Transport
Roads & Maritime Services

Nambucca Heads to Urunga Pacific Highway Upgrade

Water Quality Monitoring Annual Report

Roads and Maritime Services | August 2018

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Nambucca Heads to Urunga Pacific Highway Upgrade

Water Quality Monitoring Annual Report – August 2018

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Aquatic Science and Management

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1 Introduction

1.1 Introduction and Background

The Pacific Highway upgrade between Nambucca Heads and Urunga is operational. Monitoring of surface and groundwater quality has been ongoing in the pre-construction and construction phases and is to be undertaken for the first three years of operation according to the Surface Water Monitoring Program (GeoLINK 2013a) and the Groundwater Monitoring Program (GeoLINK 2013b).

This document presents the surface water and groundwater monitoring results obtained between 1 September 2017 and 31 August 2018 for the Pacific Highway upgrade between Nambucca Heads and Urunga (NH2U upgrade).

1.1.1 Aims and Objectives

The objective of ongoing surface water and groundwater monitoring is to evaluate the impact of the Pacific Highway upgrade on water quality in the relevant waterways and aquifers from Nambucca Heads to Urunga and to comply with the Department of Planning and Environment (DP&E) Ministers condition of approval B17 (MCoA B17).

RMS and the NSW government both have stated commitments and objectives with respect to the preservation of surface and groundwater quality, levels and flow. These are met by the general objective of the Statement of Commitment No. W3:- *Monitoring of groundwater impacts and surface water quality upstream and downstream of the site during construction will determine the effectiveness of mitigation strategies. Implementation of additional feasible and reasonable management measure will occur if necessary.*

Ministers Condition of Approval (MP 07_0112) B17, required RMS *to prepare and implement a Water Quality Monitoring Program to monitor the impacts of the project on SEPP 14 wetlands, surface water quality and groundwater resources during construction and operation.* In accordance with MCoA B17, RMS prepared and the Department of Planning and Environment approved the Surface Water Monitoring Program (SWMP) and the Groundwater Monitoring Program (GMP) . These documents provide guidance to:

- Monitor the impacts of the project on SEPP 14 wetlands, surface water quality and groundwater resources during construction and operation;

- Have provisions to provide RMS with timely advice about surface and groundwater quality and how they compare to relevant and appropriate guideline levels;

The aim of this report is to provide a summary of water quality sampling and analysis activities for the 2018 annual reporting period (1 September 2017 – 31 August 2018). This report is required to comply with DP&E MCoA B17.

1.2 Water Quality Guidelines and Objectives

There are a variety of guidelines available for the comparison and assessment of results obtained from surface water and groundwater sampling. Choosing appropriate guidelines to assess water quality depends on the environmental values of the site, human uses, the objectives for water quality, the level of protection required for the site and the issues and associated risks present.

Most often, guidelines are derived from the Australian and New Zealand Environment Conservation Council (ANZECC) Guidelines for Water Quality (ANZECC 2000), The Australian Drinking Water Guidelines (National Health and Medical Research Council (NHMRC) 2013) and the Guidelines for Managing Risks in Recreational Waters (NHMRC 2011).

In the case of large datasets collected regularly over time and with an appropriate sampling design the ANZECC Guidelines suggest the use of median and 80th percentile (P80) concentrations from the collected data as guideline values. The SWMP and the GMP employ a before/after, control/impact (BACI) sampling design to assess the impact of the highway upgrade on water quality. They recommend the use of the median values from the impact (downstream) sites and the P80 values from the control (upstream) sites for assessing impacts with the intention of informing ongoing management of water quality.

The ANZECC guidelines prescribe default guideline values for many water quality parameters. The individual values depend on the desired use of the water, perceived values of the water and the level of protection required. The default guideline values are intended to trigger further water quality investigations and to be used where there is an absence of locally derived guideline values. The ANZECC default guideline concentrations will be used in this report for providing context where potential impacts upon surface water and groundwater from highway operation are identified. The relevant ANZECC guideline concentrations are presented in **Table 1.1**.

The Australian Drinking Water Guidelines (ADWG, NHMRC 2013) provide guideline values for many water quality parameters that have potential impacts upon human health. In accordance with the Guidelines for the Assessment and Management of Groundwater Contamination (DEC 2007) the ADWG guidelines will be used in conjunction with the relevant ANZECC guidelines to provide quantitative context where potential impacts upon groundwater from highway operation are identified. Importantly, results that exceed the ANZECC and ADWG guidelines are not necessarily an indication of an impact. The relevant ADWG concentrations are presented in **Table 1.1**.

Table 1.1 Available ANZECC and ADWG guideline concentrations for relevant parameters

Parameter	***ANZECC Guideline Concentrations for Aquatic Ecosystem Protection (95% of spp.) in moderately disturbed ecosystems***		***ADWG Concentrations***
	Freshwater	***Marine***	
Silver (µg/L)	0.05	1.4	100
Aluminium (µg/L)	55	0.5[a]	200[b]
Antimony	9	270	3
Arsenic (V) (µg/L)	13	4.5[a]	10
Cadmium (µg/L)	0.2	5.5	2
Chromium (VI) (µg/L)	1.0	4.4	50
Copper (µg/L)	1.4	1.3	2000
Iron (µg/L)	-	-	300[b]
Manganese (µg/L)	1900	-	500
Nickel (µg/L)	11	7	20
Lead (µg/L)	3.4	4.4	10
Selenium (µg/L)	5	-	10
Zinc (µg/L)	8.0	15	300[b]
Mercury (µg/L)	0.05	0.1	1
Total Nitrogen in water (mg/L)	0.5	0.3	-
Nitrite as N in water (mg/L)	0.04(NOx)	0.015(NOx)	3
Nitrate as N in water (mg/L)	0.04(NOx)	0.015(NOx)	50
Ammonia as N in water (mg/L)	0.02	0.015	0.5[b]
Total Phosphorus (mg/L)	0.05	0.03	-
Phosphate as P in water (mg/L)	0.02	0.005	-
Total Suspended Solids (mg/L)	-	-	-
Temperature (°C)	-	-	-
pH	6.5 – 8.0	7.0 – 8.5	6.5 – 8.5
Conductivity (mS/cm)	0.125 – 2.2	-	-
Turbidity (NTU)	6 - 50	0.5 - 10	5[b]
Dissolved Oxygen (% sat)	85-110% saturation	80 – 110% saturation	85% saturataion[b]

a – ANZECC low reliability trigger

b – No health-based guideline value, aesthetic value applied.

2 Methods

2.1 Locations

2.1.1 Surface Water Monitoring Sites

There are eleven surface water locations (20 sites) where ongoing surface water monitoring is required. Maps of the site locations are presented in **Illustrations 2.1 to 2.4** (GeoLINK 2013a). The locations (from south to north) are as follows:

- Boggy Creek, approximate chainage 62700, sites SW208U and SW208D
- Cow Creek, approximate chainage 63600, sites SW217U and SW217D
- Deep Creek, approximate chainage 65000, sites SW231U and SW231D
- Unnamed Tributary of Oyster Creek, approximate chainages 68000 and 68100, Sites SW261 and SW262
- McGraths Creek, approximate chainage 72000, sites SW301U and 3SW01D
- Dalhousie Creek, approximate chainage 73400, sites SW315U and SW315D
- Kalang River, approximate chainage 77800, sites SW359U and SW359D
- Unnamed Tributary of SEPP Wetland No 353, approximate chainage 77900, sites SW360U and SW360D
- Unnamed Tributary of SEPP Wetland No 351, approximate chainage 79900 and 80000, sites SW380 and SW381
- SEPP Wetland No. 353, approximate chainage 78000, site SW353
- SEPP Wetland No. 351, approximate chainage 80900, site SW351

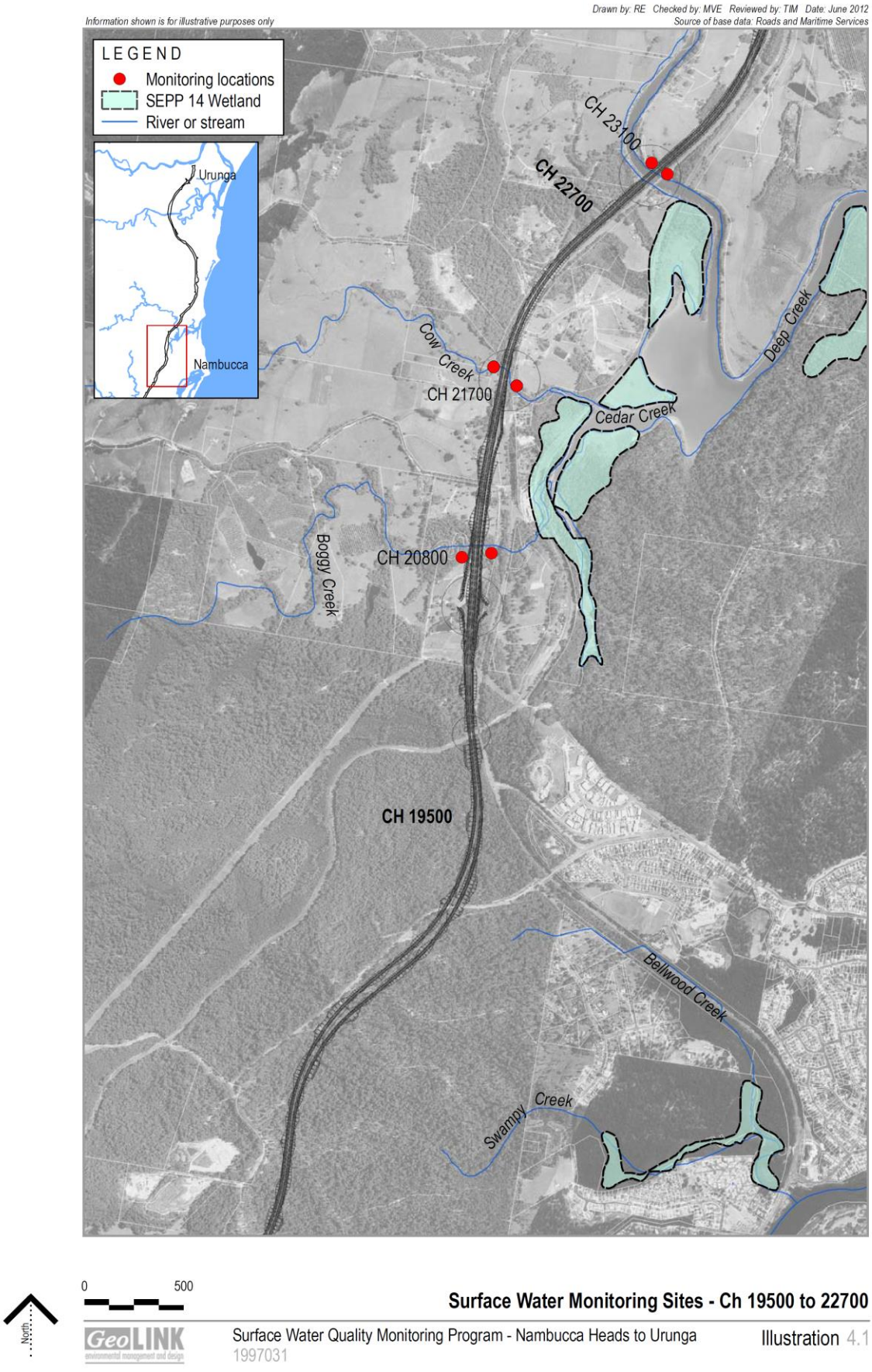

Illustration 2.1 Surface water monitoring sites – Ch 19500 to 22700 (GeoLINK 2013a)

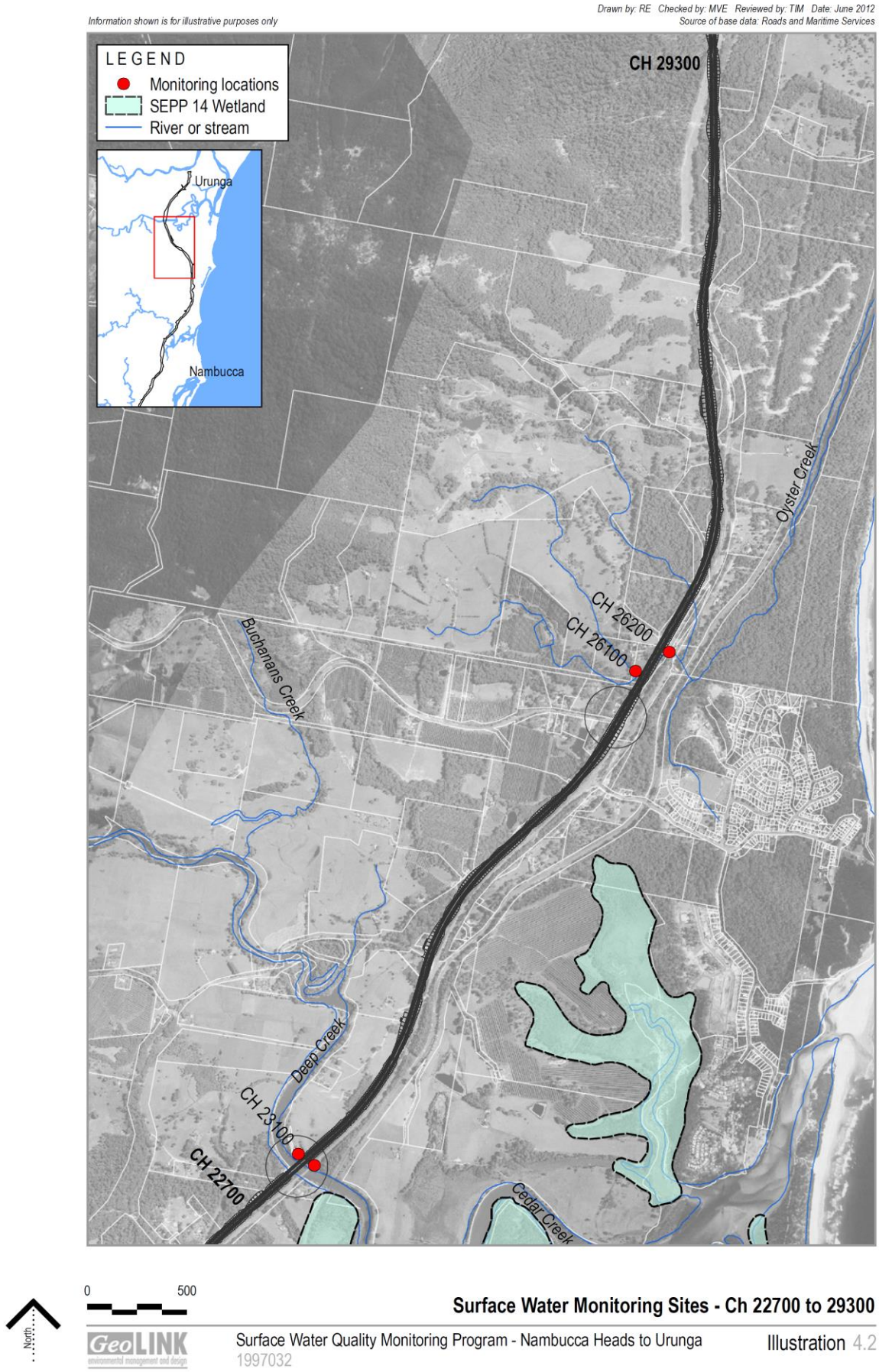

Illustration 2.2 Surface water monitoring sites – Ch 22700 to 29300 (GeoLINK 2013a)

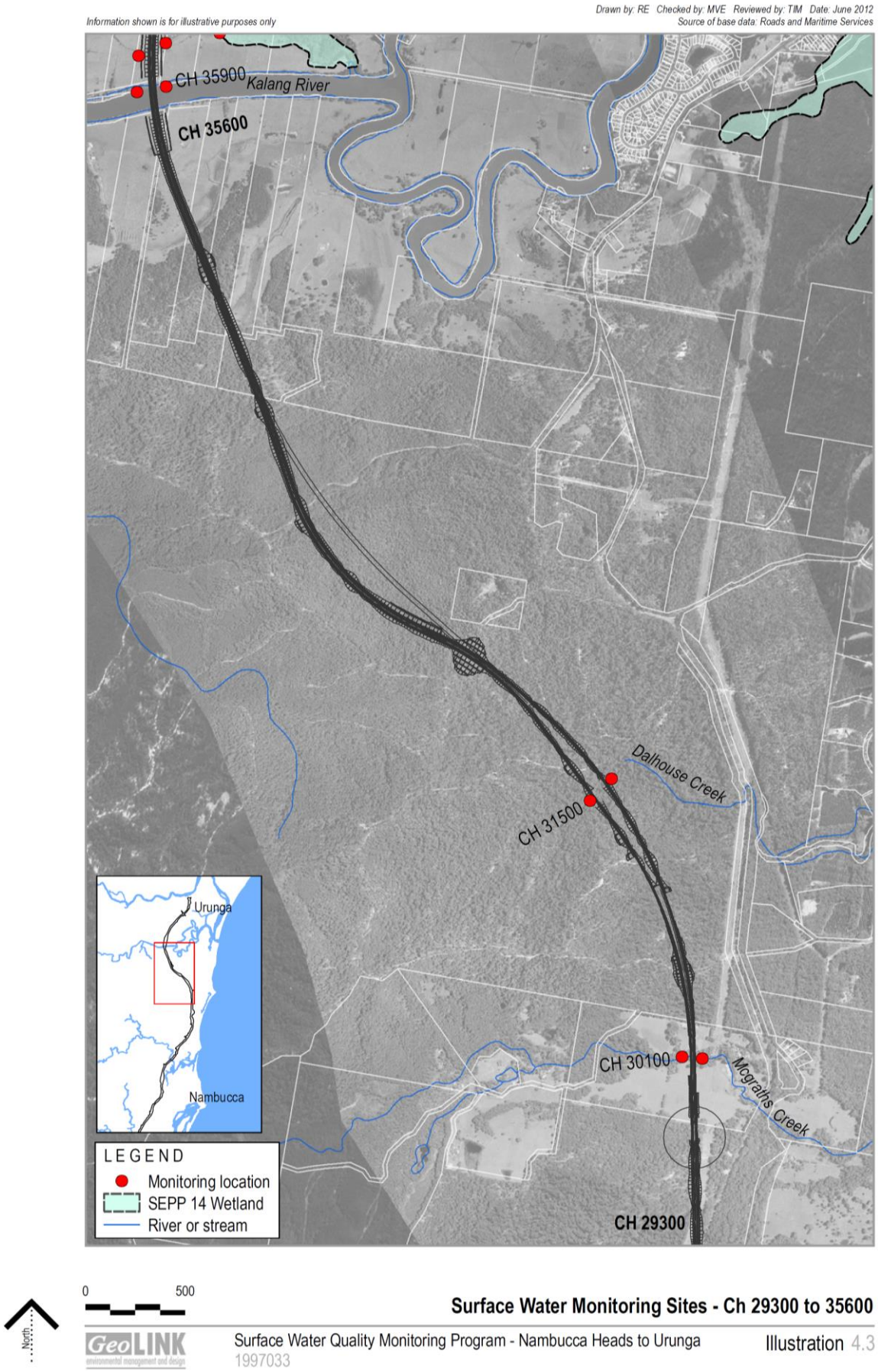

Illustration 2.3 Surface water monitoring sites – Ch 29300 to 35600 (GeoLINK 2013a)

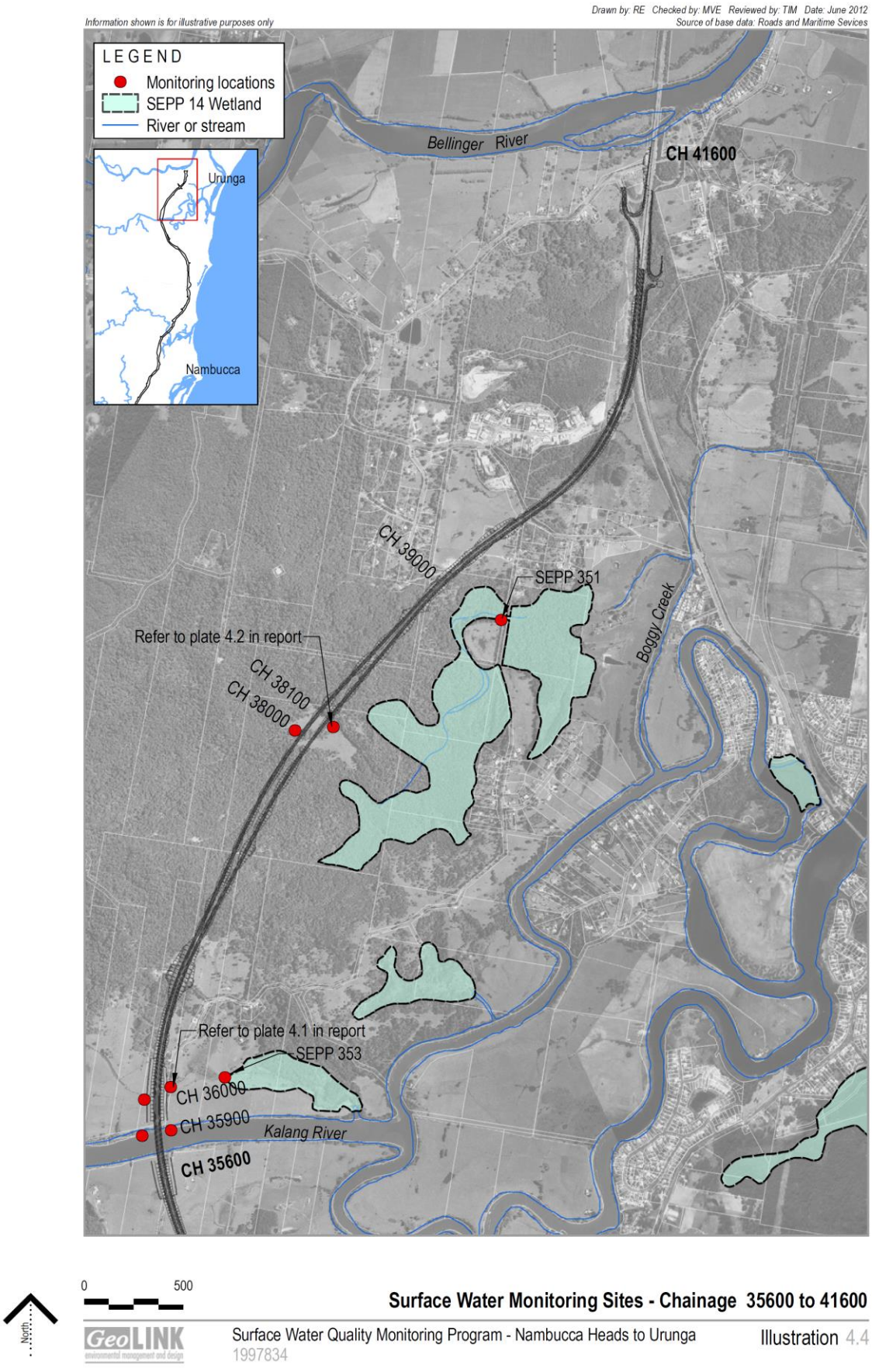

Illustration 2.4 Surface water monitoring sites – Ch 35600 to 41600 (GeoLINK 2013a)

2.1.2 Groundwater Monitoring Sites

There are six locations (11 piezometers) where ongoing groundwater monitoring is required. Maps of the site locations are presented in **Illustrations 2.5 to 2.7** (GeoLINK 2013b). The locations (from south to north) are as follows:

- Cutting No 3.5, approximate chainage 63200
- Fill upslope of SEPP Wetland No. 357, approximate chainage 64600
- Cutting No. 4.2, approximate chainage 72400
- Cutting No. 4.5, approximate chainage 74400
- Cutting No. 4.7, approximate chainage 75500
- Cutting No. 4.10, approximate chainage 78500

Monitoring at Cutting No. 4.14 (approximate chainage 80700) ceased prior to the construction phase.

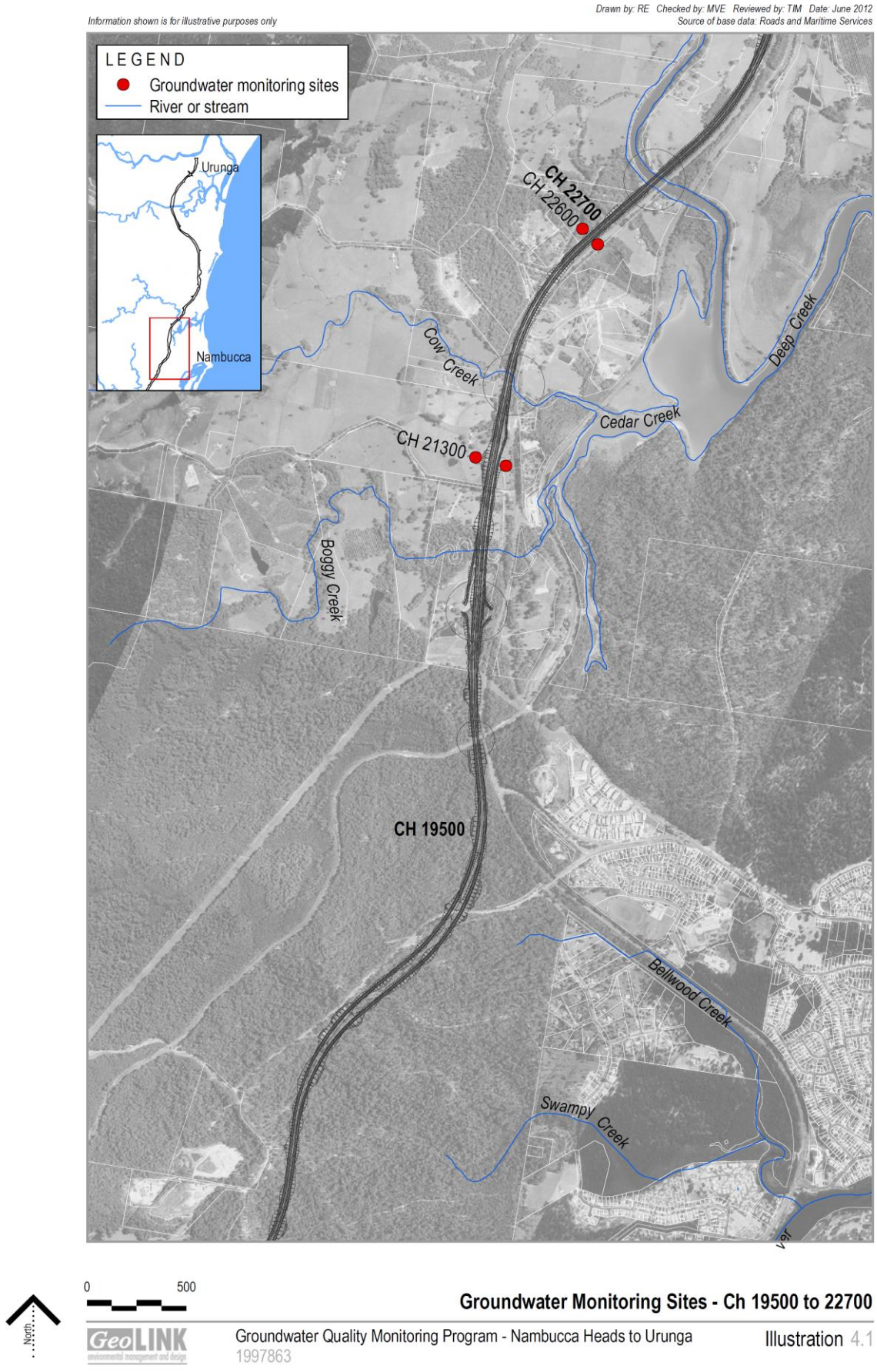

Illustration 2.5 Groundwater monitoring sites – Ch 19500 to 22700 (GeoLINK 2013b)

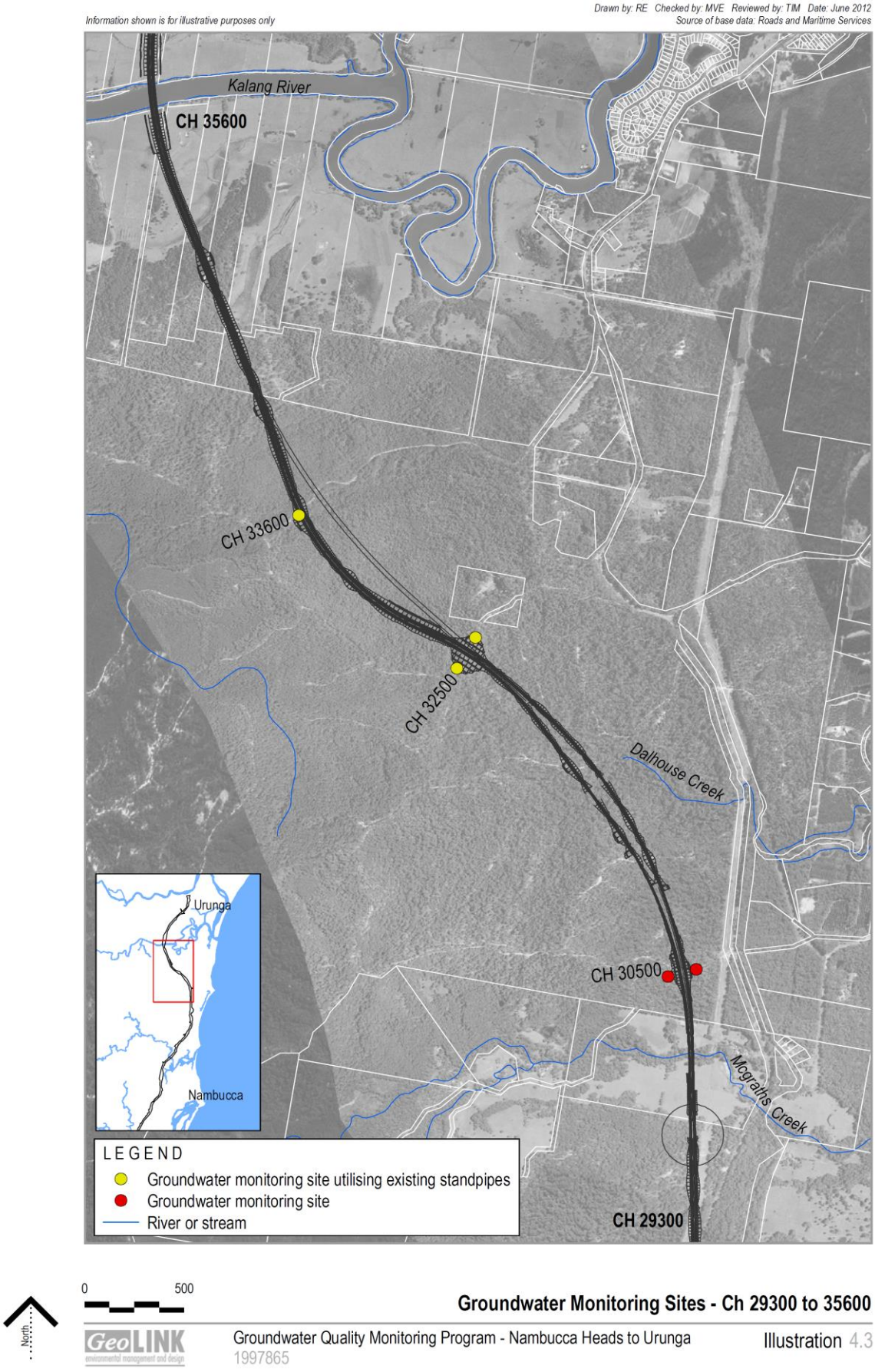

Illustration 2.6 Groundwater monitoring sites – Ch 29300 to 35600 (GeoLINK 2013b)

