options in the Oldbury Creek catchment.

The Oldbury Creek hydrologic model was used to estimate runoff for the cumulative Oldbury Creek HEC-RAS model. The Oldbury Creek HEC-RAS model was revised to include cross-sections targeting key infrastructure for both the Hume Coal Project and Berrima Rail Project during operation and rehabilitation. The cumulative Oldbury Creek HEC-RAS model cross-sections are shown on Figure 2.16.

The cumulative Oldbury Creek HEC-RAS model was run for the 2 year, 5 year, 100 year ARI and PMF events for the following scenarios:

- The cumulative operation scenario, which incorporates the proposed surface infrastructure for the Hume Coal Project and the proposed infrastructure for the Berrima Rail Project.
- The cumulative rehabilitation scenario, which incorporates the proposed final landform at completion of the Hume Coal Project and the proposed final landform at completion of the Berrima Rail Project.

Proposed cross drainage structures were included in the cumulative Oldbury Creek HEC-RAS model. These structures will allow flow to pass through the proposed rail embankments and reduce flooding impacts on nearby land that would otherwise have occurred. The proposed structures included in the models are described in Table 2.15.

2.5.1 Flood extent

Figure 2.17 presents a comparison of the cumulative 100 year ARI flood extent for the existing and operation scenarios. Figures comparing the cumulative 5 and 20 year ARI and PMF flood extents for the existing and operation scenarios are presented in Appendix G.

Figure 2.18 presents a comparison of the cumulative 100 year ARI flood extent for the existing and rehabilitation scenarios. Figures comparing the cumulative 5 and 20 year ARI and PMF flood extents for the existing and rehabilitation scenarios are presented in Appendix H.

It should be noted that the cumulative impact assessment results are the same as those for the Berrima Rail Project only (as reported in Section 2.3) as the impacts are not hydraulically linked and there is therefore no cumulative impact associated with the combination of both projects.

Comparison of the 100 year ARI flood extents shows that changes in flood extent during operation of the rail infrastructure will occur:

- upstream of where the rail line crosses Oldbury Creek south west of Berrima Cement works;
- just upstream of the Hume Highway on a tributary of Oldbury Creek; and
- in the vicinity of the rail loop.

The changes in flood extent all occur on land owned by Hume Coal or Boral. The increased flood extent upstream of the Hume Highway is minor.

The increase in flood levels up to the PMF to the south west of Berrima Cement works has no impact on the works or the pit.

As for the previous cases, the high order flood event behaviour will change within the rail loop in the area containing the colony of Paddy's River Box trees; however, the dominant flow regime in the area of the trees will not change.

As shown in Figure 2.18, once the rail infrastructure is removed during rehabilitation, the flood extent in these areas will return to existing conditions, apart from just upstream of the Hume Highway where the minor increase in flood extent will remain.

2.5.2 Flood levels

Cumulative afflux results for Oldbury Creek are presented in Table 2.22. Results are presented for the cross-sections shown in red on Figure 2.16. The cross-sections target key areas of interest including privately owned land, locations where existing roads cross streams and locations where new infrastructure is proposed to cross streams.

Cumulative afflux results are presented for the operation and rehabilitation cases. The results are the difference between the flood levels under the operational or rehabilitation and existing cases. As noted in the previous section, the results are the same as those for the Berrima Rail Project only as the impacts are not hydraulically linked.

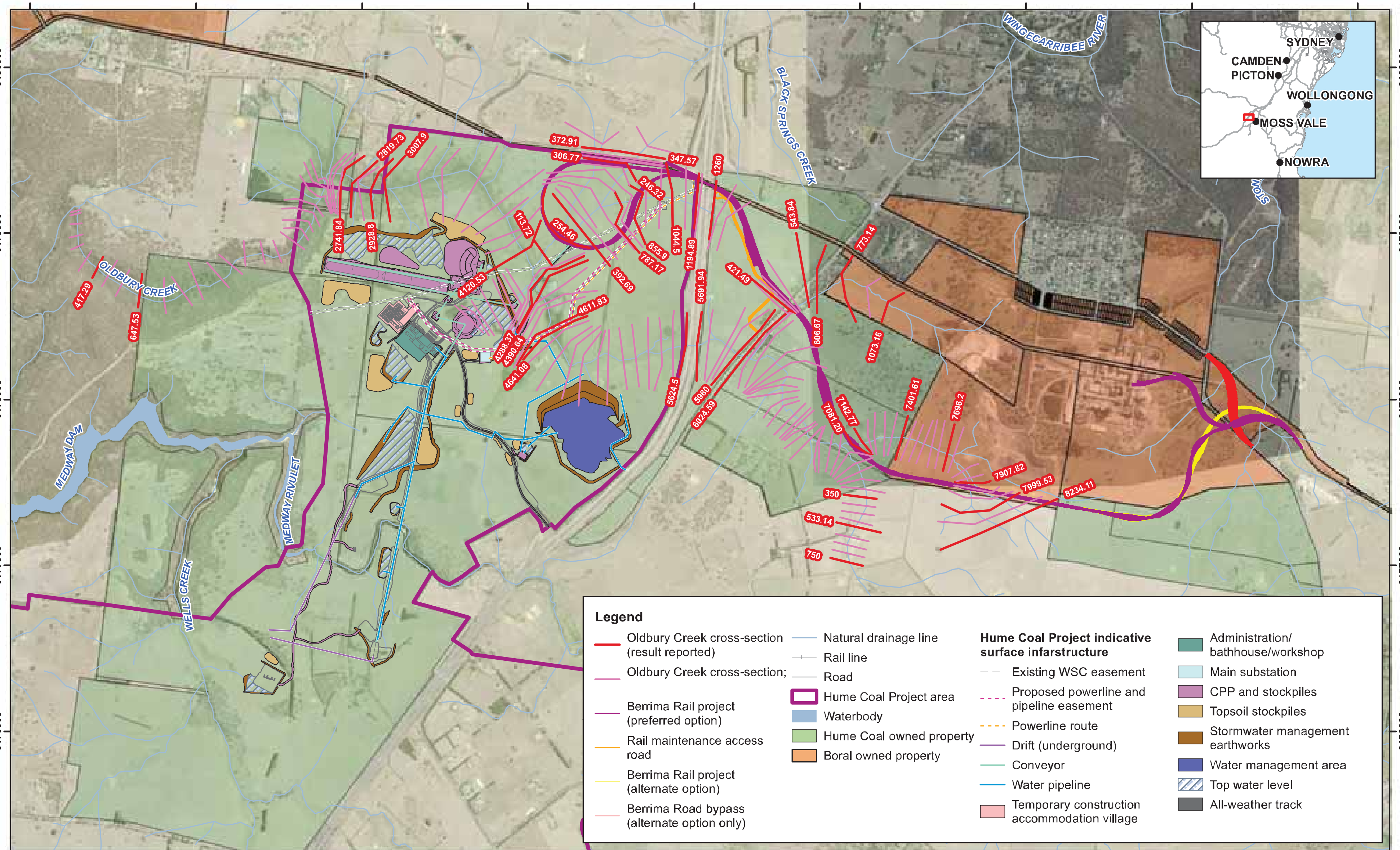
Comparison to the acceptability criteria for flooding events up to 100 year ARI for the operation and rehabilitation scenarios indicates the following:

- Buildings – there are no buildings located within the flood extents
- Public roads/rail – predicted afflux will generally be less than 100 mm. The afflux at Oldbury Creek cross-section 421.49, which is just downstream of the bridge, exceeds the proposed acceptable limit, however this impact is localised and the water level is lower than the Old Hume Highway road level in any event.
- Private properties – most land located along the Berrima Rail alignment is owned by Hume Coal or Boral. Predicted afflux at private properties downstream is within the acceptability criteria (less than 250 mm).

2.5.3 Flood velocities

Peak velocities downstream of new infrastructure crossing streams in the project area (see Table 2.15) are presented in Table 2.23. Note that in some cases the PMF velocity is reduced downstream of the structures due to backing up of flow behind the rail embankment. As noted in the previous section, the results are the same as those for the Berrima Rail Project only as the impacts are not hydraulically linked.

Changes in peak velocity downstream of the new infrastructure are generally within the range +/- 0.8 m/s. Higher velocity changes are predicted at culvert outlets on Oldbury Creek at cross section 7081.2 and on the Oldbury Creek Tributary at cross section 113.72; however, the table shows that these velocity changes reduce downstream of the culvert outlets and the velocity changes can therefore be managed locally at the outlets. The velocity increases at these locations exceed the acceptability criterion, but these exceedances are local to the culvert outlets and can be managed through appropriate energy dissipating structures. At detailed design opportunities to reduce pipe and/or channel grades at the inlet and outlet of the structures should be investigated to reduce the high velocities at these locations.



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Date: 14/11/2016	Approved by: - LR

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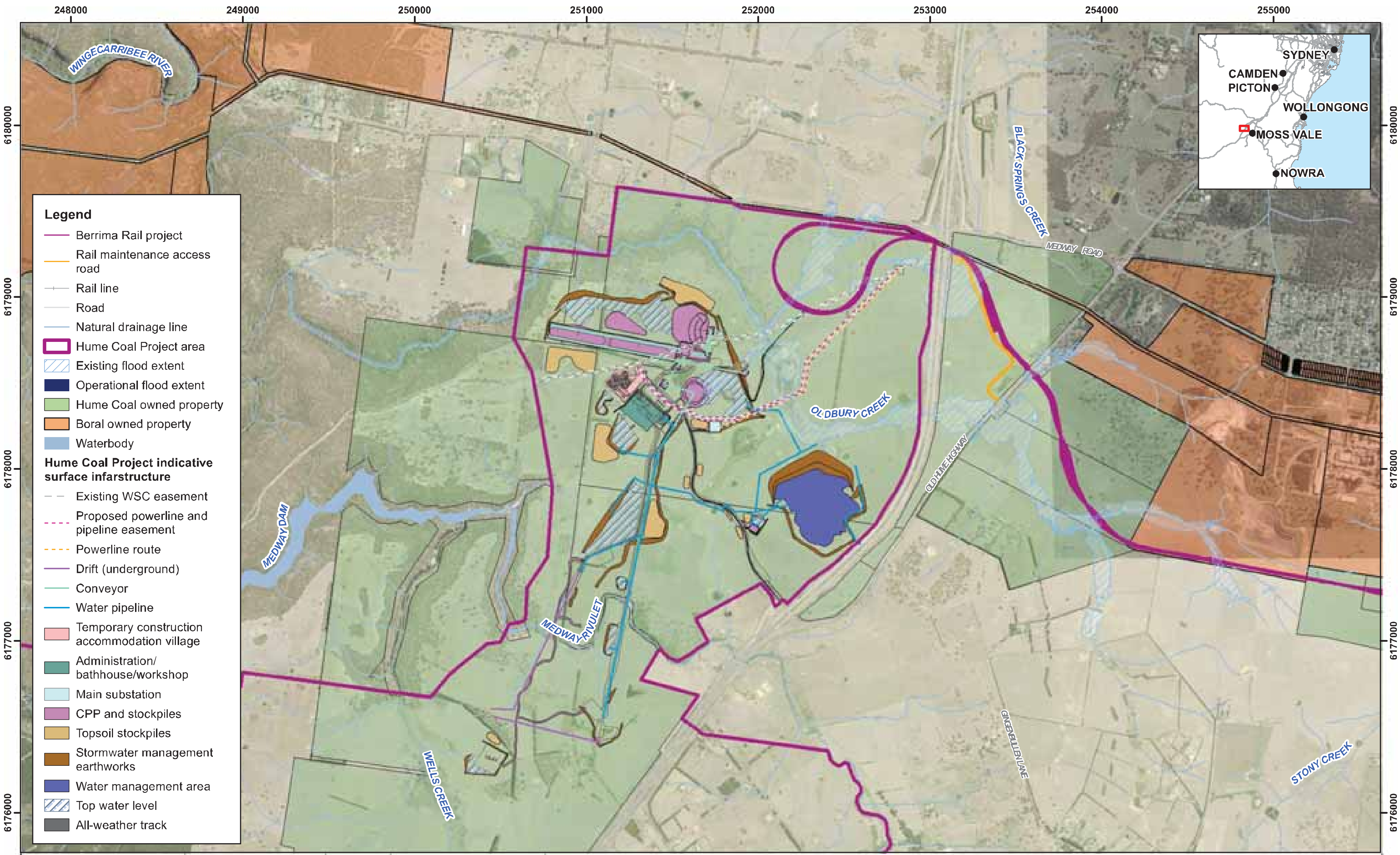
Figure 2.16
Cumulative Oldbury Creek model cross-sections



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Date: 14/11/2016	Approved by: LR	

Data source: © Land and Property Information 2015, Hume Coal

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Berrima Rail Project

Figure 2.17

Cumulative 100 Year ARI flood extent - Operation

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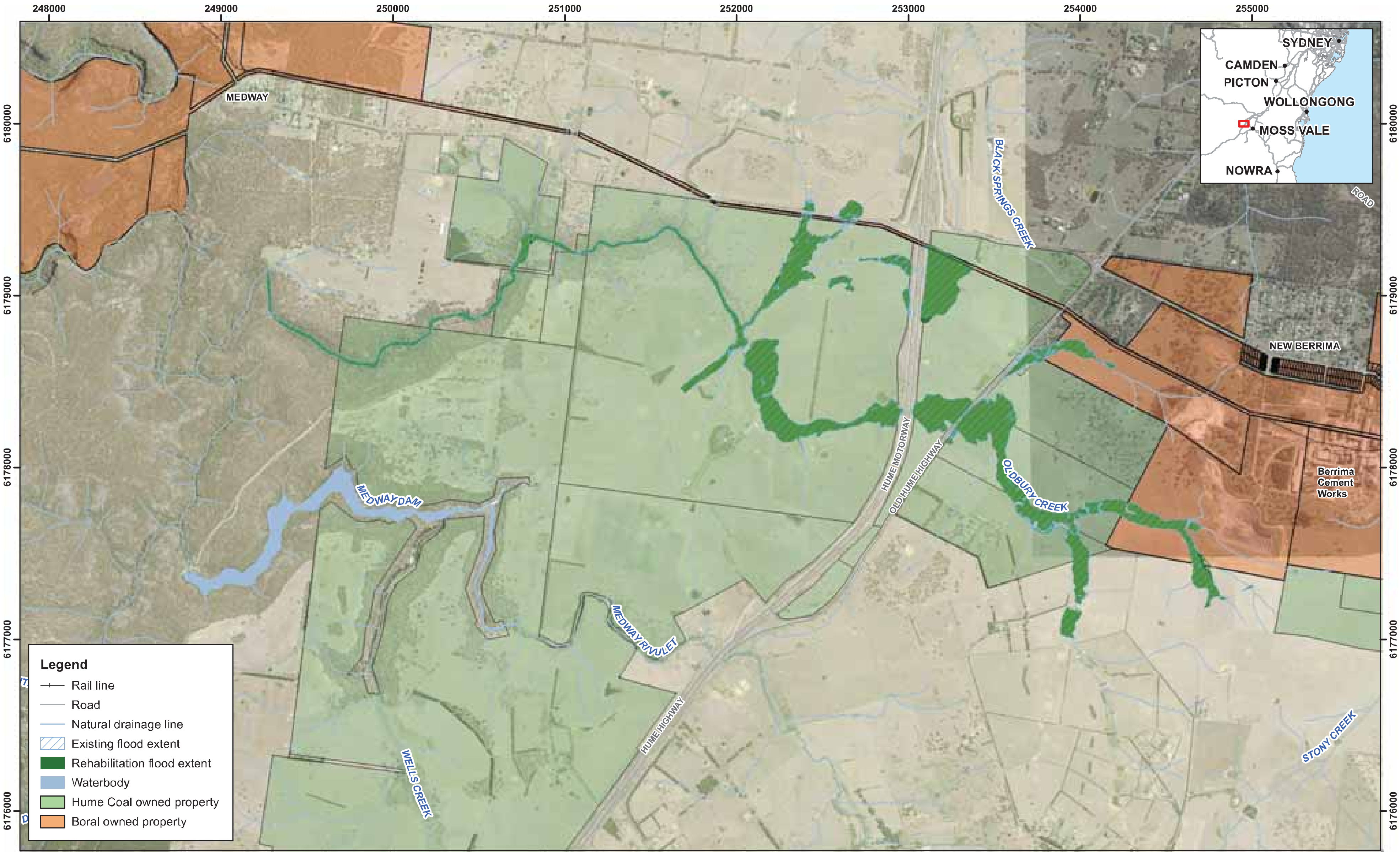

Map: 2200569A_GIS_028_A6	Author: RP
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Figure 2.18

Cumulative 100 Year ARI flood extent - Rehabilitation

Table 2.22 Oldbury Creek afflux results (cumulative assessment)

Cross section number	Stream	Location	Operation afflux (m)				Rehabilitation afflux (m)			
			5 yr	20 yr	100 yr	PMF	5 yr	20 yr	100 yr	PMF
246.32	Tributary 2b	DS Medway Road	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.05
306.77	Catchment tributary 2	DS Medway Road	0.01	0.02	0.03	0.53	0.00	0.00	0.00	0.00
347.57	Tributary 2b	US Medway Road	-0.02	-0.01	0.00	-0.01	0.01	0.00	0.00	0.01
350	Branch	Private land	-0.13	-0.16	-0.20	-0.62	0.00	0.00	0.00	0.00
372.91	Catchment tributary 2	US Medway Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
417.29	Oldbury Creek	Private land	-0.16	-0.25	-0.33	-1.95	0.00	0.00	0.00	0.00
533.14	Branch	Private land	-0.17	-0.19	-0.21	-0.62	0.00	0.00	0.00	0.00
543.84	Tributary T1	Old Hume Hwy	-0.05	-0.06	-0.07	0.8	0.04	0.06	0.06	0.00
606.67	Tributary T1	Private land and Old Hume Hwy	0.03	0.05	0.06	1.05	0.00	0.00	0.00	0.00
647.53	Oldbury Creek	Private land	-0.05	-0.09	-0.18	0.00	0.00	0.00	0.00	0.00
750	Branch	Private land	-0.18	-0.22	-0.25	-0.67	0.00	0.00	0.00	0.00
773.14	Tributary T1	Private land	-0.04	-0.04	-0.04	-0.10	0.01	0.01	0.01	0.03
1073.16	Tributary T1	Private land	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
1194.89	Tributary 2	DS Hume Hwy	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
1260	Tributary 2	US Hume Hwy	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
2741.84	Oldbury Creek	Private land	0.00	-0.13	-0.2	-0.04	0.00	0.00	0.00	0.00
2819.73	Oldbury Creek	Private land	0.009	0.01	-0.04	-0.31	0.00	0.00	0.00	0.00
2928.8	Oldbury Creek	Private land	-0.06	0.01	-0.05	-0.31	0.00	0.00	0.00	0.00
3007.9	Oldbury Creek	Hume Coal land	0.00	0.02	0.03	-0.16	0.00	0.00	0.00	0.00
4120.53	Oldbury Creek	Hume Coal land	-0.03	-0.03	-0.04	-0.04	0.04	0.07	0.09	0.06
4288.37	Oldbury Creek	Embankment DS inline storage	0.34	0.30	0.27	0.00	0.39	0.37	0.34	0.10
4390.64	Oldbury Creek	Embankment US inline storage	0.22	0.22	0.19	0.16	0.00	0.00	0.00	0.00
4611.83	Oldbury Creek	US inline storage	0.22	0.22	0.19	0.15	0.00	0.00	0.00	0.00
4641.08	Oldbury Creek	US inline storage	0.20	0.20	0.16	0.02	0.00	0.00	0.00	0.00
5624.5	Oldbury Creek	DS Hume Hwy	0.01	0.01	0.01	0.08	0.00	0.00	0.00	0.00
5691.94	Oldbury Creek	US Hume Hwy	0.02	0.03	0.04	-0.01	0.00	0.00	0.00	0.00
5980	Oldbury Creek	DS Old Hume Hwy	0.01	0.02	0.04	-0.01	0.00	0.00	0.00	0.00
6024.59	Oldbury Creek	US Old Hume Hwy	0.02	0.02	0.02	-0.01	0.01	0.01	0.10	0.00
7081.2	Oldbury Creek	DS 5 x 2000 mm x 2000 mm RCBC on Oldbury Creek	0.03	0.02	0.01	0.06	0.05	0.04	0.02	0.00
7142.77	Oldbury Creek	Hume Coal Land	0.02	0.01	0.01	2.86	0.00	0.00	0.00	0.00
7401.61	Oldbury Creek	Hume Coal Land	0.01	0.00	0.01	1.32	0.00	0.00	0.00	0.01
7696.2	Oldbury Creek	Private land (Boral)	0.01	0.02	0.01	0.05	0.00	0.00	0.00	0.01
7907.82	Oldbury Creek	Private land (Boral)	0.01	0.02	0.02	0.03	0.07	0.10	0.14	0.26
7999.53	Oldbury Creek	US 5 x 2000 mm x 1200 mm RCBC on Oldbury Creek Private Land	0.00	0.00	0.00	2.04	0.15	0.18	0.23	0.47
8234.11	Oldbury Creek	Private land	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00
421.49	Oldbury Creek	DS drainage depression alongside Hume Highway with 4 x 1800 mm x 900 mm RCBC	0.10	0.11	0.12	0.28	0.00	0.00	0.01	0.19
392.69	Tributary 2	US 2 x 1400 mm diameter pipe under rail loop	0.00	0.62	1.78	4.09	0.03	0.04	0.05	0.15
855.9	Tributary 2	US 1400 mm diameter pipe under rail loop	3.42	3.88	4.74	5.89	0.00	0.00	0.00	0.00
787.17	Oldbury Creek	DS 1400 mm diameter pipe under rail loop	0.01	0.03	0.04	0.30	0.03	0.03	0.02	0.30
254.46	Tributary 2	US 2 x 1400 mm diameter pipe on tributary of Oldbury Creek	1.32	1.90	3.02	4.81	0.14	0.16	0.17	0.02
113.72	Oldbury Creek Tributary 2	DS 2 x 1400 mm diameter pipe on tributary of Oldbury Creek	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