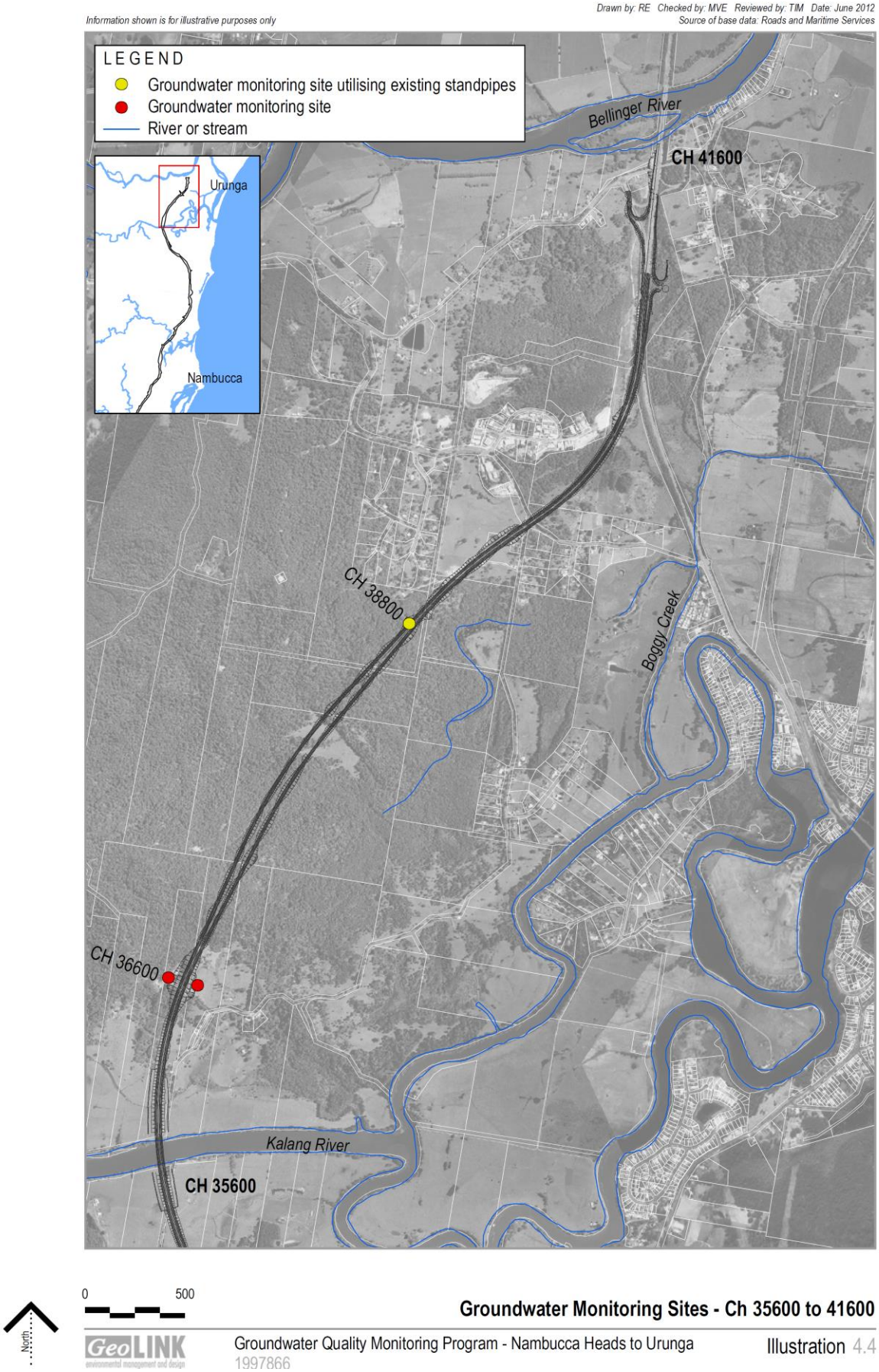

Illustration 2.7 Groundwater monitoring sites – Ch 35600 to 41600 (GeoLINK 2013b)

2.2 Sampling and Analysis

2.2.1 Surface Water Quality Monitoring

The SWMP outlines the parameters required for monitoring in the operational phase of the project. The requirement for monitoring of total petroleum hydrocarbons (TPH or TRH – total recoverable hydrocarbons) outlined in the SWMP was upgraded prior to the start of operational monitoring to include monitoring of a variety of hydrocarbon sub-groups. The complete list of parameters monitored is presented in **Table 2.1**.

Table 2.1 Surface water parameters for operational monitoring

Group	*Analytes*	*Method of Analysis*
Physicochemical	Temperature	Field measurement – HORIBA U52
	Electrical Conductivity (EC)	Field measurement – HORIBA U52
	pH	Field measurement – HORIBA U52
	Dissolved Oxygen (DO)	Field measurement – HORIBA U52
	Turbidity	Field measurement – HORIBA U52
	Total Suspended Solids (TSS)	Laboratory Analysis – Inorg-019
Hydrocarbons	Total Recoverable Hydrocarbons (TRH) C6 - C9	Laboratory Analysis – Org-016
	TRH C6 - C10	Laboratory Analysis – Org-016
	TRH C10 - C14	Laboratory Analysis – Org-003
	TRH C15 - C28	Laboratory Analysis – Org-003
	TRH C29 - C36	Laboratory Analysis – Org-003
	TRH >C10 - C16	Laboratory Analysis – Org-003
	TRH >C16 - C34	Laboratory Analysis – Org-003
	TRH >C34 - C40	Laboratory Analysis – Org-003
Metals	Copper (Cu)	Laboratory Analysis – Metals-022
	Lead (Pb)	Laboratory Analysis – Metals-022
	Cadmium (Cd)	Laboratory Analysis – Metals-022
	Zinc (Zn)	Laboratory Analysis – Metals-022
	Arsenic (As)	Laboratory Analysis – Metals-022
	Selenium (Se)	Laboratory Analysis – Metals-022
	Iron (Fe)	Laboratory Analysis – Metals-022
	Manganese (Mn)	Laboratory Analysis – Metals-022
	Silver (Ag)	Laboratory Analysis – Metals-022
	Chromium (Cr)	Laboratory Analysis – Metals-022
	Nickel (Ni)	Laboratory Analysis – Metals-022
	Aluminium (Al)	Laboratory Analysis – Metals-022
	Mercury (Hg)	Laboratory Analysis – Metals-021

Group	*Analytes*	*Method of Analysis*
Nutrients	Total Nitrogen (TN)	Laboratory Analysis – Inorg-055/062
	Total Phosphorus (TP)	Laboratory Analysis – Metals-020
	Nitrate (NO_3)	Laboratory Analysis – Inorg-055
	Nitrite (NO_2)	Laboratory Analysis – Inorg-055
	Ammonia (NH_4)	Laboratory Analysis – Inorg-057
	Phosphate (PO_3)	Laboratory Analysis – Inorg-060

The SWMP also defines the sampling frequency for operational monitoring, which started in September 2016. This is presented in **Table 2.2**. The pre-construction phase monitoring period was between September 2012 and February 2013. The construction phase monitoring period was between March 2013 and August 2016.

Table 2.2 Operational phase sample frequency (GeoLINK 2013a)

Period	*Dates*	*Parameters*	*Sample Frequency*
First Year	September 2016 – August 2018	Physicochemical	1 wet sample monthly and 1 dry sample six-monthly
		Hydrocarbons, Metals, Nutrients and Solids	1 wet sample bi-monthly and 1 dry sample six-monthly
Second Year	September 2018 – August 2019	Physicochemical	1 wet sample bi-monthly and 1 dry sample six-monthly
		Hydrocarbons, Metals, Nutrients and Solids	1 wet sample six-monthly and 1 dry sample six-monthly
Third Year	September 2019 – June 2020	Physicochemical	1 wet sample six-monthly and 1 dry sample six-monthly
		Hydrocarbons, Metals, Nutrients and Solids	1 wet sample six-monthly and 1 dry sample six-monthly

The dates of surface water quality monitoring sampling for the current monitoring period were 3/10/2017 (wet), 9/10/2017 (wet), 15/10/2017 (wet), 6/11/2017 (wet), 22/12/2017 (wet), 5/2/2018 (wet), 19/2/2018 (dry), 26/2/2018 (wet), 6/3/2018 (wet), 25/4/2018 (wet), 7/6/2018 (wet), 3/7/2018 (wet) and 9/8/2018 (dry).

Rainfall conditions at the time of sampling are presented in **Figure 3.1**.

During the operational phase monitoring surface waters were sampled from a depth of approximately 0.1 – 0.2 m. Samples were collected by dipping the sampling vessel into the water by sampling pole. Sample vessels were 500 mL plastic containers, sample rinsed three times. Separate 100 mL plastic containers pre-charged with acid were used for analyses of metals and separate 40 mL glass containers were used for hydrocarbon analyses.

All samples with a requirement for laboratory analysis were sent in cooled eskys by overnight courier to Envirolab in Chatswood, NSW on the day of collection.

2.2.2 Groundwater Quality Monitoring

The GMP outlines the parameters required for monitoring in the operational phase of the project. The requirement for monitoring of total petroleum hydrocarbons (TPH, or total recoverable hydrocarbons – TRH) outlined in the GMP was upgraded prior to the start of operational monitoring to include monitoring of a variety of hydrocarbon sub-groups. The complete list of parameters monitored is the same as for surface water (see **Table 2.1**), except there is no requirement to measure DO concentration or turbidity.

The frequency of groundwater monitoring is also defined by the GMP. This is presented in **Table 2.3**. Groundwater measurements were collected four times during this reporting period, on the 25/9/2017, 30/11/2017. 28/3/2018 and 6/7/2018.

Table 2.3 Operational phase groundwater sample frequency (GeoLINK 2013b)

Period	***Dates***	***Parameters***	***Sample Frequency***
Entire Monitoring Period	September 2016 – June 2020	Physicochemical	1 sample three-monthly
		Hydrocarbons, Metals, Nutrients and Solids	1 sample six-monthly

2.2.3 Groundwater Level Monitoring

Groundwater levels are monitored using HOBO data loggers for the operational phase monitoring. These were deployed at most sites in 29 July 2017, collecting data at 2-hour intervals (2-hour intervals chosen as a suitable period to collect data in adequate detail and extend battery life). The HOBO loggers are deployed at a point approximately 0.3 m above the bottom of each piezometer. There is an extra HOBO deployed at Chainage 63200 that captures barometric pressure information, later used to offset barometric pressure fluctuations in the data collected from the piezometers.

Logged groundwater data from this reporting period was retrieved throughout the reporting period. Due to battery problems and a need to construct a new piezometer there is some

missing data in the retrieved HOBO datasets from approximate chainages 63200 (upstream) and 72400 (upstream).

Some of the groundwater piezometers used for monitoring in the pre-construction phase were decommissioned during the construction phase and new piezometers constructed. These include the groundwater piezometers at approximate chainages 63200 (upgradient), 64600 (upgradient), 72400 (downgradient), 74300 (upgradient and downgradient) and 75500 (upgradient).

In addition, the monitoring bore at approximate chainage 63200 (upgradient) was found to be collapsed during the inspection on 29/06/2017 and a new bore was constructed.

3 Results and Discussion

3.1 Rainfall

The surface water monitoring is governed by rainfall. A rainfall event triggering a wet episode sample is a minimum of 10 mm rain in 24 hours. A dry episode sampling run is triggered by 96 hours with no rainfall and 240 hours with less than 20mm rainfall. Three Bureau of Meteorology (BOM) stations, Kalang, Kooroowi and Nambucca Heads, were monitored to ensure wet conditions or dry conditions occurred across the entire upgrade section. Daily rainfall for the reporting period is displayed in **Figure 3.1**.

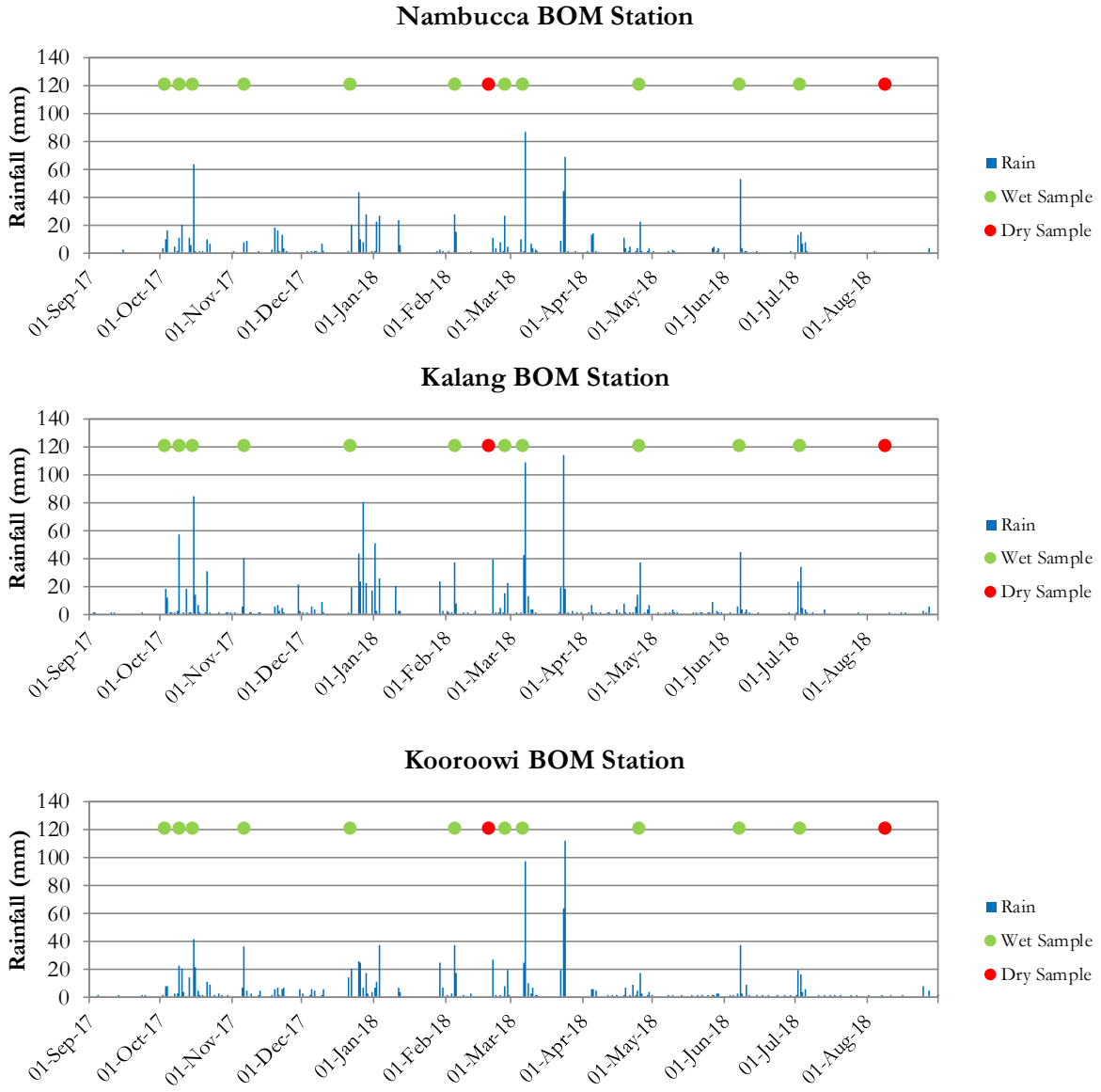

Figure 3.1 Daily rainfall at the Kalang, Kooroowi and Nambucca weather stations for the reporting period (BOM 2018)

Rainfall was relatively evenly distributed throughout the reporting period although the start and end of the reporting period were dry. The wettest month of the reporting period was March, in line with seasonal trends for the area.

3.2 Surface Water

Summary surface water quality results are provided in **Appendix A**.

Sampling dates for all surface water samples collected during this reporting period are displayed in **Table 3.1**. Extra wet samples were collected in October 2017 to cover missed samples in August 2017 and September 2017 when there was insufficient rainfall to trigger an event sample. A 10mm rainfall event on the 3rd of January 2018 was missed as no staff were available.

Table 3.1 Surface water quality sampling undertaken during this reporting period

Date	*Sample type (wet/dry)*	*Parameters*
03/10/2017	Wet	Physicochemical only
09/10/2017	Wet	All parameters
15/10/2017	Wet	Physicochemical only
06/11/2017	Wet	All parameters
22/12/2017	Wet	Physicochemical only
05/02/2018	Wet	All parameters
19/02/2018	Dry	All parameters
06/03/2018	Wet	All parameters
25/04/2018	Wet	All parameters
07/06/2018	Wet	Physicochemical only
03/07/2018	Wet	All parameters
09/08/2018	Dry	All parameters only

The SWMP suggests that the analysis of impacts can involve a comparison of the median sampling results from downstream (impact) sites with the 80th percentile (P80) value of upstream (control) sites. The downstream median data for the operational monitoring period from each site is presented in Appendix A with the rolling upstream P80 values. To provide historical context the summary data from the pre-construction and construction phases, in addition to the summary data at the end of the first year of operational phase monitoring is also presented.

A summary of relevant statistics for each waterway is presented in **Tables A.1** to **A.11** (**Appendix A**). A brief description of the summary results from each waterway follows.

For the purposes of analysing the results of operational phase monitoring we have defined results of interest as those where the operational phase downstream median is greater than the combined preconstruction/construction/operational phase upstream P80.

3.2.1 SEPP 14 Wetland No.351

There were few results of interest from SEPP14 wetland No.351 (**Table A.1**). Results of interest were the downstream median TN and DO concentrations. However, the TN concentrations measured during this reporting period were within the limits of variation measured during pre-construction and construction phase monitoring (**Figure 3.4**). Additionally, the median downstream TN concentration measured during the operational phase to date is lower than the median downstream TN concentration from either the pre-construction or construction phase monitoring (**Table A.1**). The DO measurements collected from SEPP 14 wetland No.351 during this reporting period were very low on some occasions and were the lowest measured since the beginning of water quality monitoring.

Turbidity and TSS measurements during this reporting period were within the variation observed in pre-construction and construction phase monitoring (**Figures 3.2** and **3.3**).

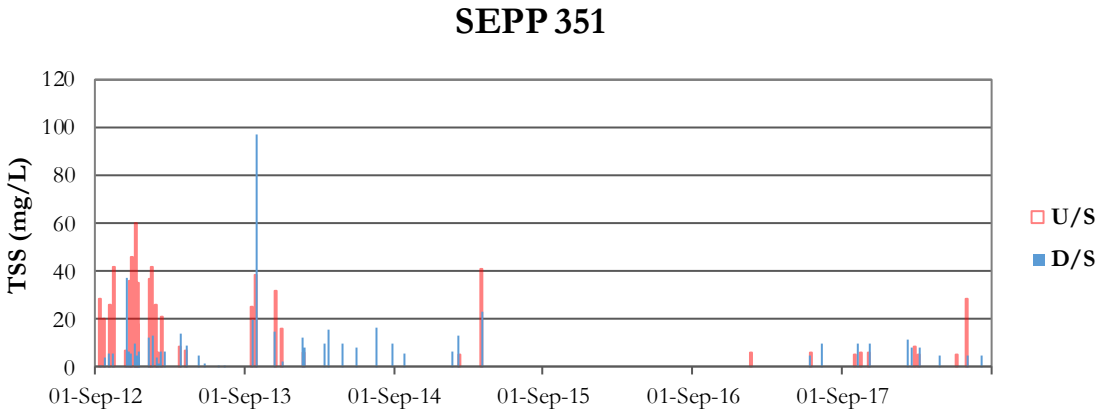

Figure 3.2 Total Suspended Sediment concentrations from SEPP 351 wetland and upstream waters since September 2012

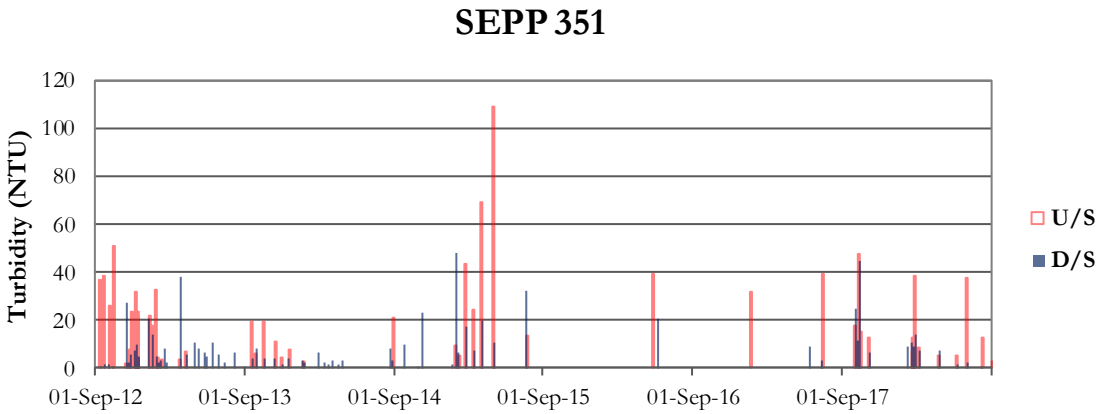

Figure 3.3 Turbidity measurements from SEPP 351 wetland and upstream waters since September 2012

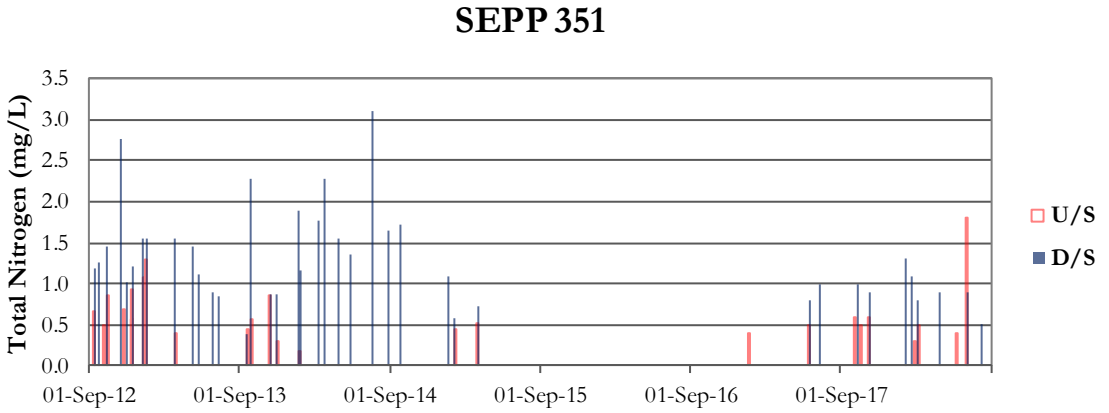

Figure 3.4 Total nitrogen concentrations from SEPP 351 wetland and upstream waters since September 2012

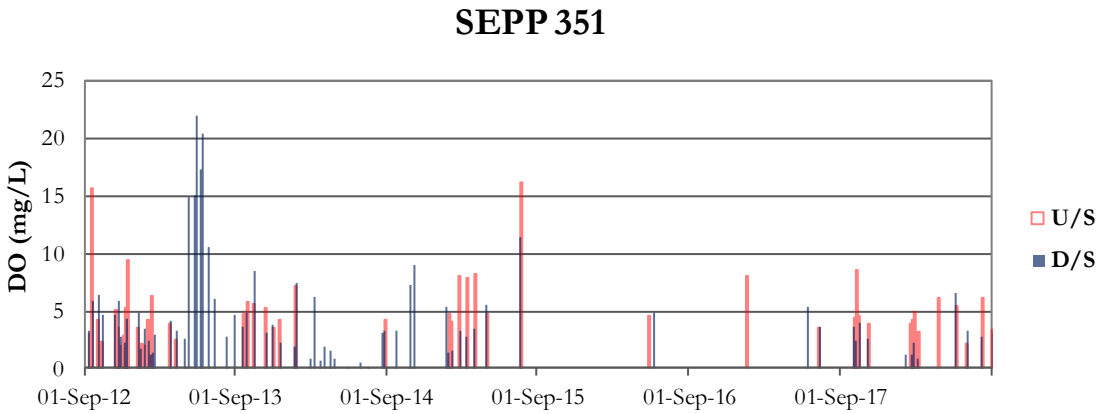

Figure 3.5 Dissolved Oxygen concentrations from SEPP 351 wetland and upstream waters since September 2012

Summary for SEPP Wetland No. 351 – Higher concentrations of TN measured in the construction and operational phases, both upstream and downstream of the highway (with the exception of one upstream measurement during the operational phase). Reduced concentrations of DO measured during this reporting period in the downstream environment.

3.2.2 SEPP14 Wetland No. 353

There were few results of interest from SEPP14 wetland No.353 (**Table A.2**). Results of interest were the downstream median NO_3 and PO_3 concentrations. Of the results of interest there were two downstream NO_3 concentrations and several downstream PO_3 concentrations measured during this reporting period that were outside of the variation observed in pre-construction and construction phase monitoring (**Figures 3.8** and **3.9**). In the operation phase high concentrations of PO_3 and NO_3 were measured in upstream waters, indicating that high downstream concentrations may have originated from the catchment rather than being related to the highway operation.

During this reporting period there were downstream TSS and turbidity measurements that were outside of the variation observed in pre-construction and construction phase monitoring in SEPP 14 wetland No. 353 (**Figures 3.6** and **3.7**). However, the median downstream TSS and turbidity measurements did not register as results of interest.

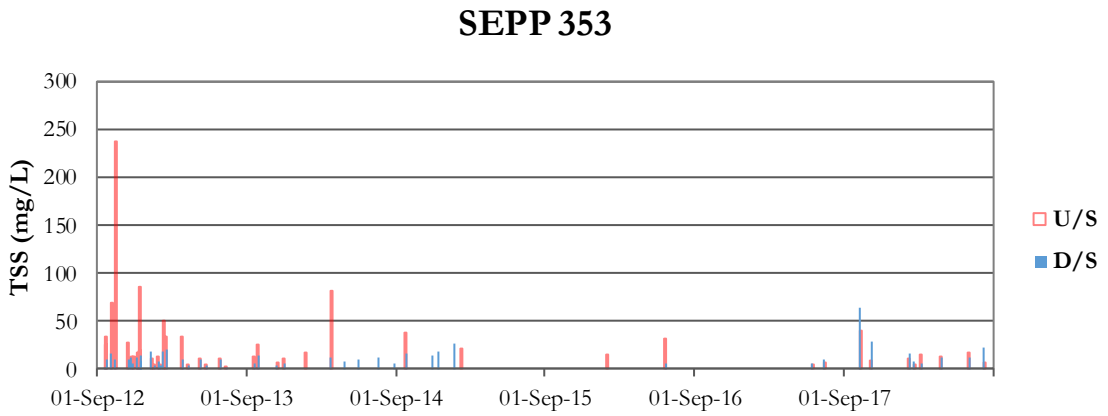

Figure 3.6 TSS concentrations from SEPP 353 wetland and upstream waters since September 2012

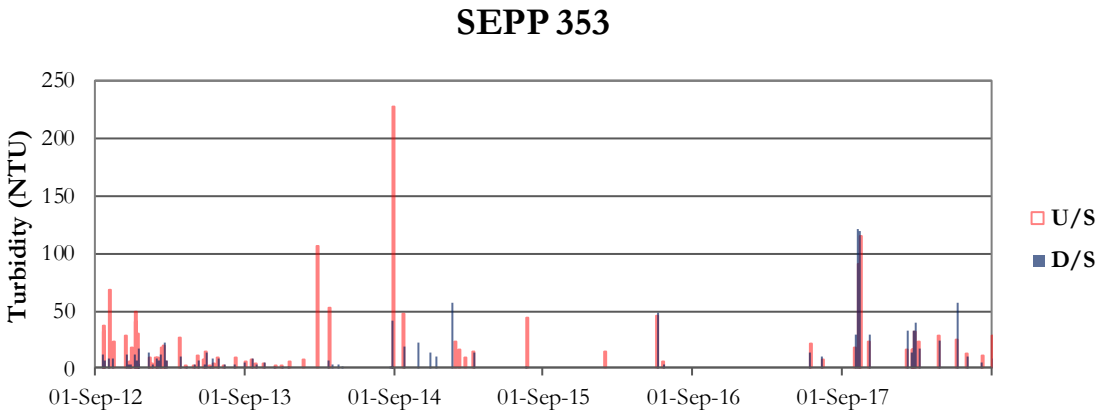

Figure 3.7 Turbidity measurements from SEPP 353 wetland and upstream waters since September 2012

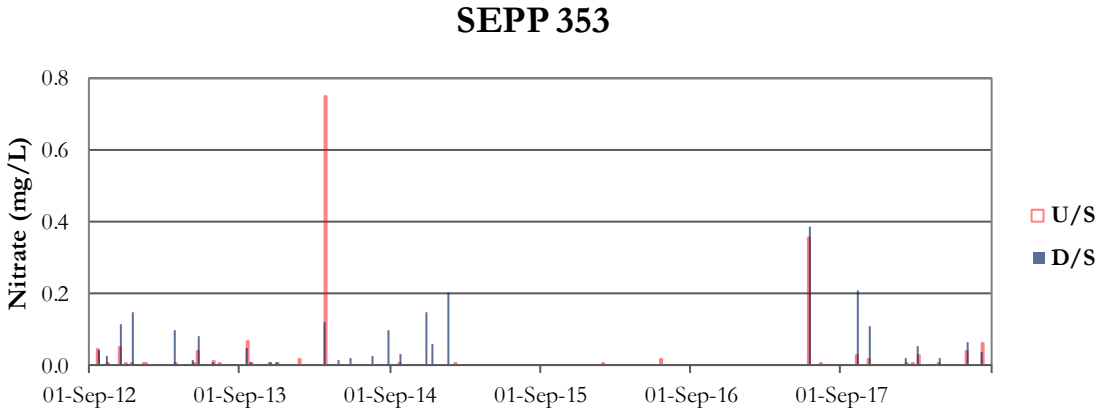

Figure 3.8 Nitrate measurements from SEPP 353 wetland and upstream waters since September 2012

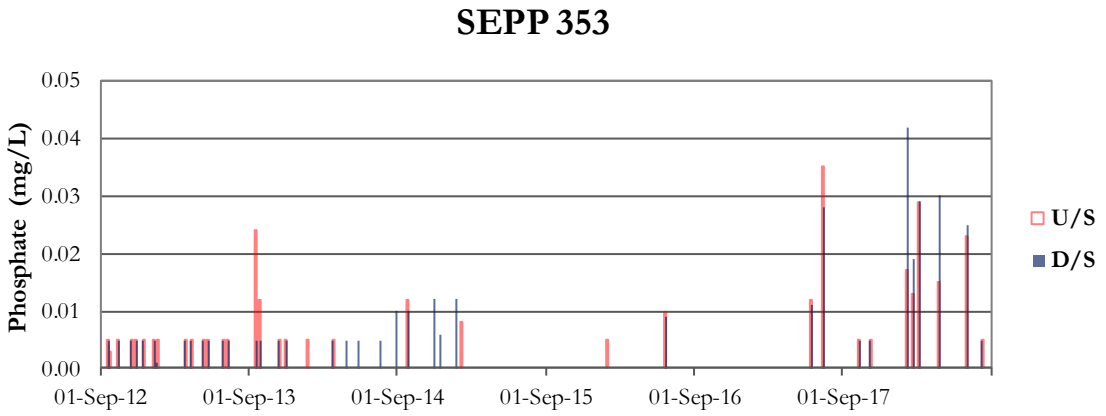

Figure 3.9 Phosphate measurements from SEPP 353 wetland and upstream waters since September 2012

For each of NO_3 and PO_3 the highest concentrations measured at SEPP 353 in the construction and operational phases have been higher than the range measured in the pre-construction phase (**Figures 3.8** and **3.9**)

Summary for SEPP Wetland No. 353 – Highest downstream concentrations of NO_3 and PO_3 measured in the operational phases of monitoring. However, high concentrations of these parameters measured both upstream and downstream of the highway crossing. The highest downstream turbidity measurements and TSS concentrations also captured during the operational phase of monitoring.