US – upstream; DS – downstream; Hwy - Highway

Table 2.23 Peak flood velocities downstream of new infrastructure (cumulative assessment)

Cross-section	Stream	Proposed structure	Cross-section distance downstream from infrastructure (m)	5 year ARI velocities (m/s)			20 year ARI velocities (m/s)			100 year ARI velocities (m/s)			PMF velocities (m/s)		
				Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff
4288.37	Oldbury Creek	Embankment inline storage	12	1.05	0.74	-0.31	1.09	0.86	-0.23	1.12	0.96	-0.16	1.35	1.55	0.20
4611.83	Oldbury Creek	Embankment inline storage	0.5	0.21	0.18	-0.30	0.28	0.24	-0.40	0.35	0.31	-0.40	1.65	1.56	-0.09
421.49	Oldbury Creek	Drainage depression alongside Hume Highway with 4 x 1.8m x 0.9m RCBC	3	1.05	1.74	0.69	1.13	1.89	0.76	1.21	2.03	0.82	3.44	2.76	-0.68
			38	1.29	1.33	0.04	1.38	1.37	-0.01	1.45	1.51	0.06	2.93	2.82	-0.11
787.13	Overland flow path (flowing to tributary of Oldbury Creek)	1.4m dia pipe	22	0.57	0.52	-0.05	0.72	0.59	-0.13	0.78	0.66	-0.12	1.33	0.72	-0.61
113.72	Tributary of Oldbury Creek	2 x 1.4m dia pipes	0	0.71	3.08	2.37	0.78	3.77	2.99	0.86	5.49	4.63	1.52	7.29	5.77
			2	0.71	1.71	1.00	0.78	1.86	1.08	0.86	2.04	1.18	1.52	3.56	2.04
7907.82	Tributary of Oldbury Creek	5 x 2m x 1.2m RCBC	0	0.88	1.93	1.13	1.00	2.19	1.19	1.1	2.41	1.31	1.94	5.36	3.42
			2	0.88	0.95	0.07	1.00	1.06	0.06	1.1	1.11	0.01	1.94	2.16	0.22
			14	1.06	1.05	-0.01	1.21	1.18	-0.03	1.35	1.29	-0.06	2.63	2.29	-0.34
7081.2	Oldbury Creek	5 x 2m x 2m RCBC	0	1.86	1.2	-0.66	1.88	1.33	-0.55	1.91	1.48	-0.43	1.32	5.79	4.47
			82	0.87	0.87	0.00	0.96	0.95	-0.01	1.06	1.05	-0.01	1.55	1.86	0.31

Ex – Existing; Op – Operation; Diff – Difference

2.6 Sensitivity analyses

Sensitivity analyses were undertaken for key hydrologic and hydraulic parameters in order to understand the sensitivity of the model predictions of the flood behaviour to variations in these parameters. This section provides an understanding of the range of results possible due to model uncertainty. This has focussed on the Oldbury Creek catchment as this catchment will experience most change in flood hydraulics due to the impact of the surface infrastructure.

2.6.1 Sensitivity of rainfall loss rates

Sensitivity testing was undertaken at Oldbury Creek of the continuing loss rate by using a continuing loss of 2.5 mm/hr, which is the default value used in XP-RAFTS, and comparing the results against those using a continuing loss of 3.7 mm/hr which was adopted from the model calibration. The sensitivity test demonstrated that, while the peak flow increased by up to 15%, peak flood level only differed by up to 100mm and afflux by up to 0.01m, as demonstrated in Table 2.24 which provides a sample of results from the sensitivity test.

Table 2.24 Sensitivity of continuing loss values at cross section 3007.9 on Oldbury Creek

ARI	XP-RAFTS node DN2 peak flow (m^3/s)		HEC-RAS cross-section 3007.9 on Oldbury Creek water levels (mAHD)		Afflux (m)
	Existing	Operation	Existing	Operation	
Continuing loss 3.7mm/hr adopted from calibration for design event modelling					
5	29.3	30.0	631.09	630.78	-0.31
20	50.5	51.5	631.54	631.13	-0.41
100	73.9	75.2	631.97	631.52	-0.45
Continuing loss 2.5mm/hr					
5	33.8	34.0	631.19	630.87	-0.32
20	54.4	54.6	631.61	631.19	-0.42
100	77.6	78.9	632.03	631.57	-0.46

2.6.2 Sensitivity of hydraulic roughness

Sensitivity testing was undertaken on the hydraulic roughness by varying the adopted Manning's *n* values in Table 2.14 by +/-20%. The results are provided below at a sample of cross sections in Tables 2.25 and 2.26.

The sensitivity test demonstrated that water levels and afflux levels are not particularly sensitive to significant variations in the Manning's *n* values, with differences of less than 50mm predicted.

Table 2.25 Results of sensitivity tests on hydraulic roughness at cross section 4120.53 on Oldbury Creek

ARI	Water levels at cross-section 4120.53 on Oldbury Creek (mAHD)		Afflux (m)
	Existing	Operation	
Mannings values unchanged			
5	640.10	640.14	0.04
20	640.45	640.52	0.07
100	640.77	640.85	0.08
PMF	644.47	644.45	-0.02
Mannings values increased by 20%			
5	640.19	640.23	0.04
20	640.57	640.63	0.06
100	640.90	640.98	0.08
PMF	644.63	644.60	-0.03
Mannings values decreased by 20%			
5	640.02	640.04	0.02
20	640.35	640.39	0.04
100	640.65	640.72	0.07
PMF	644.25	644.22	-0.03

Table 2.26 Results of sensitivity tests on hydraulic roughness at cross section 1044.5 on Oldbury Creek Tributary

ARI	Water levels at cross-section 1044.5 on Oldbury Creek Tributary (mAHD)		Afflux (m)
	Existing	Operation	
Mannings values unchanged			
5	657.84	657.84	0.00
20	657.88	657.88	0.00
100	657.91	657.91	0.00
PMF	658.38	658.44	0.06
Mannings values increased by 20%			
5	657.86	657.87	0.01
20	657.90	657.91	0.01
100	657.94	657.94	0.00
PMF	658.45	658.49	0.04
Mannings values decreased by 20%			
5	657.81	657.82	0.01
20	657.84	657.84	0.00
100	657.87	657.87	0.00
PMF	658.28	658.39	0.11

2.7 Summary of results

The impacts of the project on flood level are generally within the proposed impact criteria given in Section 2.1.4 for events up to and including the 100 year ARI event. Exceptions occur in the following areas for the operation phase:

- upstream of where the rail line crosses Oldbury Creek south west of Berrima Cement works;
- upstream of where the rail line crosses a tributary of Stony Creek to the east of the Berrima Cement works (preferred option);
- just upstream of the Hume Highway on a tributary of Oldbury Creek;
- in the vicinity of the rail loop; and
- downstream of some culverts where high velocities occur due to constriction of flow.

In all cases the impacts are confined to land owned by either Hume Coal or Boral and generally are removed for the rehabilitation phase, with the exception of the impact east of the Berrima Cement works where the rail infrastructure is to be retained under the preferred option.

The cumulative impacts of the Hume Coal and Berrima Rail projects on flood level are also generally within the proposed impact criteria, with the same exceptions noted above.

The key difference between the preferred and alternate options is the rail crossing at Stony Creek. Under the preferred option, a 4 m high rail embankment with box culverts is proposed to the north of Berrima Road. Under the alternate option, the existing rail bridge over Stony Creek will be duplicated. These design differences mean that, for the preferred option, an additional impact occurs along the tributary of Stony Creek east of Berrima Cement works for both operation and rehabilitation phases (refer to Figure 2.12).

Downstream of some structures energy dissipating measures will be required to prevent high outlet velocities causing scour of the channel. Opportunities should be investigated at detailed design to reduce culvert and/or channel grades to reduce velocities and avoid or minimise the requirement for energy dissipating structures.

2.8 Management and mitigation measures

Peak velocities are expected to increase immediately upstream and downstream of culverts. Erosion and scour protection measures will be required around piers and culvert inlets and outlets, which will typically take the form of rock rip-rap protection. For crossings where waterways are ill-defined, a flow spreader should be provided to transition concentrated flow back to more a natural overland flow pattern, in accordance with standard erosion and sediment control practices (refer to Section 3 for further discussion). The erosion and scour protection should be nominated as part of detailed civil design.

2.9 Conclusions

The flooding assessment has been based on flood models developed from recent LiDAR and ground survey data and calibrated against a recently observed flood event. The Oldbury Creek model achieved a good fit to the calibration event and therefore provides reliable predictions of flood behaviour in Oldbury Creek and Stony Creek. A check against the PRM confirmed model parameters for use in hydrologic modelling. Sensitivity analyses on both the hydrologic and hydraulic model input parameters have been carried out with only minor changes to model results.

Culverts will be constructed in a number of locations to allow water to pass the proposed infrastructure and reduce flooding impacts on nearby land. The modelling results indicate that with these culverts in place, for flooding events up to 100 year ARI for the operation and rehabilitation scenarios, the flood impacts will generally remain within the proposed acceptable limits, with some exceptions on land owned by Hume Coal or Boral. These impacts are generally removed following rehabilitation, with the exception of the impact east of Berrima Cement works which is due to the retained rail infrastructure on a tributary of Stony Creek at this location (refer to Figure 2.13). The same impact findings apply to the cumulative scenario also.

Peak velocities are expected to increase immediately upstream and downstream of culverts. Erosion and scour protection measures will be required around culvert inlets and outlets so that any localised increases in stream velocity do not cause erosion of the channel lining downstream of the culvert.

2.10 Limitations

The limitations of this flooding assessment are as follows:

- The XP-RAFTS models for the Oldbury Creek catchment relies on the stream gauge rating curve in Figure 2.4.
- The XP-RAFTS model for the Oldbury Creek catchments was only calibrated to one rainfall event. The XP-RAFTS model for the Stony Creek catchment was not calibrated.
- The HEC-RAS models for the Oldbury Creek and Stony Creek catchments are steady state models which assume that peak flow will occur simultaneously in all locations and storage effect is ignored. The models will over predict water levels and are therefore conservative.
- HEC-RAS provides a one dimensional representation of open channel flow which results in estimates of cross-section averaged velocity. In reality flows downstream of culverts and other constrictions will vary locally and with depth and will have complex turbulent flow distributions. This needs to be considered during detailed civil design of scour protection works.
- The existing landform model relies on the accuracy of the LiDAR dataset, which is approximately +/- 150mm.

2.11 Recommendations

The following recommendations are made based on the findings of this study:

- The XP-RAFTS for the Oldbury Creek catchment should ideally be calibrated to more than one rainfall event. Further calibration of this model is recommended once data from a longer baseline monitoring period becomes available.
- Typical scour protection measures will be required at crossing structures such as access road culverts. This model should be used and refined as necessary at the detailed design stage to inform the scour analysis and design of scour protection measures.

3 EROSION, SEDIMENTATION AND SCOUR ASSESSMENT

This section provides an assessment of:

- Existing geomorphic conditions of creeks and drainage lines intersected by the rail corridor;
- Scour risk of the main structures crossing waterways and appropriate concepts for mitigating the risk;
- Scour and erosion risk around drainage outlets and typical treatment measures to protect adjacent land and receiving watercourses; and
- Erosion and sediment control measures required during construction.

3.1 Methodology

A geomorphology assessment was undertaken to establish the baseline stability and characteristics of the creeks and drainage lines that will be intersected by the rail corridor. The assessment involved a site inspection to determine bed and bank condition and follow up desktop assessments of the hydraulic characteristics based on the available flood models and topographic data. The assessment was used to inform the erosion and sediment control and scour assessment.

The site inspection was conducted on 31 May 2016 and 1 June 2016 to assess the existing geomorphic conditions of the waterways the proposed railway will cross. The inspection sites are shown on Figure 3.1.

Potential erosion and scour risk at the new rail infrastructure crossing streams in the project area has been assessed considering the baseline geomorphic characteristics of the streams and the predicted change in peak velocity of flow at the new infrastructure. The results of the hydraulic modelling undertaken for the flooding assessment (Sections 2.3 to 2.5) have been used to assess peak velocities downstream of the new infrastructure. Assessment of erosion and scour risk has been undertaken for the new infrastructure proposed for the preferred and alternate options.

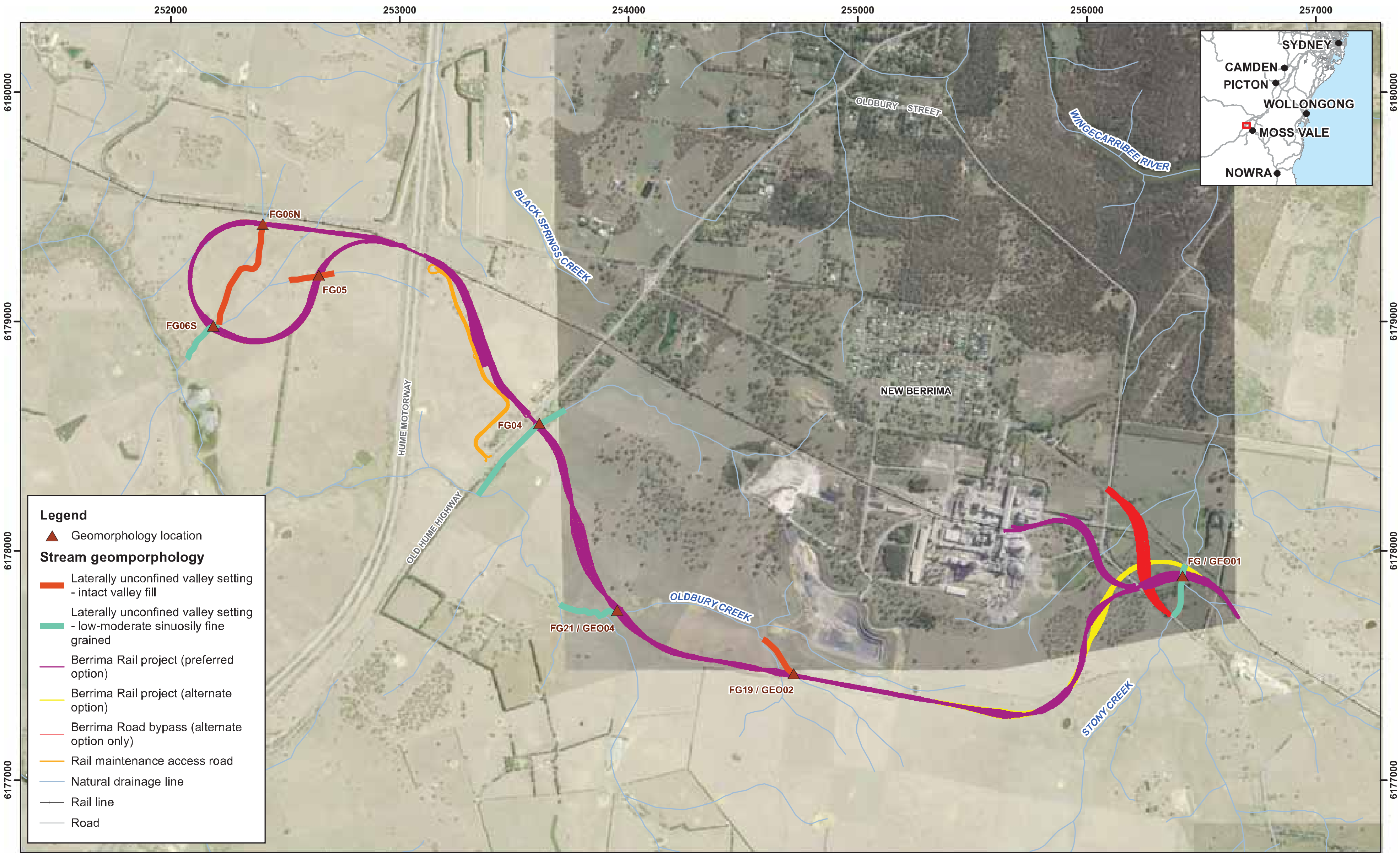
3.2 Existing environment

A detailed description of the geomorphology and flow conditions at each site is provided in Table 3.1. Photographs of each site are provided in Photos 3.1 to 3.8 (note: all photos are viewing from downstream to upstream).

The creeks and drainage lines that will be intersected by the rail corridor can be grouped into two categories: well defined (which includes FG/GEO01, FG04, FG21/GEO04 and FG06 (South)) and ill-defined (which includes FG19/GEO02, FG05 and FG06 (North)).

No flow was observed in the waterways visited during the site inspection. Stagnant pools were observed at FG/GEO01 on Stony Creek. Flow is expected in the well-defined waterways during rainfall events. Of the well-defined waterways, FG/GEO01 on Stony Creek is the largest waterway. FG21/GEO04 is an artificial channel draining stormwater intercepted by the Old Hume Highway to Oldbury Creek. The waterway at FG04 on Oldbury Creek is intercepted by multiple farm dams and flow is only likely to occur if the rainfall event is large enough to fill the storage of the farm dams. FG06 (South) is a small waterway locally formed possibly due to the presence of tree stumps and an existing culvert crossing. There is minimal evidence of erosion in the well-defined waterways under existing conditions.

The ill-defined waterways are basically depressions in farmland that convey overland flow during rain events, which would be expected to produce relatively shallow flow over a relatively large flood extent. The ill-defined waterways in the project area are well vegetated.



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Data source: © Land and Property Information 2015, Hume Coal

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Coordinate system: GDA 1994 MGA Zone 56

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Figure 3.1

Inspection sites for geomorphology assessment

Table 3.1 Description of locations visited for geomorphology assessment

Location	Watercourse	Valley setting	River style	Sinuosity	Bed composition	Description	Geomorphic units	River behaviour - Low	River behaviour - Med	River behaviour - Overbank
FG / GEO01	Stony Creek	Laterally unconfined valley setting	Low-moderate sinuosity fine grained	Low	Silty clay	Channelised with major road and rail crossings and broken by local assess road	Ridge and swale topography	Disconnected pools	Free flowing with backwater created by culvert	Backwater due to rail embankment. Erosion downstream of the rail embankment due to spilling
FG19 / GEO02	Tributary of Oldbury Creek	Laterally unconfined valley setting	Intact valley fill	N/A	Silty clay	Low point of vegetated pasture	Valley fill	No flow observed but anticipated to be free flowing	No flow observed but anticipated to be free flowing	Free flowing and possibly flood storage
FG21 / GEO04	Oldbury Creek	Laterally unconfined valley setting	Low-moderate sinuosity fine grained	Low	Silty clay	Dry, disconnected channel. Broken up by multiple farm dams	Bench	Disconnected pools	Free flowing with backwater created by farm dams and road crossings	Free flowing with backwater created by farm dams and road crossings possible flood storage. Some scouring could occur at outlet of farm dams or crossways
FG04	Drainage channel alongside Old Hume Highway (tributary of Oldbury Creek)	Laterally unconfined valley setting	Low-moderate sinuosity fine grained	Low	Silty clay	Defined drainage line. Dense vegetation upstream of Old Hume highway crossing. Otherwise, moderate vegetation at bank and close to stage flow.	Bench	No flow observed but anticipated to be free flowing	Backwater created by culvert	Backwater created by culvert. Scour occurs at downstream end.

Location	Watercourse	Valley setting	River style	Sinuosity	Bed composition	Description	Geomorphic units	River behaviour - Low	River behaviour - Med	River behaviour - Overbank
FG05	Overland flow path (flowing to tributary of Oldbury Creek)	Laterally unconfined valley setting	Intact valley fill	N/A	Silty clay	Low point of vegetated pasture	Valley fill	No flow observed but anticipated to be free flowing	No flow observed but anticipated to be free flowing	Free flowing and possibly flood storage
FG06 North	Overland flow path (flowing to tributary of Oldbury Creek)	Laterally unconfined valley setting	Intact valley fill	N/A	Silty clay	Low point of vegetated pasture	Valley fill	No flow observed but anticipated to be free flowing	No flow observed but anticipated to be free flowing	Free flowing and possibly flood storage
FG06 South	Tributary of Oldbury Creek	Laterally unconfined valley setting	Low-moderate sinuosity fine grained	Low	Silty clay	Start of channelisation with small culvert. The channel is ill defined	Forced pool due to tree stamp and culvert	Dry but anticipated to be riffled due to effect of tree stump and culvert	Dry but anticipated to be riffled due to effect of tree stump and culvert	Free flowing and possibly flood storage. The small gully will be submerged.

Photo 3.1 Overland flow path to Oldbury Creek (FG06N)

Photo 3.2 Tributary of Oldbury Creek (FG06S)

Photo 3.3 Overland flow path to Oldbury Creek (FG05)

Photo 3.4 Drainage depression alongside old Hume Highway (FG04)

Photo 3.5 Oldbury Creek with instream storage (FG21)

Photo 3.6 Tributary of Oldbury Creek (FG19 / GEO02)

Photo 3.7 Stony Creek (FG / GEO01)

Photo 3.8 Stony Creek under existing rail line (FG / GEO01)

3.3 Preferred option impact assessment

The new rail infrastructure crossing streams for the preferred option is summarised in Table 3.2. The new infrastructure comprises drainage structures, including pipes, culverts and diversion drains.

Table 3.2 New rail infrastructure crossing streams (preferred option)

Crossing location	Waterway where rail will cross	Proposed structures
FG / GEO01	Stony Creek	9 x 3600 mm x 3000 mm RCBC
FG19 / GEO02	Tributary of Oldbury Creek	2 x 1400 mm diameter pipe
FG21 / GEO04	Oldbury Creek	5 x 2000 mm x1200mm RCBC
FG04	Drainage depression alongside Hume Highway	4 x 1800 mm x 900 mm RCBC
FG05	Overland flow path (flowing to tributary of Oldbury Creek)	1400 mm diameter pipe
FG06 North	Overland flow path (flowing to tributary of Oldbury Creek)	This section of rail is in cut. A diversion drain will be installed to intercept overland flow from the north.
East of FG06 North	Overland flow path (flowing to tributary of Oldbury Creek)	3 x 750mm diameter pipe
FG06 South	Tributary of Oldbury Creek	5 x 2000 mm x1200mm RCBC

Peak velocities downstream of the new infrastructure are presented in Table 2.18. Changes in peak velocity are generally within the range +/- 0.8 m/s. Higher velocity changes are predicted at culvert outlets on Oldbury Creek at cross section 7081.2 (refer to Figure 2.9 for cross section locations) and on the Oldbury Creek Tributary at cross section 113.72; however, Table 2.18 shows that these velocity changes reduce downstream of the culvert outlets and the velocity changes can therefore be managed locally at the outlets.

3.4 Alternate option assessment

The new rail infrastructure crossing streams for the alternate option is summarised in Table 3.3. The new infrastructure includes crossing structures (bridges) and drainage outlets (pipes, culverts and diversion drains).

Table 3.3 New rail infrastructure crossing streams (alternate option)

Crossing location	Waterway where rail will cross	Proposed structures
FG / GEO01	Stony Creek	Duplication of existing bridge structure
FG19 / GEO02	Tributary of Oldbury Creek	2 x 1400 mm diameter pipe
FG21 / GEO04	Oldbury Creek	5 x 2000 mm x1200mm RCBC
FG04	Drainage depression alongside Hume Highway	4 x 1800 mm x 900 mm RCBC
FG05	Overland flow path (flowing to tributary of Oldbury Creek)	1400 mm diameter pipe
FG06 North	Overland flow path (flowing to tributary of Oldbury Creek)	This section of rail is in cut. A diversion drain will be installed to intercept overland flow from the north.
East of FG06 North	Overland flow path (flowing to tributary of Oldbury Creek)	3 x 750 mm diameter pipe
FG06 South	Tributary of Oldbury Creek	5 x 2000 mm x1200mm RCBC

Peak velocities downstream of the new infrastructure are presented in Table 2.21. Changes in peak velocity are generally within the range +/- 0.8 m/s. Higher velocity changes are predicted at culvert outlets on Oldbury Creek at cross section 7081.2 (refer to Figure 2.9 for cross section locations) and on the Oldbury Creek Tributary at cross section 113.72; however, Table 2.21 shows that these velocity changes reduce downstream of the culvert outlets and the velocity changes can therefore be managed locally at the outlets.

3.5 Summary of results

Construction of the rail embankment will intercept overland flow and will concentrate the flow at culvert locations. This will likely cause increased ponding upstream of the culvert locations and increased flow velocity downstream of the culvert locations which could increase the risk of erosion and scouring. Erosion and scour protection measures, which are part of the standard culvert crossing design features, will be required to protect the creek and culvert against localised scouring immediately downstream of the crossings (refer to Section 3.6)

The key difference between the preferred and alternate options is the rail crossing at Stony Creek. Under the preferred option, a 4 m high rail embankment with box culverts is proposed to the north of Berrima Road. Under the alternate option, the existing rail bridge over Stony Creek will be duplicated. These design differences are not expected to result in any difference to erosion and scour requirements in the project area (to be confirmed during detailed civil design).

3.6 Management and mitigation measures

3.6.1 Operation phase

Erosion and scour protection measures will be required around bridges and culvert inlets and outlets, which will typically take the form of concrete aprons and rock rip-rap protection (to be confirmed during detailed civil design). The proposed erosion and scour control measures for the stream crossing infrastructure are summarised in Table 3.4.

For crossings where waterways are well-defined, scour protection should be provided at the downstream end of the culvert so that localised increases in flow velocity do not cause erosion of the channel lining downstream of the culvert.

For crossings where waterways are ill-defined, a flow spreader would be used to transition concentrated flow back to more a natural overland flow pattern.

Table 3.4 Sour and erosion protection measures

Crossing location	Design option	Waterway rail will cross	Proposed structures	Proposed erosion and scour control measures
FG / GEO01	Preferred option	Stony Creek	9 x 3600 mm x 3000 mm RCBC	Rip rap apron or basin
FG / GEO01	Alternate option	Stony Creek	Duplication of existing bridge structure	Standard abutment and pier rock protection measures as required
FG19 / GEO02	Preferred and alternate option	Tributary of Oldbury Creek	2 x 1400 mm diameter pipe	Rip rap apron and flow spreader
FG21 / GEO04	Preferred and alternate option	Oldbury Creek	5 x 2000 mm x1200mm RCBC	Rip rap apron or basin
FG04	Preferred and alternate option	Drainage depression alongside Hume Highway	4 x 1800 mm x 900 mm RCBC	Rip rap apron or basin

Crossing location	Design option	Waterway rail will cross	Proposed structures	Proposed erosion and scour control measures
FG05	Preferred and alternate option	Overland flow path (flowing to tributary of Oldbury Creek)	1400 mm diameter pipe	Rip rap apron and flow spreader
FG06 South	Preferred and alternate option	Tributary of Oldbury Creek	5 x 2000 mm x1200mm RCBC	Rip rap apron and flow spreader

3.6.2 Construction phase

An erosion and sedimentation control plan, developed in accordance with Landcom (2004) and DECC (2008) guidelines, will be prepared to ensure the erosion and sedimentation induced by construction activities will not adversely affect the surrounding environment. With the implementation of this plan, erosion and sedimentation impacts during the construction phase are expected to be minimal.

Temporary erosion and sedimentation controls applicable to the construction phase of the project include sedimentation basins, sediment fences, diversions banks (for on and off-site water), check dams, batter chutes, temporary culverts and scour protection. Depending on the construction staging and the extent of disturbance at each stage, the temporary works may involve local controls, such as sediment fences and diversion berms that are expected to be utilised by the civil works contractor in day to day management, or more extensive measures such as temporary sedimentation basins.

The intent of the erosion and sediment control practices used on site will be to:

- Minimise the extent of disturbance, by clearing only as required, by clearing and grubbing to leave the surface rough and by minimising the time in which watercourses are disturbed.
- Control stormwater flows onto, through and from the site by separating runoff from disturbed and undisturbed areas, by constructing drainage structures early including sediment basins, cut-off drains and cross drainage culverts and by minimising runoff down batters by using batter drains.
- Minimise scour in waterways by using linings as appropriate.
- Have surfaces revegetated as soon as possible to minimise the duration of disturbance.
- Have the civil works contractor utilise local controls such as diversion banks and sediment fences to minimise erosion and sediment transport and have them progressively update these measures as required during construction.
- Have the civil works contractor maintain and inspect the erosion and sediment control measures to ensure their effectiveness remains intact.

3.7 Conclusion

Construction of the rail embankment will intercept overland flow and concentrate the flow through culverts, resulting in an increase in flow velocity at the culvert outlet and an increase in the risk of erosion and scouring. These risks can be successfully managed through implementation of industry standard controls.

For crossings where waterways are well-defined (FG/GEO01, FG04, FG21/GEO04 and FG06 (South)), scour protection should be provided at the upstream and downstream ends of the culvert so that localised increases in velocity at the outlet do not cause erosion of the channel lining downstream of the culvert.

For crossings where waterways are ill-defined (FG19/GEO02, FG05 and FG06 (North)), a flow spreader should be provided to transition concentrated flow back to more a natural overland flow pattern.

For the construction phase, an erosion and sediment control plan will be prepared to ensure that erosion and sedimentation induced by construction activities will not adversely affect the surrounding environment.

4 FISH PASSAGE ASSESSMENT

The new rail infrastructure crossing streams in the project area has the potential to restrict fish passage. The free passage of fish within rivers and streams is a critical aspect of aquatic ecology. Obstructions to fish passage due to the construction of waterway crossings can negatively impact on native fish by restricting the migration and spawning of fish, limiting the passage of fish between feeding grounds and fragmenting fish communities and resulting in reduced gene flow within fish populations. Maintenance of connectivity between upstream and downstream habitats (longitudinal connectivity) and adjacent riparian and floodplain habitats (lateral connectivity) is an essential part of fish habitat management (DPI 2013).

The NSW Department of Primary Industries (DPI) have published guidelines (DPI 2013) which nominate the preferred waterway crossing type depending on waterway class. Using these guidelines all waterways in the project area are classified as unlikely key fish habitat (Class 4). A Class 4 waterway is a "waterway (generally unnamed) with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools post rain events (e.g. dry gullies or shallow floodplain depressions with no aquatic flora present) (DPI 2013, p.19).

The preferred waterway crossing type for Class 4 waterways under the DPI guidelines (2013) is relatively broad; however, culverts and fords are preferred to causeways. The waterway crossing types proposed for the project are provided in Table 4.1. The proposed crossings are consistent with the DPI guidelines (2013) for Class 4 waterways with the exception of the two crossings near FG06 North on Oldbury Creek. The proposed rail line is in cut at this location and flow will need to be diverted around the rail line. The detailed civil design of the diversions will need to take the DPI requirements for fish passage into account.

Given the unlikely fish habitat classification for all assessed waterways, the design of the proposed crossings is appropriate for the waterways and, therefore, there is no restriction of fish passage predicted.

Table 4.1 Fish passage assessment

Crossing location	Waterway where rail will cross	Fish habitat classification	Proposed crossing type	Design option
FG / GEO01	Stony Creek	Class 4 Unlikely key fish habitat	9 x 3600 mm x 3000 mm RCBC	Preferred
FG / GEO01	Stony Creek	Class 4 Unlikely key fish habitat	Duplication of bridge over Stony Creek	Alternate
FG19 / GEO02	Tributary of Oldbury Creek	Class 4 Unlikely key fish habitat	2 x 1400 mm diameter pipe	Preferred and alternate
FG21 / GEO04	Oldbury Creek	Class 4 Unlikely key fish habitat	5 x 2000 mm x1200mm RCBC	Preferred and alternate
FG04	Drainage depression alongside Hume Highway	Class 4 Unlikely key fish habitat	4 x 1800 mm x 900 mm RCBC	Preferred and alternate
FG05	Overland flow path (flowing to tributary of Oldbury Creek)	Class 4 Unlikely key fish habitat	1400 mm diameter pipe	Preferred and alternate
East of FG06 North	Overland flow path (flowing to tributary of Oldbury Creek)	Class 4 Unlikely key fish habitat	3 x 750mm diameter pipe	Preferred and alternate
FG06 North	Overland flow path (flowing to tributary of Oldbury Creek)	Class 4 Unlikely key fish habitat	This section of rail is in cut. A diversion drain will be installed to intercept overland flow from the north.	Preferred and alternate
FG06 South	Tributary of Oldbury Creek	Class 4 Unlikely key fish habitat	5 x 2000 mm x1200mm RCBC	Preferred and alternate

5 WATER QUALITY ASSESSMENT

The project is located in the Hawkesbury-Nepean River catchment which is part of the Sydney drinking water catchment. This section provides an assessment of the impacts of the project on surface water quality in the Sydney drinking water catchment during construction, operation and rehabilitation stages, as well as detail of proposed mitigation measures to minimise potential impacts. It should be noted that the project will not involve the discharge of wastewater and, therefore, this assessment is only concerned with the management of stormwater runoff from the project to the receiving catchments.

5.1 Methodology

5.1.1 Relevant policies and guidelines

This section lists policies and guidelines that are relevant to the surface water quality assessment.

5.1.1.1 State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011

Under section 34B of the *Environment Protection and Assessment Act 1979*, provision is to be made in a State Environmental Planning Policy (SEPP) requiring consent authorities to refuse consent to development applications relating to any part of the Sydney drinking water catchment, unless the consent authority is satisfied that the proposed development would have a neutral or beneficial effect (NorBE) on water quality.

The resulting SEPP sets out the planning and assessment requirements for all new developments in the Sydney drinking water catchment to prove a NorBE on water quality.

5.1.1.2 Neutral or Beneficial Effect on Water Quality Assessment Guideline

Guidelines for the assessment of a NorBE on water quality have been published by WaterNSW (2015) and provide clear direction on what a NorBE means, how to achieve it, and how to assess an application.

As defined in the guidelines (WaterNSW 2015), NorBE on water quality is satisfied if the development:

- has no identifiable potential impact on water quality;
- will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on the site; and
- will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.

The type and complexity of the development will determine the type and extent of information needed to demonstrate that a development has a NorBE on water quality.

5.1.1.3 Using MUSIC in Sydney's Drinking Water Catchment

Within the Sydney drinking water catchment, the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software must be used to assess the potential impacts of large and complex developments on water quality. MUSIC is a water quality decision support system which estimates stormwater pollutant generation and simulates the performance of stormwater management measures to assess whether water quality targets can be achieved.

WaterNSW released standards in 2012 to assist consultants in preparing MUSIC models to demonstrate a NorBE on water quality for proposed urban and rural land use developments. NorBE is assessed by comparing the quality of runoff from the pre-development site with that from the post-development site including proposed stormwater treatment measures that may be needed to mitigate pollutant loads and concentrations resulting from the proposed land use change.

The standard shows practitioners how to set up a MUSIC model for pre-development and post-development site layouts, considering the existing site characteristics, drainage configuration, the climatic region, and the configuration of post-development site layout and treatment measures in the context of NorBE. The manual also provides conservative NorBE assessment criteria which account for uncertainty in MUSIC predictions.

MUSIC has been used to assess potential impacts of the Project on surface water quality in accordance with the WaterNSW manual (2012).

5.1.1.4 National Water Quality Management Strategy

The *National Water Quality Management Strategy* (NWQMS) is a joint national approach to improving water quality in Australian and New Zealand waterways. It was originally endorsed by two Ministerial Councils - the former Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ) and the former Australian and New Zealand Environment and Conservation Council (ANZECC).

The NWQMS aims to protect the nation's water resources by improving water quality while supporting the businesses, industry, environment and communities that depend on water for their continued development. The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development.

The NWQMS includes water quality guidelines that define desirable ranges and maximum levels for certain parameters that can be allowed (based on scientific evidence and judgement) for specific uses of waters or for protection of specific values. They are generally set at a low level of contamination to offer long-term protection of environmental values. The NWQMS water quality guidelines include the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) and the Australian Drinking Water Guidelines (NHMRC 2011). The water quality objectives (WQOs) in the NWQMS guidelines have been adopted as the WQOs for the receiving environment of the Berrima Rail Project (refer Section 5.7).

5.1.1.5 NSW Water Quality Objectives

The *NSW Water Quality Objectives* (OEH 2006) are the agreed environmental values and long-term goals for NSW's surface waters. They set out:

- the community's values and uses for our rivers, creeks, estuaries and lakes (i.e. healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water); and
- a range of water quality indicators to help us assess whether the current condition of our waterways supports those values and uses.

The water quality objectives for surface waters in catchments are NSW are consistent with the agreed NWQMS WQOs.

5.1.1.6 Healthy Rivers Commission Inquiry into the Hawkesbury-Nepean River

The Healthy Rivers Commission (HRC) was established in 1995 to make recommendations to government on:

- suitable objectives for water quality, flows and other goals central to achieving ecologically sustainable development in a realistic time frame;
- the known or likely views of stakeholder groups on the recommended objectives;
- the economic and environmental consequences of the recommended objectives; and
- strategies, instruments and changes in management practices needed to implement the recommended objectives.

The HRC conducted independent public inquiries for selected rivers, including for the Hawkesbury-Nepean River, to assist the community to consider the options that are available in terms of river health and the use of river resources for commercial and recreational purposes. The findings of the inquiries are provided in the report *Healthy Rivers Commission Inquiry into the Hawkesbury Nepean River* (HRC 1998).

The report details the environmental values of the catchment, which are the values that the community considers important for water use (HRC 1998). The environmental values adopted by the HRC for the Hawkesbury-Nepean River catchment are the environmental values that have been adopted for the Berrima Rail Project. These are discussed in Section 5.2.2.

The report recommends that the ANZECC guidelines be adopted as suitable WQOs for the Hawkesbury-Nepean River catchment, with the exception of nutrients and chlorophyll-a. Catchment specific WQOs are provided for total nitrogen, total phosphorous and chlorophyll-a because these parameters promote algal growth. Management of blue-green algae is one of the most important issues in the Sydney drinking water catchment as blue-green algae can release toxins into the water.

The Hawkesbury-Nepean catchment specific WQOs for nutrients and chlorophyll-a are provided in Table 5.1. These WQOs, together with the WQOs for other parameters in the ANZECC guidelines, have been adopted as the WQOs for the receiving environment of the project (refer Section 5.7.3.4).

Table 5.1 HRC recommended WQOs for nutrients

Water quality indicator	Concentration (µg/L)				
	Forested areas and drinking water catchment	Mixed use rural areas and sandstone plateau	Urban areas – main stream	Urban areas – tributary stream	Estuarine areas
Total nitrogen	700	700	500	~1000	400
Total phosphorous	50	35	30	~50	30
Chlorophyll-a	7	7	10 - 15	~20	7

Source: Adopted from HRC (1998)

5.1.1.7 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000) have been prepared as part of the NWQMS. The guidelines provide a process for developing WQOs required to sustain current or likely future environmental values for natural and semi-natural water resources. The process involves the following:

1. Identify the environmental values that are to be protected in a particular water body. Environmental values (sometimes referred to as beneficial uses) are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits. The following environmental values are recognised in the ANZECC guidelines:
   - aquatic ecosystems
   - primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods)
   - recreation and aesthetics
   - drinking water
   - industrial water
   - cultural and spiritual values
2. Identify management goals and then select the relevant water quality guidelines for measuring performance. A water quality guideline is a numerical concentration limit or narrative statement recommended to support and maintain a designated water use. Based on these guidelines, set water

quality objectives that must be met to maintain the environmental values. Water quality objectives are the specific water quality targets agreed between stakeholders, or set by local jurisdictions, that become the indicators of management performance.

3. Develop statistical performance criteria to evaluate the results of the monitoring programs (e.g. statistical decision criteria for determining whether the water quality objectives have been exceeded or not).
4. Develop tactical monitoring programs focusing on the water quality objectives.
5. Initiate appropriate management responses to attain (or maintain if already achieved) the water quality objectives.

The environmental values adopted for the project are provided in Section 3.5.2. The water quality guidelines for the environmental values are provided in Table 5.2. Bold values are the most conservative guideline value for the parameter. The guidelines for physical and chemical stressors are those for south-east Australian upland rivers and streams for slightly disturbed ecosystems. The guidelines for other parameters are those for freshwater with a 95% level of protection. The water quality guidelines in Table 5.2 have been used to establish the WQOs for the Berrima Rail Project (refer to Section 3.5.7).

5.1.1.8 Australian Drinking Water Guidelines

The *Australian Drinking Water Guidelines* (ADWG) (NHMRC 2011) provide a framework for good management of drinking water supplies that, if implemented, will assure safety at point of use. The ADWG have been developed after consideration of the best available scientific evidence and are designed to provide an authoritative reference on what defines safe, good quality water, how it can be achieved and how it can be assured.

Drinking water is defined as water intended primarily for human consumption, either directly, as supplied from the tap, or indirectly, in beverages, ice or foods prepared with water. Drinking water is also used for other domestic purposes such as bathing and showering.