3.2.3 Unnamed Tributary to SEPP14 Wetland No. 351

The only result of interest from the unnamed tributary to SEPP14 wetland No.351 was the downstream median pH measurement (**Table A.3**). The downstream pH measurements collected during this reporting period were within the variation observed in pre-construction and construction phase monitoring (**Figure 3.12**). Additionally, the pH measurements from upstream waters were also high during this reporting period, indicating that the high values may not be related to the highway operation.

Turbidity and TSS measurements during this reporting period were within the variation observed in pre-construction and construction phase monitoring (**Figures 3.10** and **3.11**).

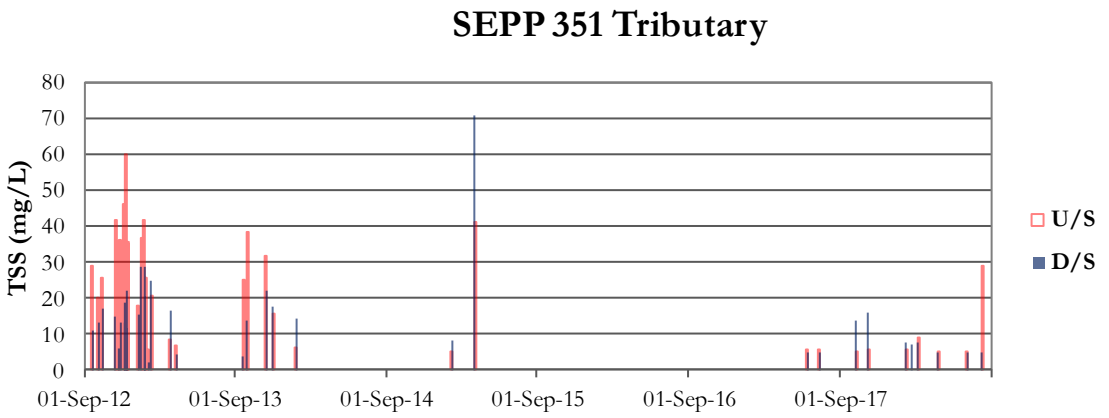

Figure 3.10 TSS concentrations from SEPP 351 tributary and upstream waters since September 2012

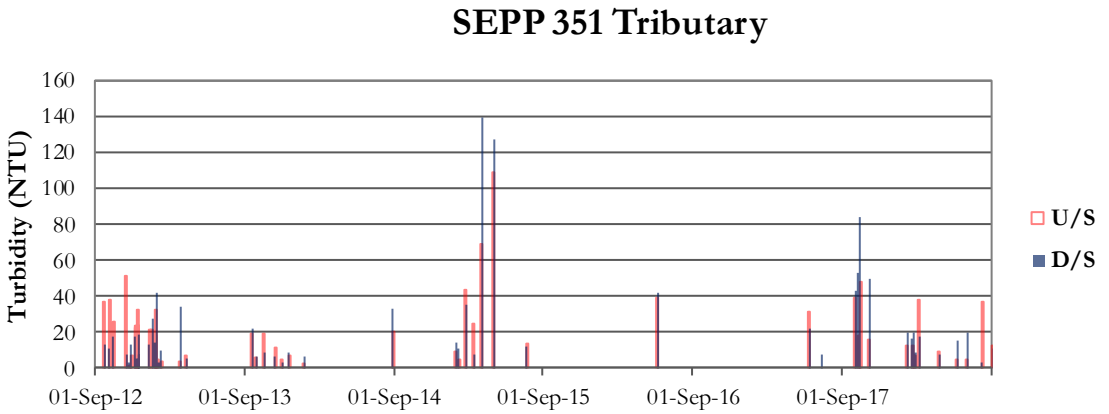

Figure 3.11 Turbidity measurements from SEPP 351 tributary and upstream waters since September 2012

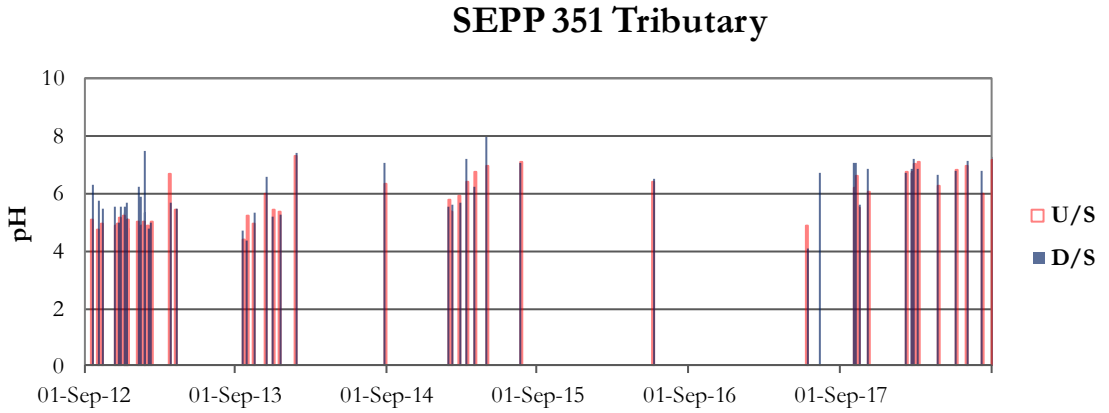

Figure 3.12 pH measurements from SEPP 351 tributary and upstream waters since September 2012

For both upstream and downstream pH measurements, the highest measurements collected at the SEPP 351 tributary in the construction and operational phases have been higher than the range measured in the pre-construction phase (**Figure 3.12**)

Summary for tributary to SEPP Wetland No. 351 – Highest pH measurements collected in the construction and operational phases of monitoring.

3.2.4 Unnamed Tributary to SEPP14 Wetland No. 353

There were few results of interest from the tributary to SEPP14 wetland No.353 (**Table A.4**). The only result of interest was the downstream median PO_3 concentration. Several of the upstream and downstream PO_3 concentrations measured from the tributary to SEPP wetland

No. 353 during this reporting period were outside of the variation observed in pre-construction and construction phase monitoring (**Figure 3.15**). The high upstream PO_3 concentrations indicate that the PO_3 may originate in the catchment upstream of the highway crossing.

The upstream and downstream turbidity and TSS measurements collected during this reporting period were within the variation observed in construction phase monitoring (**Figures 3.13** and **3.14**).

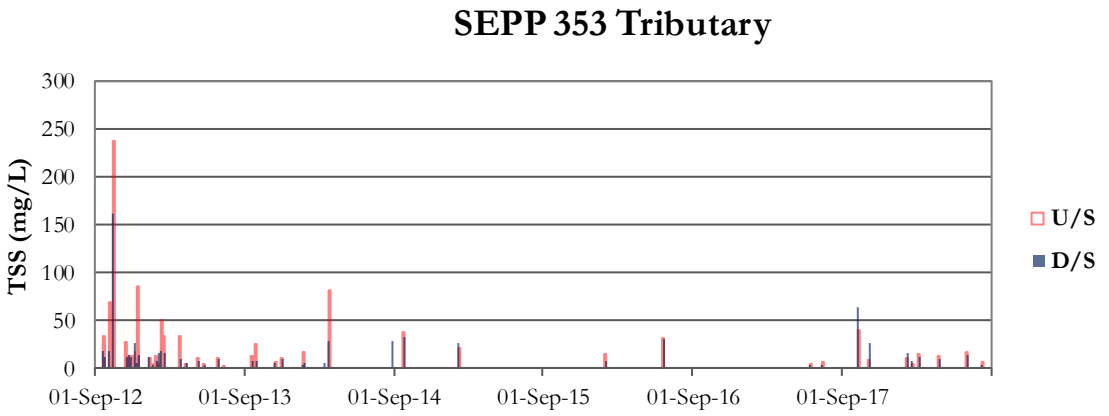

Figure 3.13 TSS concentrations from SEPP 353 tributary and upstream waters since September 2012

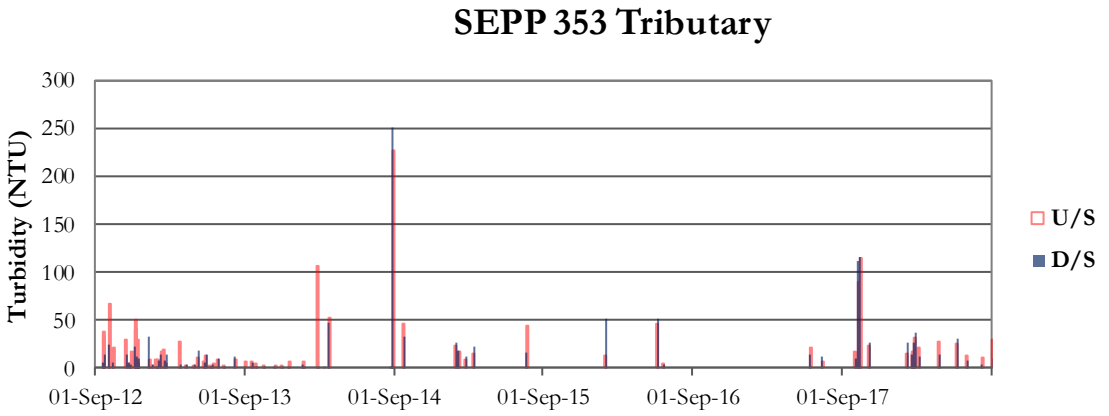

Figure 3.14 Turbidity measurements from SEPP 353 tributary and upstream waters since September 2012

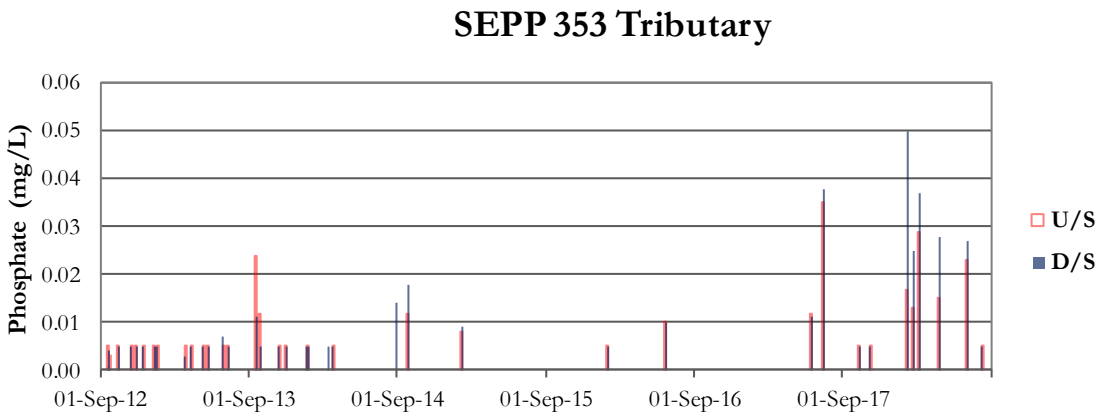

Figure 3.15 Phosphate measurements from SEPP 353 tributary and upstream waters since September 2012

The highest upstream and downstream concentrations of PO_3 measured at the SEPP 353 tributary in both the construction and operational phases have been higher than the range measured in the pre-construction phase (**Figure 3.15**)

Summary for tributary to SEPP Wetland No. 353 – Highest concentrations of PO_3 measured in the construction and operational phases of monitoring. Elevated concentrations of PO_3 measured upstream and downstream of the highway crossing.

3.2.5 Kalang River

Results of interest from the Kalang River were the downstream median Al, Fe, PO_3 and DO concentrations (**Table A.5**). Of the results of interest two pairs of upstream and downstream Fe and Al concentrations measured during wet events in the operational monitoring period have been outside of the variation observed in pre-construction and construction phase monitoring (**Figures 3.18** and **3.19**). However, because the Kalang is strongly tidal underneath the highway alignment it is not certain whether the Al and Fe originate at the highway crossing, further down or further up the catchment. A number of the upstream and downstream PO_3 concentrations measured in this reporting phase were also outside of the range of measurements collected during both pre-construction and construction phase monitoring.

Both upstream and downstream turbidity and TSS measurements collected during this reporting period were within the variation observed in pre-construction and construction phase monitoring (**Figures 3.16** and **3.17**).

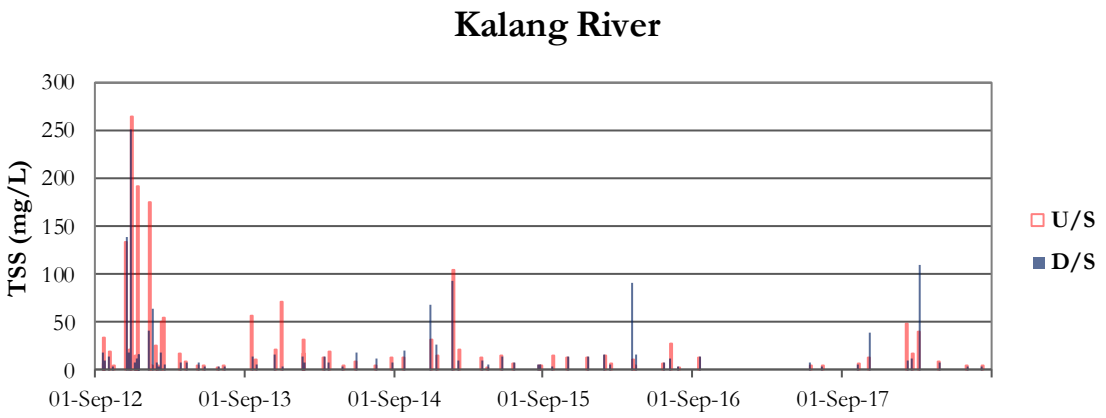

Figure 3.16 TSS concentrations from the Kalang River since September 2012

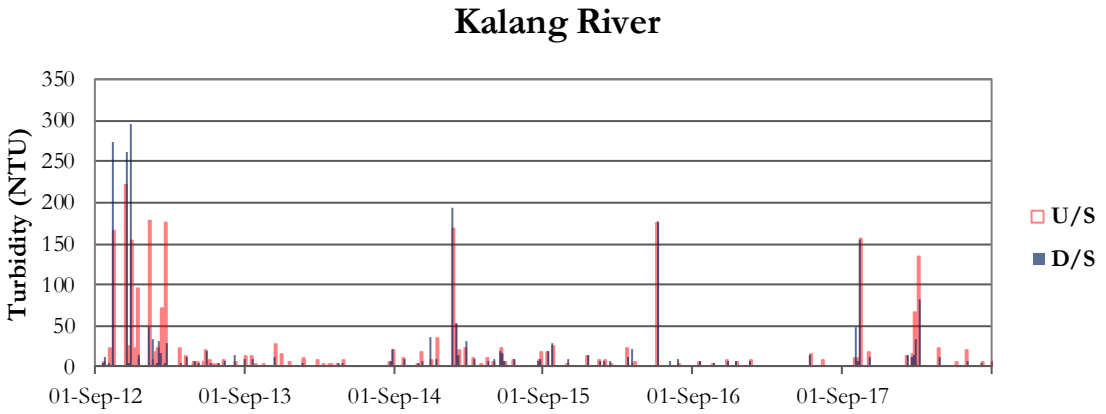

Figure 3.17 Turbidity measurements from the Kalang River since September 2012

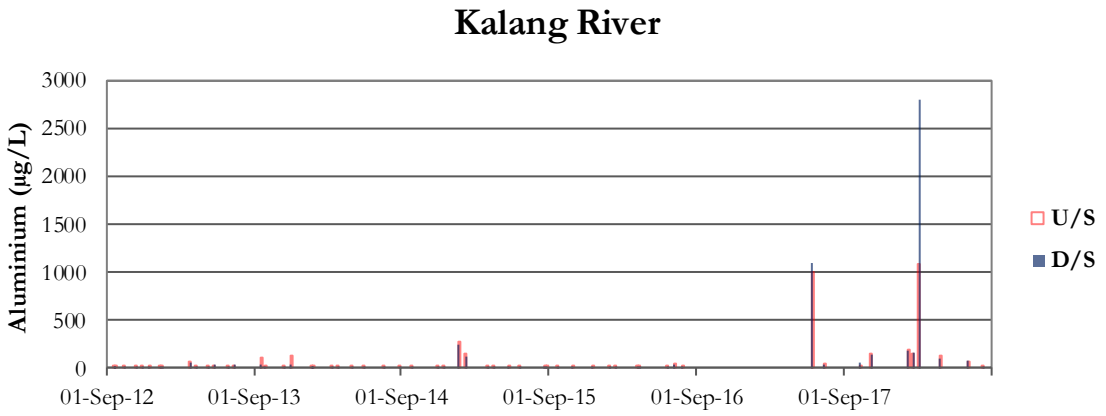

Figure 3.18 Aluminium measurements from the Kalang River since September 2012

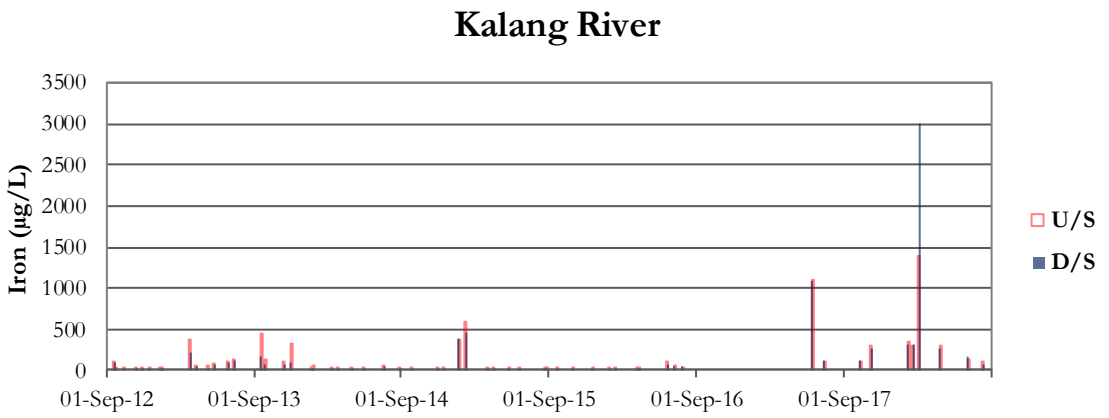

Figure 3.19 Iron measurements from the Kalang River since September 2012

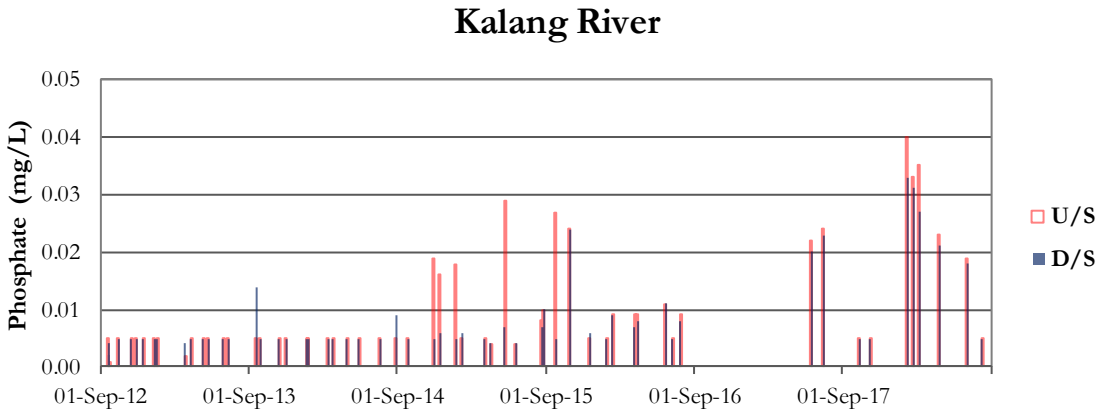

Figure 3.20 Phosphate measurements from the Kalang River since September 2012

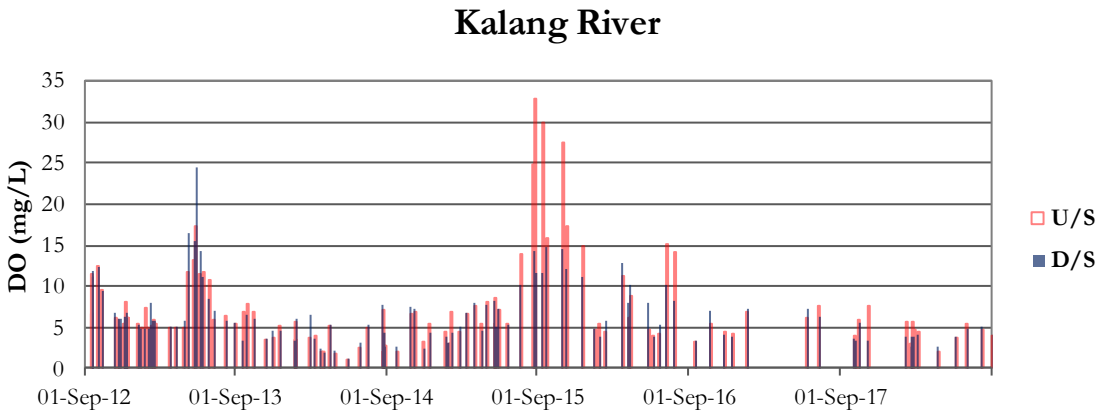

Figure 3.21 DO measurements from the Kalang River since September 2012

For Fe, Al and PO_3 the highest concentrations both upstream and downstream of the Kalang River Bridge in the construction and operational phases have been higher than the ranges measured in the pre-construction phase (**Figures 3.18, 3.19** and **3.20**). The DO concentrations

measured during the operational phase monitoring to date all fall within the boundaries of variation measured during the pre-construction and construction phase monitoring.

Summary for the Kalang River – Highest concentrations of Fe, Al, and PO_3 both upstream and downstream measured in the operational phase of monitoring.

3.2.6 Dalhousie Creek

There were no results of interest from Dalhousie Creek (**Table A.6**).

The TSS measurements during this reporting period were within the variation observed in both pre-construction and construction phase monitoring (**Figures 3.22**). The turbidity measurements collected during this reporting period were all within the variation observed in the pre-construction and construction phase monitoring with the exception of 1 upstream and 1 downstream measurement (**Figure 3.23**).

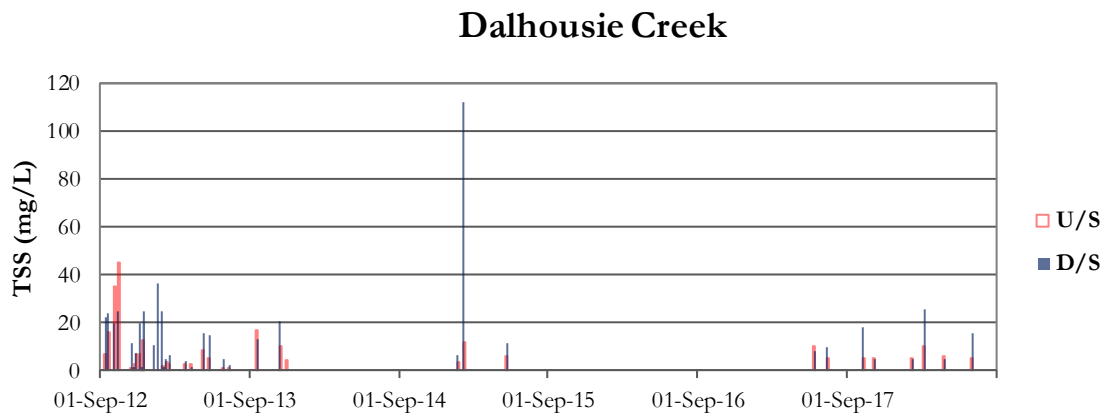

Figure 3.22 TSS concentrations from Dalhousie Creek since September 2012

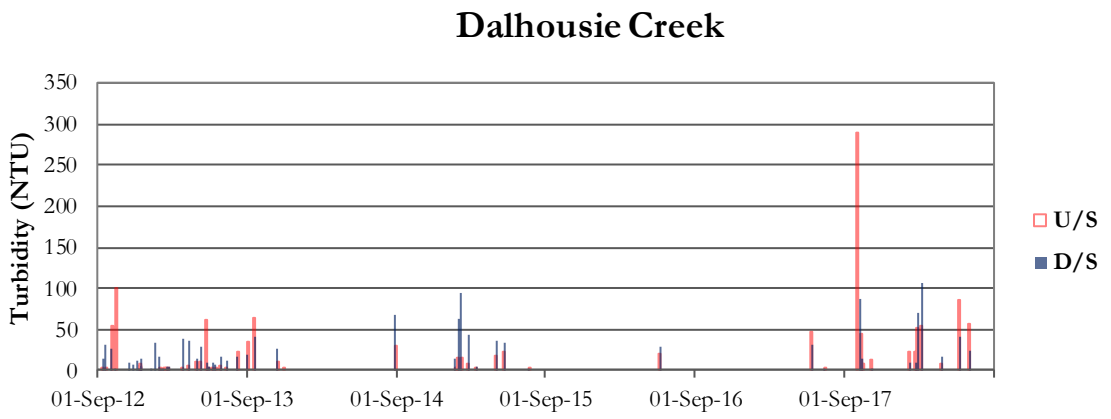

Figure 3.23 Turbidity measurements from Dalhousie Creek since September 2012

Summary for Dalhousie Creek – Highest upstream and downstream turbidity measurements collected in the operational phases of monitoring. However, there were no results of interest generated for Dalhousie Creek during this monitoring period.

3.2.7 McGraths Creek

There were three results of interest from McGraths Creek (**Table A.7**). Results of interest were the downstream median Al and PO_3 concentrations and turbidity measurements. Of the results of interest both Al and PO3 concentrations measured upstream and downstream of the crossing during this reporting period were outside of the variation observed in pre-construction and construction phase monitoring (**Figures 3.25**, **3.26** and **3.27**). In each of these cases high measurements were collected both downstream and upstream of the highway during wet events, indicating that they may have originated upstream of the highway crossing.

TSS measurements during this reporting period were within the variation observed upstream of the crossing in pre-construction and construction phase monitoring (**Figure 3.24**). Elevated TSS measurements in downstream waters were accompanied by elevated measurements in upstream waters indicating that sediment may be entering the site from the catchment upstream of the crossing.

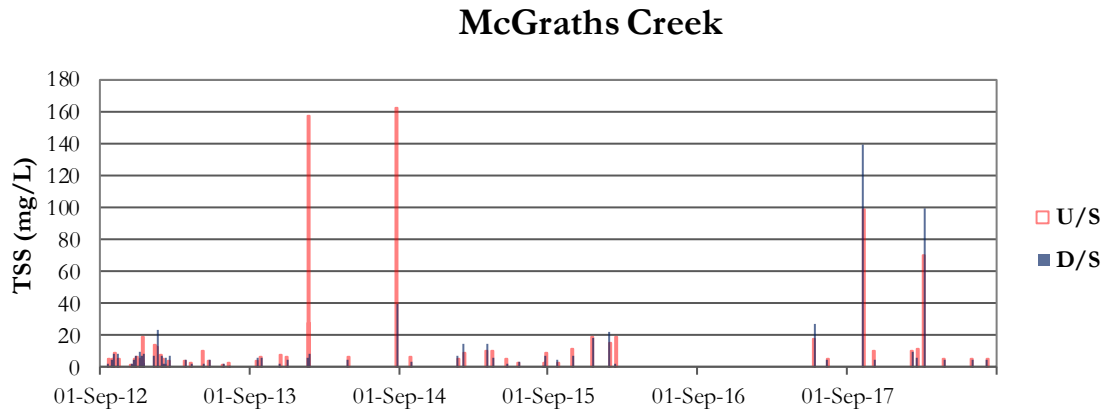

Figure 3.24 TSS concentrations from McGraths Creek since September 2012

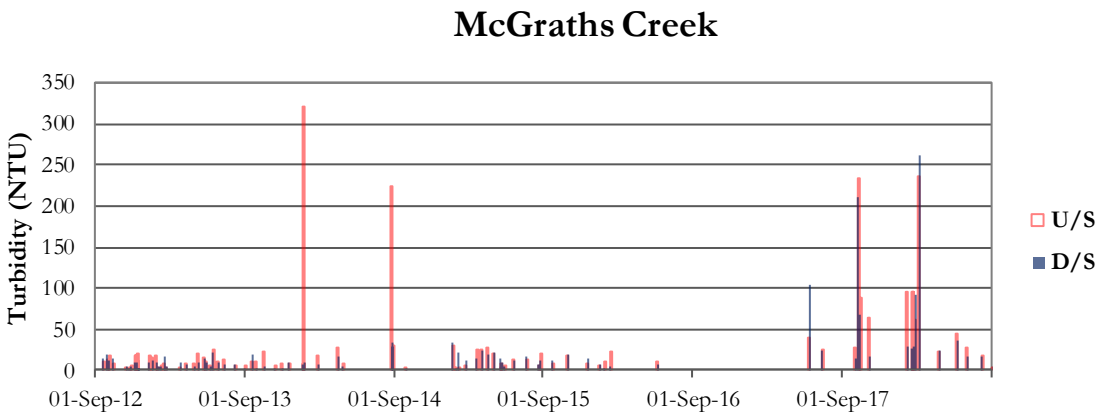

Figure 3.25 Turbidity measurements from McGraths Creek since September 2012

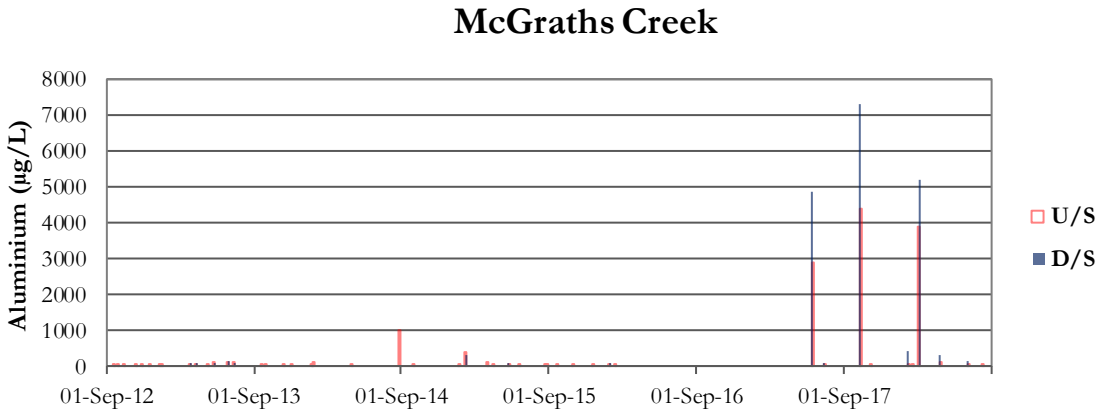

Figure 3.26 Aluminium measurements from McGraths Creek since September 2012

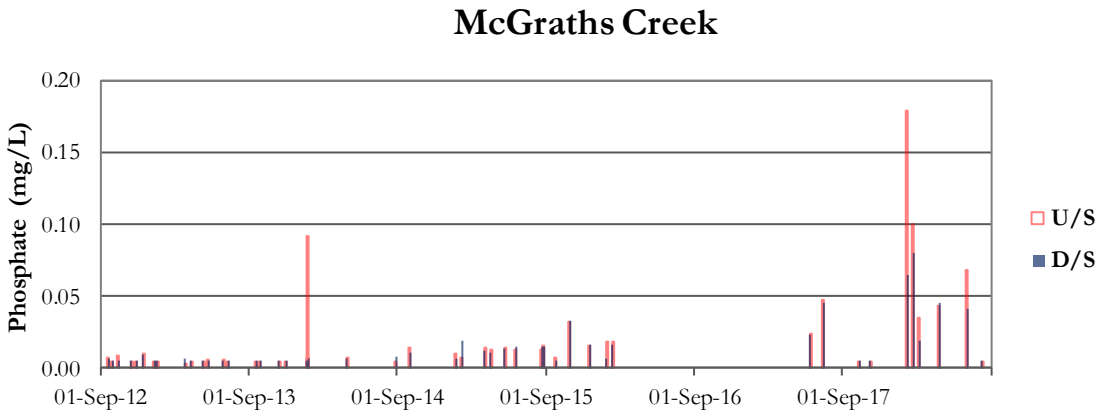

Figure 3.27 Phosphate measurements from McGraths Creek since September 2012

For TSS, turbidity, Al and PO_3 the highest measurements from McGraths Creek in the construction and operational phases have been higher than the ranges measured in the pre-construction phase (**Figures 3.24**, **3.25**, **3.26** and **3.27**).