The safety of drinking water in public health terms is determined by its microbial, physical, chemical and radiological quality; of these, microbial quality is usually the most important. As conventional water treatment methods are not designed to remove some of these compounds from raw water, it is preferable to avoid them in the raw water supply through catchment and storage management practices.

The ADWG include two different types of guideline value:

- a health-related guideline value, which is the concentration or measure of a water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption
- an aesthetic guideline value, which is the concentration or measure of a water quality characteristic that is associated with acceptability of water to the consumer; for example, appearance, taste and odour.

The ADWG guideline values are provided in Table 5.2. The water quality guidelines in Table 5.2 have been used to establish the WQOs for the Berrima Rail Project (refer to Section 3.5.7).

Table 5.2 ANZECC and ADWG water quality guidelines

Parameter	unit	ADWG (2011) Health	ADWG (2011) Aesthetic	ANZECC Irrigation	ANZECC Livestock drinking	ANZECC Aquatic ecosystem	ANZECC Recreation
Physical parameters							
Conductivity	µS/cm	-	-	-	-	**30 - 350**	-
Temperature	°C	-	-	-	-	**-**	-
Turbidity	NTU	-	5	-	-	**2 - 25**	-

Parameter	unit	ADWG (2011) Health	ADWG (2011) Aesthetic	ANZECC Irrigation	ANZECC Livestock drinking	ANZECC Aquatic ecosystem	ANZECC Recreation
pH	pH units	-	6.8 – 8.5	6.0 - 9.0	-	**6.5 - 8.0**	6.5 - 8.5
Total dissolved solids (TDS)	mg/L	-	**600**		2,000	**-**	-
Total suspended solids (TSS)	mg/L	-	-	-	-	**-**	-
Nutrients							
Ammonia as N	mg/L	-	**0.5**	-	-	0.9	-
Nitrate (as N)	mg/L	-	-	-	400	**0.7**	10
Nitrite (as N)	mg/L	-	-	-	30	-	**1**
Total nitrogen as N	mg/L	-	-	5	-	**0.25**	-
Phosphorus	mg/L	-	-	0.05	-	**0.02**	-
Major ions							
Calcium	mg/L	-	-	-	**1,000**	-	-
Chloride	mg/L	-	250	**175**	-	-	400
Magnesium	mg/L	-	-	-	**2,000**	-	-
Sodium	mg/L	-	180	**115**	-	-	300
Sulfate as SO_4	mg/L	-	**250**	-	1,000	-	400
Heavy metals							
Aluminium	mg/L	-	0.2	5	5	**0.055**	-
Antimony	mg/L	**0.003**	-	-	-	-	-
Arsenic	mg/L	**0.01**	-	0.1	0.5	0.013	0.05
Barium	mg/L	2	-	-	-	-	**1**
Beryllium	mg/L	**0.06**	-	0.1	-	-	-
Boron	mg/L	4	-	0.5	5	**0.37**	-
Cadmium	mg/L	0.002	-	0.01	0.01	**0.0002**	0.005
Chromium	mg/L	0.05	-	0.1	1	**0.001**	0.05
Cobalt	mg/L	-	-	**0.05**	1	-	-
Copper	mg/L	2	1	0.2	0.4	**0.0014**	1
Iron	mg/L	-	0.3	**0.2**	-	-	0.3
Lead	mg/L	0.01	-	2	0.1	**0.0034**	0.05
Manganese	mg/L	0.5	0.1	0.2	-	1.9	**0.1**
Mercury	mg/L	0.001	-	0.002	0.002	**0.0006**	0.001

Parameter	unit	ADWG (2011) Health	ADWG (2011) Aesthetic	ANZECC Irrigation	ANZECC Livestock drinking	ANZECC Aquatic ecosystem	ANZECC Recreation
Molybdenum	mg/L	0.05	-	**0.01**	0.15	-	-
Nickel	mg/L	0.02	-	0.2	1	**0.011**	0.1
Selenium	mg/L	**0.01**	-	0.02	0.02	-	-
Silver	mg/L	0.1	-	-	-	**0.00005**	-
Zinc	mg/L	-	3	2	20	**0.008**	5
Hydrocarbons							
Benzene	µg/L	**1**	-	-	-	950	-
Toluene	µg/L	800	**25**	-	-	-	-
Ethylbenzene	µg/L	300	**3**	-	-	-	-
Xylene	µg/L	600	**20**	-	-	-	-
Naphthalene	µg/L	-	-	-	-	**16**	-

Source: Adopted from ANZECC (2000) and ADWG (2011)
***Bold** guideline values denote the lowest guideline value*
'-' denotes that no guideline value has been developed

5.1.2 Project activities with potential to impact on surface water quality

Project activities with potential to impact on surface water quality during construction, operation and rehabilitation stages of the project and provided in Table 5.3.

Table 5.3 Project activities with potential to impact on surface water quality

Project activity or component	Catchment	Potential contaminants	Potential contamination pathway	Likelihood of impact
Construction				
Earthworks/ grading, construction of rail and road infrastructure and rail maintenance facility	Oldbury Creek and Stony Creek	TSS, hydrocarbons	Runoff from working areas to local waterways	Unlikely - short term potential impact that can be suitably managed
Rail temporary construction facility	Oldbury Creek	TSS	Runoff from construction facility to local waterways	Unlikely - short term potential impact that can be suitably managed
		Hydrocarbons	Runoff from areas where spills or leaks have occurred	Unlikely - a hazardous materials plan will be developed which details the management of hazardous materials, including fuels and lubricants. A contingency plan for environmental incidents will be developed which details the response actions during an environmental incident such as an oil spill.

Project activity or component	Catchment	Potential contaminants	Potential contamination pathway	Likelihood of impact
		TN, TP	Runoff and discharge of sewage from facilities	Unlikely - general waste will be managed to prevent contamination of waterways; grey water (eg from sinks and showers) will be subject to primary treatment and reused for drip irrigation of landscaped areas and black water (raw sewage) will be subject to tertiary treatment and reused in site operations
Operation				
Coal trains on rail line	Oldbury Creek and Stony Creek	TSS, metals	Runoff from rail line to local waterway	Potential impact during period of operation
Rail embankments	Oldbury Creek and Stony Creek	None	Runoff from rail line to local waterway	No impact - clean fill will be used to construct rail embankments. The embankments will be compacted and vegetated to avoid impacts to waterways.
Topsoil stockpiles	Oldbury Creek and Stony Creek	None	Runoff from topsoil stockpiles to local waterways	No impact - the topsoil stockpiles will comprise clean fill. The stockpiles will be stabilised with vegetation to avoid impacts to waterways.
Rail maintenance facility	Oldbury Creek	TSS, metals	Runoff from rail line to local waterway	Potential impact during period of operation
		Hydrocarbons	Runoff from working areas to local waterways	Unlikely - drainage from working areas of the rail maintenance facility will be fully contained and oil water separators will be used
		TN, TP	Runoff and discharge of sewage from facilities	Unlikely - general waste will be managed to prevent contamination of waterways; grey water (eg from sinks and showers) will be subject to primary treatment and reused for drip irrigation of landscaped areas and black water (raw sewage will be subject to tertiary treatment and reused in site operations
Rail maintenance access road	Oldbury Creek	TSS, metals	Runoff from road to local waterways	Potential impact during period of operation
Rehabilitation				
Decommissioning of mine infrastructure and rehabilitation	Medway Rivulet and Oldbury Creek	TSS	Runoff from working areas to local waterways	Short term potential impact that can be suitably managed
		Hydrocarbons	Runoff from areas where spills or leaks have occurred	Unlikely - a hazardous materials plan will be developed which details the management of hazardous materials, including fuels and lubricants. A contingency plan for environmental incidents will be developed which details the response actions during an environmental incident such as an oil spill.

5.1.3 MUSIC modelling methodology

Stormwater quality modelling using MUSIC has been undertaken to assess the potential impacts of the following activities during the operation phase on the receiving creek systems:

- coal trains on the rail line;
- coal trains at the rail maintenance facility; and
- vehicles using the rail maintenance access road.

Three scenarios were modelled using MUSIC: existing conditions and operation of the preferred and alternate Berrima Rail Project options. The operational phase scenarios included simulation of stormwater quality treatment measures to achieve the NorBE criteria. Details of these measures are provided in Section 5.1.3.3. Modelling has been undertaken in accordance with the WaterNSW standards (2012).

Water quality modelling has not been undertaken to assess potential short-term impacts during construction and rehabilitation as the potential impacts and associated mitigation controls and measures are dependent on the construction methods and staging, which would be determined at the detailed design phase of the project. Typical stormwater quality management measures to be considered during construction and rehabilitation of the project are provided in Section 5.7.1.

5.1.3.1 MUSIC model set up

Model nodes were established for each section of the rail corridor that is located within an external surface water catchment. The rail corridor spans four sub-catchments of Oldbury Creek and one sub-catchment of Stony Creek (denoted as 'segments' on Figure 5.1). Within each catchment the rail corridor runoff is assumed to discharge to the creek line or overland flow path at the lowest point within the sub-catchment, and it is assumed that the treatment measures will be located at these discharge points.

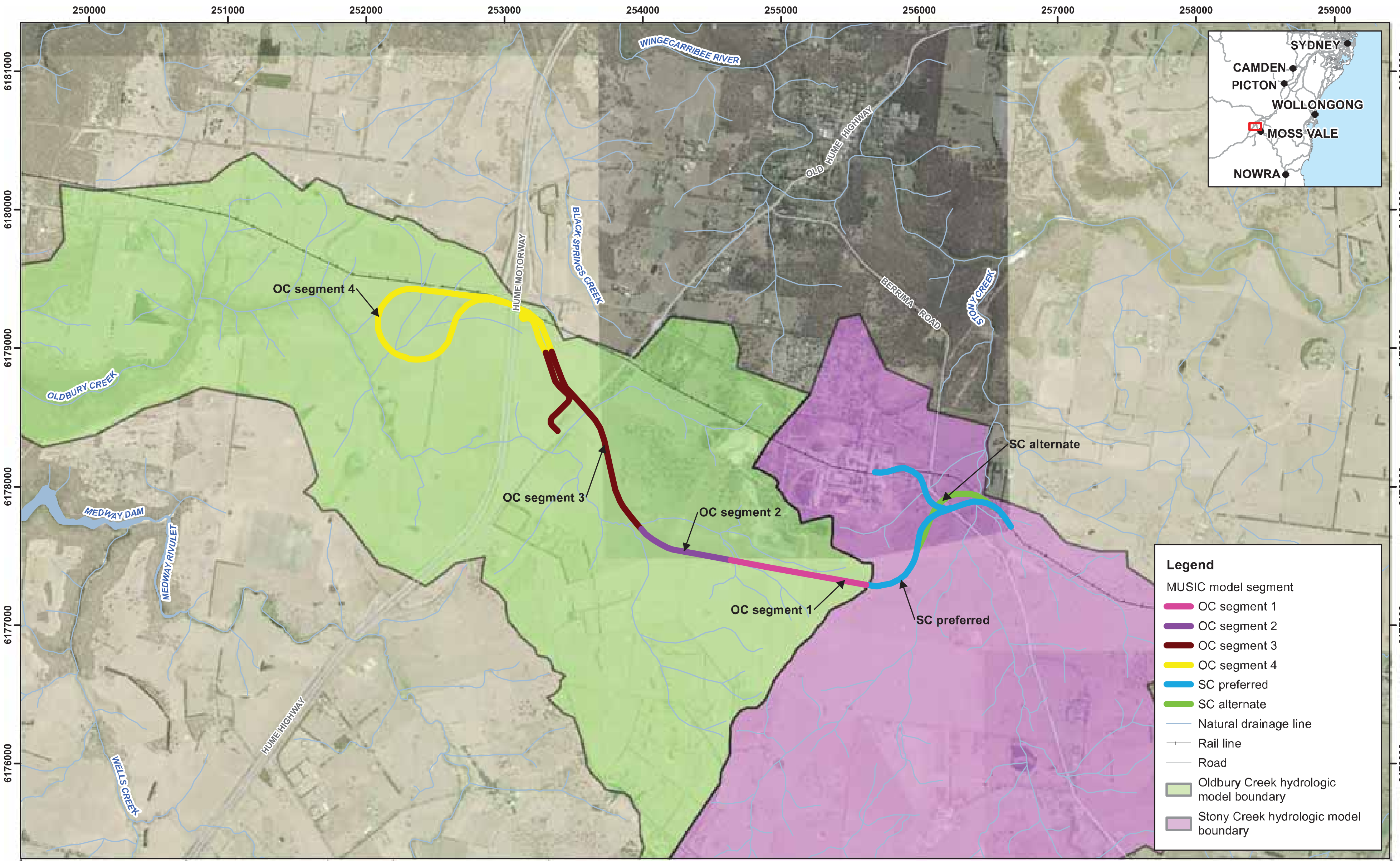
Each model node was set up to represent the following:

- The part of the catchment taken up by the proposed rail and access road corridors (including cut/fill embankments) in its current undeveloped state, i.e. under existing conditions. The land use under existing conditions is assumed to be 'agricultural' (see Section 5.1.3.3 for further definition of land use).
- The part of the catchment taken up by the proposed rail and access road corridors in its proposed developed state, for the preferred and alternate rail options. The land use under these proposed conditions is an operational rail and access road corridor (see Section 5.1.3.3 for further definition of land use).
- The part of the catchment taken up by the batters of the rail and road embankments in its proposed developed state, for the preferred and alternate rail options. The land use under these proposed conditions is revegetated land (see Section 5.1.3.3 for further definition of land use).

Model nodes were separated out into sub-nodes for the proposed rail corridor, sealed access roads and revegetated cut/fill embankments. The catchment area of the proposed rail corridor or road was taken as the top width of the rail or road embankment, which includes the rail ballast and road surface and rail/road formation. The embankment areas were taken as the top width of the rail or road embankment to the toe of the embankment. The embankments will be constructed of vegetated clean fill.

5.1.3.2 Climate data

The WaterNSW standard (2012) provides meteorological templates that include the rainfall and potential evapotranspiration data for various catchment areas and which form the basis for the hydrologic calculations in MUSIC. The appropriate climate zone for the meteorological template file was identified as Zone 3 using the WaterNSW website (http://www.waternsw.com.au/water-quality/catchment/development/). The template files were downloaded from WaterNSW website and directly input into MUSIC. The rainfall files were at a 6 minute time step over a period of 5 years from 1997 to 2001. They include a range of wet and dry years to ensure conditions simulated are realistic and representative of a range of rainfall patterns.



Map: 2200569A_GIS_039_A3	Author: RP
Date: 4/11/2016	Approved by: LR

Data source: , Hume Coal

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Berrima Rail Project

Figure 5.1

MUSIC model layout

5.1.3.3 Modelled scenarios

The existing conditions scenario was set up for each of the sub-catchments using the 'agricultural' MUSIC source node and assumed to be 100% pervious based on the land use identified from aerial photography. The stormwater pollutant parameters used for the agricultural source node are given in Table 5.4 and are in accordance with the WaterNSW standards (2012).

Operational scenarios were set up for each of the sub-catchments for the preferred and alternate project options. The rail corridor sub-catchments were assumed to have the MUSIC pollutant parameters of 'unsealed roads', assuming that the sub-catchment is 50% pervious and 50% impervious. The sealed road and hardstand areas were assumed to have the MUSIC pollutant parameters of 'sealed roads', assuming that the sub-catchment is 100% impervious. The cut/fill embankments were assumed to have the MUSIC pollutant parameters of 'revegetated land'. The stormwater pollutant parameters used for unsealed roads, sealed roads and revegetated land source nodes are given in Table 5.4 and are in accordance with the WaterNSW standards (2012).

Table 5.4 Source node mean pollutant inputs into MUSIC

Base flow	TSS		TP		TN	
	Mean log(mg/L)	S.D. log(mg/L)	Mean log(mg/L)	S.D. log(mg/L)	Mean log(mg/L)	S.D. log(mg/L)
Unsealed roads (rail formation)	1.20	0.17	-0.85	0.19	0.11	0.12
Sealed roads	1.2	0.17	-0.85	0.19	0.11	0.12
Agricultural	1.30	0.13	-1.05	0.13	0.04	0.13
Revegetated land	1.15	0.17	-1.22	0.19	-0.05	0.12
Storm flow	**TSS**		**TP**		**TN**	
	Mean log(mg/L)	**S.D. log(mg/L)**	**Mean log(mg/L)**	**S.D. log(mg/L)**	**Mean log(mg/L)**	**S.D. log(mg/L)**
Unsealed roads (rail formation)	3.00	0.32	-0.30	0.25	0.34	0.19
Sealed roads	2.43	0.32	-0.30	0.25	0.34	0.19
Agricultural	2.15	0.31	-0.22	0.3	0.48	0.26
Revegetated land	1.95	0.32	-0.66	0.25	0.30	0.19
S.D. – Standard Deviation						

For the operational scenarios treatment measures were included in the MUSIC model to address the changes in pollutant loads and concentrations caused by the development of the rail corridor. Vegetated swales were adopted as the site specific treatment measures, which are a secondary measure mainly to treat fine materials. Primary treatment measures may be required to remove gross pollutants at some locations (e.g. the rail maintenance facility) but such measures were not included in the MUSIC model.

Vegetated swales are typically trapezoidal open channels that convey and filter stormwater runoff through vegetation to remove coarse sediment (ie reduce TSS). The performance of swales is largely dependent on the vegetation height and the gradient and length of the swale. MUSIC has default parameters for these, however, the following parameters were adjusted from the default settings:

→ Bed slope: adjusted from the default value of 3% to 2%. This is more realistic assumption as the topography within the project area suggests that swales should generally have a slope of 1% or less over most of the rail corridor, with some steeper sections at 2%. Adopting 2% in general is a conservative assumption.

- Top width: adjusted from the default value of 5 m to 3m. This is a conservative assumption to allow for less land take for the rail corridor.
- Exfiltration rate was selected from the MUSIC default values based on soil type.
- The background concentration (C* and C**) for a swale is defaulted to be relatively high. These values were adjusted in accordance with the approach detailed in Fletcher et al (2004) so that a more realistic reduction of pollutant load would be determined. Further details are presented in Appendix I.

The adopted parameters for the swales are given below in Table 5.5.

Table 5.5 Adopted swale parameters used in MUSIC modelling

Swale properties	Adopted values
Length (m)	varies
Bed Slope (%)	2
Base width (m)	1
Top Width (m)	3
Depth (m)	0.6
Vegetation Height (m)	0.3
Exfiltration rate (mm/hr)	2
C* C** TN	0.89
C* C** TP	0.096

Length is not provided in Table 5.5 because the swale length is specified for each sub-catchment to meet the treatment targets.

5.1.3.4 Assessment criteria

To assess whether the project and its associated treatment measures will have a NorBE on water quality, existing conditions and operational scenario pollutant loads and concentrations from MUSIC have been assessed against the following criteria outlined in the WaterNSW standards (2012):

- The mean annual pollutant loads for the operational scenario (including mitigation measures) must be 10% less than the existing conditions for TSS, TP and TN. For gross pollutants, the operational scenario load only needs to be equal to or less than existing conditions load.
- Pollutant concentrations for TP and TN for the operational scenario (including mitigation measures) must be equal to or better compared to the existing conditions for between the 50th and 98th percentiles over the five-year modelling period when runoff occurs. Periods of zero flow are not accounted for in the statistical analysis as there is no downstream water quality impact. To demonstrate this, comparative cumulative frequency graphs, which use the Flow-Based Sub-Sample Threshold for both the existing and operational cases, must be provided. As meeting the pollutant percentile concentrations for TP generally also meets the requirements for TSS, cumulative frequency analysis is not required for TSS. Cumulative frequency is also not applied to gross pollutants.

A third criterion is provided in the WaterNSW standards (2012); however, only applies to developments where the catchment is more than 70% impervious, and hence does not apply to this development which is assumed 50% impervious. The criteria above are conservative to account for uncertainty in MUSIC predictions.

5.2 Existing environment

5.2.1 Catchment overview

The project area crosses Oldbury Creek, Stony Creek and several of their tributaries. Oldbury Creek flows in a westerly direction from its headwaters in New Berrima to its discharge into Medway Rivulet, downstream of Medway Dam. Stony Creek flows in a northerly direction. The natural flow in both streams is impeded by several instream farm dams used for agricultural water supply. Oldbury Creek and Stony Creek ultimately discharge to Wingecarribee River, located to the north of the project area.

The Wingecarribee River catchment is a sub-catchment of the Hawkesbury Nepean River catchment which is located within the upper reaches of the Warragamba drinking water catchment (Figure 5.2). The Warragamba drinking water catchment covers an area of 9,051 km^2 and is part of the Sydney drinking water catchment. Warragamba Dam and its reservoir Lake Burragorang are located at the downstream end of the Warragamba drinking water catchment. This is WaterNSW's largest reservoir with a total capacity of more than two million megalitres (SCA 2015) and the capacity to supply up to 80% of Sydney's water. One quarter of the catchment is a declared Special Area, where the land is mostly pristine bushland and public access is restricted to protect water quality. The rest of the catchment is divided between eight local council areas, including the Wingecarribee Shire Council (WSC) area where the project is located.

The catchments surrounding the project area are in a semi-rural setting, with the wider region characterised by grazing properties, small-scale farm businesses, hobby farms, natural areas, forestry, scattered rural residences, villages and towns, industrial activities such as the Berrima Cement works and Berrima Feed Mill, and some extractive industry and major transport infrastructure such as the Hume Highway.

5.2.2 Environmental values

Environmental values are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits. Environmental values are sometimes referred to as beneficial uses.

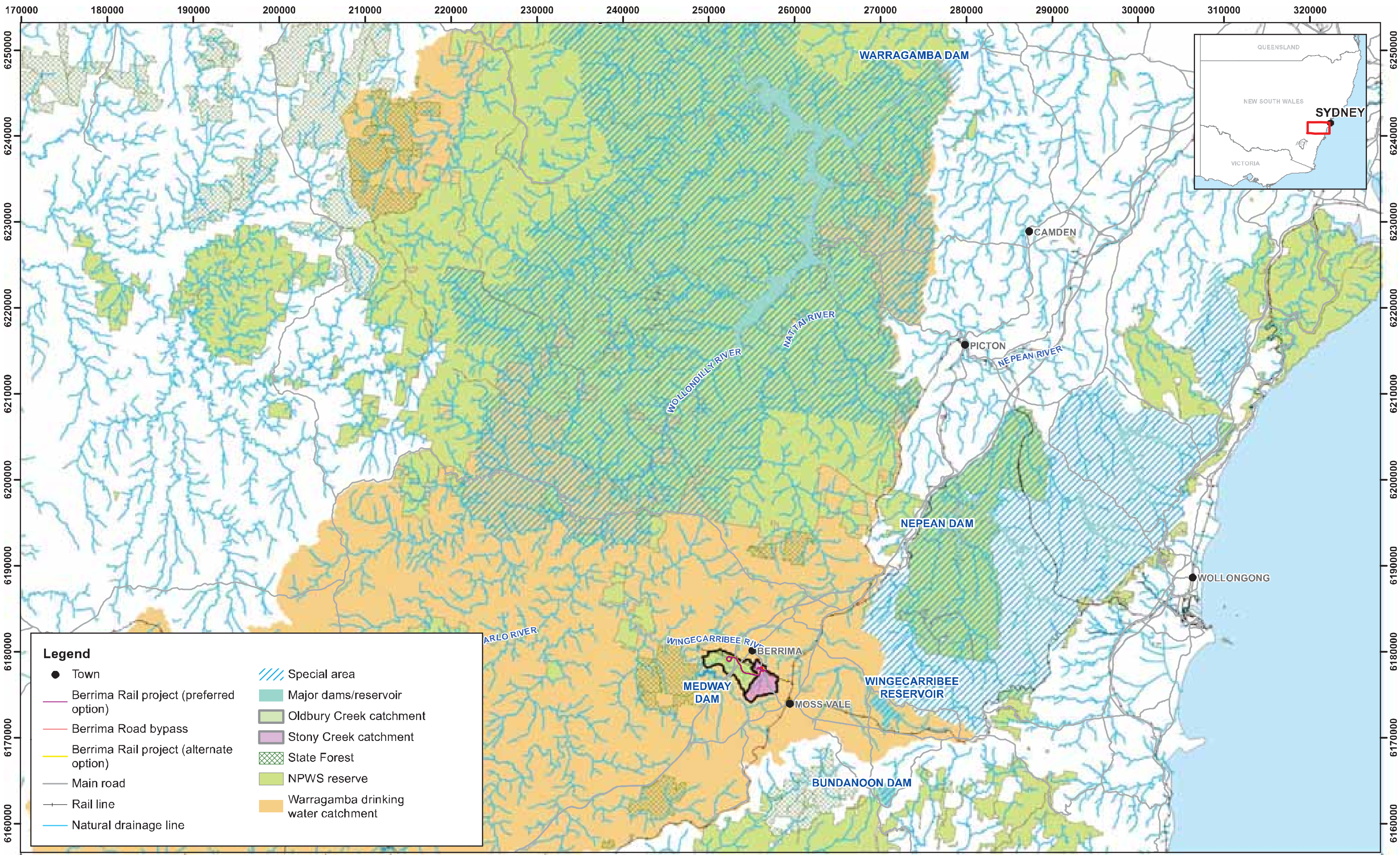
The report *Healthy Rivers Commission Inquiry into the Hawkesbury-Nepean River* (HRC 1998) provides regional environmental values based on land use regions within the Hawkesbury-Nepean catchment. The land use region within the project area and applicable environmental values are provided in Table 5.6. These environmental values have been adopted for the project.

Table 5.6 Environmental values in the Berrima Rail Project area

LAND USE REGIONS	REGIONAL ENVIRONMENTAL VALUES
Mixed-use rural and drinking water with clarification and disinfection	Aquatic ecosystems Primary contact recreation Secondary contact recreation Visual amenity Drinking water – clarification and disinfection Irrigation water supply Homestead water supply Aquatic foods (cooked)

Source: Independent Inquiry into the Hawkesbury-Nepean River System (HRC 1998)

Downstream of the confluence of the Wollondilly and Wingecarribee Rivers, the land use is predominantly drinking water catchment where environmental values include aquatic ecosystems, visual amenity, drinking water – disinfection only, and drinking water - groundwater.



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Author: RP

Date: 15/09/2016

Approved by: LR

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Data source: , Hume Coal, Google Earth

Berrima Rail Project

Figure 5.2

Regional setting of the Berrima rail project

5.2.3 Surface water users

Surface waters in the project area are managed under the *Greater Metropolitan Region Unregulated Water Sources Water Sharing Plan 2011*. The project area is located within the Upper Nepean and Upstream Warragamba Water Source, within the Medway Rivulet and Lower Wingecarribee River management zones.

Under the *Water Management Act 2000*, surface water users (other than for basic water rights) must hold a Water Access Licence (WAL) to take water from streams in the project area. The WAL specifies the annual volume that may be taken and the conditions under which water may be taken.

In the Medway Rivulet Management Zone, WALs have an Environmental Flow Protection Rule that prevents pumping when there is no visible flow at the pump site. In the Lower Wingecarribee River Management Zone, WALs are divided into classes (A, B and C) and have flow conditions that indicate when pumping may commence and/or must cease. A class WAL holders are subject to daily flow sharing within a total daily extraction limit to protect instream values from risks associated with over extraction.

Figure 5.3 shows the location of surface water diversion works (pumps) and storages (dams) associated WALs in the Medway Rivulet and Lower Wingecarribee River management zones. A breakdown of the WAL volumes by water source and management zone is presented in Table 5.7.

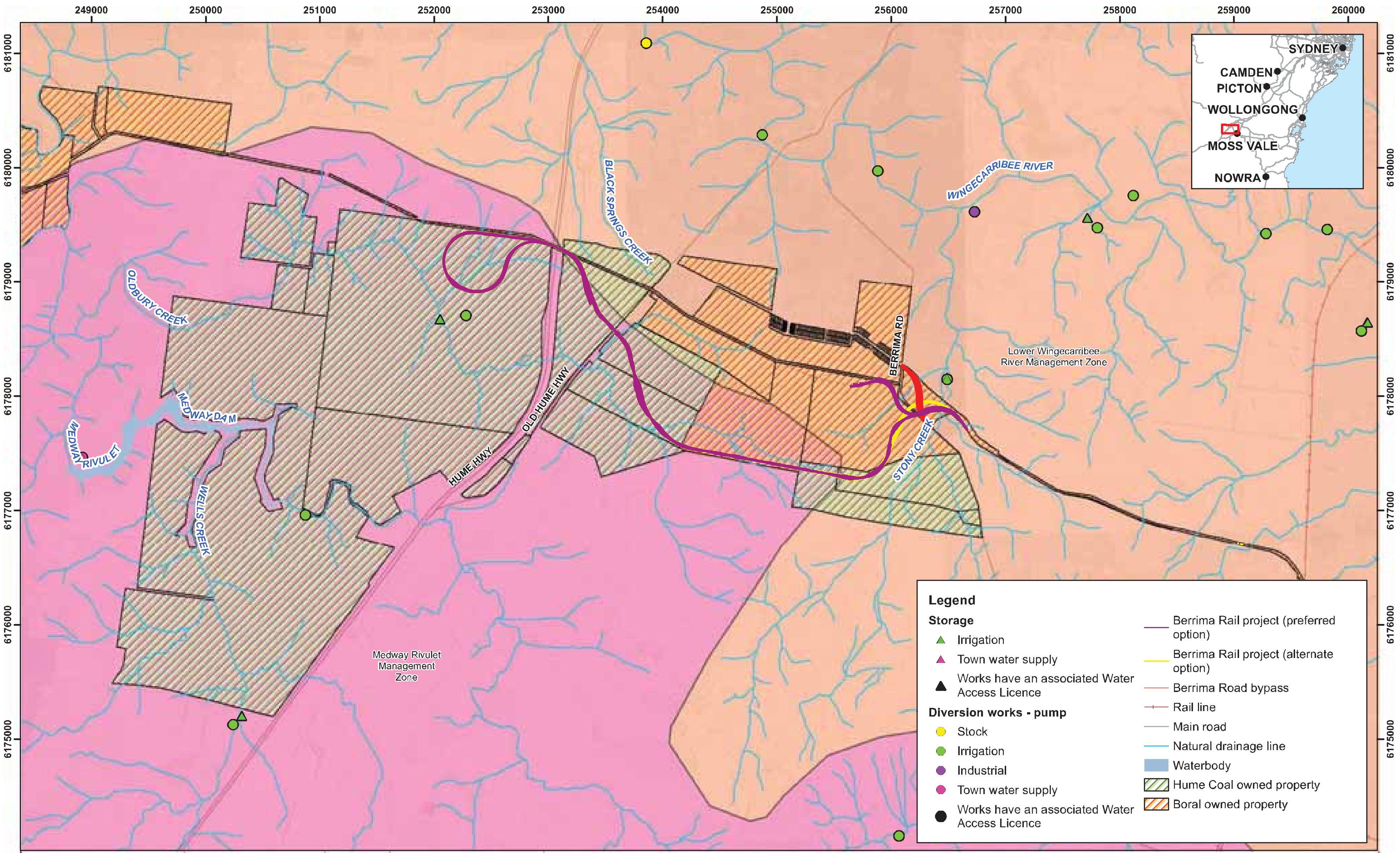
Table 5.7 Water access licence volumes

Water source	Water management zone	Number of diversion works	Number of storages	Water access licence volume (ML/a)
Upper Nepean and Warragamba water source	Medway Rivulet management zone	13	7	1,027
	Lower Wingecarribee River management zone	29	12	1,072

5.2.3.1 Town water supply

There is one WAL in the Medway Rivulet Management Zone used by WSC for town water supply. The WAL is to take 900 ML per year from the reservoir behind Medway Dam. The Berrima Rail Project is not within the upstream catchment of Medway Dam (as Oldbury Creek discharges into Medway Rivulet downstream of Medway Dam) and therefore the project will have no impacts on this water user.

Lake Burragorang, the reservoir behind Warragamba Dam, is located approximately 30 km downstream of the project area in the Lower Wollondilly River Management Zone.



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Date: 15/11/2016	Approved by: LR

Data source: NSW Property and Information 2015, Hume Coal, Google Earth

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

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Figure 5.3

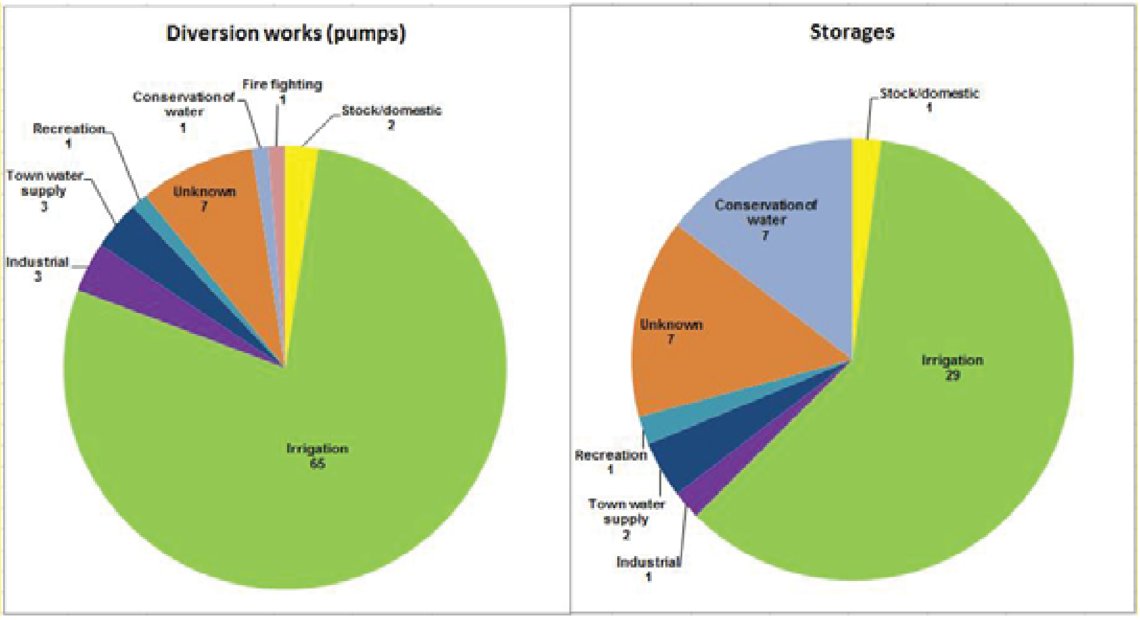
Surface water users

5.2.3.2 Local water users

There are 83 pumps and 48 dams in the study area (which includes the Medway Rivulet and Lower Wingecarribee River management zones). Of these, 7 pumps and 5 dams are located in the project area. An additional 2 pumps and 1 dam are located on properties owned by Hume Coal or subsidiaries of Hume Coal and have not been considered in this assessment.

Figure 5.4 shows the number of pumps and dams in the study area by purpose. Most pumps and dams in the study area are used for irrigation purposes or a combination of irrigation, stock and domestic purposes.

Figure 5.4 Diversion works and storages in the Upper Nepean and Warragamba water source



5.2.3.3 Basic water rights

Within the Berrima Rail Project area, water may be taken for stock or domestic purposes without a licence under basic water rights. Basic water rights in the study area include:

- Domestic and stock rights - Owners or occupiers of land which has stream frontage can take water without a licence. Water taken under a domestic and stock right may be used for normal household purposes around the house and garden and/or for drinking water for stock.
- Native title rights - Anyone who holds native title with respect to water, as determined under the *Commonwealth Native Title Act 1993*, can take and use water for a range of personal, domestic and non-commercial purposes.
- Harvestable rights – Landholders are allowed to build dams on minor streams that capture 10% of the average regional rainfall-runoff on their property without a licence to take water. The maximum harvestable right dam capacity (MHRDC) is the total dam capacity allowed under the harvestable right for a property and takes into account rainfall and variations in rainfall pattern.

The *Greater Metropolitan Region Unregulated Water Sources Water Sharing Plan 2011* estimates the water requirements of persons entitled to domestic and stock rights to be 21 ML/day in the Upper Nepean and Warragamba Water Source.

There are no native title rights in the study area. Harvestable rights are not estimated in the water sharing plan.

5.2.4 Ecosystems reliant on surface water

Ecosystems reliant on surface water in the study area include:

- Instream ecosystems; and
- Riparian ecosystems that access overbank flows and flooding.

Refer to the Berrima Rail Project Biodiversity Assessment Report (EMM, 2016) for further details.

5.2.5 Baseline surface water quality

Surface water quality monitoring has been undertaken in the project area since July 2014 and is ongoing to establish baseline (pre-development) surface water quality conditions. Monitoring is undertaken monthly at the locations shown on Figure 5.5. Details of the monitoring program and locations are provided in the *Water Fieldwork and Monitoring Report* (Parsons Brinckerhoff 2016).

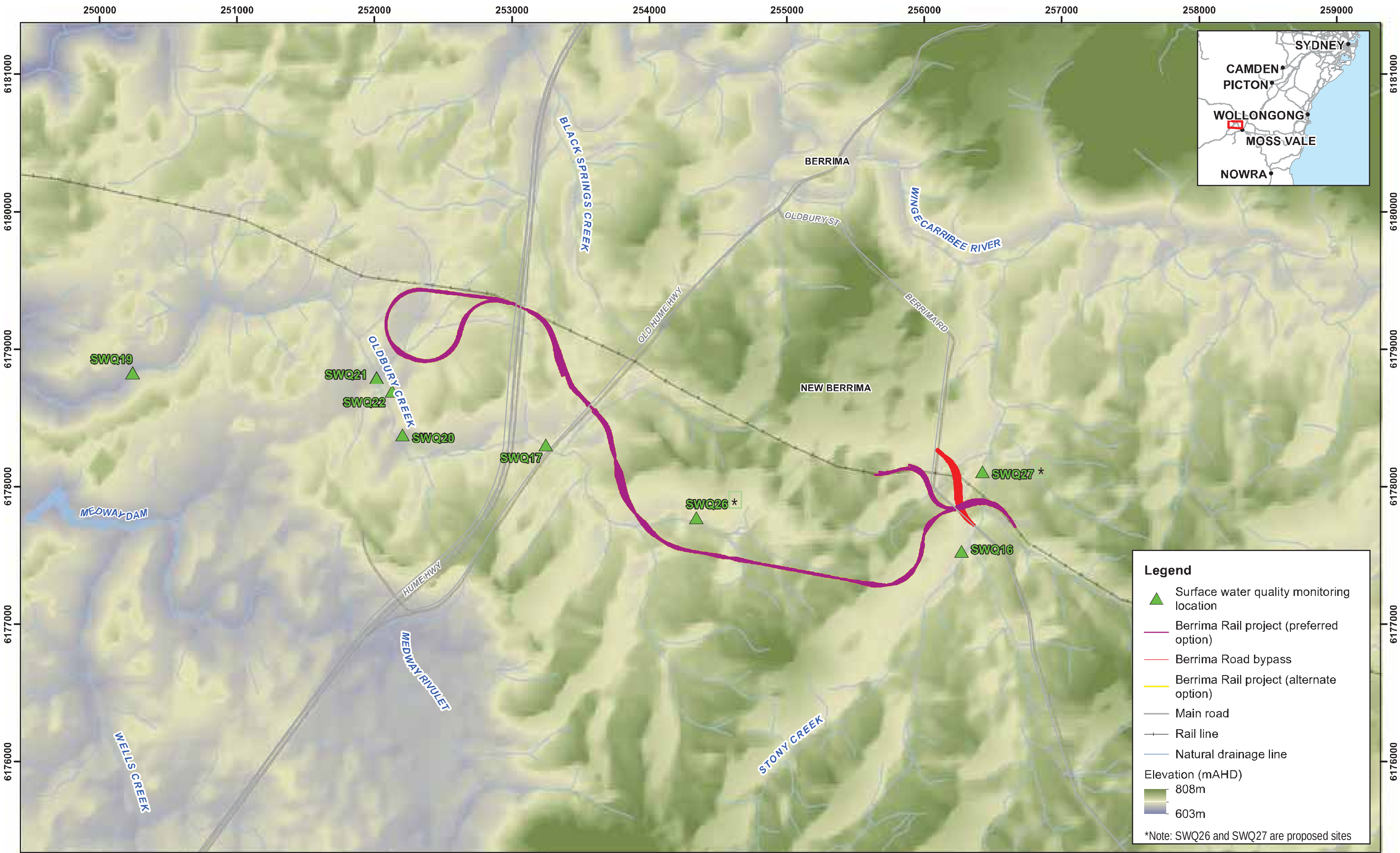
A summary of baseline surface water quality conditions in Oldbury Creek and Stony Creek for the period July 2014 to September 2015 is provided in Table 5.8. Results have been presented as a statistical analysis for monitoring locations SWQ17and SWQ19 on Oldbury Creek, SWQ20, SWQ21 and SWQ22 on farm dams on Oldbury Creek and SWQ16 on Stony Creek. There are more samples on Oldbury Creek due to there being more monitoring locations (i.e. five compared with one).

The results have been compared to the most conservative water quality guideline values for the environmental values in the project area, with the exception of nutrients which have been compared to the recommended WQOs in the report *Healthy Rivers Commission Inquiry into the Hawkesbury-Nepean River* (HRC 1998). Median and 80th percentile concentrations that exceed guideline values are shaded in grey in Table 5.8.