Summary for McGraths Creek – Highest measurements of TSS, turbidity, Al and PO_3 collected in the construction and operational phases of monitoring. High concentrations/measurements of each of these parameters in the operational phase occurring downstream and upstream of the highway crossing, indicating a potential source other than the highway.

3.2.8 Oyster Creek

There were two results of interest from Oyster Creek (**Table A.8**). Results of interest were the downstream median PO_3 concentration and turbidity measurement. For both PO_3 and turbidity the highest measurement since monitoring began was recorded during this reporting period (**Figures 3.29** and **3.30**).

TSS measurements during this reporting period were within the variation observed in pre-construction and construction phase monitoring with the exception of one downstream measurement (**Figure 3.28**).

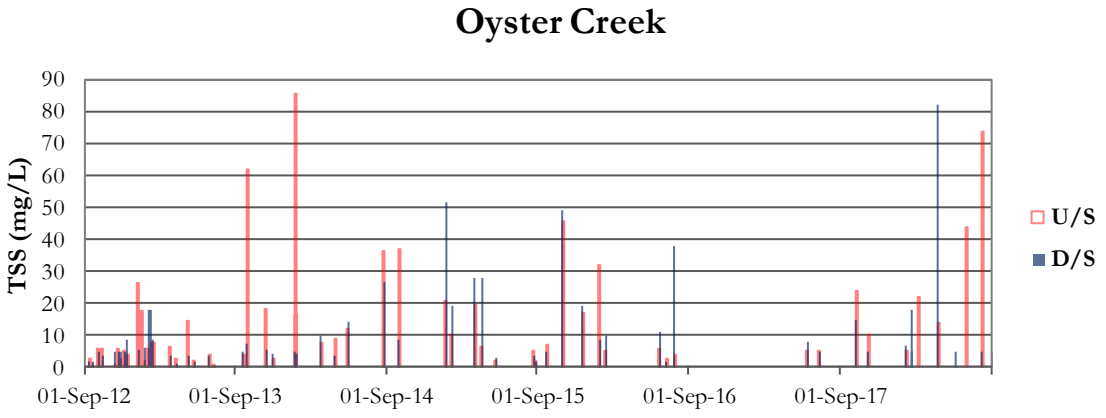

Figure 3.28 TSS concentrations from Oyster Creek since September 2012

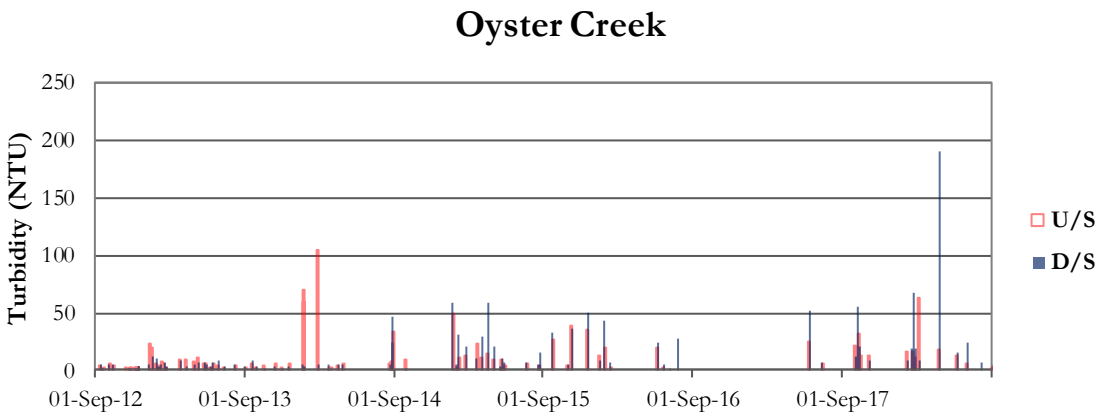

Figure 3.29 Turbidity measurements from Oyster Creek since September 2012

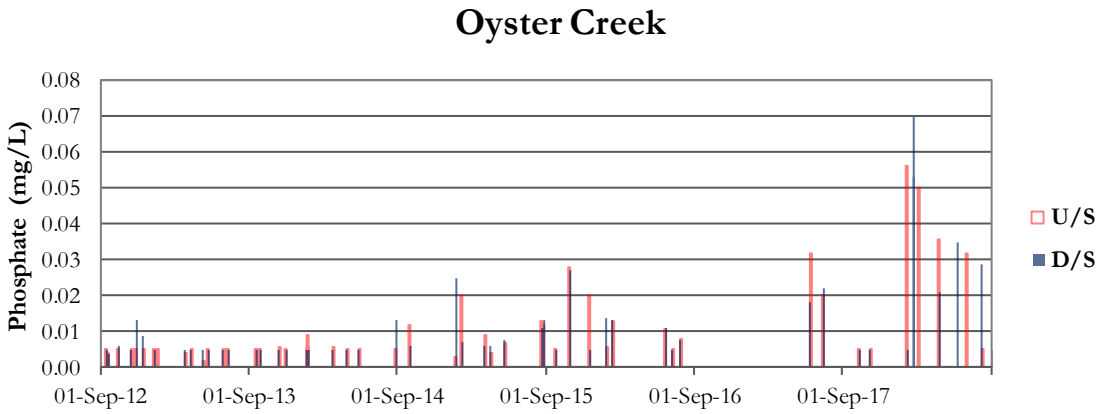

Figure 3.30 Phosphate measurements from Oyster Creek since September 2012

For PO_3, turbidity and TSS the highest measurements from Oyster Creek in the construction and operational phases have been higher than the ranges measured in the pre-construction phase (**Figures 3.28** to **3.30**).

Summary for Oyster Creek – The highest downstream measurements of PO_3, turbidity and TSS collected in the operational phase of monitoring. High downstream measurements of each of these parameters indicate that there is a potential impact from the highway operation on Oyster Creek. To provide context, the median downstream values of PO_3 and turbidity comply with the relevant default ANZECC guideline concentrations of 0.02 mg/L and 50 NTU respectively (**Table 1.1**).

3.2.9 Deep Creek

There was one result of interest from Deep Creek, the downstream median PO_3 concentration (**Table A.9**). However, the PO3 concentrations measured in Deep Creek in the operational phase have all been within the range measured during the construction phase (**Figure 3.33**). Additionally, the highest downstream PO_3 measurements from the operational phase have been accompanied by high upstream measurements and because Deep Creek is strongly tidal at the point of the highway crossing it is not possible to identify whether the source is upstream, downstream or the highway crossing itself.

TSS and turbidity measurements during this reporting period were within the variation observed in pre- construction phase monitoring (**Figures 3.31** and **3.32**).

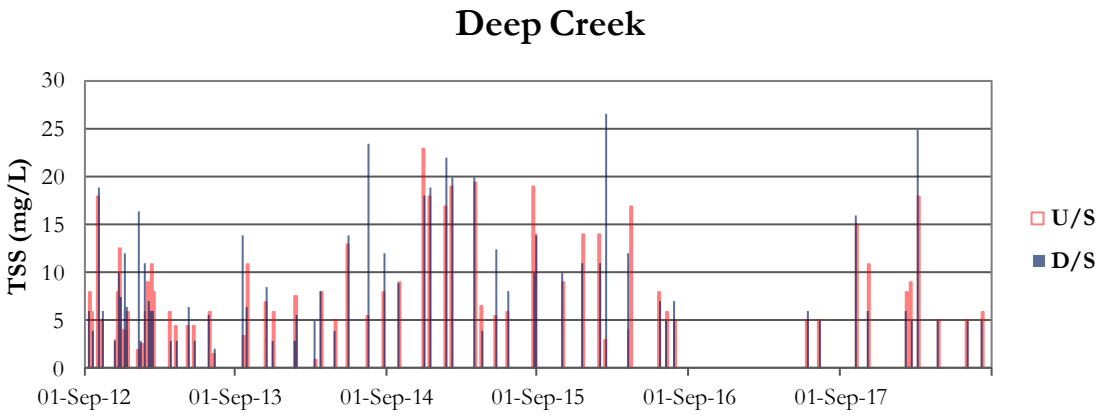

Figure 3.31 TSS concentrations from Deep Creek since September 2012

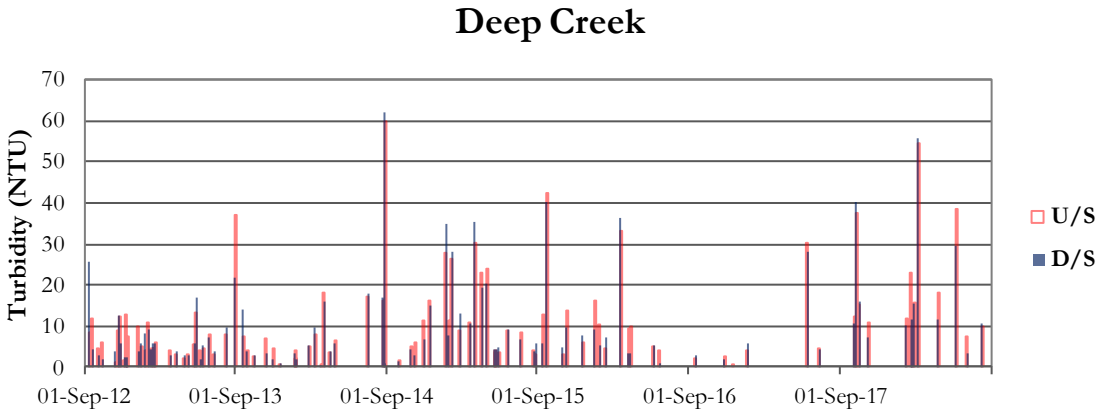

Figure 3.32 Turbidity measurements from Deep Creek since September 2012

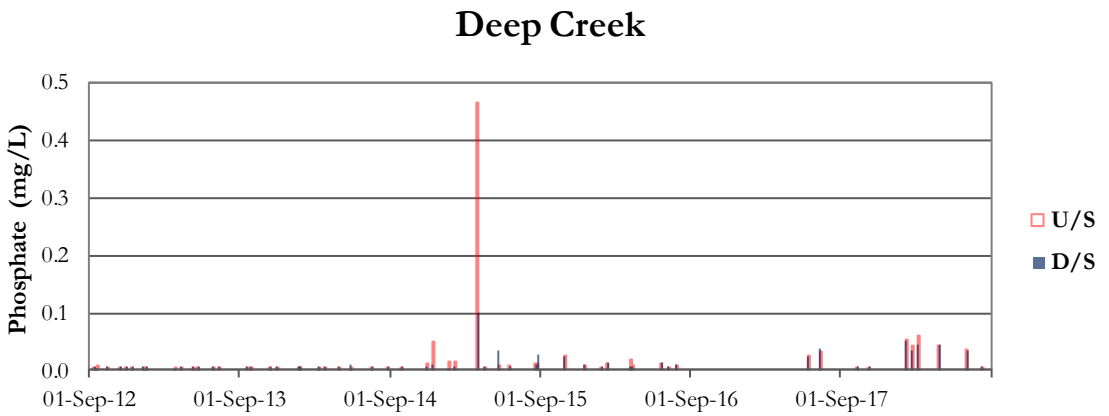

Figure 3.33 Phosphate measurements from Deep Creek since September 2012

For PO_3, TSS and turbidity the highest measurements from Deep Creek in the construction and operational phases have been higher than the ranges measured in the pre-construction phase (**Figures 3.31** to **3.33**).

Summary for Deep Creek – Highest measurements of PO_3, TSS and turbidity collected in the construction and operational phases of monitoring. High measurements of all of these parameters collected both upstream and downstream of the highway crossing. Deep Creek is tidal at the point of the highway crossing, making it difficult to draw conclusions about the source.

3.2.10 Cow Creek

There were several results of interest from Cow Creek (**Table A.10**). Results of interest were the downstream median Al, Fe, PO_3, conductivity and turbidity measurements. Of the parameters that registered a result of interest Al, Fe and PO_3 all had the highest downstream concentration since monitoring began during operational monitoring (**Figures 3.36** to **3.38**). The highest measurements of Al, Fe, PO_3 and turbidity since the beginning of operational monitoring were all registered during wet events and in all cases high values were collected from both upstream and downstream of the highway crossing. This indicates that the source is further up the catchment rather than at the highway crossing. The tidal limit of Cow Creek is at the highway crossing and the high conductivity measurement collected during this monitoring period is highly likely to be related to the tide.

TSS measurements during this reporting period were within the variation observed in construction phase monitoring (**Figure 3.34**). (Note: There were only three samples from Cow Creek collected during pre-construction monitoring and they were limited to physicochemical parameters.)

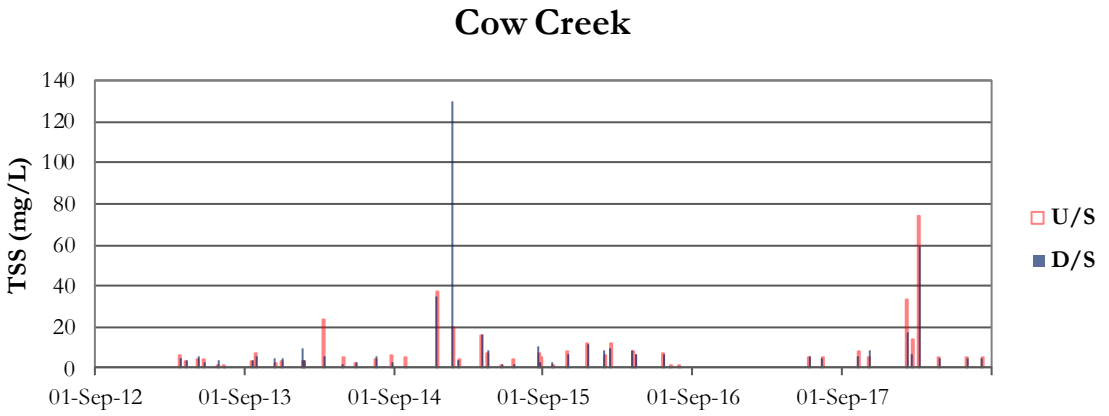

Figure 3.34 TSS concentrations from Cow Creek since September 2012

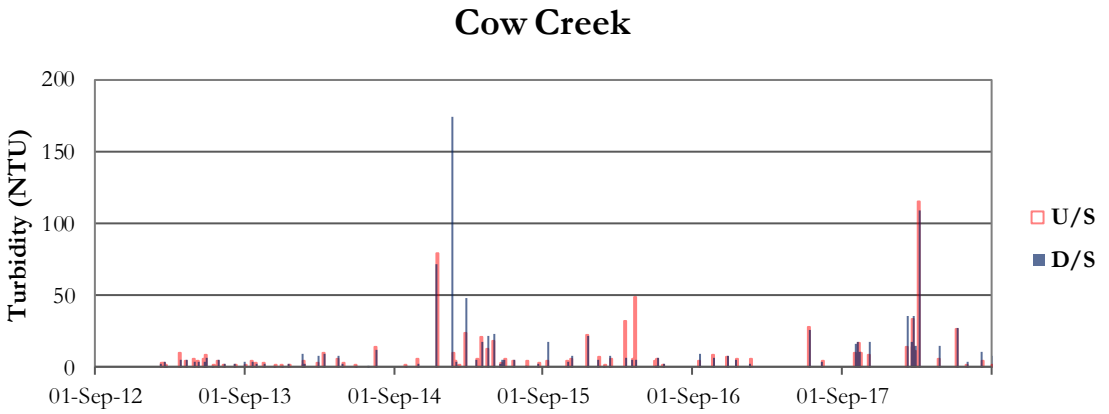

Figure 3.35 Turbidity measurements from Cow Creek since September 2012

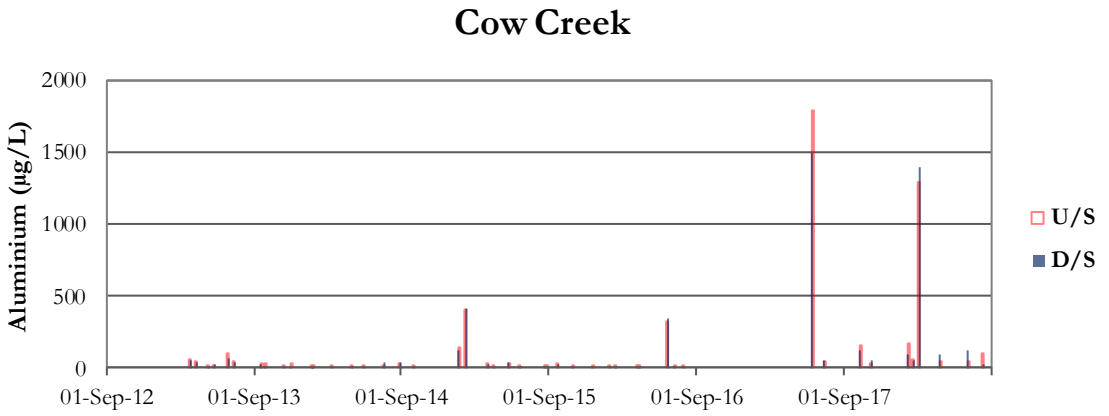

Figure 3.36 Aluminium measurements from Cow Creek since September 2012

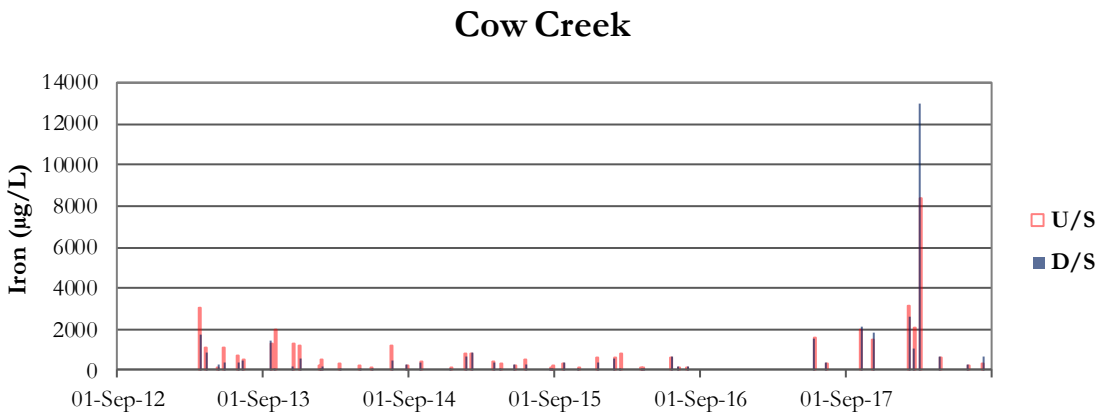

Figure 3.37 Iron measurements from Cow Creek since September 2012

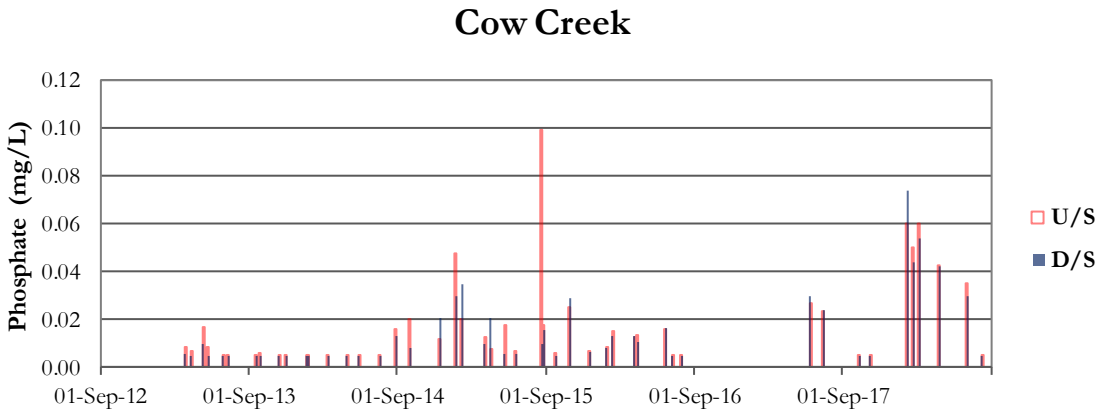

Figure 3.38 Phosphate measurements from Cow Creek since September 2012

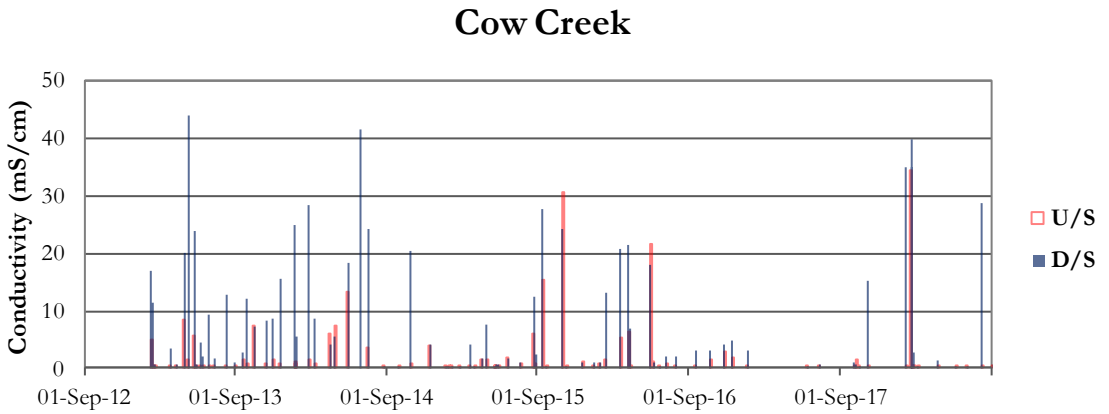

Figure 3.39 Conductivity measurements from Cow Creek since September 2012

The highest measurements of Al and Fe from Cow Creek in the operational phase have been higher than the ranges measured in the construction phase (**Figures 3.36** and **3.37**).

Summary for Cow Creek – Limited pre-construction data available. The highest measurements of Al and Fe collected in the operational phase of monitoring. Elevated measurements of all parameters that registered a result of interest were collected both upstream and downstream of the highway crossing.

3.2.11 Boggy Creek

There were three results of interest from Boggy Creek (**Table A.11**). Results of interest were the downstream median Al, Fe and turbidity measurements. Of the parameters that registered a result of interest Al and Fe have both had the highest downstream measurements since monitoring began during the operational phase (**Figures 3.42** and **3.43**). For turbidity and Al high measurements have been collected both upstream and downstream during operational monitoring but not always during the same monitoring event. In the case of Fe the high downstream concentrations have been accompanied by high upstream concentrations, indicating a source from further up the catchment rather than at the highway crossing.

With the exception of one downstream measurement, TSS measurements from operational phase monitoring were within the variation observed in pre-construction and construction phase monitoring (**Figure 3.40**).

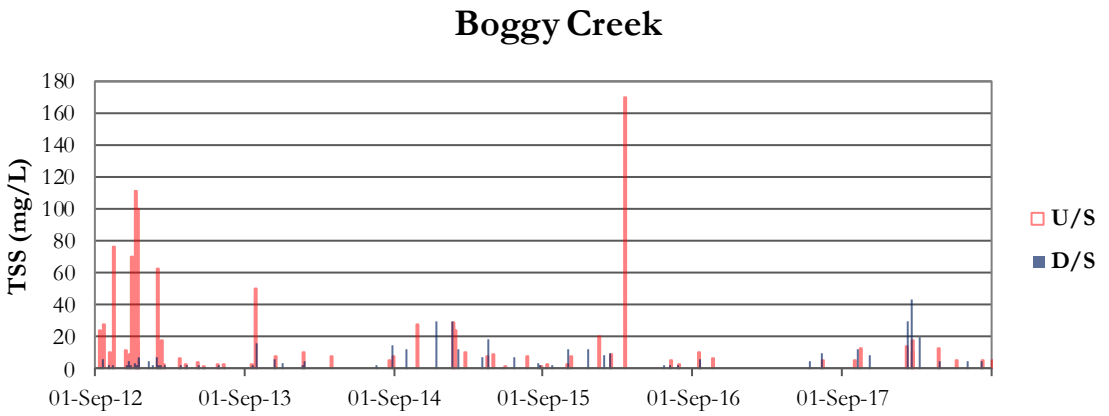

Figure 3.40 TSS concentrations from Boggy Creek since September 2012

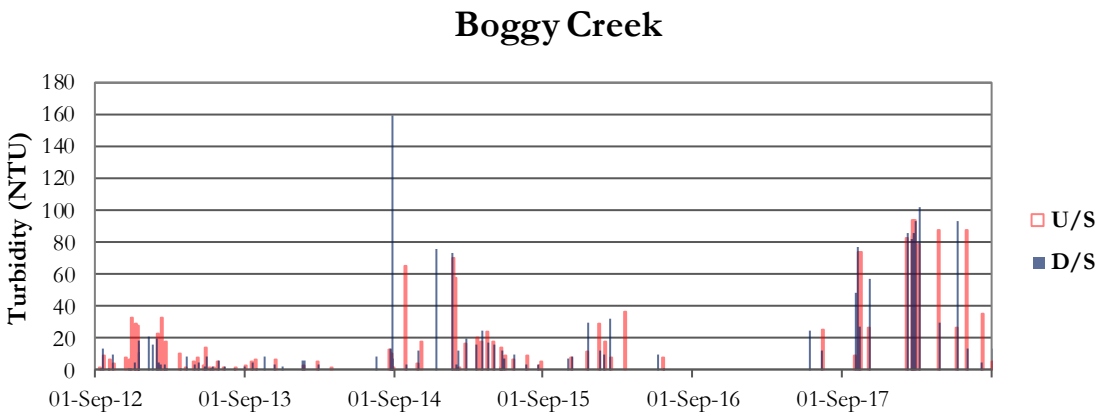

Figure 3.41 Turbidity measurements from Boggy Creek since September 2012

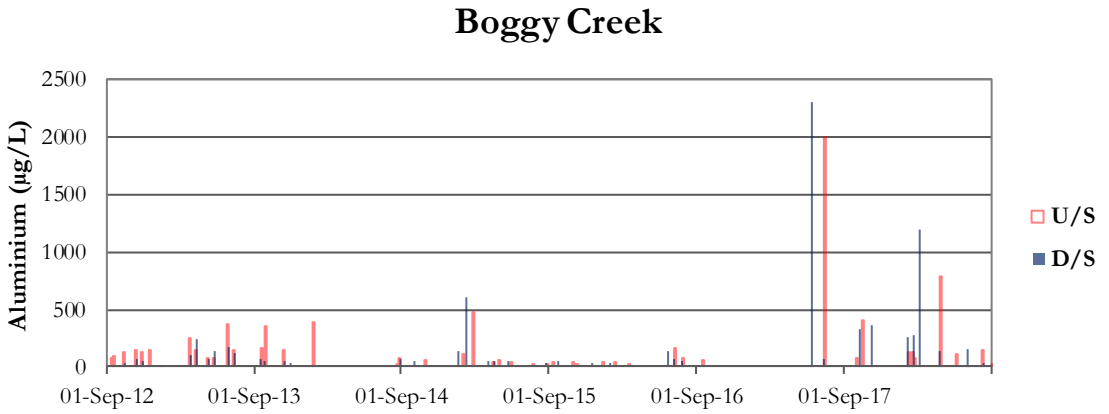

Figure 3.42 Aluminium measurements from Boggy Creek since September 2012

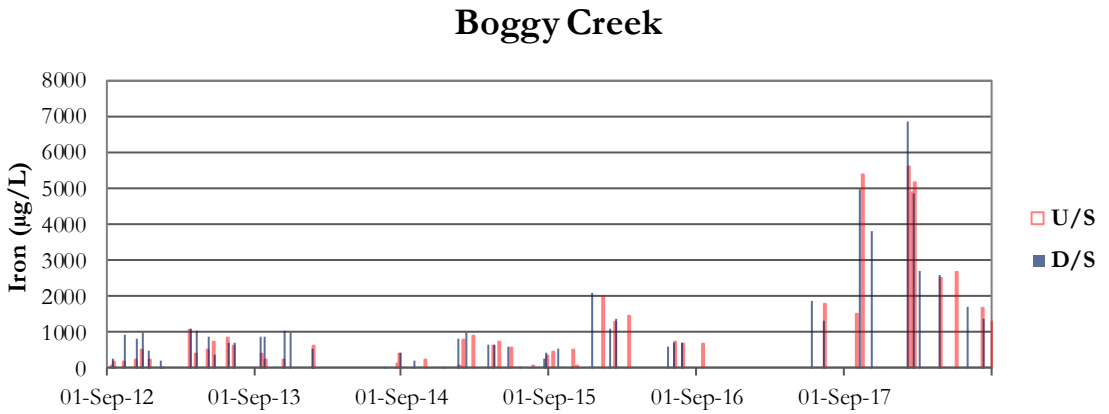

Figure 3.43 Iron measurements from Boggy Creek since September 2012

The highest measurements of turbidity, Al and Fe from Boggy Creek have occurred during the construction and operational phases of monitoring (**Figures 3.41** to **3.43**).