Baseline concentrations of key water quality parameters in Oldbury Creek and Stony Creek comply with guideline values with the exception of the following:

- Median and 80th percentile conductivity values for Oldbury Creek and Stony Creek exceed the ANZECC (2000) guideline for aquatic ecosystems
- Median and 80th percentile concentrations of nitrogen and phosphorous in Oldbury Creek and Stony Creek exceed the WQOs recommended by the Healthy Rivers Commission (HRC 1998)
- Median and 80th percentile concentrations of aluminium and copper in Stony Creek exceed the ANZECC (2000) guideline for aquatic ecosystems and 80th percentile concentrations of aluminium in Oldbury Creek exceed the ANZECC (2000) guideline for aquatic ecosystems
- Median and 80th percentile concentrations of iron in Oldbury Creek and Stony Creek exceed the ANZECC (2000) guideline for irrigation
- 80th percentile concentrations of manganese in Oldbury Creek and Stony Creek exceed the ANZECC (2000) guideline for recreation
- Median and 80th percentile concentrations of silver in Oldbury Creek and Stony Creek exceed the ANZECC (2000) guideline for aquatic ecosystems
- 80th percentile concentrations of zinc in Oldbury Creek exceed the ANZECC (2000) guideline for aquatic ecosystems.

Site specific WQOs will need to be developed for these parameters. This is discussed in Section 5.7.



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Date: 4/11/2016	Approved by: LR

Data source: Hume Coal, Google Earth

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Berrima Rail Project

Figure 5.5

Baseline surface water quality monitoring locations

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Table 5.8 Baseline surface water quality conditions in the project area

Parameter	unit	Guideline	Oldbury Creek					Stony Creek				
			No. of samples	Min	Median	80th %ile	Max	No. of samples	Min	Median	80th %ile	Max
Physical parameters												
Conductivity	µS/cm	35 – 350	39	178	456	571	1060	13	348	640	732	764
Temperature	°C	-	37	8.8	12	19	26	12	8.5	16	20	23
Turbidity	NTU	2 - 25	39	1.7	6.5	12	57	13	5.8	13	23	25
pH	pH units	6.5 - 8.0	39	5.0	7.4	7.8	9.2	13	6.4	7.3	7.6	7.9
TDS	mg/L	600	39	116	287	366	480	13	226	416	465	496
TSS	mg/L	-	39	2.0	5.0	9.0	34	13	<5	12	17	23
Nutrients												
Ammonia as N	mg/L	0.5	39	<0.01	0.04	0.12	0.42	13	<0.01	0.01	0.04	0.07
Nitrate (as N)	mg/L	0.7	39	<0.01	0.09	0.66	2.6	13	<0.01	<0.01	0.04	0.17
Nitrite (as N)	mg/L	1	39	<0.01	<0.01	0.03	0.11	13	<0.01	<0.01	<0.01	0.06
Total nitrogen as N	mg/L	0.5*	39	0.6	1.2	2.1	4.4	13	1.2	1.8	2.4	3.4
Phosphorus	mg/L	0.03*	39	<0.01	0.07	0.12	0.18	13	0.08	0.30	0.47	1.8
Major ions												
Calcium	mg/L	1,000	39	14	23	40	48	13	17	38	48	56
Chloride	mg/L	175	39	35	55	66	112	13	62	106	133	147
Magnesium	mg/L	2,000	39	7.0	9.0	13	21	13	8	18	20	20
Sodium	mg/L	115	39	20	37	50	75	13	31	53	63	72
Sulfate as SO_4	mg/L	250	39	5.0	27	73	138	13	<1	5.0	10	29
Heavy metals												
Aluminium	mg/L	0.055	39	<0.01	0.04	0.12	0.32	13	<0.01	0.06	0.16	0.30
Antimony	mg/L	0.003	39	<0.001	<0.001	<0.001	<0.001	13	<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	0.01	39	<0.001	<0.001	<0.001	0.001	13	<0.001	0.002	0.002	0.003
Barium	mg/L	1	39	0.01	0.04	0.04	0.07	13	0.004	0.04	0.06	0.08
Beryllium	mg/L	0.06	39	<0.001	<0.001	<0.001	<0.001	12	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	0.37	39	<0.05	<0.05	<0.05	0.05	13	<0.05	<0.05	<0.05	<0.05
Cadmium	mg/L	0.0002	39	<0.0001	<0.0001	<0.0001	<0.0001	13	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	39	<0.001	<0.001	<0.001	<0.001	13	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/L	0.05	39	<0.001	<0.001	<0.001	0.003	13	<0.001	<0.001	0.002	0.006

Parameter	unit	Guideline	Oldbury Creek					Stony Creek				
			No. of samples	Min	Median	80th %ile	Max	No. of samples	Min	Median	80th %ile	Max
Copper	mg/L	0.0014	39	<0.001	0.001	0.001	0.002	13	<0.001	0.002	0.003	0.008
Iron	mg/L	0.2	39	0.06	0.22	0.35	0.57	13	0.10	0.35	0.54	2.4
Lead	mg/L	0.0034	39	<0.001	<0.001	<0.001	<0.001	13	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.1	39	0.007	0.06	0.13	2.2	13	0.006	0.08	0.84	3.4
Mercury	mg/L	0.0006	1	<0.0001	N/A	N/A	<0.0001	13	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	mg/L	0.01	39	<0.001	<0.001	<0.001	0.001	13	<0.001	<0.001	0.002	0.002
Nickel	mg/L	0.011	39	<0.001	<0.001	0.002	0.002	13	<0.001	0.002	0.003	0.004
Selenium	mg/L	0.01	39	<0.01	<0.01	<0.01	0.01	13	<0.01	<0.01	0.01	0.01
Silver	mg/L	0.00005	7	<0.001^	0.02	0.02	0.02	3	<0.001^	<0.01	0.01	0.01
Zinc	mg/L	0.008	39	<0.005	0.005	0.01	0.03	13	<0.005	<0.005	<0.005	0.01
Hydrocarbons												
Benzene	µg/L	1	39	<1	<1	<1	<1	13	<1	<1	<1	<1
Toluene	µg/L	25	39	<2	<2	<2	<2	13	<2	<2	<2	<2
Ethylbenzene	µg/L	3	39	<2	<2	<2	<2	13	<2	<2	<2	<2
Total xylene	µg/L	20	39	<2	<2	<2	<2	13	<2	<2	<2	<2
Naphthalene	µg/L	16	39	<5	<5	<5	<5	13	<5	<5	<5	<5

*WQO recommended by *Healthy Rivers Commission Inquiry into the Hawkesbury-Nepean River* (HRC 1998).
^ Standard and trace laboratory limits of reporting exceed the ANZECC guideline for aquatic ecosystems.
N/A indicates low number of samples statistical value not possible to determine until more data is collected

Time series plots of TDS concentrations in Oldbury Creek and Stony Creek are presented in Figure 5.6. TDS at downstream monitoring location SWQ19 on Oldbury Creek is fresher than at upstream monitoring locations SWQ17, SWQ20, SWQ21 and SWQ22. TDS concentrations at SWQ16 on Stony Creek are comparable to concentrations at SWQ17 on Oldbury Creek, ranging between 200 mg/L and 500 mg/L. The results generally show a freshening of surface waters following rainfall events, although this is not always apparent as surface water quality samples are collected on a monthly basis and the timing of sampling does not always correspond with rainfall events.

Time series plots of TSS concentrations in Oldbury Creek and Stony Creek are presented in Figure 5.7. TSS concentrations in Oldbury Creek are generally lower than in Stony Creek. TSS concentrations in the farm dams on Oldbury Creek are comparable to concentrations in Stony Creek. The results show a reduction in TSS following a number of rainfall events, although this is not always apparent as surface water quality samples are collected on a monthly basis and the timing of sampling does not always correspond with rainfall events.

Time series plots of pH in Oldbury Creek and Stony Creek are presented in Figure 5.8. pH in Oldbury Creek, the farm dams on Oldbury Creek and Stony Creek generally ranges between 6.5 and 8.0, although a number of samples in the farm dams on Oldbury Creek had pH above 8.0. One sample at SWQ19 recorded a pH of 5.0 and one sample at SWQ21 recorded a pH of 9.2, however these results are likely to be anomalous.

Time series plots of TN concentrations in Oldbury Creek and Stony Creek are presented in Figure 5.9. Concentrations of TN at SWQ16 on Stony Creek and SWQ17 on Oldbury Creek were generally within the range 1.0 mg/L to 3.5 mg/L. Concentrations of TN in the farm dams on Oldbury Creek were generally less than 2.0 mg/L and concentrations of TN at downstream location SWQ19 on Oldbury Creek were generally around 1.0 mg/L or less.

Time series plots of total phosphorous (TP) concentrations in Oldbury Creek and Stony Creek are presented in Figure 5.10. TP concentrations in Stony Creek are higher than in Oldbury Creek. TP concentrations at downstream location SWQ19 were lower than at upstream locations SWQ17, SWQ20, SWQ21 and SWQ22 on Oldbury Creek.