Summary for Boggy Creek – The highest measurements of Al, Fe and turbidity collected in the construction and operational phases of monitoring. During the operational monitoring period high concentrations of each of these parameters have been measured upstream and downstream of the highway crossing.

3.3 Groundwater

3.3.1 Groundwater Quality

A summary of groundwater quality results to date is provided in **Appendix B**.

Sampling dates for all groundwater samples collected during this reporting period are displayed in **Table 3.2**.

Table 3.2 Groundwater quality sampling undertaken during this reporting period

Date	***Parameters***
25/09/2017	All parameters and data loggers
30/11/2017	Field parameters and data loggers
28/03/2018	All parameters and data loggers
06/07/2018	Field parameters and data loggers

The GMP suggests that the analysis of impacts should involve a comparison of the median sampling results from downgradient (impact) sites with the 80th percentile (P80) value of upgradient (control) sites. The summary data from each site is presented in **Appendix B** with the upgradient P80 values from the combined preconstruction, construction and operational phases.

The relevant summary statistics for each groundwater site are presented in **Tables B.1** to **B.6**. A brief description of the summary results from each waterway follows. For the purposes of assessing the results of operational phase monitoring with earlier results we have defined results of interest as those where the operational phase downgradient median is greater than the combined preconstruction, construction and operational phase upgradient P80. Note that the summary values for operational phase monitoring between 1 September 2016 and 31 August 2018 are derived from between 2 and 5 samples at most sites.

3.3.2 Ch 63200

Results of interest from Ch 63200 (**Table B.1**) were the downgradient median Al, As, Cr, Cu, Fe, Pb, TN, PO_3 and Ca^+ measurements. There was no water in the upgradient piezometer for most of the construction phase monitoring. A new piezometer was constructed in September 2017 when the existing piezometer was found to be collapsed. The lack of upgradient construction phase data and missing upgradient data from the earlier stages of operational phase monitoring limit the capacity to draw conclusions about potential impacts from highway operation. Of the parameters that generated a result of interest, the downgradient Al, As, Cr, Cu, Fe and Pb concentrations measured during this reporting period were the highest since monitoring started (**Figures 3.44** to **3.49**). However, in each of these cases the highest concentrations have occurred as an isolated measurement, rather than as part of a pattern.

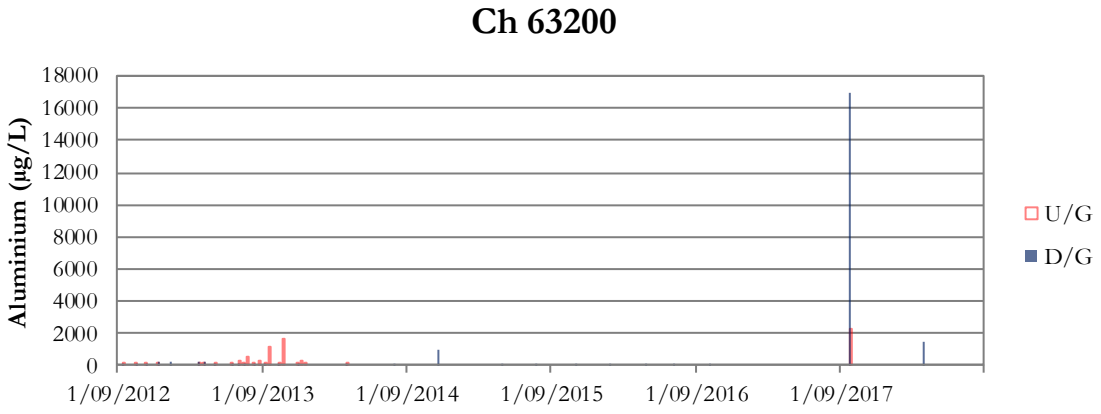

Figure 3.44 Aluminium concentrations from Ch 63200 since September 2012

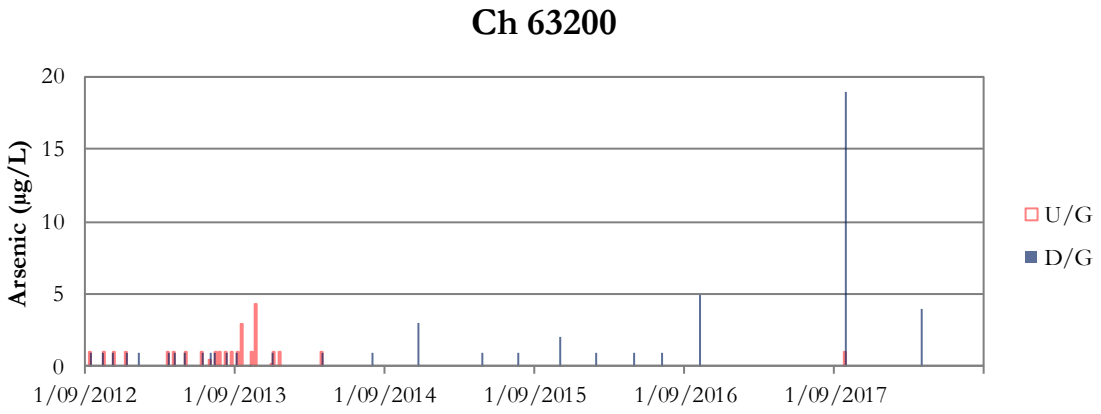

Figure 3.45 Arsenic concentrations from Ch 63200 since September 2012

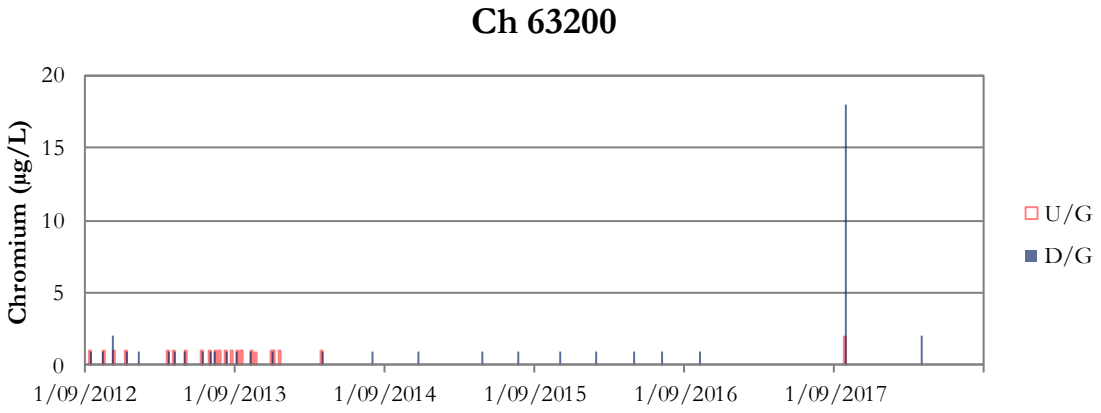

Figure 3.46 Chromium concentrations from Ch 63200 since September 2012

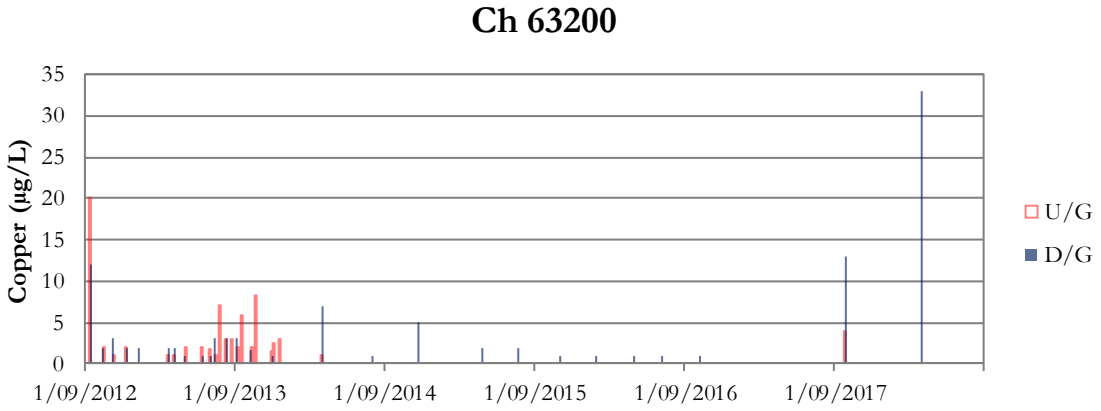

Figure 3.47 Copper concentrations from Ch 63200 since September 2012

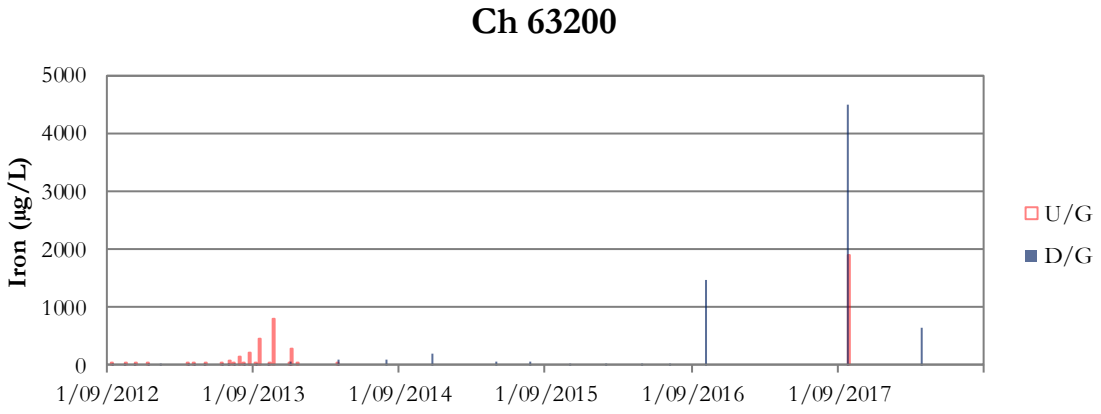

Figure 3.48 Iron concentrations from Ch 63200 since September 2012

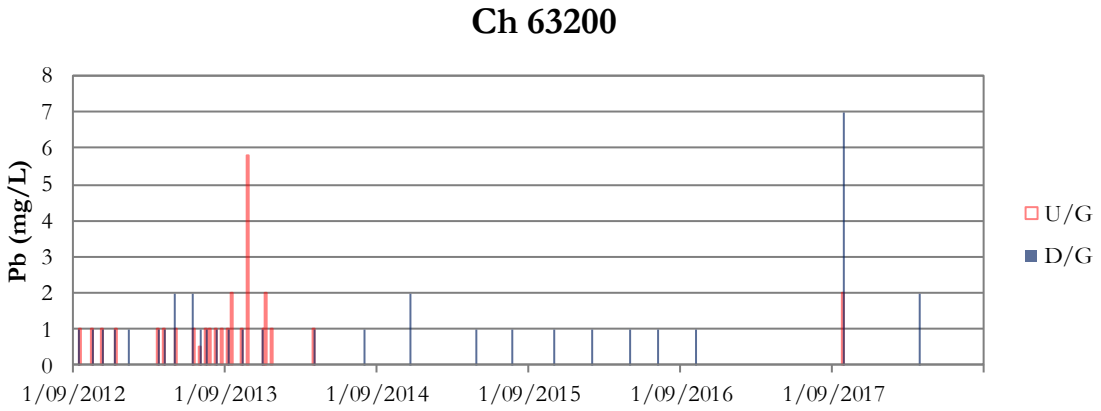

Figure 3.49 Lead concentrations from Ch 63200 since September 2012

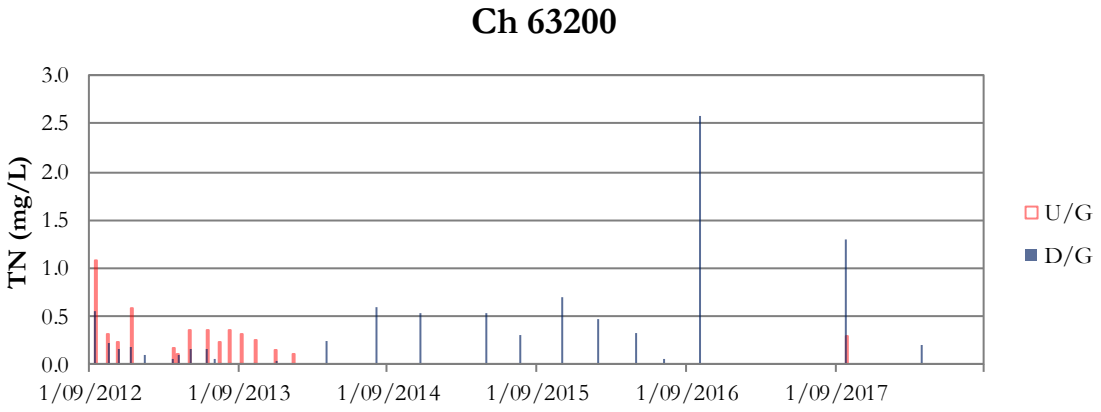

Figure 3.50 TN concentrations from Ch 63200 since September 2012

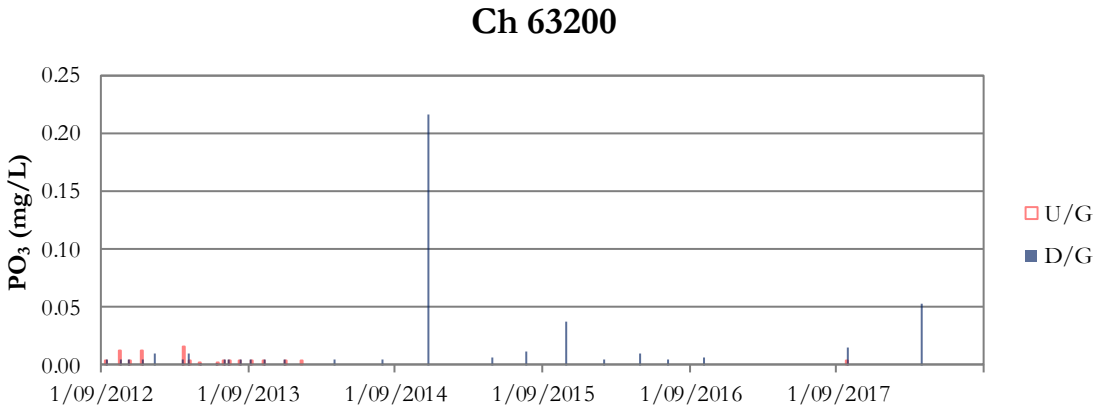

Figure 3.51 Phosphate measurements from Ch 63200 since September 2012

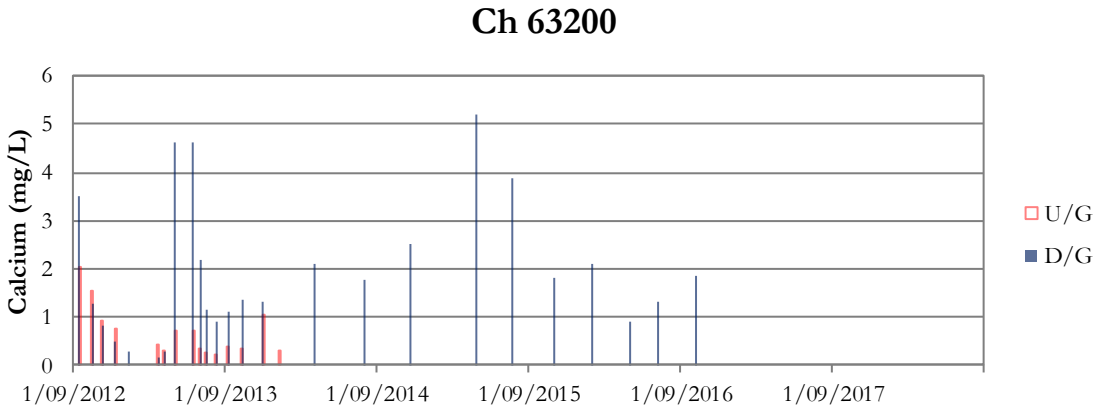

Figure 3.52 Calcium ion concentrations from Ch 63200 since September 2012

Summary for Ch 63200: Highest downgradient Al, As, Cr, Cu, Fe and Pb concentrations since the start of monitoring occurred during this monitoring period. Dry upgradient piezometer for most of the construction phase monitoring period and some of the early operation phase monitoring period limits the capacity to draw conclusions about potential impacts from construction and operation. A new upgradient piezometer was installed at the beginning of this monitoring period.

3.3.3 Ch 64600

Results of interest from Ch 64600 (**Table B.2**) were the downgradient median Fe, NO_3, PO_3 and HCO_3^- concentrations. Of the parameters that registered a result of interest, the downgradient Fe, NO_3 and HCO_3^- were all within the ranges measured during construction phase monitoring (and pre-construction phase monitoring in the case of NO_3 and HCO_3^-). In all cases except for PO_3 and HCO_3^- the upgradient measurements during this reporting period were equivalent to or greater than the downgradient measurements, indicating that the high measured concentrations may not be related to highway construction or operation (**Figures 3.53** to **3.56**). A new upgradient piezometer was constructed at Ch 64600 in April 2014.

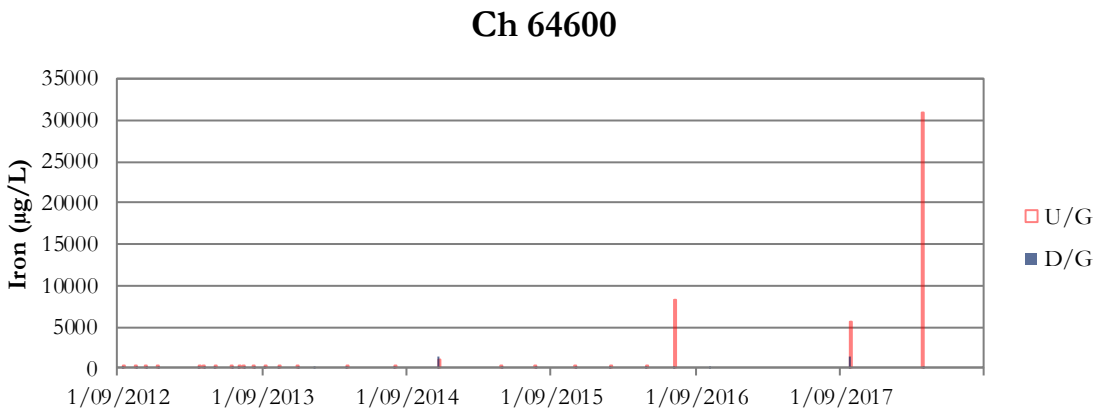

Figure 3.53 Iron concentrations from Ch 64600 since September 2012

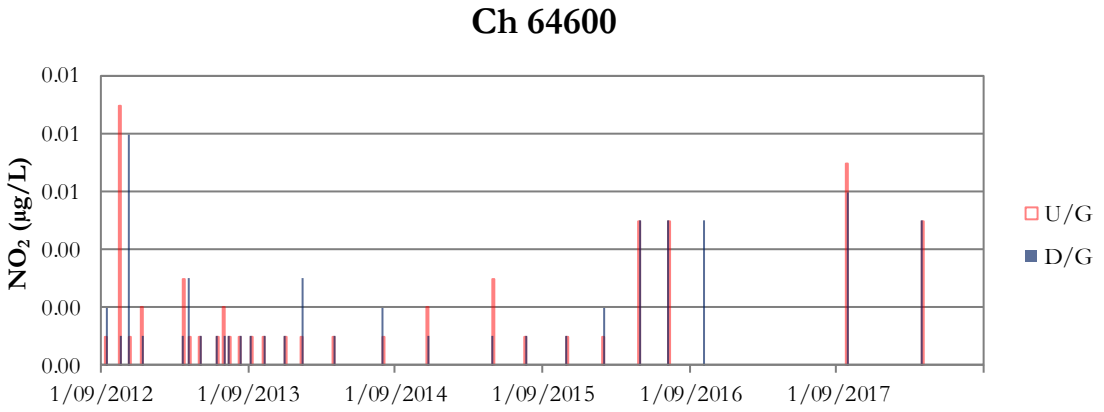

Figure 3.54 Nitrite measurements from Ch 64600 since September 2012

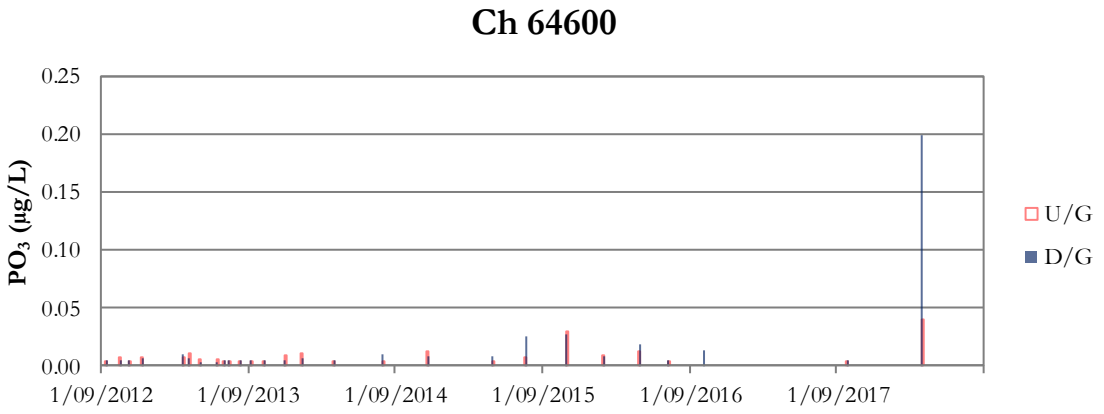

Figure 3.55 Phosphate measurements from Ch 64600 since September 2012

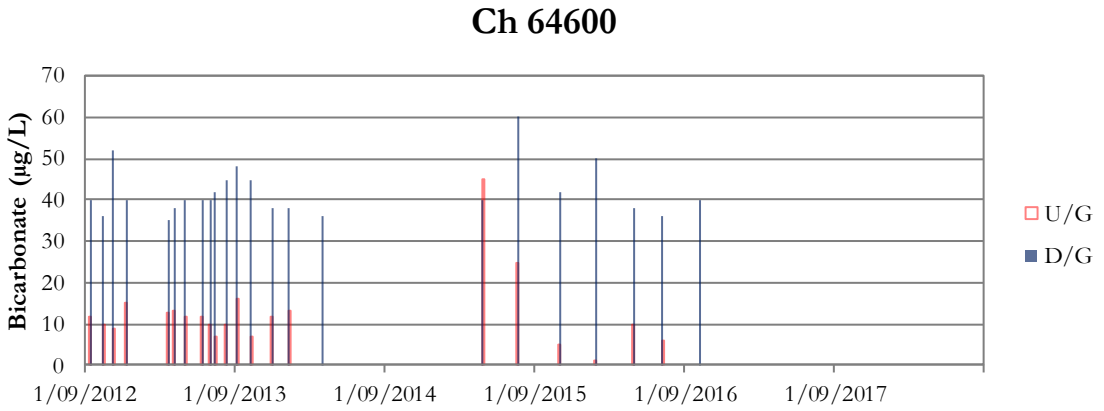

Figure 3.56 Bicarbonate measurements from Ch 64600 since September 2012

Summary for Ch 64600: All parameters which registered results of interest, except for PO_3 and HCO_3^- had the highest recorded measurements during this reporting period from the upgradient piezometer, indicating that higher concentrations of contaminants may not have originated from highway construction or operation. In the case of bicarbonate the result of interest is generated from a single sample. In the case of PO_3 the high downgradient median for the operational phase relates to a single, isolated, outlying data point.

3.3.4 Ch 72400

Results of interest from Ch 72400 (**Table B.3**) were the downgradient median Al, As, Cu, Ni, NH_4, PO_3, pH, HCO_3^-, K^+, Ca^{2+} and Mg^{2+} measurements. There was no water in the upgradient piezometer during this reporting period, the previous reporting period or most of the construction phase monitoring period, limiting the capacity to draw conclusions about groundwater quality. With the exception of NH_4 and PO_3 all of the parameters that generated a result of interest were measured within the ranges observed during construction phase monitoring (**Figures 3.57** to **3.67**). Additionally, the downgradient concentrations of HCO_3^- and K^+ were measured within the ranges observed during pre-construction phase monitoring.