Figure 5.6 Baseline total dissolved solids in Oldbury and Stony Creeks

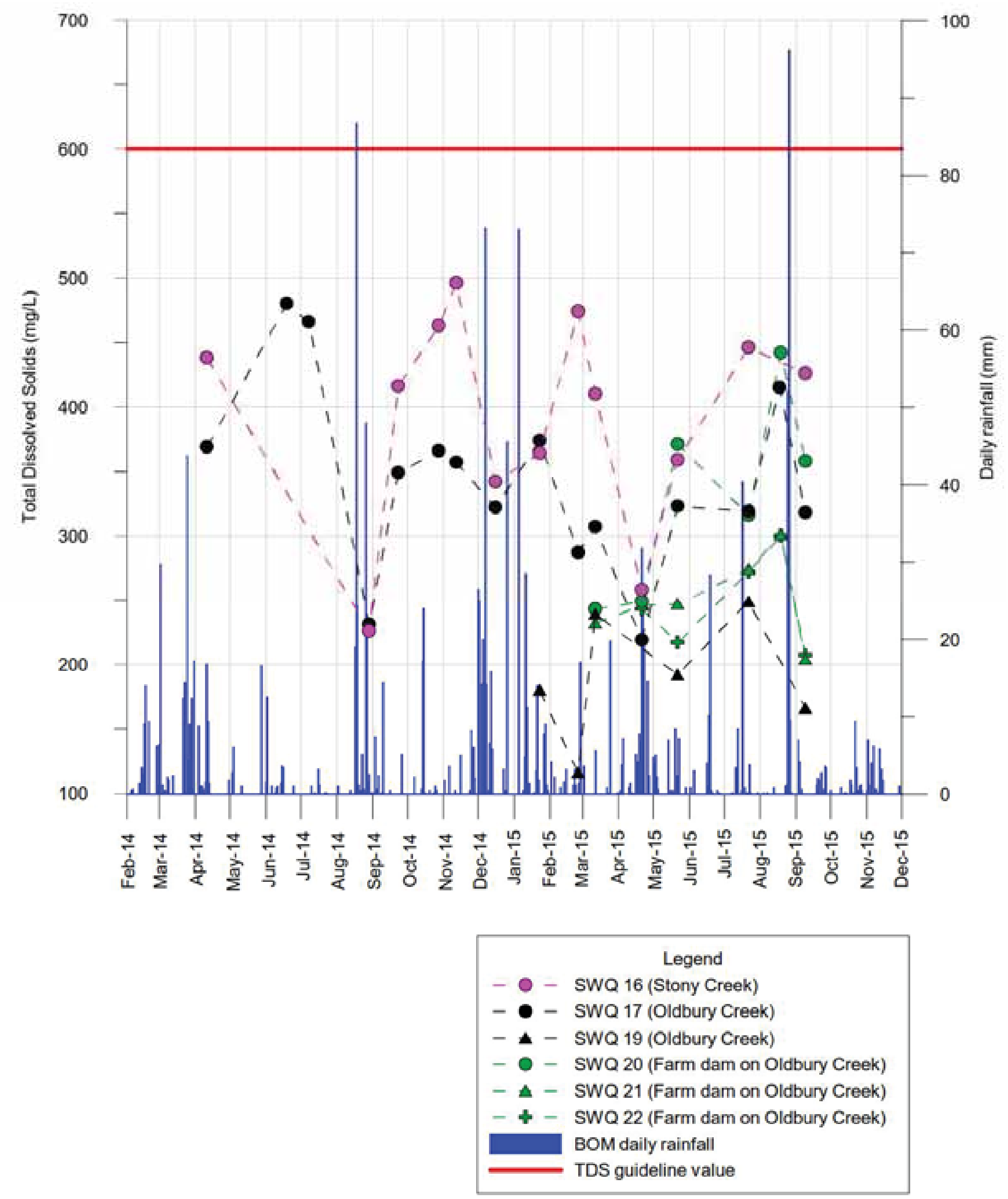


Figure 5.7 Baseline total suspended solids in Oldbury and Stony Creeks

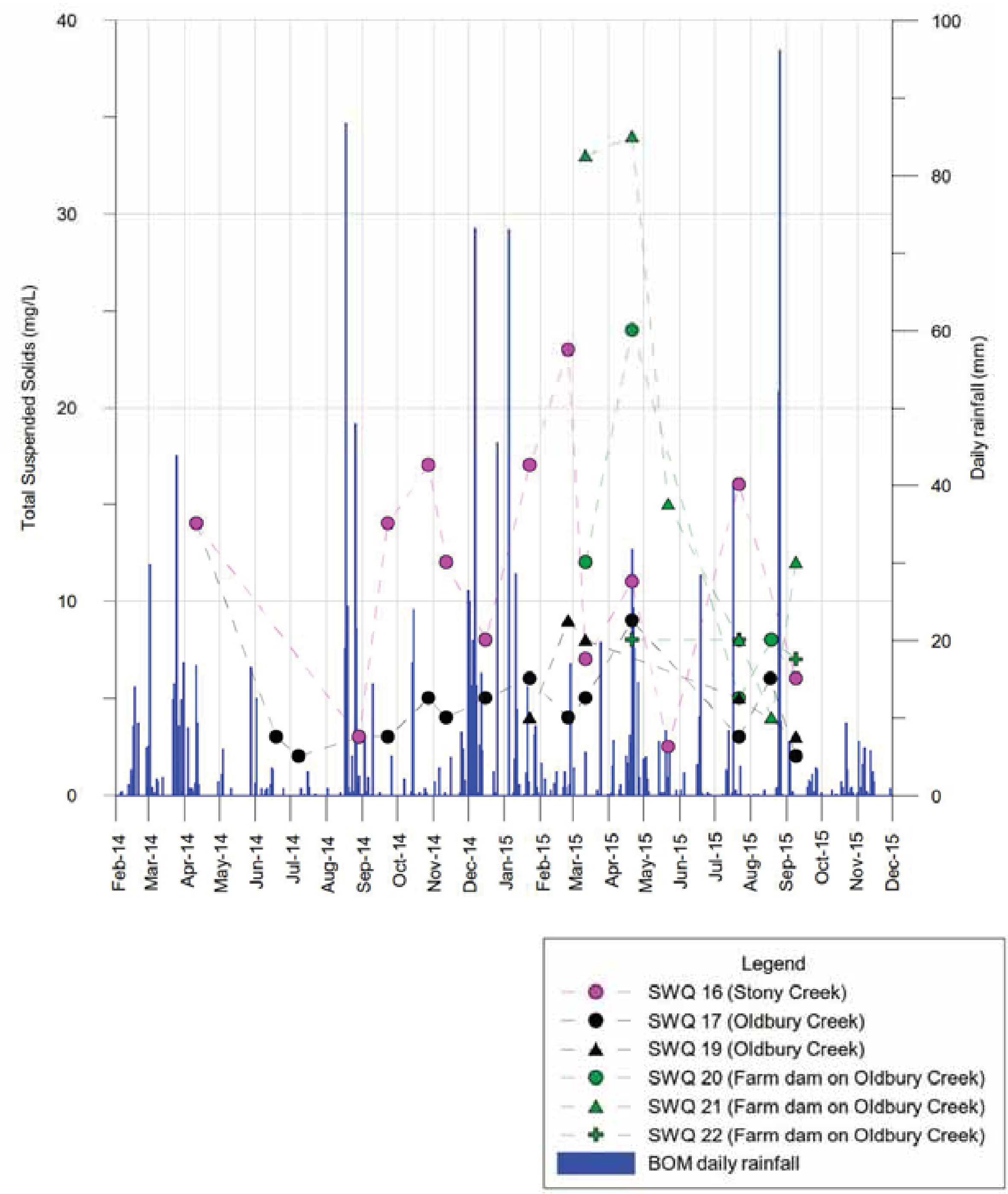


Figure 5.8 Baseline pH in Oldbury and Stony Creeks

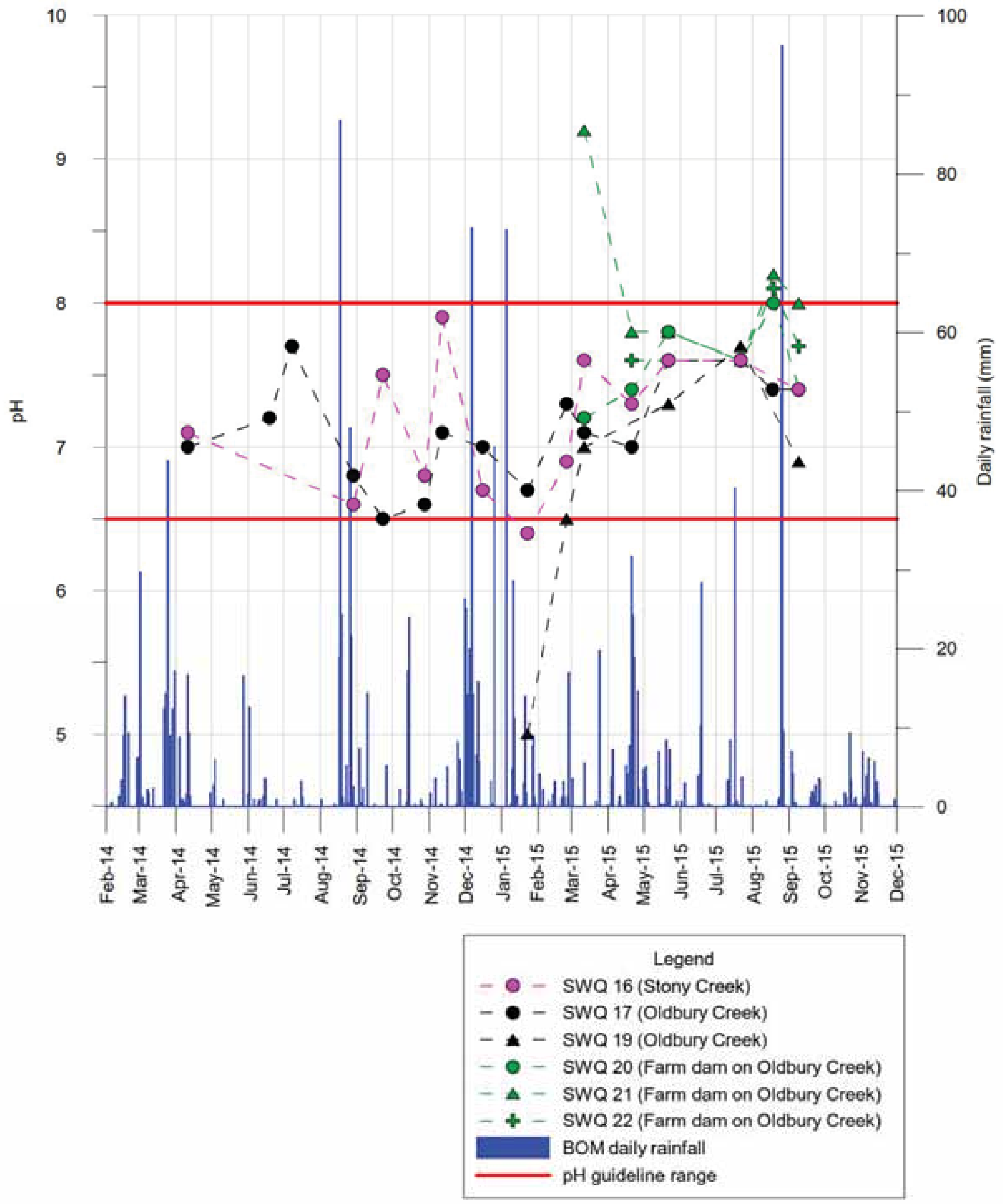


Figure 5.9 Baseline total nitrogen in Oldbury and Stony Creeks

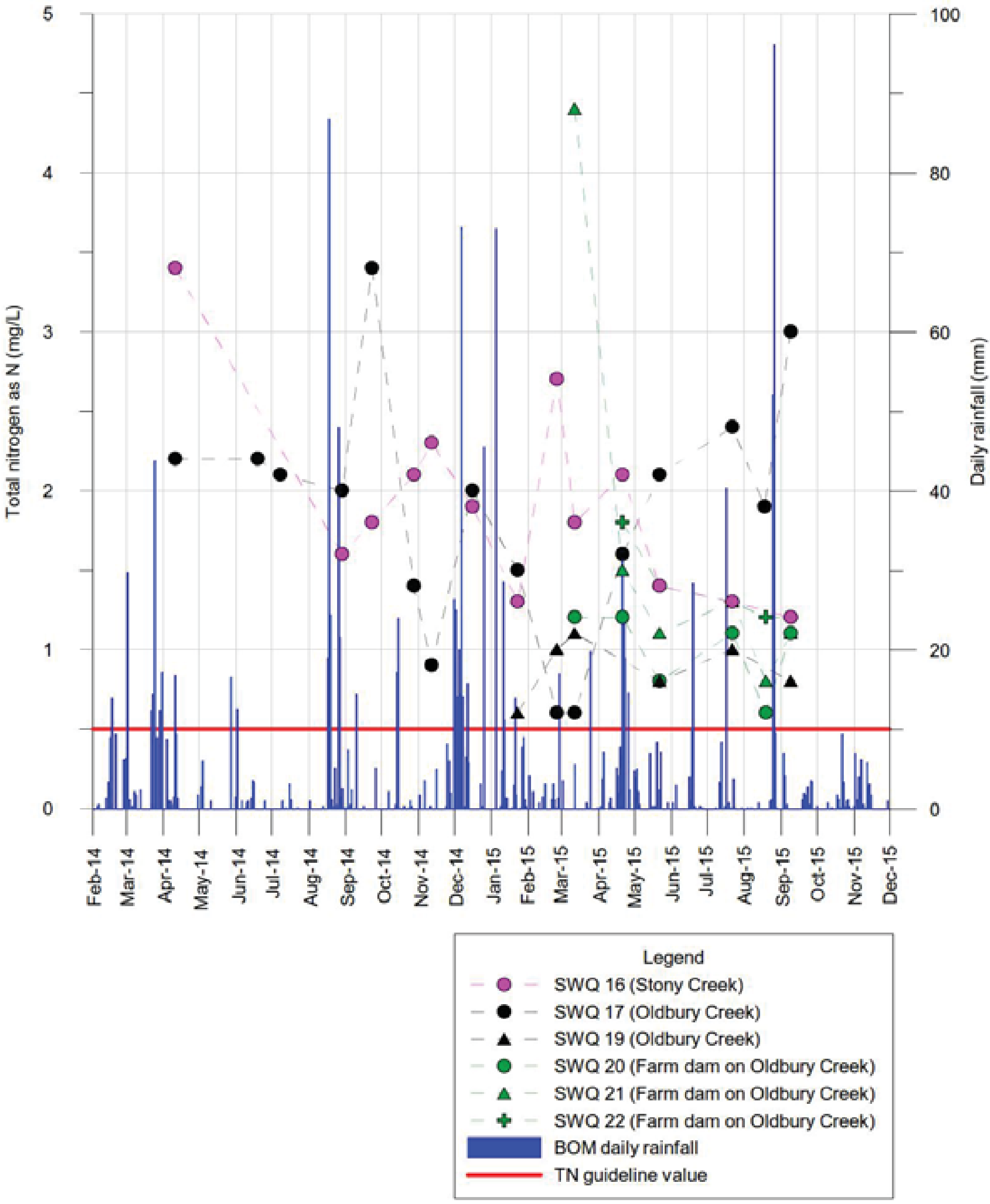
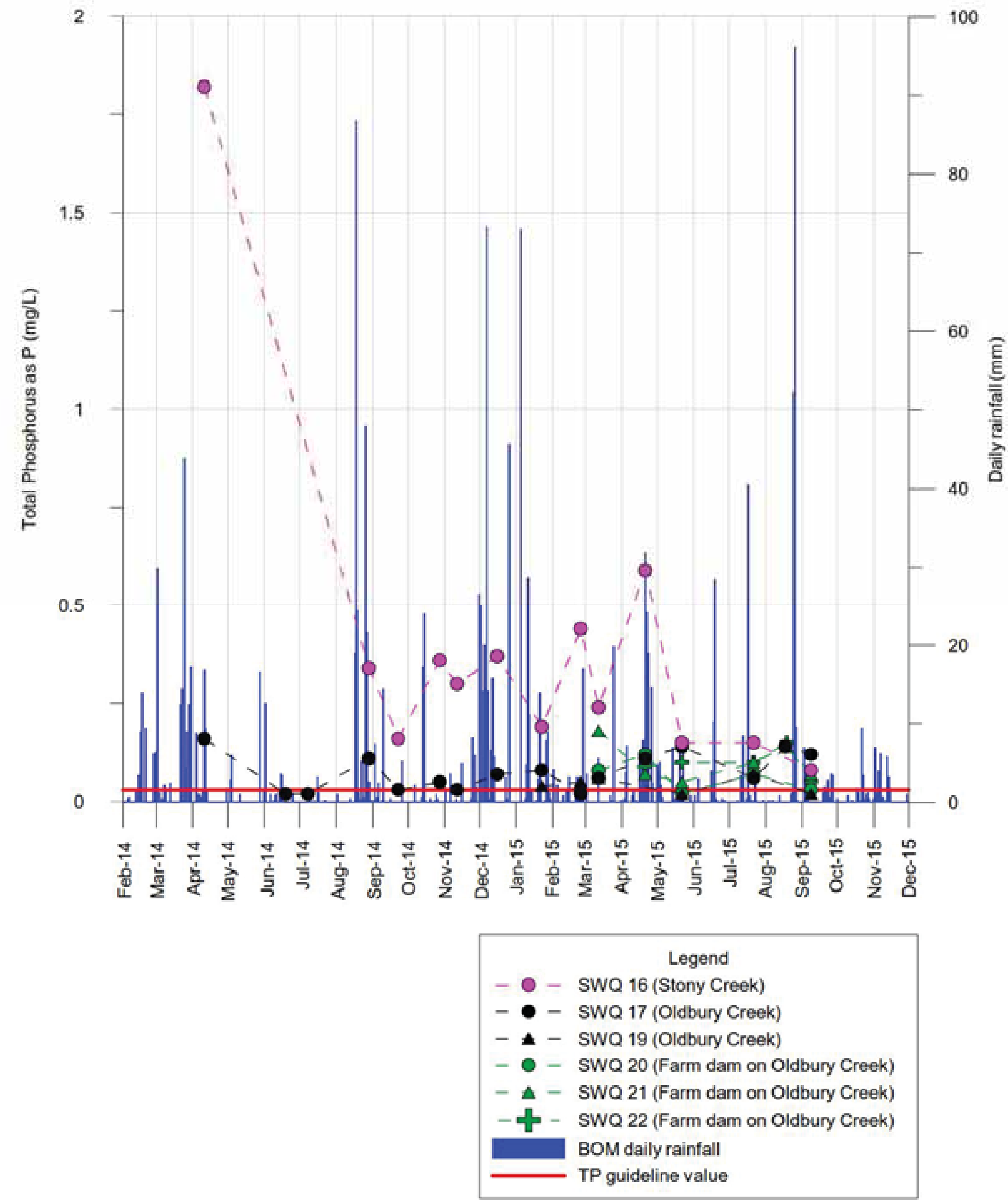


Figure 5.10 Baseline total phosphorus in Oldbury and Stony Creeks



5.3 Preferred option impact assessment

This section presents the results of the MUSIC modelling for the preferred project option. Results are presented for the existing conditions and operational scenario with treatment for the four sub-catchments (denoted as 'segments' on Figure 5.1) of Oldbury Creek and the single sub-catchment (or 'segment' – see Figure 5.1) of Stony Creek.

To assess whether the project and its associated treatment measures will have a NorBE on water quality, modelling results for the operation with treatment scenario have been compared to modelling results for the existing scenario and assessed against the criteria for mean annual pollutant loads and pollutant concentrations between the 50th and 98th percentiles as specified in the WaterNSW standards (2012) and summarised in Section 5.1.3.4.

5.3.1 Comparison of mean annual pollutant loads

Table 5.9 provides a summary of the existing, operation and operation with swale treatment scenarios for the Oldbury Creek and Stony Creek sub-catchments. Varying swale lengths were modelled to identify the length of swale that provides at least a 10% reduction in the mean annual load for the most onerous parameter, which was TN in all sub catchments, apart from Oldbury Creek Sub Catchment 2, where the most onerous parameter was TSS. This resulted in significantly higher reductions in mean annual load for the other parameters. The resulting lengths of swale for each sub-catchment are given in Table 5.10. As well as the rail corridor, a sealed access road and hardstand areas are also located within Oldbury Creek sub-catchments 3 and 4, and a significant component of the swale length is therefore due to the access road and hardstand areas.

Table 5.9 Mean annual pollutant load reduction (preferred option)

Parameter	Existing* (kg/yr)	Operation with treatment (kg/yr)	Difference to existing
Oldbury Creek Sub-Catchment 1			
TSS	346	271	-22%
TP	1.37	0.613	-55%
TN	7.73	6.94	-10%
Oldbury Creek Sub-Catchment 2			
TSS	494	444	-10%
TP	2.09	0.916	-56%
TN	11.8	10.1	-14%
Oldbury Creek Sub-Catchment 3			
TSS	1100	93.3	-92%
TP	4.77	0.626	-87%
TN	25.5	22.8	-11%
Oldbury Creek Sub-Catchment 4			
TSS	1390	915	-34%
TP	6.00	2.38	-60%
TN	31.3	27.8	-11%
Stony Creek Sub-Catchment			
TSS	1060	712	-33%
TP	4.49	1.94	-57%
TN	24.5	21.7	-11%

*Existing is agricultural node which is 100% pervious

Table 5.10 Swale length (preferred option)

Sub-catchment	Rail/access road corridor length (m)	Swale length (m)
Oldbury Creek 1	1,000	90
Oldbury Creek 2	1,050	85
Oldbury Creek 3 rail corridor	1,200	400
Oldbury Creek 3 road corridor	700	180
Oldbury Creek 4 rail corridor	2,800	500
Oldbury Creek 4 road corridor	400	180
Stony Creek	2,350	450

The results show that the preferred project option meets the NorBE criteria for mean annual pollutant loads in the Oldbury Creek and Stony Creek catchments, i.e. more than a 10% reduction in mean annual pollutant load in each sub-catchment.

5.3.2 Comparison of pollutant concentrations

Cumulative frequency graphs of TN and TP concentrations for each modelled sub-catchment for the existing and operation with treatment scenarios are provided in Appendix J. Graphs are provided for each modelled sub-catchment.

Comparison indicates that pollutant concentrations for the operation with treatment scenario were equal to or better than the existing scenario between the 50th and 98th percentiles, and therefore compliance with the NorBE assessment criteria is achieved.

5.4 Alternate option impact assessment

This section presents the results of the MUSIC modelling for the alternate project option. Results are presented for the existing and operation with treatment scenarios for the single sub-catchment of Stony Creek only (see Figure 5.1), as the rail infrastructure is the same in Oldbury Creek for both the preferred and alternate options. The rail corridor is 1000 m shorter within the Stony Creek sub-catchment for the alternate option.

To assess whether the project and its associated treatment measures will have a NorBE on water quality, modelling results for the operation with treatment scenario have been compared to modelling results for the existing scenario and assessed against the criteria for mean annual pollutant loads and pollutant concentrations between the 50th and 98th percentiles as specified in the WaterNSW standards (2012) and summarised in Section 5.1.3.4.

5.4.1 Comparison of annual pollutant loads

Table 5.11 provides a summary of the existing, operation and operation with treatment scenarios for the Stony Creek sub-catchment. Varying swale lengths were modelled to identify the minimum length of swale that provides at least a 10% reduction in the mean annual load for the most onerous parameter, which was TSS. This resulted in significantly higher reductions in mean annual load for TSS and TP. A swale length of 120 m was adopted to treat the rail corridor length of 1350 m.

Table 5.11 Mean annual pollutant load reduction (alternate option)

Parameter	Existing* (kg/yr)	Operation with treatment (kg/yr)	Difference to existing
Stony Creek Sub-Catchment			
TSS	571	515	-10%
TP	2.5	1.1	-56%
TN	13.7	12.1	-12%

*Existing is agricultural node which is 100% pervious

The results show that the alternate project option meets the NorBE criteria for mean annual pollutant loads in the Stony Creek catchment, i.e. more than a 10% reduction in mean annual pollutant load in the sub-catchment.

5.4.2 Comparison of pollutant concentrations

Cumulative frequency graphs of TN and TP concentrations for the pre-development and post-development with treatment scenarios are provided in Appendix J.

Comparison indicates that pollutant concentrations for the operation with treatment scenario were equal to or better than the existing scenario between the 50^{th} and 98^{th} percentiles, and therefore compliance with the NorBE assessment criteria is achieved.

5.5 Cumulative impact assessment

The results of modelling undertaken to assess potential impacts to surface water quality associated with the Hume Coal Project are presented in the Hume Coal Project EIS. The surface water quality assessment undertaken for the Hume Coal Project (EMM 2016) indicates that with the implementation of appropriate management plans and treatment measures in place (i.e. swales), the water quality in Oldbury Creek will not be impacted by construction, operation or rehabilitation of the Hume Coal Project. Cumulative impacts to surface water quality associated with the Hume Coal and Berrima Rail projects will therefore be negligible.

5.6 Summary of results

MUSIC modelling has shown that the preferred and alternate project options comply with the NorBE assessment criteria for pollutant loads and pollutant concentrations. The preferred option requires an extra 330m of swale within the Stony Creek sub-catchment as the rail corridor is 1000 m longer within this sub-catchment compared to the alternate option.

5.7 Mitigation measures and monitoring program

This section presents the mitigation and management measures to be implemented for the Berrima Rail Project to avoid impacts on surface water quality. Mitigation and management measures will be implemented during construction and rehabilitation as well as during operation of the rail line.

5.7.1 Construction and rehabilitation

The construction and rehabilitation phases of the project will involve earthworks activities which have the potential to cause erosion and sedimentation of local waterways if not appropriately managed.

An erosion and sedimentation control plan will be prepared, as specified in Section 3.6.2. The erosion and sedimentation control plan will also be part of the Water Cycle Management Plan for the project, as required by Developments in Sydney's Drinking Water Catchment – Water Quality Information Requirements (WaterNSW 2015). The erosion and sediment control plan will be developed to achieve the surface water management objective below, and will incorporate the soil and water management principles set out in Section 5.7.1.2 below.

5.7.1.1 Surface water management objective

According to Vol. 2 of Managing Urban Stormwater: Soils and Construction the goal for surface water management is:

> '…to ensure that there is no pollution of surface or ground waters. Current best-practice erosion and sediment control techniques are, however, unlikely to achieve this goal, due to the limited effectiveness of most of these techniques. An appropriate management objective is therefore to take all reasonable measures (i.e. implement best-practice) to minimise water-quality impacts from erosion and sedimentation.
>
> Given the limited effectiveness of techniques for retaining eroded sediment, a strong emphasis should be placed on pollution prevention through erosion control, rather than relying on treatment techniques to capture these sediments.'

Therefore, with the paramount objective of not polluting surface waters in the first place, the strategy should be to minimise the discharge of sediment-laden waters from the sites to the adjacent waterways and drainage lines.

5.7.1.2 Soil and water management principles

The primary principle for surface water management at the site is to minimise erosion and sediment generation at the source, and where this is not possible, to capture and treat any sediment generated before discharge into receiving waterways. The following general principles provide a framework for the development of site-specific options to achieve this:

- Minimise the volume of clean surface water running onto the site from off site
- Minimise the extent of disturbed areas
- Minimise surface water from running onto disturbed areas of the site by staging operations and, where necessary, utilising surface water diversion drains and bunds for disposal and processing areas
- Implement erosion control strategies to minimise generation of sediment in the surface water
- Implement sediment control strategies to reduce the release of sediment in surface water from the site
- Minimising the amount of surface water runoff discharged from the site and maximising reuse onsite
- Maintain all erosion and sediment controls properly by implementing an inspection schedule
- Vegetate disturbed areas progressively.
- Adopt strategies for early identification of potential surface water issues

5.7.1.3 Specific measures

The project would utilise standard measures to minimise water quality impacts during the construction and rehabilitation phases. The principle of minimal disturbance during construction/rehabilitation would be observed and the primary focus would be on implementing erosion controls over sediment controls. By minimising erosion, less pressure is placed on sediment controls, thus reducing the risk of the project causing water pollution.

For particularly sensitive areas, the following measures would be adopted to avoid impacts:

- Clearly delineating the construction boundary;
- Clearly fencing and delineating environmentally sensitive areas that remain within the project boundary;
- Marking out vegetation within the corridor that can be retained as a buffer;

- Providing fencing and sediment fences supported by gravel filters along the edge of the footprint to prevent access and filter run-off where required;
- Addressing the importance of environmentally sensitive areas, and buffer zones, and compliance through induction and environmental training;
- Ensuring that temporary drainage does not directly contaminate run-off into the sensitive areas; and
- Providing appropriate erosion and sediment controls to prevent erosion at the source.

Where significant areas of disturbance may be required during construction, temporary sediment basins would be provided. These would be sized using Managing Urban Stormwater: Soils and Construction (the 'Blue Book') (Landcom 2004, DECC 2008). The sediment basins would provide sufficient volume for settling and storage of sediments. The settling zone volume would be estimated using the appropriate design rainfall depth and disturbed catchment areas and the storage zone would be estimated using the Revised Universal Soil Loss Equation. The sediment basins would be designed as Type C (coarse-grained soils), Type F (fine-grained soils) or Type D (dispersive soils) basins, as per the Blue Book classifications and the assumed soil parameters.

5.7.2 Operation

5.7.2.1 Modelled treatment measures

A swale system has been modelled to convey and filter stormwater runoff through vegetated channels. The adopted parameters are described in Section 5.1.3.3. The swales will generally be located at the downstream extent of the rail corridor within each sub-catchment to treat the runoff before discharge into the local stream channels or overland flow paths. The lengths of the rail / access road corridors and required swales within each sub-catchment are provided in Table 5.10.

5.7.2.2 Management measures

The Water Cycle Management Plan will outline all surface water management works following the relevant guidelines set out in the Blue Book, Volume 1 (Landcom, 2004) and the Blue Book, Volume 2 (DECC, 2008). As the exact location of encampments, stockpiles and machinery compounds along with the fine details of proposed works are yet to be finalised, the information is intended to provide for general stormwater management strategies. The following site-specific controls would be finalised in the Water Cycle Management Plan:

- Minimise land disturbance
- Vegetate disturbed areas progressively
- Stabilisation and drainage of site access roads
- Control vehicular access to site
- Dust control
- Soil and stockpile management
- Clean water diversion
- Sediment basin systems for long-term work areas, if required
- Vegetation establishment
- Site induction and staff training and education
- Inspection and monitoring
- Maintenance of surface water management measures
- Minimise surface water runoff discharged from the site and maximise reuse onsite
- Properly maintain all erosion and sediment controls by implementing an inspection schedule
- Adopt strategies for early identification of potential surface water issues.

5.7.3 Surface water quality monitoring program

A surface water quality monitoring program will be implemented for the waterways receiving runoff from the project area during construction, operation and rehabilitation of the project. The program will involve surface water quality monitoring in Oldbury Creek and Stony Creek upstream and downstream of working areas during construction and rehabilitation and upstream and downstream of rail infrastructure during operation.

Results of the surface water quality monitoring will be compared to site specific WQOs developed in accordance with the National Water Quality Management Strategy to assess impacts to surface water quality in the receiving environment associated with the project and trigger the implementation of mitigation and remediation measures if required.

5.7.3.1 Monitoring locations

Surface water quality monitoring will be undertaken at existing monitoring locations SWQ17 and SW19 on Oldbury Creek and SWQ16 on Stony Creek. Two additional locations will also be monitored: SWQ26 on Oldbury Creek, upstream of the rail alignment, and SWQ27 on Stony Creek downstream of the rail alignment.

Monitoring at locations upstream and downstream of working areas and the rail alignment will allow the impacts of the project to be assessed. The surface water quality monitoring locations for the project are shown on Figure 5.11.

5.7.3.2 Monitoring frequency

Surface water quality monitoring will be undertaken on a monthly basis at the locations shown on Figure 5.11. Monitoring will be undertaken throughout the construction, operation and rehabilitation phases of the project.

Monthly surface water quality monitoring will continue at the locations shown on Figure 5.11 prior to construction of the project to continue development of the baseline dataset. Depending on the level of construction activity, the monitoring frequency during the construction and rehabilitation phases may be reviewed and reduced during periods of little or no activity.

5.7.3.3 Key parameters

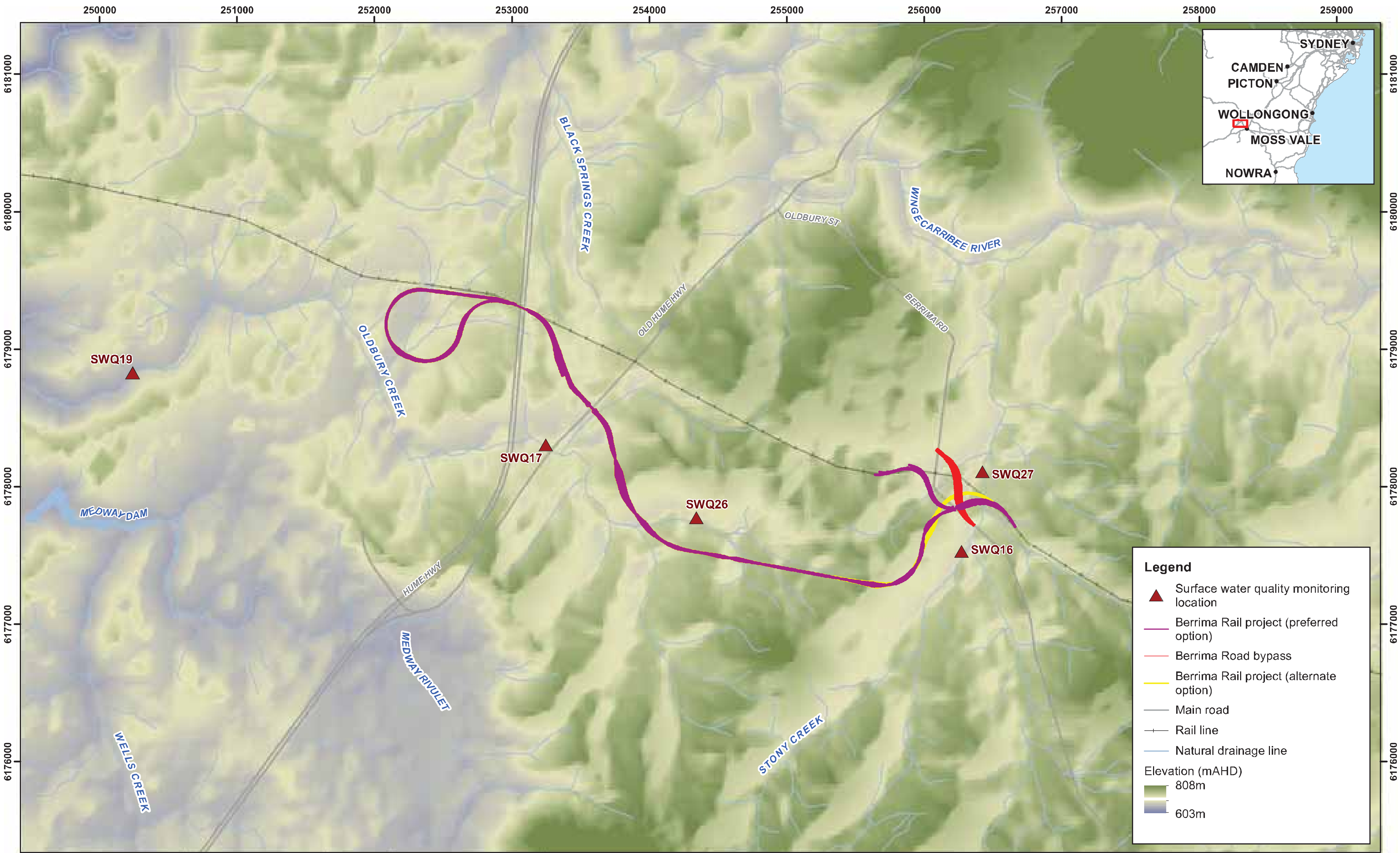
Surface water quality monitoring will be undertaken for the potential contaminants associated with project activities during construction, operation and rehabilitation of the project. Key parameters of concern in the Hawkesbury-Nepean catchment, as identified in the report *Healthy Rivers Commission Inquiry into the Hawkesbury-Nepean River* (HRC 1998), will also be monitored (refer Section 5.1.1.6). Provision should be made to review the monitoring program annually or every two years so that redundancies and other improvements can be made based on the results of the monitoring program.

The key parameters for the surface water quality monitoring program are summarised in Table 5.12.

Table 5.12 Parameters for surface water quality monitoring program

Category	Suite of analytes
Physical parameters	Total dissolved solids, suspended solids, turbidity
Major ions	Calcium, magnesium, sodium, potassium, chloride, sulfate, alkalinity, reactive silica
Metals – dissolved	Aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, zinc.
Nutrients	Ammonia, nitrate, nitrite, nitrogen (total), phosphorous (total and reactive)
Hydrocarbons	TRH/TPH, BTEX, naphthalene

TRH/TPH – Total Recoverable Hydrocarbons/Total Petroleum Hydrocarbons
BTEX – Benzene, Toluene, Ethylbenzene, Xylene



Map: 2200569A_GIS_038_A4

Author: RP

Date: 4/11/2016

Approved by: LR

Data source: , Hume Coal, Google Earth

0 500 1,000 m

1:25,000

Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

WSP | PARSONS BRINCKERHOFF

Berrima Rail Project

Figure 5.11

Receiving environment monitoring locations

5.7.3.4 Water quality objectives

WQOs are specific water quality targets that can be used as indicators of management performance.

The environmental values in the project area are provided in Section 5.2.2 and guideline values for these provided in Table 5.8.

For total nitrogen and total phosphorous, the WQOs will be adopted from the report *Healthy Rivers Commission Inquiry into the Hawkesbury Nepean River* (HRC 1998), which provides catchment specific WQOs for these nutrients.

In circumstances where the median or 80th percentile baseline concentration exceeds the guideline value in the NWQMS guidelines or the WQO in the Healthy Rivers Commission report, site specific WQOs will be developed in accordance with the referential approach in ANZECC (2000). The referential approach involves calculating WQOs on the basis of maximum acceptable departure from reference condition. The acceptable departure suggested is that the WQO be based on the 20th and/or 80th percentile (whichever is most appropriate for the indicator) of values at the reference site.

Ideally site specific WQOs should be based on 24 months of monthly baseline or reference data. The surface water quality results presented in this report are for the period July 2014 to September 2015, however monthly surface water quality monitoring is ongoing and further data will be available in future. Preliminary WQOs and the relevant source basis are provided in Table 5.13. Final WQOs will be developed using the additional surface water quality data collected prior to commencement of construction of the project.

Table 5.13 Preliminary water quality objectives for the Berrima Rail Project

Parameter	Unit	Oldbury Creek		Stony Creek	
		Preliminary WQO	Source	Preliminary WQO	Source
Physical parameters					
Conductivity	µS/cm	571	Preliminary WQO (80th percentile of baseline)	732	Preliminary WQO (80th percentile of baseline)
Turbidity	NTU	–25*	ANZECC aquatic ecosystems	–25*	ANZECC aquatic ecosystems
pH	pH units	6.5 - 8.0	ANZECC aquatic ecosystems	6.5 - 8.0	ANZECC aquatic ecosystems
Total dissolved solids (TDS)	mg/L	600	ADWG aesthetic	600	ADWG aesthetic
Total suspended solids (TSS)	mg/L	9	Preliminary WQO (80th percentile of baseline)	17	Preliminary WQO (80th percentile of baseline)
Nutrients					
Ammonia as N	mg/L	0.5	ADWG aesthetic	0.5	ADWG aesthetic
Nitrate (as N)	mg/L	0.7	ANZECC aquatic ecosystems	0.7	ANZECC aquatic ecosystems
Nitrite (as N)	mg/L	1	ANZECC recreational	1	ANZECC recreational
Total nitrogen as N	mg/L	2.1	Preliminary WQO (80th percentile of baseline)	2.4	Preliminary site specific WQO

Parameter	Unit	Oldbury Creek		Stony Creek	
		Preliminary WQO	Source	Preliminary WQO	Source
Phosphorus	mg/L	0.12	Preliminary WQO (80th percentile of baseline)	0.47	Preliminary WQO (80th percentile of baseline)
Major ions					
Calcium	mg/L	1,000	ANZECC livestock	1,000	ANZECC livestock
Chloride	mg/L	175	ANZECC irrigation	175	ANZECC irrigation
Magnesium	mg/L	2,000	ANZECC livestock	2,000	ANZECC livestock
Sodium	mg/L	115	ANZECC irrigation	115	ANZECC irrigation
Sulfate as SO_4	mg/L	250	ADWG aesthetic	250	ADWG aesthetic
Metals					
Aluminium	mg/L	0.12	Preliminary WQO (80th percentile of baseline)	0.16	Preliminary WQO (80th percentile of baseline)
Antimony	mg/L	0.003	ADWG health	0.003	ADWG health
Arsenic	mg/L	0.01	ADWG health	0.01	ADWG health
Barium	mg/L	1	ANZECC recreational	1	ANZECC recreational
Beryllium	mg/L	0.06	ADWG health	0.06	ADWG health
Boron	mg/L	0.37	ANZECC aquatic ecosystems	0.37	ANZECC aquatic ecosystems
Cadmium	mg/L	0.0002	ANZECC aquatic ecosystems	0.0002	ANZECC aquatic ecosystems
Chromium	mg/L	0.001	ANZECC aquatic ecosystems	0.001	ANZECC aquatic ecosystems
Cobalt	mg/L	0.05	ANZECC irrigation	0.05	ANZECC irrigation
Copper	mg/L	0.0014	ANZECC aquatic ecosystems	0.003	Preliminary WQO (80th percentile of baseline)
Iron	mg/L	0.35	Preliminary WQO (80th percentile of baseline)	0.5	Preliminary WQO (80th percentile of baseline)
Lead	mg/L	0.0034	ANZECC aquatic ecosystems	0.0034	ANZECC aquatic ecosystems
Manganese	mg/L	0.13	Preliminary WQO (80th percentile of baseline)	0.84	Preliminary WQO (80th percentile of baseline)
Mercury	mg/L	0.0006	ANZECC aquatic ecosystems	0.0006	ANZECC aquatic ecosystems
Molybdenum	mg/L	0.01	ANZECC irrigation	0.01	ANZECC irrigation

Parameter	Unit	Oldbury Creek		Stony Creek	
		Preliminary WQO	Source	Preliminary WQO	Source
Nickel	mg/L	0.011	ANZECC aquatic ecosystems	0.011	ANZECC aquatic ecosystems
Selenium	mg/L	0.01	ADWG health	0.01	ADWG health
Silver	mg/L	0.02	Preliminary WQO (80th percentile of baseline)	0.01	Preliminary WQO (80th percentile of baseline)
Zinc	mg/L	0.01	Preliminary WQO (80th percentile of baseline)	0.008	ANZECC aquatic ecosystems
Hydrocarbons					
Benzene	µg/L	1	ADWG health	1	ADWG health
Toluene	µg/L	25	ADWG aesthetic	800	ADWG health
Ethylbenzene	µg/L	3	ADWG aesthetic	300	ADWG health
Xylene	µg/L	20	ADWG aesthetic	600	ADWG health
Naphthalene	µg/L	16	ANZECC aquatic ecosystems	16	ANZECC aquatic ecosystems
**Upper limit used*					

5.7.3.5 Water quality objective exceedance response

Exceedances of the WQOs at downstream monitoring locations SWQ17 and SWQ19 on Oldbury Creek and SWQ27 on Stony Creek will be investigated as follows:

- The concentration at the downstream monitoring location would be compared to the concentration at the upstream monitoring location and:
  - if the concentration at the upstream location exceeds or is equal to the concentration at the downstream location, no further action is required; or
  - if the concentration at the upstream location is lower than the concentration at the downstream location, then the monitoring locations are resampled. If resampling confirms the exceedance of the WQO at the downstream location and the lower concentrations at the upstream location, an investigation into the source of contamination and risks to environmental values would be undertaken.
- If the investigation indicates potential for risks to environmental values, an action plan to mitigate potential harm would be developed.

5.8 Conclusion

Construction and rehabilitation phase impacts of the project on surface water quality will be subject to development of specific measures to control erosion and sedimentation. An erosion and sedimentation control plan, developed in accordance with Landcom (2004) and DECC (2008) guidelines, will be prepared to ensure the erosion and sedimentation induced by construction activities will not adversely affect the surrounding environment. With the implementation of this plan, erosion and sedimentation impacts during the construction phase are expected to be minimal.

Operational phase impacts for both preferred and alternate options are simulated to meet NorBE criteria with the implementation of vegetated swales to treat runoff from the rail and access road corridors. The modelling analysis, which has been undertaken in accordance with the relevant guideline, demonstrates compliance with the NorBE requirements.

Surface water quality monitoring will be undertaken throughout construction, operation and rehabilitation at upstream and downstream sites on Stony Creek and Oldbury Creek to assess impacts to surface water quality in the receiving environment associated with the project and trigger the implementation of mitigation and remediation measures if required.

6 REFERENCES

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Appendix A

CATCHMENT PARAMETERS

A.1 OLDBURY CREEK CATCHMENT PARAMETERS

Subcatchment	Total area [ha]	Catchment slope [%]	Catchment Manning's 'n'	Percentage impervious [%]	
				Existing and rehabilitation case	Operation case
OC1	138.35	1.6	0.04	5	**7**
OC 2	210.43	1.4	0.04	5	5
OC 3	136.51	1.5	0.04	5	**7**
OC 4	27.26	2.7	0.04	5	5
OC 5	27.15	3.4	0.04	20	20
OC 6	95.06	2.0	0.05	15	15
OC 7	39.21	2.3	0.05	5	5
OC 8	21.81	1.5	0.04	5	**8**
SW08	134.88	2.2	0.075	7	7
OC 10	156.89	2.4	0.08	7	7
OC 11	134.32	4.6	0.09	5	5
T1	105.76	0.86	0.05	15	**17**
T2a	58.30	1.4	0.04	5	**8**
T2b	15.48	1.4	0.04	10	**12**
T3	30.57	2.4	0.04	5	**8**

Bold – factors adjusted for operation case

A.2 STONY CREEK CATCHMENT PARAMETERS

Subcatchment	Total area [ha]	Catchment slope [%]	Catchment Manning's 'n'	Percentage impervious [%]	
				Existing and rehabilitation case	Operation case
SC1	169.95	1.67	0.06	7	7
SC2	102.24	1.52	0.05	5	5
SC3	113.84	1.26	0.075	15	15
SC4	73.88	1.92	0.06	7	7
SC5	54.37	1.25	0.05	5	5
SC6	35.91	1.38	0.05	5	5
SC7	79.07	2.65	0.06	7	7
SC8	68.53	1.47	0.05	5	**10**
SC9	21.54	1	0.05	5	5
SC10	6.09	2.97	0.075	5	**7**
T1	22.12	6	0.05	5	5
T2	47.07	2	0.05	7	7
T3	23.12	1.25	0.04	40	40
T4	8.19	2	0.05	25	**30**
NW1	73.03	1.88	0.04	80	80
NW2	92.2	2.8	0.04	40	40

Bold – factors adjusted for operation case

Appendix B

SURVEYED STRUCTURES

B.1 OLDBURY CREEK STRUCTURES

B.1.1 Old Hume Highway plank bridge

Oldbury Creek flows under a plank bridge at the Old Hume Highway. The HEC-RAS model has included this structure based on a survey undertaken by Southern Cross Consulting Surveyors on 21 March 2014. The dimensions of the bridge structures included in the HEC-RAS model are:

- 650 mm thick plank
- No piers
- 5.4 m opening.

Photo 1.1 Old Hume Highway plank bridge

B.1.2 Hume Highway box culverts

Oldbury Creek flows through three large box culverts under the Hume Highway. The HEC-RAS model has included these structures based on a survey undertaken by Southern Cross Consulting Surveyors on 21 March 2014. The dimensions of the culvert structures included in the HEC-RAS model are:

- Three cells, each 2 m high by 3 m wide.

Photo 1.2 Hume Highway box culverts

B.1.3 Inline structures

There are two inline structures on Oldbury Creek. The most upstream one is a concrete pad, and dirt mound. Under the concrete pad there are 5,300 mm pipes.

Photo 1.3 Upstream inline structure on Oldbury Creek

The downstream inline structure has a high embankment and the spillway is located near the road. There is a single1.6 diameter pipe. The pipe inlet is located at an RL 644.4 mAHD. Only when the water level is above this, will water be able to go through the pipe. At the time of survey the water level was 644.17 mAHD. This was assumed the initial water level in the XP RAFTS model.

Photo 1.4 Downstream inline structure on Oldbury Creek

B.1.4 Culverts under Medway Road

There are two 600mm pipes located under Medway Road to the west and a 900mm x 350mm box culvert located to the east.

Photo 1.5 Photo of Western twin pipe culvert looking upstream

Photo 1.6 Photo of Eastern box culvert looking downstream

B.1.5 Culvert under Hume Highway

There is a single 1.2 diameter pipe located under the Hume Highway, on a tributary that is North of Oldbury Creek. The culvert is located under a steep embankment.

Photo 1.7 Photo of culvert under Hume Highway on western side

B.1.6 Culvert under Old Rail embankment

There are 2 x 600mm diameter pipes located under the old Rail Embankment to the east and 2 x 450 mm diameter pipes located to the west. These are located south of Medway Road Culverts.

Photo 1.8 Photo of culvert under old rail embankment on eastern side

Photo 1.9 Photo of culvert under old rail embankment on eastern side

B.2 STONY CREEK STRUCTURES

B.2.1 Rail Bridge over Stony Creek

A rail bridge is located approximately 150m downstream of Berrima Road. The dimensions of the bridge structures used in the HEC-RAS model are listed below.

- 1.3m thick deck from top of track to bottom of bridge
- One pier under each of the northbound and southbound spans
- 12m opening

Photo 1.10 Photo of Stony Creek rail crossing facing downstream

B.2.2 Berrima Road culvert

A culvert is located on Stony Creek under Berrima Road. The HEC-RAS model has included these structures based on survey undertaken by Southern Cross Consulting Surveyors in February 2016. The Culvert has 4 box culverts each 3.6m x 2.15m. Cad drawings are shown of this culvert.

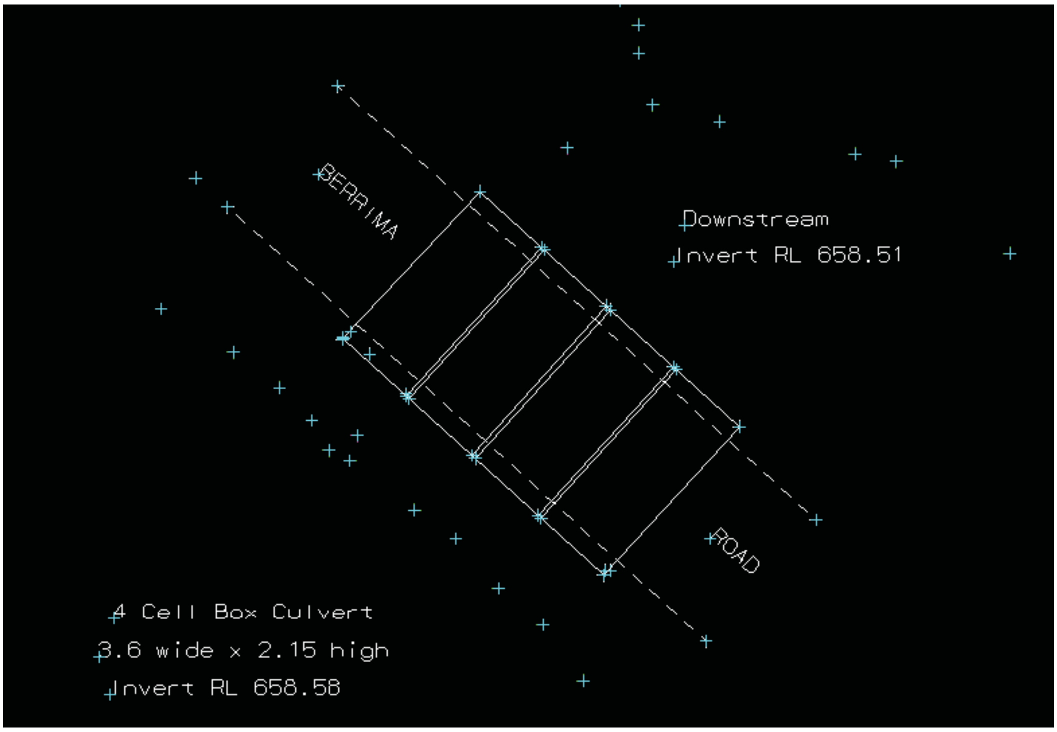

Figure 1.1 Cad drawing of culvert structure under Berrima Road

B.2.3 Structure at the northwest tributary of Oldbury Creek

B.2.3.1 CULVERT UNDER RAIL EMBANKMENT

There is a single box culvert 3.3 x 1.0 located under the railway, downstream of Berrima Road at the northwest tributary.

Photo 1.11 Photo of culvert structure under rail embankment on the northwest tributary facing upstream

B.2.3.2 CULVERT UNDER BERRIMA ROAD

There is a single 600mm diameter pipe located under Berrima Road at the northwester tributary of Stony Creek.

Photo 1.12 Photo of culvert structure under Berrima Road on the northwest tributary facing downstream

B.2.3.3 INLINE STORAGES ON NORTHWEST TRIBUTARY

There are two inline storages located on the northwest tributary of Stony Creek. The dam walls and water levels were surveyed and included in the RAFTS model.

Photo 1.13 Photo of downstream inline storage on the north-western tributary