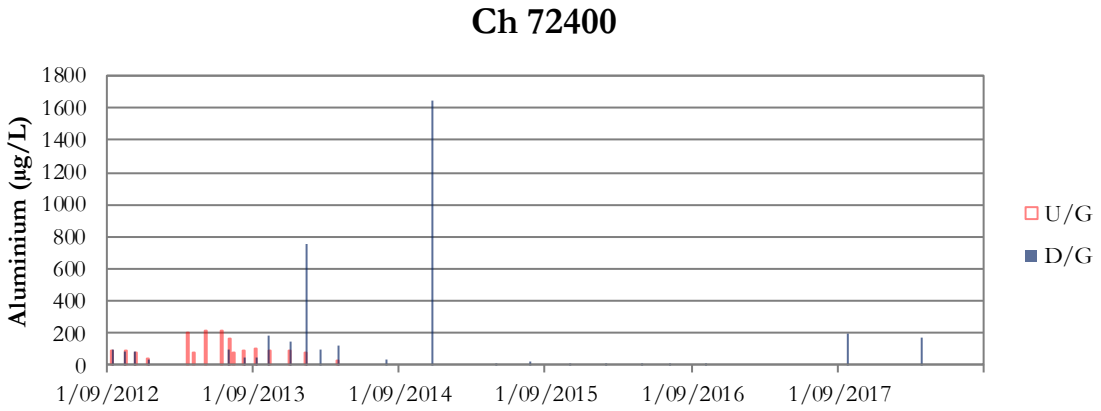

Figure 3.57 Aluminium concentrations from Ch 72400 since September 2012

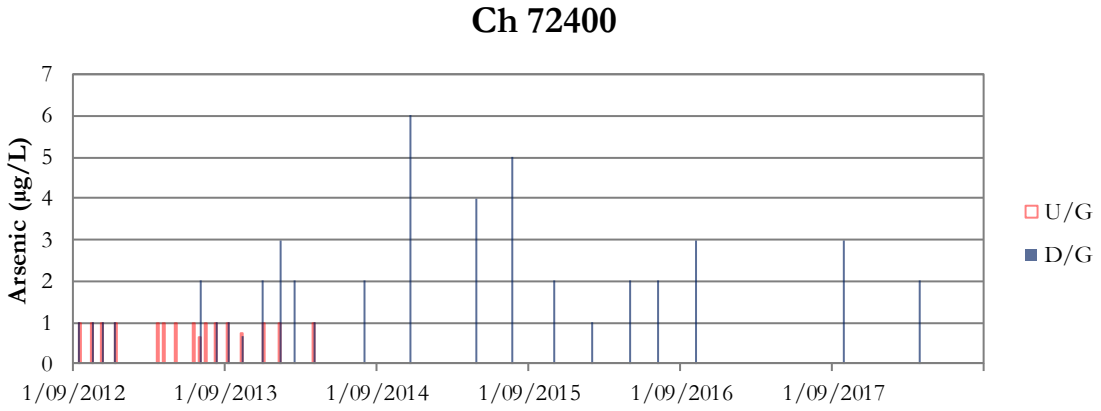

Figure 3.58 Arsenic concentrations from Ch 72400 since September 2012

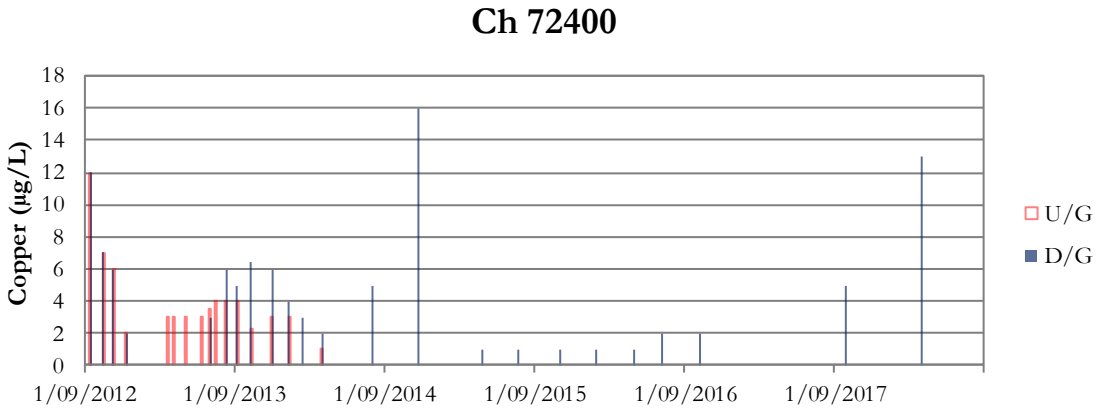

Figure 3.59 Copper concentrations from Ch 72400 since September 2012

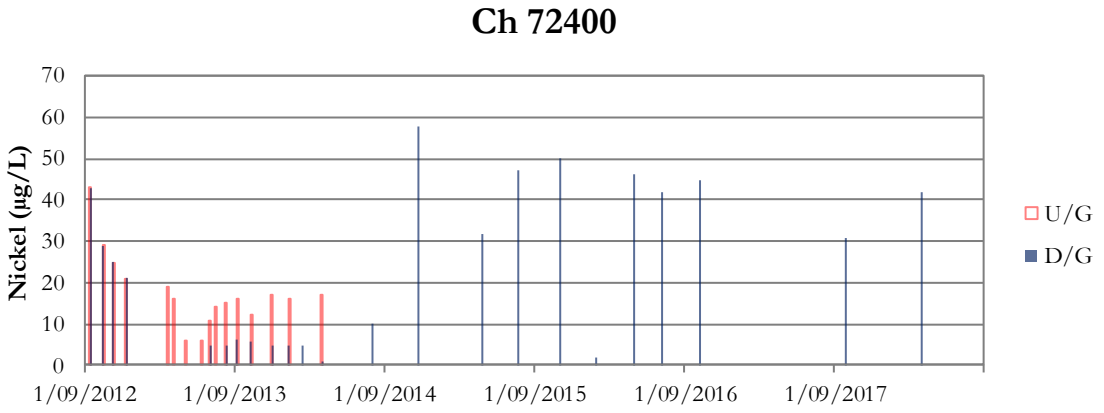

Figure 3.60 Nickel concentrations from Ch 72400 since September 2012

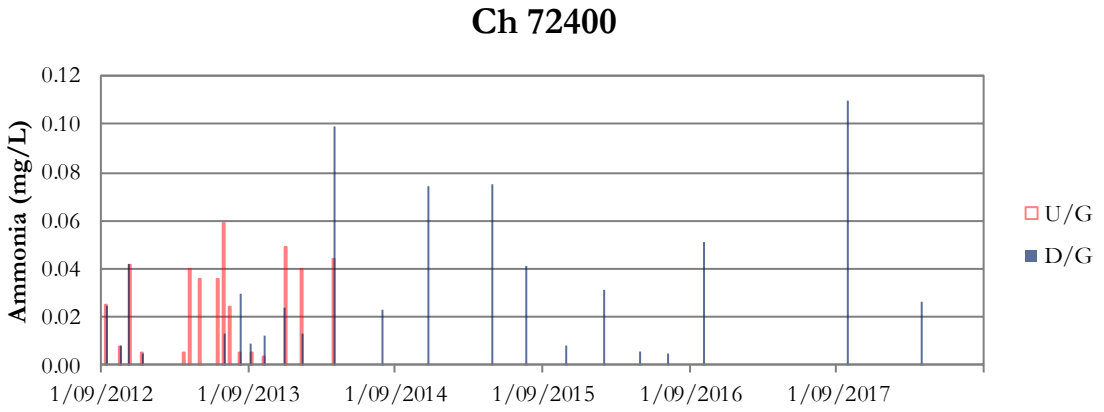

Figure 3.61 Ammonia measurements from Ch 72400 since September 2012

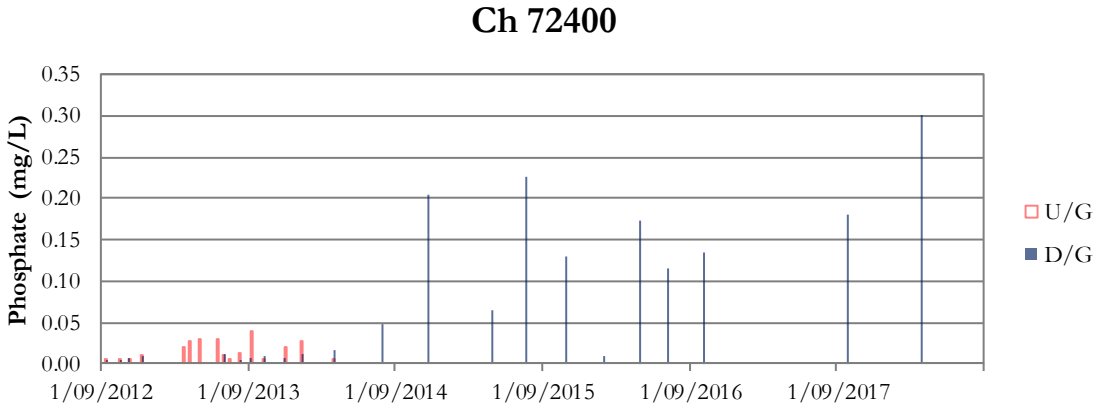

Figure 3.62 Phosphate measurements from Ch 72400 since September 2012

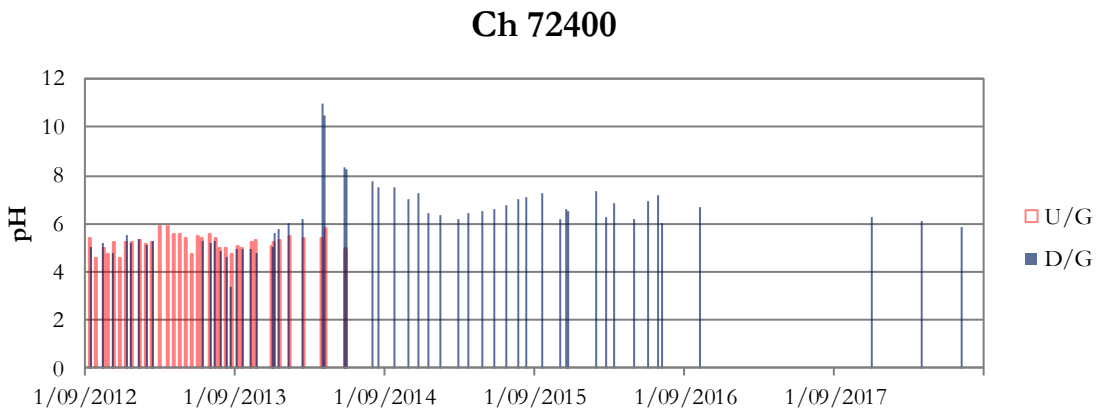

Figure 3.63 pH measurements from Ch 72400 since September 2012

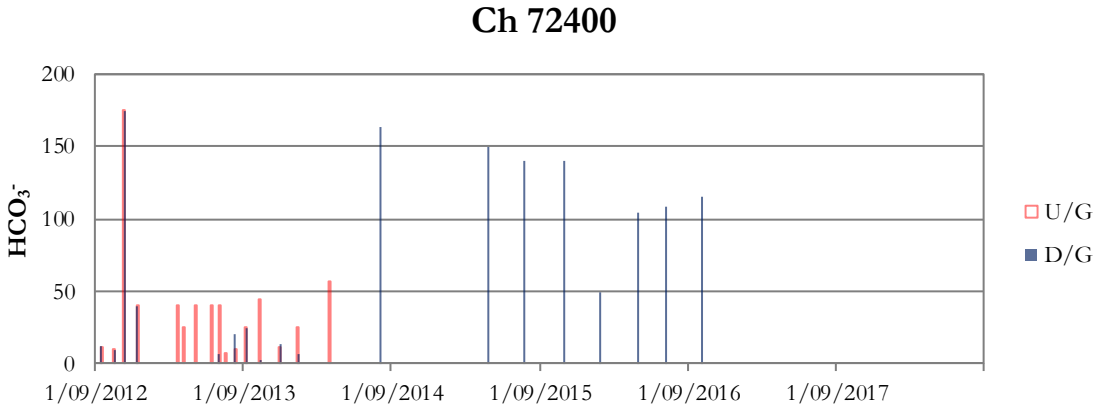

Figure 3.64 Bicarbonate measurements from Ch 72400 since September 2012

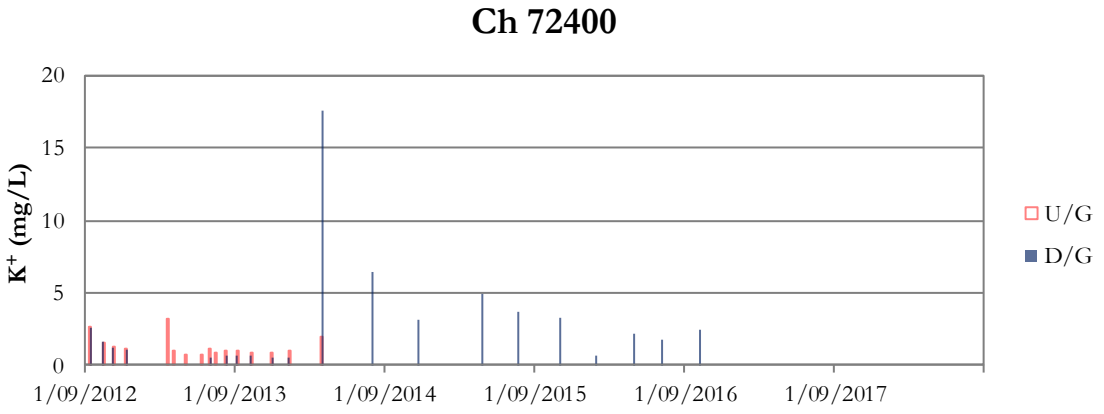

Figure 3.65 Potassium measurements from Ch 72400 since September 2012

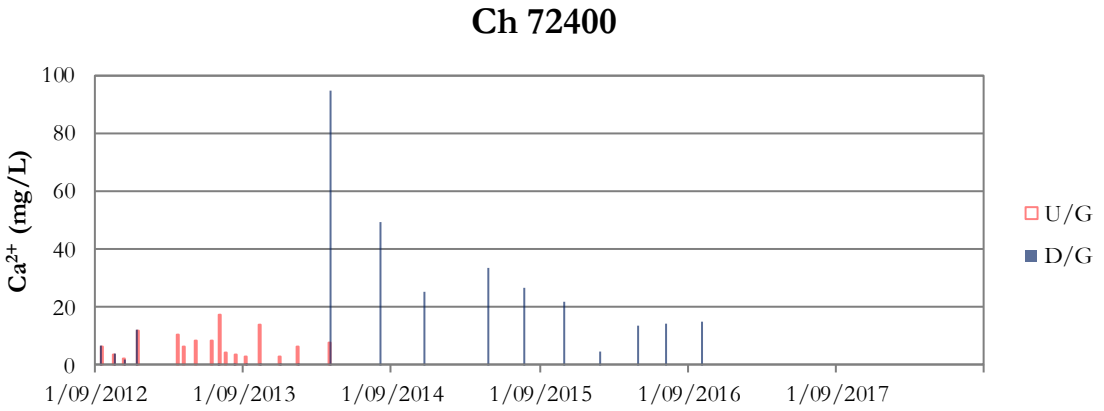

Figure 3.66 Calcium measurements from Ch 72400 since September 2012

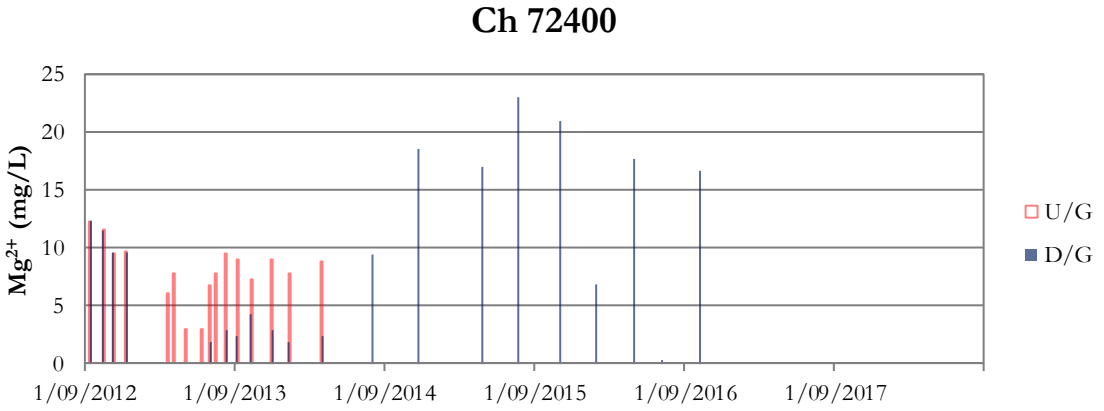

Figure 3.67 Magnesium measurements from Ch 72400 since September 2012

Summary for Ch 72400: All of the parameters that generated a result of interest were measured within the ranges observed during construction phase monitoring except for NH_3 and PO_3. The highest downgradient measurements of all parameters that generated a result of interest have been measured during the construction or operational phases of monitoring. However, the capacity to draw conclusions about the source of elevated concentrations is limited by the dry upgradient piezometer.

3.3.5 Ch 74400

Results of interest from Ch 74400 (**Table B.4**) were the downgradient median Al, Cr, Fe, Ni, HCO_3^- and Cl^- and Mg^{2+} measurements. With the exception of Fe, all of the parameters that generated a result of interest were measured at the downgradient piezometers during this

monitoring period within the ranges observed during construction phase monitoring. Cr, Ni, Cl^- and Mg^{2+} were also measured this monitoring period within the ranges observed during pre-construction monitoring (**Figures 3.68** to **3.74**).

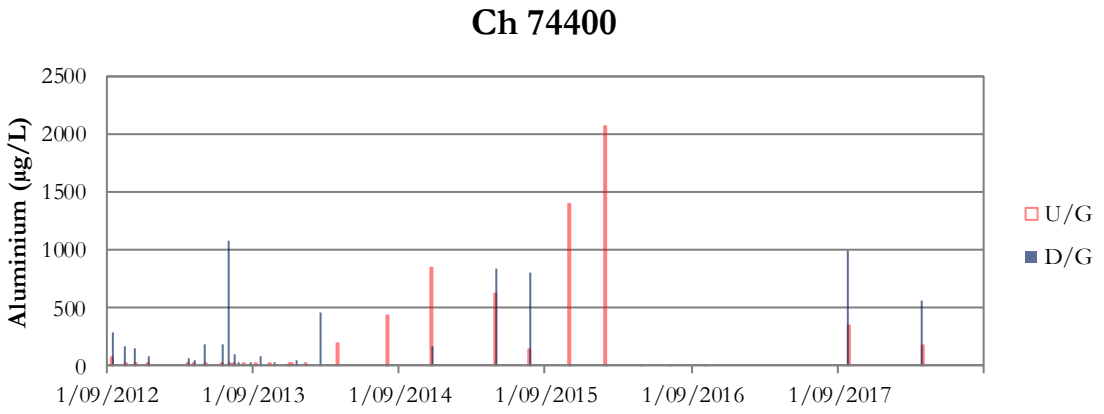

Figure 3.68 Aluminium measurements from Ch 74400 since September 2012

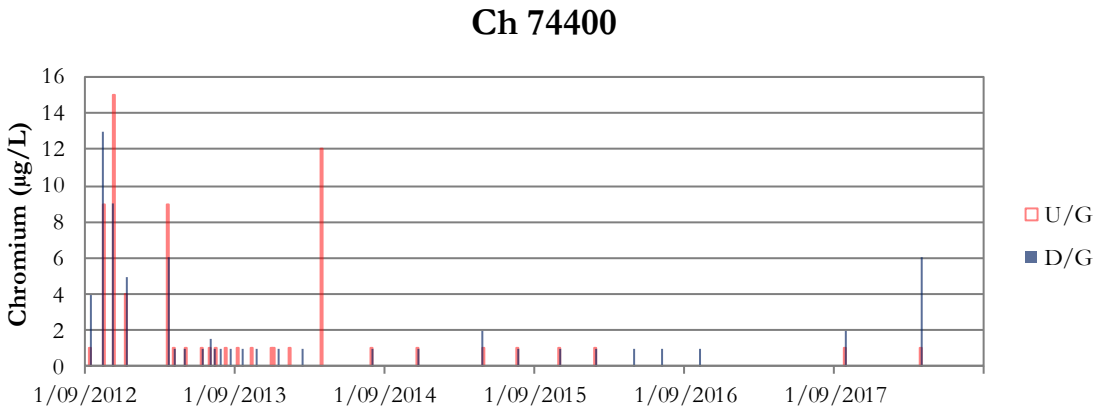

Figure 3.69 Chromium measurements from Ch 74400 since September 2012

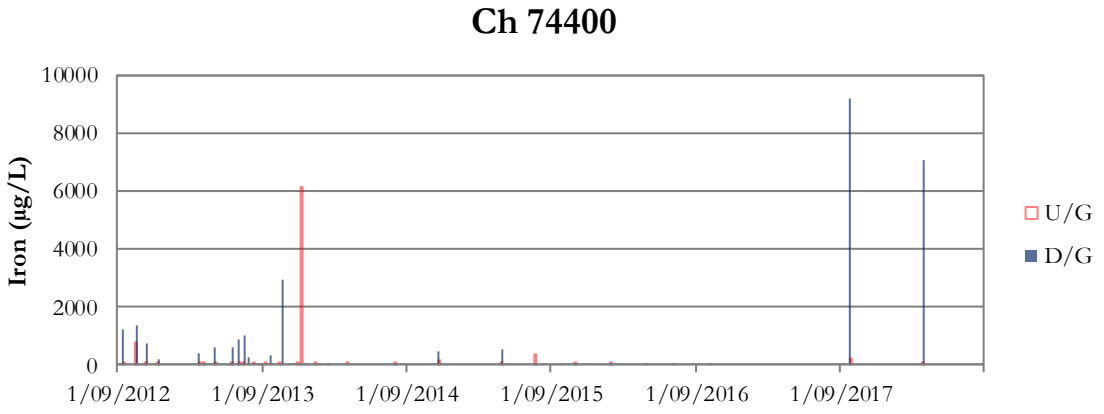

Figure 3.70 Iron measurements from Ch 74400 since September 2012

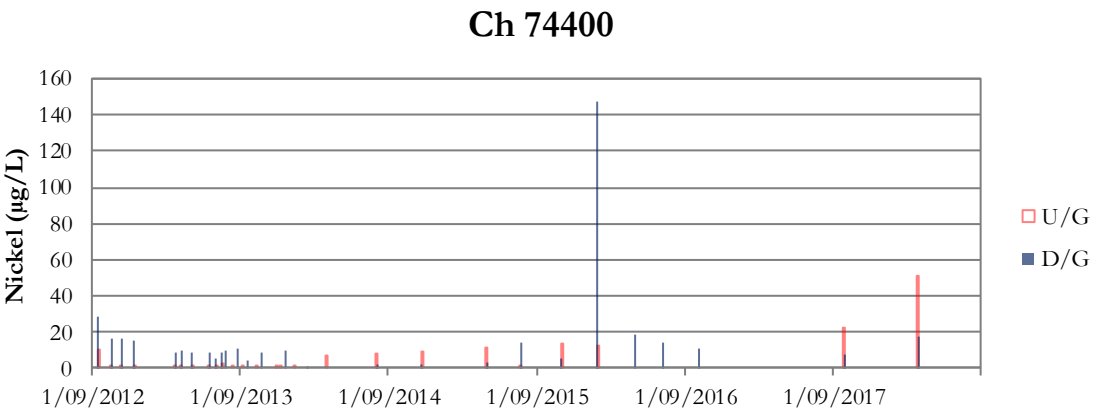

Figure 3.71 Nickel measurements from Ch 74400 since September 2012

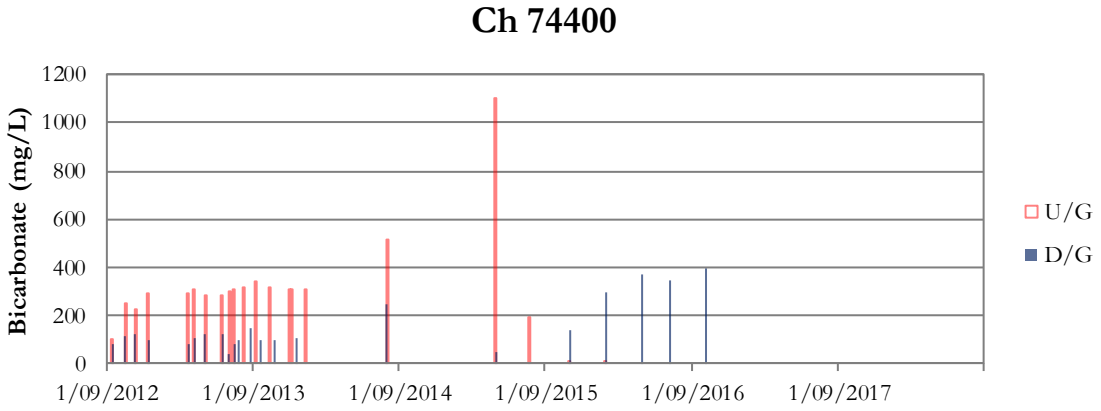

Figure 3.72 Bicarbonate measurements from Ch 74400 since September 2012

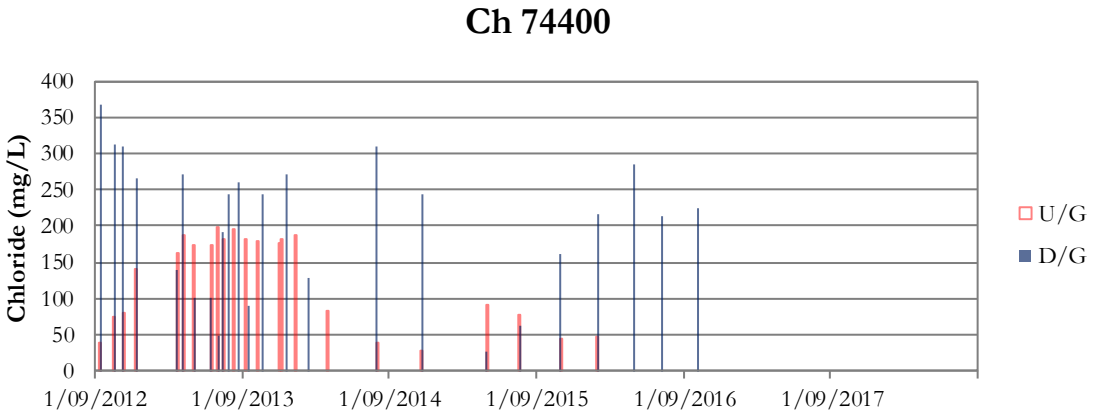

Figure 3.73 Chloride measurements from Ch 74400 since September 2012

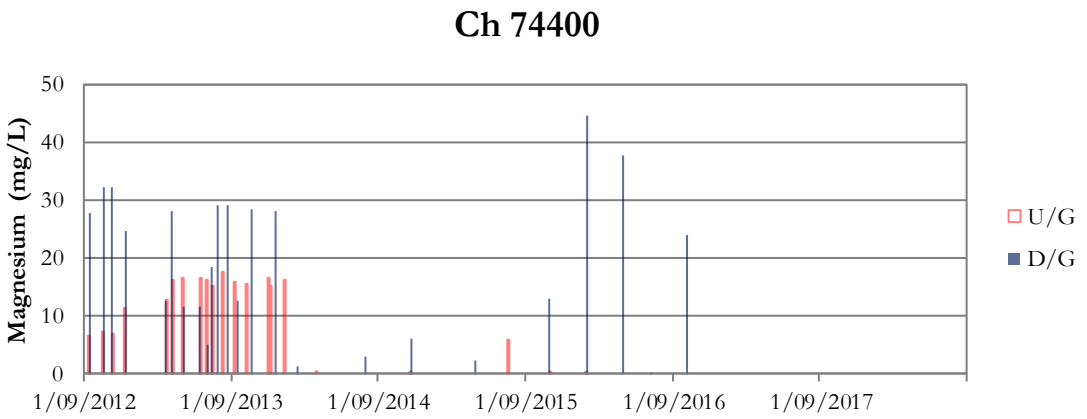

Figure 3.74 Magnesium measurements from Ch 74400 since September 2012

Summary for Ch 74400: Almost all of the parameters that generated a result of interest were measured within the ranges observed during pre-construction and/or construction phase monitoring. However, the Fe concentrations in the downgradient piezometer during this reporting period were the highest since monitoring began. The upgradient piezometer at this location appears to be disconnected from the water table (see **Figure 3.82**), limiting the capacity to draw conclusions about the source of elevated concentrations.

3.3.6 Ch 75500

There were no results of interest from Ch 75500 (**Table B.5**). There is no downgradient piezometer at Ch 75500, limiting the capacity to draw conclusions about groundwater quality. All measurements at the upstream piezometer were within the ranges observed during preconstruction and construction phase monitoring.

Summary for Ch 75500: No results of interest from Ch75500.

3.3.7 Ch 78500

The results of interest from Ch 78500 (**Table B.6**) were the downgradient median Al, Fe, pH and TSS measurements. There was no water in the upgradient piezometer during this reporting period or most of the construction phase monitoring period, limiting the capacity to draw conclusions about groundwater quality. With the exception of Fe, all of the parameters that

registered results of interest during this reporting period were measured within the range of the results from the pre-construction and/or construction phase monitoring during this reporting period.

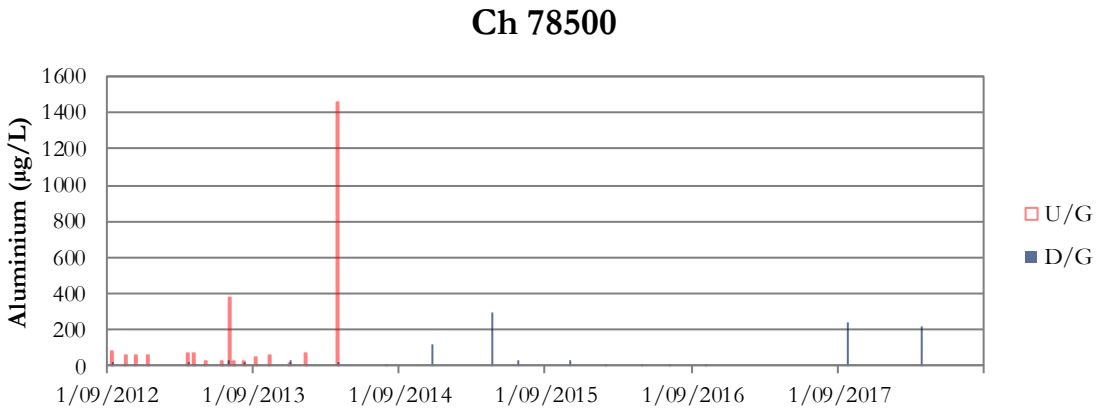

Figure 3.75 Aluminium measurements from Ch 78500 since September 2012

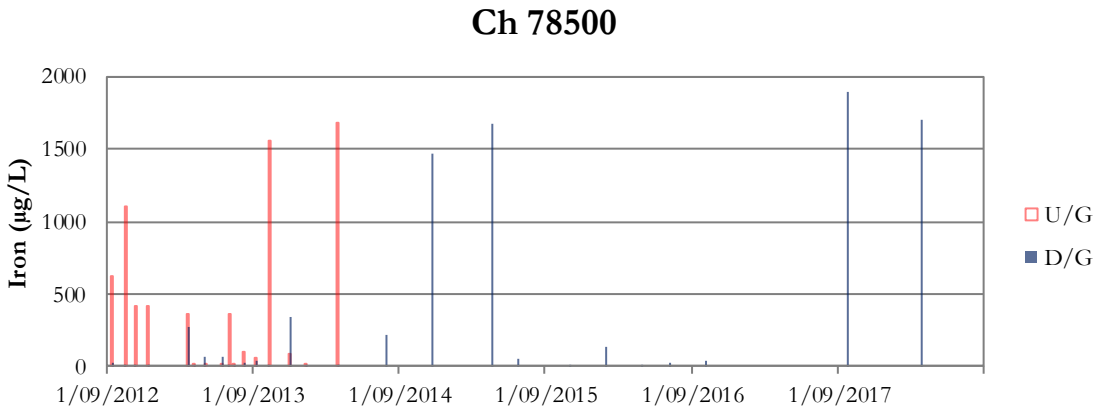

Figure 3.76 Iron measurements from Ch 78500 since September 2012

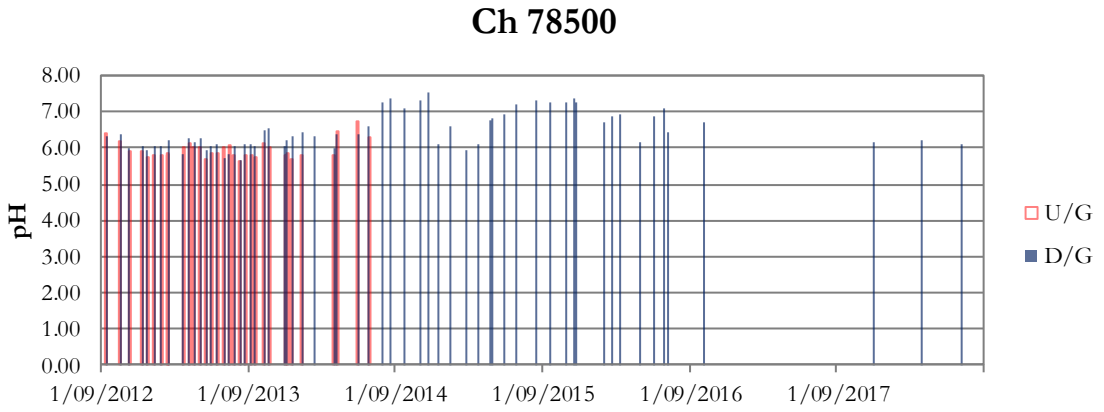

Figure 3.77 pH measurements from Ch 78500 since September 2012

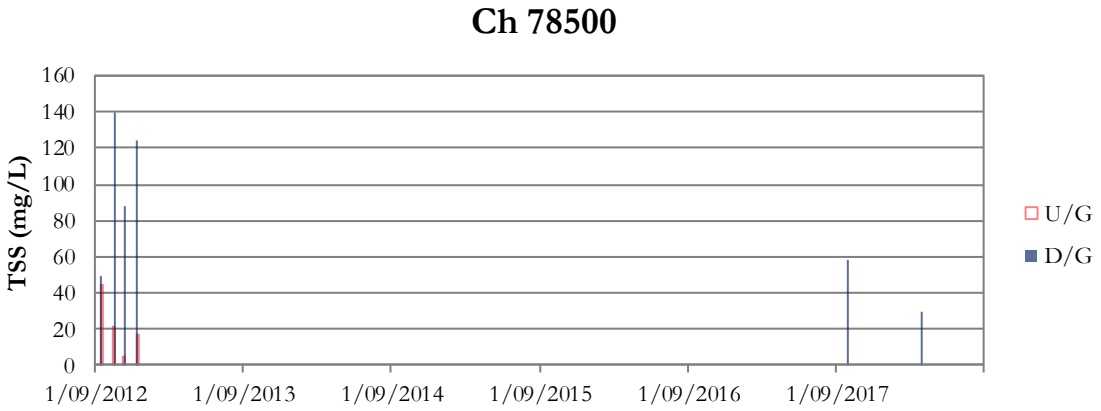

Figure 3.78 TSS measurements from Ch 78500 since September 2012

Summary for Ch 78500: Most of the parameters that generated a result of interest were measured within the ranges observed during pre-construction and/or construction phase monitoring. Downgradient Fe concentrations measured during this reporting period were the highest since monitoring began, though only slightly higher than the upgradient concentrations from the early construction phase monitoring. The capacity to draw conclusions about the source of elevated concentrations is limited by the dry upgradient piezometer.

3.3.8 Groundwater Level

The logged groundwater results for the period between 1 September 2017 and 31 August 2018 are displayed in **Figures 3.79 to 3.84**.

The median relative difference between groundwater levels at the pair of bores at Ch63200 was 5.5 m during pre-construction monitoring. For this reporting period the mean relative difference was 3.26 m (**Figure 3.79**).

The median relative difference between groundwater level at the pair of bores at Ch64600 was 0.16m during pre-construction monitoring. During the current monitoring period the median relative difference was 1.37 m (**Figure 3.80**).

The median relative pre-construction difference between groundwater level at the pair of bores at Ch72400 was not reported because the upgradient well (30500.1) was dry. During the current reporting period the upgradient well was also dry (**Figure 3.81**).

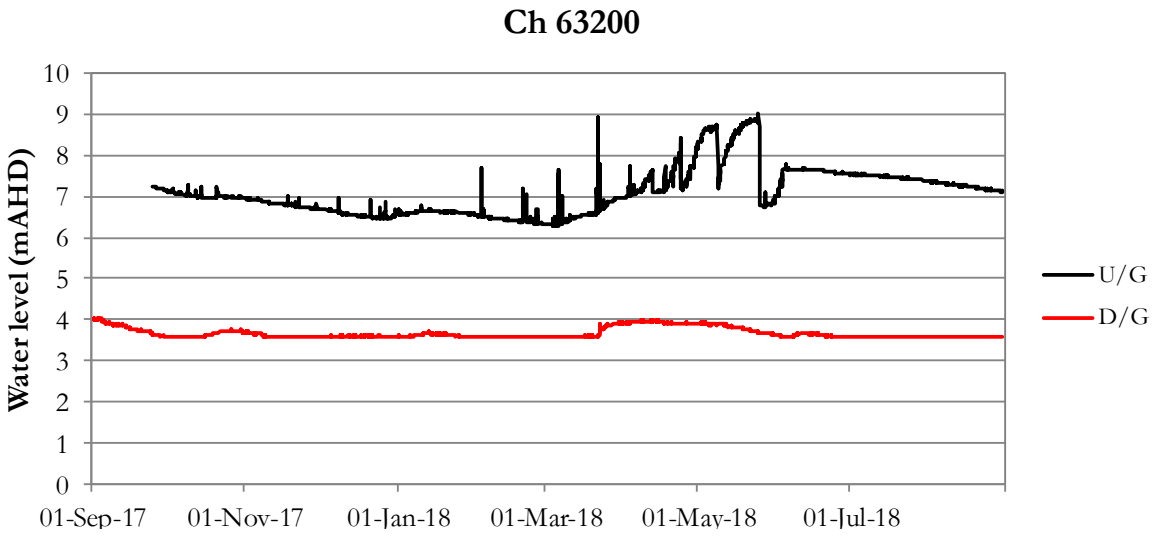

Figure 3.79 Groundwater levels at chainage 63200

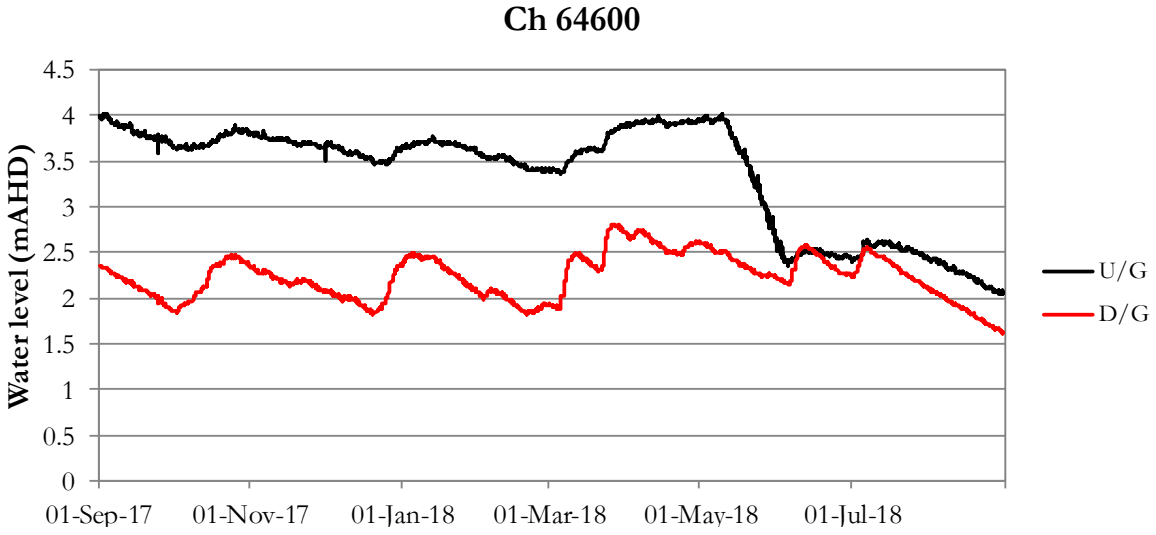

Figure 3.80 Groundwater levels at chainage 64600

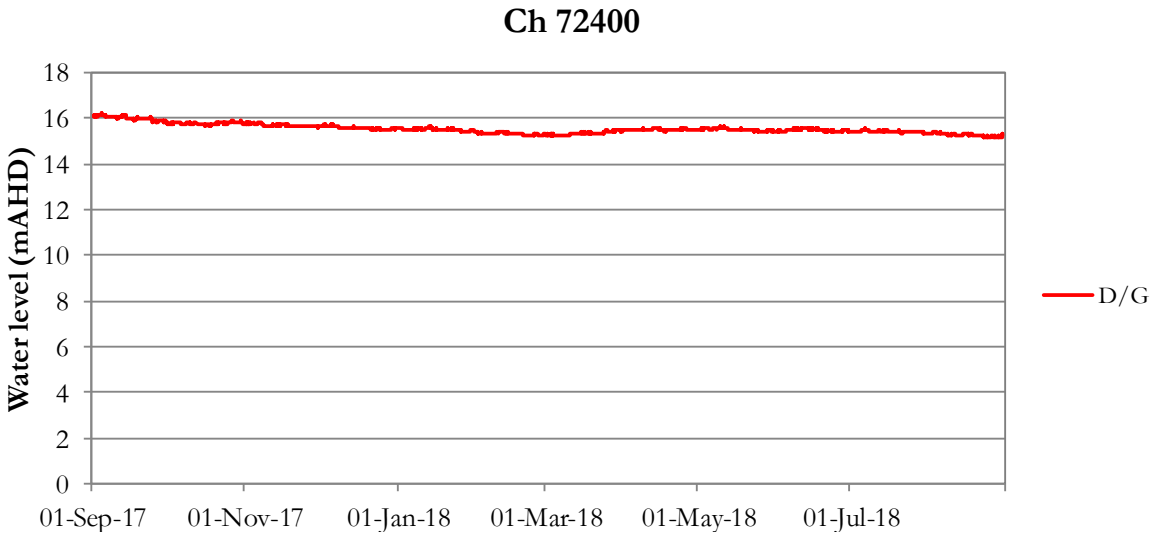

Figure 3.81 Groundwater levels at chainage 72400

The median relative difference between groundwater level at the pair of bores at Ch74400 was not reported for the pre-construction period because the second well monitored (32500.1) was not located on the correct side of the cut. The level of the upstream bore at 74400 was static during the current monitoring period indicating that the water level is below the screened area and the well is effectively dry (**Figure 3.82**).

There was no downgradient bore installed at approximate chainage 75500 for the pre-construction period and no relative difference between levels reported (**Figure 3.83**).

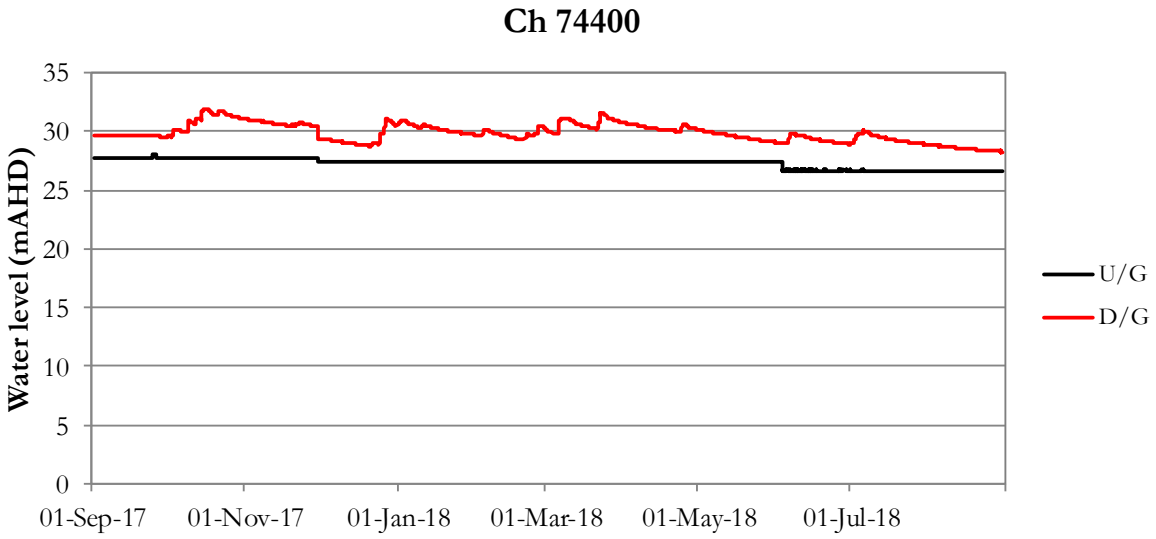

Figure 3.82 Groundwater levels at chainage 74400

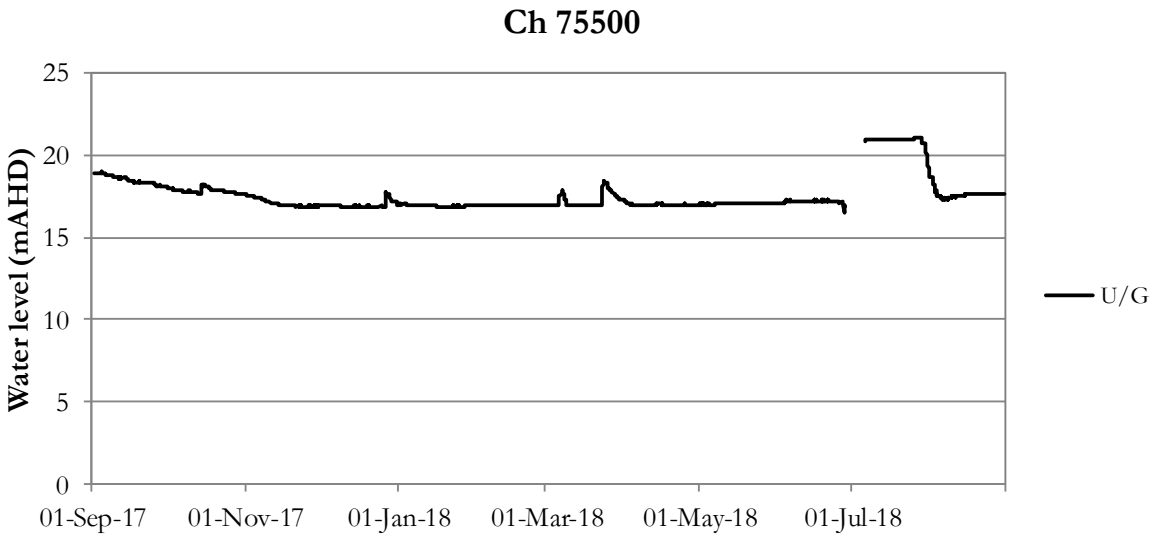

Figure 3.83 Groundwater levels at chainage 75500

The median relative difference in the groundwater levels for the two piezometers at approximate chainage 78500 was reported as 4.70m for the pre-construction period. During the current monitoring period the upgradient well was dry (**Figure 3.84**).

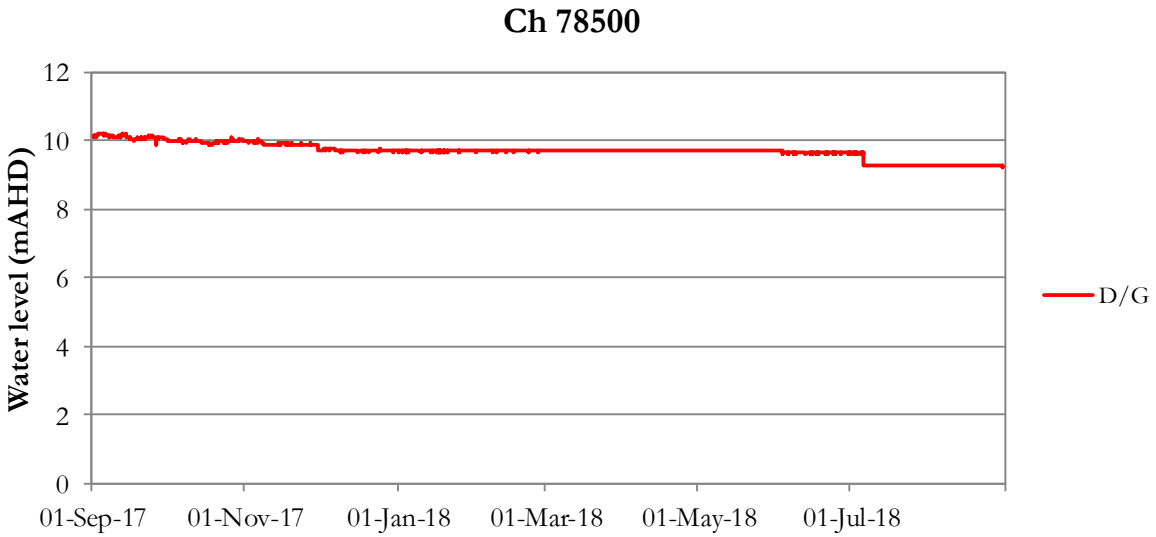

Figure 3.84 Groundwater levels at chainage 78500

4 Conclusions

Monitoring during this reporting period was undertaken according to the requirements of the GMP and SWMP. The following general conclusions can be drawn from the past 12 months of operational monitoring:

- The majority of results indicate that water quality protection measures have been successful, and that there has not been a significant impact from operation of the NH2U upgrade upon surface water quality. However, there have been several results of interest identified at this stage in the operational monitoring.
- There were less results of interest generated during this reporting period than the previous reporting period. As the operational monitoring data set grows, there is a lower impact from outlying results upon the summary statistics.
- Hydrocarbons have only been detected in one groundwater sample at this stage of operational monitoring. No hydrocarbons have been detected in any surface water samples. There were no results of interest generated from hydrocarbon analyses.
- There are some indications of generally increased concentrations of some parameters in surface waters at both control and impact sites in the operational data when compared with the pre-construction data. In particular, concentrations of iron and aluminium are higher both upstream and downstream at almost all surface water sites in the operational dataset. There is no default ANZECC guideline concentration for iron and iron concentrations vary widely in waterways in relation to local geology and other chemical components (ANZECC 2000). The median construction phase downstream concentrations of aluminium in surface water are all significantly greater than the relevant default ANZECC guideline concentration of 55 μg/L. However, the upstream p80 aluminium concentrations at all sites are also greater than the relevant default ANZECC guideline concentration.
- Additionally, maximum phosphate concentrations are higher at many sites in the operational dataset. In many cases the data suggests that the source of the higher concentrations is upstream of the highway crossings, because upstream concentrations have also been elevated. All of the median downstream surface water phosphate

concentrations are within 0.01 mg/L of the relevant default ANZECC guideline concentration of 0.02 mg/L.

- Furthermore, the highest downstream TSS concentrations and turbidity measurements since monitoring began have been collected during the operational phase at some sites. The downstream median turbidity measurements at McGraths Creek, Oyster Creek tributary, Cow Creek and Boggy Creek were all results of interest. However, the maximum operational phase turbidity measurements from all these sites except Oyster Creek tributary were still lower than the upstream maximum from the pre-construction and construction phases and, also, associated with elevated upstream measurements, indicating that the source of elevated turbidity was not the highway. In the case of Oyster Creek the highest downstream turbidity and TSS results were not associated with elevated upstream measurements but they were from a single sample and represent an outlying data point rather than a trend. In all cases the downstream median surface water turbidity measurements were less than the relevant default ANZECC guideline value of 50 NTU.

- The results include some elevated measured concentrations of various groundwater parameters at some of the cuttings and embankments. Appropriate comparisons of summary statistics have drawn attention to some results of interest among the groundwater quality monitoring data. Further investigations show that the highest concentrations of aluminium, iron, arsenic, copper and phosphate since monitoring began were measured during the construction and operational phase monitoring at more than one of the groundwater sites. However;

    - In many cases the capacity to draw conclusions about groundwater quality is restricted by a lack of upgradient data.

    - Elevated concentrations of metals from the downgradient piezometer at Ch63200 were mostly isolated to a single sampling event.

    - The water level in the downgradient piezometer at Ch63200 appears to fall below the screened level on some occasions and individual poor water quality events could be related to this factor.

    - At most sites the concentrations of metals appear to be trending downwards since peaks were measured during the construction phase.

- Where results of interest were recorded the downgradient median concentrations of aluminium and iron were much greater than the relevant ANZECC and ADWG values at many sites. However, in most cases the upgradient p80 concentrations were also greater. In summary:
    - At Ch 63200 the downgradient median aluminium and iron concentrations were greater than the relevant ANZECC and ADWG guideline values. The upgradient p80 aluminium concentration was also greater.
    - At Ch72400 the downgradient median aluminium, copper and phosphate concentrations were greater than the relevant ANZECC guideline values. At this site the upgradient p80 values for aluminium copper and phosphate were also greater than the relevant ANZECC guideline values. In addition, there has been no water in the upgradient piezometer since the pre-construction phase for the purposes of comparison.
    - At Ch74400 the downgradient median aluminium and iron concentrations were greater than the relevant ANZECC and ADWG guideline values. The upgradient p80 aluminium concentration was also greater. At this location the upgradient piezometer appears to be disconnected from the groundwater table, limiting the capacity to draw conclusions.
    - At Ch78500 the downgradient median aluminium and iron concentrations were greater than the relevant ANZECC and ADWG guideline values. The upgradient p80 iron concentration was also greater than the relevant ADWG concentration and the upgradient p80 aluminium concentration was also greater than the relevant ANZECC guideline concentration. At this site the upgradient piezometer was dry for the entire reporting period, limiting the capacity to draw conclusions.
- Where results of interest were recorded, the downgradient median concentrations of arsenic, and to a lesser extent, copper and phosphate were generally less than the relevant ANZECC and ADWG guideline concentrations. In summary:
    - At Ch 63200 the median downgradient arsenic and phosphate concentrations were less than the relevant ADWG and ANZECC guideline concentrations and

the median downgradient copper concentration was less than the relevant ADWG concentration.

  - At Ch 64600 the downgradient median iron and phosphate concentrations were less than the relevant ADWG and ANZECC guideline concentrations.
  - At Ch 72400 the downgradient median arsenic concentration was less than the relevant ADWG and ANZECC guideline concentrations.

- Measured groundwater levels declined at all sites with water between 1 September 2017 and 31 August 2018. Rainfall was below average for much of the period measured. At two of the three sites (Ch63200 and Ch64600) where comparisons of relative groundwater levels from the pre-construction period are available, the operational relative levels appear to be relatively consistent. At the other site (Ch78500) the upgradient piezometer ran dry during the construction period.
- Generating conclusions about groundwater levels and quality may be restricted by the fact that several piezometers were decommissioned during construction, new piezometers were relocated, and some piezometers ran dry.
- Some of the groundwater loggers are returning results suggesting that groundwater levels are below the screened section. Specifically, the upgradient piezometers at Ch72400, Ch74400 and Ch78500, and the downgradient piezometer at Ch78500 are either dry or not recharging.
- The upgradient piezometer at Ch72400 is dry but was also dry during the pre-construction phase monitoring, so no change in level or water quality can been detected at that site.
- The upgradient piezometer at Ch78500 became dry during construction phase monitoring and has not recharged since. If water quality or level information is required from this site a new piezometer will need to be constructed.
- The upgradient piezometer at Ch74400 and the downgradient piezometer at Ch78500 have water in them but are not recharging, indicating that groundwater levels have dropped below the screened section. As a result, water quality information collected from these piezometers may not be reliable. If accurate water quality and level information are required from these sites new piezometers will need to be constructed.

The following factors need to be considered in the interpretation of the results presented:

- The PQLs for some of the pre-construction analyses were lower than those utilised for operational monitoring. Some of the results included in this report need to be interpreted carefully as a result.
- Many of the results reported for this monitoring period are based upon small numbers of samples.
- The comparison between upstream P80 and downstream median values will increase in value as more data is collected.

References

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Schubert, S. (2016b) Nambucca Heads to Urunga – Pacific Highway Upgrade – NH2U Construction Groundwater Quality Report.

Appendix A
Surface Water – Summary Monitoring Data

Table A.1 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for SEPP14 Wetland Number 351

Parameter	*PQL*	*Upstream SW380 Pre P80*	*Downstream SW351 Pre Med*	*Upstream SW380 Pre/Con P80*	*Downstream SW351 Con Med*	*Upstream SW380 Pre/Con/Op P80*	*Downstream SW351 Op Med (2016-17)*	*Downstream SW351 Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	149.80	106.50	330.78	184.00	427.00	790.00	250.00
Arsenic-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	2.50	1.00
Copper-Total (µg/L)	1	1.00	1.00	1.00	1.00	2.00	1.00	1.00
Iron-Total (µg/L)	10	727.67	390.50	3017.80	864.50	2621.00	1400.00	1700.00
Manganese-Total (µg/L)	5	335.20	29.51	329.62	43.51	296.00	22.00	67.00
Nickel-Total (µg/L)	1	3.00	1.00	3.00	1.00	3.00	1.00	1.00
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1	2.00	1.00	2.00	2.00	2.00	1.00	1.00
Zinc-Total (µg/L)	1	4.60	3.50	6.64	3.50	6.00	3.50	3.00
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	1.02	1.36	0.87	1.35	0.85	0.90	0.90
Nitrite as N in water (mg/L)	0.005	0.002	0.005	0.006	0.008	0.005	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.006	0.009	0.006	0.005	0.007	0.005	0.005
Ammonia as N in water (mg/L)	0.005	0.646	0.198	0.475	0.095	0.377	0.008	0.005
Phosphorus – Total (mg/L)	0.05	0.02	0.06	0.03	0.04	0.05	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.005	0.005	0.005	0.005	0.013	0.012	0.013
Total Suspended Solids (mg/L)	5	41.80	6.00	39.16	10.00	36.64	7.50	8.00
Temperature (°C)	0.01	23.24	23.16	23.25	20.82	23.68	11.75	20.12
pH	0.01	5.09	6.19	6.36	6.79	6.71	5.37	5.87
Conductivity (mS/cm)	0.01	0.90	0.55	0.89	1.04	0.85	0.11	0.24
Turbidity (NTU)	0.01	33.20	4.45	34.80	4.60	37.36	6.00	9.10
Dissolved Oxygen (mg/L) (P20)*	0.01	2.36	3.36	3.30	3.53	3.51	4.56	2.65

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.2 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for SEPP14 Wetland Number 353

Parameter	*PQL*	*Upstream SW360U Pre P80*	*Downstream SW353 Pre Med*	*Upstream SW360U Pre/Con P80*	*Downstream SW353 Con Med*	*Upstream SW360U Pre/Con/Op P80*	*Downstream SW353 Op Med (2016-17)*	*Downstream SW353 Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	3.40	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	12.80	5.00	401.20	35.50	840.00	1025.00	340.00
Arsenic-Total (µg/L)	1	1.60	1.00	1.00	1.00	1.00	1.00	1.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Copper-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.50	1.00
Iron-Total (µg/L)	10	913.60	52.20	2702.40	255.86	3037.20	3300.00	1700.00
Manganese-Total (µg/L)	5	388.00	118.11	422.80	131.00	404.00	238.00	215.00
Nickel-Total (µg/L)	1	10.60	2.50	13.20	2.00	13.20	6.00	3.50
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1	9.60	3.00	5.00	2.00	4.00	1.00	1.00
Zinc-Total (µg/L)	1	64.40	6.50	69.40	8.50	69.40	26.00	12.50
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	1.65	0.72	1.29	0.55	1.12	0.80	0.70
Nitrite as N in water (mg/L)	0.005	0.004	0.002	0.007	0.004	0.006	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.041	0.015	0.039	0.026	0.042	0.199	0.048
Ammonia as N in water (mg/L)	0.005	0.239	0.087	0.314	0.119	0.300	0.029	0.125
Phosphorus – Total (mg/L)	0.05	0.07	0.02	0.06	0.02	0.06	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.005	0.005	0.006	0.005	0.012	0.020	0.022
Total Suspended Solids (mg/L)	5	47.80	10.00	34.60	9.75	33.80	8.00	12.00
Temperature (°C)	0.01	27.14	24.59	25.87	21.40	25.59	13.00	22.09
pH	0.01	7.41	7.16	7.19	7.11	7.16	4.51	6.80
Conductivity (mS/cm)	0.01	31.20	28.00	30.92	20.90	31.18	1.63	11.20
Turbidity (NTU)	0.01	35.26	8.95	34.04	4.00	31.84	11.85	29.20
Dissolved Oxygen (mg/L) (P20)*	0.01	3.77	7.65	3.96	4.66	3.36	6.18	3.98

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.3 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for the unnamed tributary to SEPP Wetland No. 351

Parameter	*PQL*	*Upstream SW380 Pre P80*	*Downstream SW381 Pre Med*	*Upstream SW380 Pre/Con P80*	*Downstream SW381 Con Med*	*Upstream SW380 Pre/Con/Op P80*	*Downstream SW381 Op Med (2016-17)*	*Downstream SW381 Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	149.80	64.50	330.78	262.00	427.00	1200.00	360.00
Arsenic-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.50	1.00
Copper-Total (µg/L)	1	1.00	1.00	1.00	1.00	2.00	1.50	1.00
Iron-Total (µg/L)	10	727.67	475.38	3017.80	1330.00	2621.00	1130.00	695.00
Manganese-Total (µg/L)	5	335.20	295.00	329.62	150.24	296.00	19.00	42.50
Nickel-Total (µg/L)	1	3.00	2.00	3.00	2.00	3.00	1.50	1.00
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1	2.00	1.00	2.00	2.00	2.00	1.00	1.00
Zinc-Total (µg/L)	1	4.60	4.00	6.64	4.00	6.00	4.00	3.00
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	1.02	0.79	0.87	0.48	0.85	0.50	0.45
Nitrite as N in water (mg/L)	0.005	0.002	0.002	0.006	0.005	0.005	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.006	0.005	0.006	0.009	0.007	0.005	0.005
Ammonia as N in water (mg/L)	0.005	0.646	0.033	0.475	0.101	0.377	0.005	0.005
Phosphorus – Total (mg/L)	0.05	0.02	0.06	0.03	0.04	0.05	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.005	0.005	0.005	0.006	0.013	0.015	0.011
Total Suspended Solids (mg/L)	5	41.80	15.25	39.16	14.40	36.64	5.00	6.00
Temperature (°C)	0.01	23.24	24.28	23.25	22.13	23.68	13.86	20.75
pH	0.01	5.09	5.53	6.36	5.68	6.71	5.42	6.80
Conductivity (mS/cm)	0.01	0.90	0.69	0.89	0.38	0.85	0.23	0.21
Turbidity (NTU)	0.01	33.20	13.00	34.80	11.40	37.36	14.90	19.80
Dissolved Oxygen (mg/L) (P20)*	0.01	2.36	5.44	3.30	5.33	3.51	7.71	4.30

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.4 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for the unnamed tributary to SEPP Wetland No. 353

Parameter	*PQL*	*Upstream SW360U Pre P80*	*Downstream SW360D Pre Med*	*Upstream SW360U Pre/Con P80*	*Downstream SW360D Con Med*	*Upstream SW360U Pre/Con/Op P80*	*Downstream SW360D Op Med (2016-17)*	*Downstream SW360D Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	3.40	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	12.80	5.00	401.20	37.00	840.00	985.00	600.00
Arsenic-Total (µg/L)	1	1.60	1.00	1.00	1.00	1.00	1.00	1.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Copper-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.50	1.00
Iron-Total (µg/L)	10	913.60	35.50	2702.40	392.00	3037.20	3600.00	2000.00
Manganese-Total (µg/L)	5	388.00	171.50	422.80	231.00	404.00	245.50	250.00
Nickel-Total (µg/L)	1	10.60	2.50	13.20	4.00	13.20	6.00	5.00
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1	9.60	6.50	5.00	2.00	4.00	1.00	1.00
Zinc-Total (µg/L)	1	64.40	4.50	69.40	7.00	69.40	24.50	23.00
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	1.65	0.79	1.29	0.67	1.12	0.80	0.70
Nitrite as N in water (mg/L)	0.005	0.004	0.001	0.007	0.006	0.006	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.041	0.010	0.039	0.011	0.042	0.198	0.038
Ammonia as N in water (mg/L)	0.005	0.239	0.046	0.314	0.173	0.300	0.025	0.145
Phosphorus – Total (mg/L)	0.05	0.07	0.04	0.06	0.03	0.06	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.005	0.005	0.006	0.005	0.012	0.025	0.026
Total Suspended Solids (mg/L)	5	47.80	14.00	34.60	8.00	33.80	5.00	11.00
Temperature (°C)	0.01	27.14	25.08	25.87	21.78	25.59	12.80	22.64
pH	0.01	7.41	7.12	7.19	6.37	7.16	4.60	6.33
Conductivity (mS/cm)	0.01	31.20	20.10	30.92	11.20	31.18	1.58	7.67
Turbidity (NTU)	0.01	35.26	9.30	34.04	4.50	31.84	13.05	14.90
Dissolved Oxygen (mg/L) (P20)*	0.01	3.77	8.71	3.96	5.01	3.36	5.94	3.87

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.5 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for the Kalang River

Parameter	*PQL*	*Upstream SW359U Pre P80*	*Downstream SW359D Pre Med*	*Upstream SW359U Pre/Con P80*	*Downstream SW359D Con Med*	*Upstream SW359U Pre/Con/Op P80*	*Downstream SW359D Op Med (2016-17)*	*Downstream SW359D Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	3.40	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	5.60	5.00	26.40	13.00	61.20	575.00	130.00
Arsenic-Total (µg/L)	1	2.00	2.00	2.80	1.00	2.00	1.00	1.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Copper-Total (µg/L)	1	1.00	1.00	2.00	1.00	1.00	1.00	1.00
Iron-Total (µg/L)	10	28.00	15.50	101.00	22.00	139.20	610.00	265.00
Manganese-Total (µg/L)	5	99.40	11.00	47.96	28.00	65.00	33.50	62.50
Nickel-Total (µg/L)	1	2.15	1.50	2.00	1.00	1.80	1.00	1.00
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1	11.40	9.50	10.00	3.00	10.00	1.00	1.00
Zinc-Total (µg/L)	1	3.60	1.50	10.00	3.00	8.40	3.00	2.00
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	1.19	0.40	0.43	0.24	0.42	0.45	0.30
Nitrite as N in water (mg/L)	0.005	0.003	0.002	0.005	0.001	0.005	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.036	0.010	0.043	0.012	0.029	0.069	0.008
Ammonia as N in water (mg/L)	0.005	0.046	0.018	0.073	0.017	0.068	0.014	0.019
Phosphorus – Total (mg/L)	0.05	0.09	0.04	0.03	0.02	0.05	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.005	0.005	0.009	0.005	0.018	0.022	0.021
Total Suspended Solids (mg/L)	5	117.60	16.00	32.00	9.00	31.00	9.00	9.00
Temperature (°C)	0.01	26.31	25.55	25.47	22.01	25.70	23.30	23.32
pH	0.01	7.51	7.52	7.55	7.45	7.60	7.37	7.39
Conductivity (mS/cm)	0.01	36.00	33.15	37.90	33.27	38.02	32.70	36.05
Turbidity (NTU)	0.01	160.80	13.35	23.00	6.80	22.80	6.90	10.00
Dissolved Oxygen (mg/L) (P20)*	0.01	5.32	6.14	4.49	5.78	3.99	6.19	3.93

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.6 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for Dalhousie Creek

Parameter	*PQL*	*Upstream SW315U Pre P80*	*Downstream SW315D Pre Med*	*Upstream SW315U Pre/Con P80*	*Downstream SW315D Con Med*	*Upstream SW315U Pre/Con/Op P80*	*Downstream SW315D Op Med (2016-17)*	*Downstream SW315D Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	17.00	5.00	87.40	56.00	484.00	1900.00	480.00
Arsenic-Total (µg/L)	1	2.00	1.00	3.60	3.00	3.00	1.50	1.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	2.00	1.00
Copper-Total (µg/L)	1	1.00	1.00	1.00	1.00	2.00	1.50	1.50
Iron-Total (µg/L)	10	1391.00	934.00	3830.90	3139.00	2600.00	1420.00	1550.00
Manganese-Total (µg/L)	5	904.00	511.50	493.40	280.00	423.00	57.00	68.00
Nickel-Total (µg/L)	1	3.00	2.00	2.60	2.00	2.00	1.50	1.50
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1	1.00	1.00	2.00	2.00	2.00	1.00	1.00
Zinc-Total (µg/L)	1	12.00	4.50	6.00	5.00	5.00	4.00	5.00
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	0.26	0.24	0.32	0.21	0.36	0.35	0.20
Nitrite as N in water (mg/L)	0.005	0.001	0.001	0.004	0.003	0.005	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.018	0.005	0.015	0.010	0.023	0.005	0.006
Ammonia as N in water (mg/L)	0.005	0.138	0.170	0.123	0.063	0.092	0.005	0.005
Phosphorus – Total (mg/L)	0.05	0.05	0.01	0.03	0.01	0.05	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.005	0.005	0.007	0.005	0.026	0.023	0.021
Total Suspended Solids (mg/L)	5	14.20	20.00	12.00	12.00	10.00	9.00	9.00
Temperature (°C)	0.01	20.69	20.21	22.08	18.76	22.47	15.24	20.61
pH	0.01	6.23	6.05	6.52	6.21	6.53	5.48	6.09
Conductivity (mS/cm)	0.01	0.95	0.88	0.91	0.54	0.89	0.24	0.23
Turbidity (NTU)	0.01	6.86	6.70	22.00	22.45	39.78	15.55	20.85
Dissolved Oxygen (mg/L) (P20)*	0.01	2.28	2.44	3.31	5.26	3.19	5.35	3.35

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.7 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for McGraths Creek

Parameter	*PQL*	*Upstream SW301U Pre P80*	*Downstream SW301D Pre Med*	*Upstream SW301U Pre/Con P80*	*Downstream SW301D Con Med*	*Upstream SW301U Pre/Con/Op P80*	*Downstream SW301D Op Med (2016-17)*	*Downstream SW301D Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	20.80	9.00	100.00	41.62	116.00	2490.00	265.00
Arsenic-Total (µg/L)	1	3.79	1.00	2.47	1.00	4.00	2.50	2.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	2.50	1.00
Copper-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	2.50	1.00
Iron-Total (µg/L)	10	2555.60	491.08	1810.00	874.00	2700.00	2700.00	1950.00
Manganese-Total (µg/L)	5	454.85	120.00	332.00	89.50	340.00	62.00	94.00
Nickel-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.50	1.00
Selenium-Total (µg/L)	1	1.60	1.00	2.00	2.00	2.00	1.00	1.00
Zinc-Total (µg/L)	1	6.60	2.00	5.00	2.00	5.00	4.50	2.50
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	1.33	0.53	0.53	0.26	0.56	0.50	0.30
Nitrite as N in water (mg/L)	0.005	0.002	0.002	0.006	0.004	0.005	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.049	0.017	0.053	0.016	0.049	0.047	0.005
Ammonia as N in water (mg/L)	0.005	0.676	0.094	0.149	0.043	0.120	0.023	0.005
Phosphorus – Total (mg/L)	0.05	0.10	0.04	0.06	0.03	0.05	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.008	0.005	0.014	0.007	0.019	0.035	0.033
Total Suspended Solids (mg/L)	5	8.80	7.00	12.20	5.25	13.30	16.00	5.50
Temperature (°C)	0.01	22.67	22.33	23.53	20.87	23.39	14.54	21.72
pH	0.01	6.75	6.57	7.11	6.80	7.00	5.75	6.54
Conductivity (mS/cm)	0.01	0.77	0.69	0.77	0.55	0.76	0.24	0.34
Turbidity (NTU)	0.01	17.42	9.40	20.84	9.20	27.46	64.00	30.10
Dissolved Oxygen (mg/L) (P20)*	0.01	1.82	6.14	3.94	6.04	2.77	7.32	4.42

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.8 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for the tributary to Oyster Creek

Parameter	*PQL*	*Upstream SW261 Pre P80*	*Downstream SW262 Pre Med*	*Upstream SW261 Pre/Con P80*	*Downstream SW262 Con Med*	*Upstream SW261 Pre/Con/Op P80*	*Downstream SW262 Op Med (2016-17)*	*Downstream SW262 Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	54.40	60.00	156.80	95.00	207.60	950.00	180.00
Arsenic-Total (µg/L)	1	2.00	1.00	2.01	1.00	3.00	1.50	3.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.50	1.00
Copper-Total (µg/L)	1	1.00	1.00	2.00	1.00	2.00	1.50	1.00
Iron-Total (µg/L)	10	1683.20	1485.00	1870.80	1182.00	2514.00	1550.00	2500.00
Manganese-Total (µg/L)	5	58.00	27.00	127.80	36.00	179.71	33.50	120.00
Nickel-Total (µg/L)	1	1.00	1.00	2.00	1.00	2.00	1.00	1.00
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1	1.60	1.00	2.00	2.00	2.00	1.00	1.00
Zinc-Total (µg/L)	1	4.60	2.00	8.20	3.04	6.80	5.50	5.00
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	0.63	0.46	0.49	0.30	0.60	0.55	0.40
Nitrite as N in water (mg/L)	0.005	0.007	0.003	0.009	0.005	0.007	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.018	0.017	0.028	0.016	0.030	0.105	0.010
Ammonia as N in water (mg/L)	0.005	0.045	0.040	0.060	0.043	0.054	0.005	0.005
Phosphorus – Total (mg/L)	0.05	0.09	0.04	0.06	0.03	0.07	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.005	0.005	0.009	0.005	0.013	0.020	0.021
Total Suspended Solids (mg/L)	5	7.60	5.00	17.90	5.25	20.40	6.50	5.00
Temperature (°C)	0.01	23.31	22.12	23.64	21.06	23.74	14.30	21.41
pH	0.01	7.21	6.91	7.40	6.91	7.38	6.02	6.66
Conductivity (mS/cm)	0.01	0.52	0.27	0.80	0.28	0.59	0.15	0.23
Turbidity (NTU)	0.01	6.46	3.90	12.62	5.80	17.36	29.35	17.40
Dissolved Oxygen (mg/L) (P20)*	0.01	2.51	4.61	2.69	5.75	2.65	7.63	4.34

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.9 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for Deep Creek

Parameter	*PQL*	*Upstream SW231U Pre P80*	*Downstream SW231D Pre Med*	*Upstream SW231U Pre/Con P80*	*Downstream SW231D Con Med*	*Upstream SW231U Pre/Con/Op P80*	*Downstream SW231D Op Med (2016-17)*	*Downstream SW231D Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	3.40	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	8.60	5.00	52.00	17.00	106.63	925.00	85.00
Arsenic-Total (µg/L)	1	3.00	2.00	3.00	2.00	3.00	1.50	2.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Copper-Total (µg/L)	1	1.60	1.00	2.00	1.00	2.00	2.00	1.00
Iron-Total (µg/L)	10	47.80	15.00	168.81	40.50	409.00	1050.00	385.00
Manganese-Total (µg/L)	5	52.20	26.50	60.20	38.00	67.60	56.50	56.50
Nickel-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1	13.60	7.00	10.00	2.50	10.00	1.00	1.00
Zinc-Total (µg/L)	1	6.40	2.50	6.00	3.50	6.00	3.50	1.50
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	0.34	0.31	0.38	0.29	0.38	0.45	0.30
Nitrite as N in water (mg/L)	0.005	0.002	0.002	0.005	0.002	0.005	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.021	0.005	0.052	0.008	0.052	0.127	0.015
Ammonia as N in water (mg/L)	0.005	0.039	0.035	0.064	0.018	0.046	0.012	0.018
Phosphorus – Total (mg/L)	0.05	0.03	0.02	0.03	0.02	0.05	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.005	0.005	0.011	0.005	0.017	0.032	0.034
Total Suspended Solids (mg/L)	5	8.80	6.00	13.20	8.50	13.20	5.50	5.50
Temperature (°C)	0.01	26.51	24.44	25.99	21.35	25.99	19.63	20.89
pH	0.01	7.70	7.11	7.63	7.38	7.63	6.96	7.28
Conductivity (mS/cm)	0.01	38.40	22.30	41.32	25.50	39.94	16.30	22.65
Turbidity (NTU)	0.01	10.48	4.35	12.70	5.35	15.30	2.90	10.40
Dissolved Oxygen (mg/L) (P20)*	0.01	5.78	7.79	4.63	6.55	4.37	7.04	5.61

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.10 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for Cow Creek

Parameter	*PQL*	*Upstream SW217U Pre P80*	*Downstream SW217D Pre Med*	*Upstream SW217U Pre/Con P80*	*Downstream SW217D Con Med*	*Upstream SW217U Pre/Con/Op P80*	*Downstream SW217D Op Med (2016-17)*	*Downstream SW217D Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10					10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50					50	50	50
TRH C15 - C28 (µg/L)	100					100	100	100
TRH C29 - C36 (µg/L)	100					100	100	100
TRH >C10 - C16 (µg/L)	50					50	50	50
TRH >C16 - C34 (µg/L)	100					100	100	100
TRH >C34 - C40 (µg/L)	100					100	100	100
Silver-Total (µg/L)	1			1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10			37.00	14.00	65.00	780.00	90.00
Arsenic-Total (µg/L)	1			5.80	2.35	6.86	3.50	5.50
Cadmium-Total (µg/L)	0.1			1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1			1.00	1.00	1.00	1.00	1.00
Copper-Total (µg/L)	1			1.00	1.00	1.00	1.50	1.00
Iron-Total (µg/L)	10			1031.40	257.00	1249.80	935.00	1300.00
Manganese-Total (µg/L)	5			489.00	130.00	524.43	25.50	193.00
Nickel-Total (µg/L)	1			1.00	1.00	1.00	1.00	1.00
Lead-Total (µg/L)	1			1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1			4.40	2.00	2.00	1.00	1.00
Zinc-Total (µg/L)	1			4.00	2.00	4.00	3.00	2.00
Mercury-Total (µg/L)	0.05			0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1			0.27	0.24	0.31	0.40	0.30
Nitrite as N in water (mg/L)	0.005			0.005	0.002	0.005	0.005	0.005
Nitrate as N in water (mg/L)	0.005			0.016	0.012	0.016	0.049	0.006
Ammonia as N in water (mg/L)	0.005			0.048	0.030	0.044	0.005	0.005
Phosphorus – Total (mg/L)	0.05			0.05	0.03	0.06	0.05	0.05
Phosphate as P in water (mg/L)	0.005			0.017	0.006	0.023	0.027	0.030
Total Suspended Solids (mg/L)	5			7.80	5.00	8.00	5.50	6.00
Temperature (°C)	0.01	22.68	23.33	23.87	20.55	24.18	21.03	22.09
pH	0.01	6.44	6.33	7.54	7.03	7.55	7.78	6.95
Conductivity (mS/cm)	0.01	3.27	11.30	4.49	4.08	2.34	3.12	2.81
Turbidity (NTU)	0.01	2.98	3.10	8.56	3.70	11.36	7.00	14.90
Dissolved Oxygen (mg/L) (P20)*	0.01	4.62	5.57	4.37	6.38	4.02	6.95	4.88

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Table A.11 Operational (Op), construction (Con) and preconstruction (Pre) phase downstream median surface water results and rolling upstream 80th percentile (P80) results for Boggy Creek

Parameter	*PQL*	*Upstream SW208U Pre P80*	*Downstream SW208D Pre Med*	*Upstream SW208U Pre/Con P80*	*Downstream SW208D Con Med*	*Upstream SW208U Pre/Con/Op P80*	*Downstream SW208D Op Med (2016-17)*	*Downstream SW208D Op Med (2016-18)*
TRH C6 - C9 (µg/L)	10	10	10	10		10	10	10
TRH C6 - C10 (µg/L)	10					10	10	10
TRH C10 - C14 (µg/L)	50	50	50	50		50	50	50
TRH C15 - C28 (µg/L)	100	100	100	100		100	100	100
TRH C29 - C36 (µg/L)	100	100	100	100		100	100	100
TRH >C10 - C16 (µg/L)	50	50	50	50		50	50	50
TRH >C16 - C34 (µg/L)	100	100	100	100		100	100	100
TRH >C34 - C40 (µg/L)	100	100	100	100		100	100	100
Silver-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aluminium-Total (µg/L)	10	143.00	11.50	154.20	48.00	167.60	1180.00	270.00
Arsenic-Total (µg/L)	1	3.00	2.50	3.00	2.45	5.00	4.00	5.00
Cadmium-Total (µg/L)	0.1	1.00	1.00	1.00	1.00	1.00	0.10	0.10
Chromium-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.50	1.00
Copper-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.50	1.00
Iron-Total (µg/L)	10	268.00	393.50	743.00	667.00	1500.00	1600.00	2650.00
Manganese-Total (µg/L)	5	21.00	268.50	227.60	87.00	311.40	95.50	270.00
Nickel-Total (µg/L)	1	3.00	1.00	2.00	1.00	2.00	1.00	1.00
Lead-Total (µg/L)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selenium-Total (µg/L)	1	1.00	1.00	2.00	2.00	2.00	1.00	1.00
Zinc-Total (µg/L)	1	4.00	2.50	5.00	2.00	5.00	3.00	4.00
Mercury-Total (µg/L)	0.05	0.50	0.50	0.50	0.50	0.50	0.05	0.05
Total Nitrogen in water (mg/L)	0.1	1.41	0.37	0.77	0.26	0.76	0.40	0.45
Nitrite as N in water (mg/L)	0.005	0.005	0.003	0.006	0.003	0.006	0.005	0.005
Nitrate as N in water (mg/L)	0.005	0.011	0.016	0.014	0.007	0.017	0.023	0.005
Ammonia as N in water (mg/L)	0.005	0.302	0.039	0.202	0.033	0.136	0.005	0.005
Phosphorus – Total (mg/L)	0.05	0.16	0.04	0.11	0.03	0.11	0.05	0.05
Phosphate as P in water (mg/L)	0.005	0.088	0.007	0.060	0.009	0.061	0.030	0.046
Total Suspended Solids (mg/L)	5	72.80	3.00	28.00	3.75	24.00	6.10	9.00
Temperature (°C)	0.01	23.22	20.71	23.27	19.70	23.25	15.41	21.09
pH	0.01	7.00	6.63	7.52	6.89	7.47	6.64	6.75
Conductivity (mS/cm)	0.01	0.51	0.82	1.20	0.50	0.86	0.29	0.46
Turbidity (NTU)	0.01	28.60	3.95	18.40	5.70	29.36	12.90	53.05
Dissolved Oxygen (mg/L) (P20)*	0.01	2.03	3.45	2.92	6.30	2.44	9.90	4.62

Blue Shading – Indicates a result of interest (2016 - 2018) Red shading – Indicates a result of interest (2016 - 2017).

* - Upstream dissolved oxygen results are P20, not P80.

Appendix B
Summary Groundwater Monitoring Data

Table B.1 Pre-construction, combined pre-construction/construction and operational phase summary groundwater quality results for approximate chainage 63200

Parameter	*Units*	*PQL*	*U/G* *pre P80* *21300.1*	*D/G* *pre med* *21300.2*	*U/G* *pre/con P80* *21300.1*	*D/G* *con med* *21300.2*	*U/G* *pre/con/op P80* *21300.1*	*D/G* *op med* *21300.2*
TRH C6 - C9	µg/L	10	10	10	10	10	10	10
TRH C6 - C10	µg/L	10		10	10	10	10	10
TRH C10-C14	µg/L	50	50	50	50	50	50	50
TRH C15-C28	µg/L	100	160	100	100	100	100	100
TRH C29-C36	µg/L	100	100	100	100	100	100	100
TRH >C10-C16	µg/L	50	220	50	50	50	50	50
TRH >C16-C34	µg/L	100	100	100	100	100	100	100
TRH >C34-C40	µg/L	100	100	100	100	100	100	100
Ag-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	1.0
Al-Dissolved	µg/L	10	20.6	101.0	296.3	59.0	300.9	1500.0
As-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	5.0
Cd-Dissolved	µg/L	0.1	1.0	1.0	1.0	1.0	1.0	0.1
Cr-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	2.0
Cu-Dissolved	µg/L	1	9.2	2.0	3.0	1.7	3.8	13.0
Fe-Dissolved	µg/L	10	42.2	15.0	157.0	21.0	221.0	1488.0
Mn-Dissolved	µg/L	5	156.8	40.0	265.0	14.0	263.0	35.0
Ni-Dissolved	µg/L	1	13.4	3.0	5.0	1.0	5.0	4.0
Pb-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	2.0
Se-Dissolved	µg/L	1	1.0	1.0	2.0	2.0	2.0	1.0
Zn-Dissolved	µg/L	1	110.0	41.0	59.0	11.0	67.0	16.0
Hg-Dissolved	µg/L	0.05	0.50	0.50	0.50	0.50	0.50	0.05
Total Nitrogen	mg/L	0.1	0.79	0.18	0.35	0.16	0.35	1.30
Nitrite	mg/L	0.005	0.030	0.002	0.006	0.001	0.006	0.005
Nitrate	mg/L	0.005	0.346	0.018	0.156	0.032	0.149	0.088
Ammonia	mg/L	0.005	0.054	0.015	0.050	0.025	0.044	0.020
Total Phosphorus	mg/L	0.05	0.07	0.02	0.06	0.01	0.06	0.06
Phosphate	mg/L	0.005	0.012	0.005	0.006	0.005	0.005	0.016
Temp	C	0.01	20.67	19.49	21.00	19.54	21.09	19.81
pH		0.01	5.66	4.76	5.70	5.46	5.72	4.88
EC	mS/cm	0.01	0.27	0.14	0.27	0.13	0.27	0.09
TSS	mg/L	5	1553.6	168.8	1553.6		1379.8	570.0
TDS	mg/L	1	173.54	96.22	173.54		173.54	
Bicarbonate	mg/L CaCO3	1	15.0	4.0	15.0	6.0	15.0	10.0
Sodium	mg/L	1	42.4	18.4	40.2	14.4	40.2	12.2
Potassium	mg/L	1	2.71	0.73	1.70	0.41	1.70	0.88
Calcium	mg/L	1	1.74	0.81	0.94	1.76	0.94	1.84
Magnesium	mg/L	1	1.90	2.97	1.49	1.88	1.49	1.11
Chloride	mg/L	1	53.0	39.1	54.4	29.4	54.4	19.5
Sulfate	mg/L	1	21.2	2.6	7.2	4.0	7.2	4.2

Red shading – Indicates a result of interest.

Table B.2 Pre-construction, combined pre-construction/construction and operational phase summary groundwater quality results for approximate chainage 64600

Parameter	*Units*	*PQL*	*U/G*	*D/G*	*U/G*	*D/G*	*U/G*	*D/G*
			pre P80	*pre med*	*pre/con P80*	*con med*	*pre/con/op P80*	*op med*
			22600.1	*22600.2*	*22600.1*	*22600.2*	*22600.1*	*22600.2*
TRH C6 - C9	µg/L	10	10	10	75	10	72	10
TRH C6 - C10	µg/L	10			84	10	80	10
TRH C10-C14	µg/L	50	50	50	50	50	50	50
TRH C15-C28	µg/L	100	100	100	100	100	100	100
TRH C29-C36	µg/L	100	100	100	100	100	100	100
TRH >C10-C16	µg/L	50	50	50	50	50	50	50
TRH >C16-C34	µg/L	100	100	100	100	100	100	100
TRH >C34-C40	µg/L	100	100	100	100	100	100	100
Ag-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	1.0
Al-Dissolved	µg/L	10	25.8	6.0	2206.6	6.4	2838.4	10.0
As-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	3.2	2.0
Cd-Dissolved	µg/L	0.1	1.0	1.0	1.0	1.0	1.0	0.1
Cr-Dissolved	µg/L	1	2.4	2.5	2.0	1.0	2.2	1.0
Cu-Dissolved	µg/L	1	4.2	1.1	2.6	1.0	3.2	1.0
Fe-Dissolved	µg/L	10	17.4	16.0	62.8	5.0	85.0	310.0
Mn-Dissolved	µg/L	5	25.2	30.5	42.6	20.0	42.2	21.0
Ni-Dissolved	µg/L	1	16.0	2.5	3.7	1.0	4.0	1.0
Pb-Dissolved	µg/L	1	1.0	1.0	3.0	1.0	3.0	1.0
Se-Dissolved	µg/L	1	1.0	1.0	2.0	2.0	2.0	1.0
Zn-Dissolved	µg/L	1	66.6	40.0	34.0	11.0	32.0	2.0
Hg-Dissolved	µg/L	0.05	0.50	0.50	0.50	0.50	0.50	0.05
Total Nitrogen	mg/L	0.1	0.47	0.22	0.31	0.06	0.36	0.10
Nitrite	mg/L	0.005	0.005	0.002	0.002	0.001	0.003	0.005
Nitrate	mg/L	0.005	0.022	0.007	0.054	0.007	0.050	0.005
Ammonia	mg/L	0.005	0.024	0.010	0.057	0.009	0.079	0.047
Total Phosphorus	mg/L	0.05	0.05	0.03	0.05	0.01	0.06	0.05
Phosphate	mg/L	0.005	0.008	0.005	0.010	0.006	0.011	0.013
Temp	C	0.01	20.80	20.90	20.89	20.60	20.89	22.12
pH		0.01	5.49	5.82	6.84	6.16	6.82	6.24
EC	mS/cm	0.01	0.24	0.26	1.40	0.27	1.30	0.25
TSS	mg/L	5	182.1	75.3	182.1		217.5	52.5
TDS	mg/L	1	162.11	179.86	162.11		162.11	
Bicarbonate	mg/L CaCO3	1	13.2	40.0	13.0	40.0	13.0	40.0
Sodium	mg/L	1	34.5	35.0	219.2	36.3	219.2	37.8
Potassium	mg/L	1	0.80	1.00	1.25	0.84	1.25	1.11
Calcium	mg/L	1	2.06	5.00	5.82	5.02	5.82	5.26
Magnesium	mg/L	1	4.75	6.87	8.50	7.03	8.50	7.26
Chloride	mg/L	1	62.6	56.0	332.4	54.0	332.4	55.5
Sulfate	mg/L	1	5.4	4.0	11.6	3.5	11.6	3.2

Red shading – Indicates a result of interest.

Table B.3 Pre-construction, combined pre-construction/construction and operational phase summary groundwater quality results for approximate chainage 72400

Parameter	*Units*	*PQL*	*U/G*	*D/G*	*U/G*	*D/G*	*U/G*	*D/G*
			pre P80	*pre med*	*pre/con P80*	*con med*	*pre/con/op P80*	*op med*
			30500.1	*30500.2*	*30500.1*	*30500.2*	*30500.1*	*30500.2*
TRH C6 - C9	µg/L	10		10	10	10	10	10
TRH C6 - C10	µg/L	10			10	10	10	10
TRH C10-C14	µg/L	50		50	50	50	50	50
TRH C15-C28	µg/L	100		100	100	100	100	100
TRH C29-C36	µg/L	100		100	100	100	100	100
TRH >C10-C16	µg/L	50	50	50	50	50	50	50
TRH >C16-C34	µg/L	100	100	100	100	100	100	100
TRH >C34-C40	µg/L	100	100	100	100	100	100	100
Ag-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	1.0
Al-Dissolved	µg/L	10	90.0	84.0	165.7	47.5	165.7	170.0
As-Dissolved	µg/L	1	1.0	1.0	1.0	2.0	1.0	3.0
Cd-Dissolved	µg/L	0.1	1.0	1.0	1.0	1.0	1.0	0.1
Cr-Dissolved	µg/L	1	7.4	4.0	3.0	1.0	3.0	1.0
Cu-Dissolved	µg/L	1	9.0	6.5	4.0	3.0	4.0	5.0
Fe-Dissolved	µg/L	10	15.8	13.0	313.8	262.0	313.8	290.0
Mn-Dissolved	µg/L	5	823.2	485.0	388.0	181.0	388.0	320.0
Ni-Dissolved	µg/L	1	34.6	27.0	21.0	5.8	21.0	42.0
Pb-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	1.0
Se-Dissolved	µg/L	1	2.0	1.5	2.0	2.0	2.0	1.0
Zn-Dissolved	µg/L	1	147.0	125.0	107.0	36.0	107.0	76.0
Hg-Dissolved	µg/L	0.05	0.50	0.50	0.50	0.50	0.50	0.05
Total Nitrogen	mg/L	0.1	0.58	0.43	0.40	0.14	0.40	0.40
Nitrite	mg/L	0.005	0.007	0.002	0.004	0.003	0.004	0.005
Nitrate	mg/L	0.005	0.027	0.027	0.185	0.020	0.185	0.040
Ammonia	mg/L	0.005	0.032	0.017	0.042	0.023	0.042	0.051
Total Phosphorus	mg/L	0.05	0.53	0.42	0.39	0.07	0.39	0.30
Phosphate	mg/L	0.005	0.008	0.006	0.027	0.017	0.027	0.180
Temp	C	0.01	20.98	20.21	21.46	20.24	21.46	20.71
pH		0.01	5.33	5.24	5.45	6.47	5.45	6.16
EC	mS/cm	0.01	1.19	1.14	1.12	0.97	1.12	0.90
TSS	mg/L	5		894.8				24.0
TDS	mg/L	1		812.50				
Bicarbonate	mg/L CaCO3	1	94.0	26.0	40.0	50.0	40.0	115.0
Sodium	mg/L	1	209.4	204.0	203.0	66.5	203.0	185.0
Potassium	mg/L	1	2.01	1.43	1.59	1.80	1.59	2.52
Calcium	mg/L	1	8.95	5.32	10.60	13.80	10.60	15.20
Magnesium	mg/L	1	11.88	10.62	9.61	4.28	9.61	16.60
Chloride	mg/L	1	275.6	250.5	249.0	102.0	249.0	210.0
Sulfate	mg/L	1	105.4	96.0	101.1	38.4	101.1	42.0

Red shading – Indicates a result of interest.

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Table B.4 Pre-construction, combined pre-construction/construction and operational phase summary groundwater quality results for approximate chainage 74400

Parameter	*Units*	*PQL*	*U/G* *pre P80* *32500.1*	*D/G* *pre med* *32500.2*	*U/G* *pre/con P80* *32500.1*	*D/G* *con med* *32500.2*	*U/G* *pre/con/op P80* *32500.1*	*D/G* *op med* *32500.2*
TRH C6 - C9	µg/L	10	10	10	10	10	10	10
TRH C6 - C10	µg/L	10			10	10	10	10
TRH C10-C14	µg/L	50	50	50	55	50	55	50
TRH C15-C28	µg/L	100	100	100	100	100	100	100
TRH C29-C36	µg/L	100	100	100	100	100	100	100
TRH >C10-C16	µg/L	50	50	50	92	50	82	50
TRH >C16-C34	µg/L	100	100	100	100	100	100	100
TRH >C34-C40	µg/L	100	100	100	100	100	100	100
Ag-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	1.0
Al-Dissolved	µg/L	10	44.2	164.5	345.8	63.5	377.0	560.0
As-Dissolved	µg/L	1	5.2	7.5	5.0	3.0	6.2	2.0
Cd-Dissolved	µg/L	0.1	1.0	1.0	1.0	1.0	1.0	0.2
Cr-Dissolved	µg/L	1	11.4	7.0	2.8	1.0	1.6	2.0
Cu-Dissolved	µg/L	1	3.0	2.5	4.0	2.0	4.0	3.0
Fe-Dissolved	µg/L	10	375.0	1006.0	109.4	177.5	127.6	7100.0
Mn-Dissolved	µg/L	5	1547.8	410.0	1875.8	219.0	1848.6	290.0
Ni-Dissolved	µg/L	1	5.2	16.5	8.6	9.0	10.4	11.0
Pb-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	1.0
Se-Dissolved	µg/L	1	1.0	1.0	2.0	2.0	2.0	1.0
Zn-Dissolved	µg/L	1	61.6	55.5	68.2	29.0	65.4	42.0
Hg-Dissolved	µg/L	0.05	0.50	0.50	0.50	0.50	0.50	0.05
Total Nitrogen	mg/L	0.1	1.06	1.47	2.98	0.26	2.81	0.20
Nitrite	mg/L	0.005	0.005	0.002	0.023	0.005	0.022	0.005
Nitrate	mg/L	0.005	0.056	0.005	0.102	0.023	0.090	0.047
Ammonia	mg/L	0.005	0.076	0.027	2.330	0.043	2.256	0.072
Total Phosphorus	mg/L	0.05	0.07	0.36	0.08	0.10	0.08	0.06
Phosphate	mg/L	0.005	0.009	0.088	0.010	0.021	0.011	0.011
Temp	C	0.01	21.86	19.63	21.60	20.34	21.52	20.26
pH		0.01	6.81	5.91	8.29	6.79	8.31	7.10
EC	mS/cm	0.01	1.00	1.61	3.31	1.35	3.22	1.06
TSS	mg/L	5	72.3	114.9	72.3		69.5	35.5
TDS	mg/L	1	576.00	1115.50	576.00		576.00	
Bicarbonate	mg/L CaCO3	1	271.0	107.5	315.0	108.0	315.0	395.0
Sodium	mg/L	1	62.2	264.5	224.4	196.0	224.4	209.0
Potassium	mg/L	1	3.25	2.79	55.32	2.51	55.32	4.86
Calcium	mg/L	1	101.50	20.10	130.28	21.00	130.28	108.00
Magnesium	mg/L	1	8.96	29.95	16.31	12.55	16.31	23.80
Chloride	mg/L	1	105.0	311.5	182.0	203.0	182.0	225.0
Sulfate	mg/L	1	25.8	201.5	72.2	156.6	72.2	56.7

Red shading – Indicates a result of interest.

Table B.5 Pre-construction, combined pre-construction/construction and operational phase summary groundwater quality results for approximate chainage 75500

Parameter	*Units*	*PQL*	*U/G* *pre P80* *33600.1*	*D/G* *pre med* *33600.2*	*U/G* *pre/con P80* *33600.1*	*D/G* *con med* *33600.2*	*U/G* *pre/con/op P80* *33600.1*	*D/G* *op med* *33600.2*
TRH C6 - C9	µg/L	10	10	10	10		10	
TRH C6 - C10	µg/L	10			10		10	
TRH C10-C14	µg/L	50	474	315	51		50	
TRH C15-C28	µg/L	100	1220	800	100		100	
TRH C29-C36	µg/L	100	100	100	100		100	
TRH >C10-C16	µg/L	50	620	630	50		50	
TRH >C16-C34	µg/L	100	100	100	100		100	
TRH >C34-C40	µg/L	100	100	100	100		100	
Ag-Dissolved	µg/L	1	1.0	1.0	1.0		1.0	
Al-Dissolved	µg/L	10	1081.8	905.5	523.2		528.4	
As-Dissolved	µg/L	1	12.4	8.0	3.0		3.0	
Cd-Dissolved	µg/L	0.1	1.0	1.0	1.0		1.0	
Cr-Dissolved	µg/L	1	8.4	6.0	3.0		3.0	
Cu-Dissolved	µg/L	1	78.0	63.5	37.0		31.4	
Fe-Dissolved	µg/L	10	3254.8	2042.0	988.3		991.6	
Mn-Dissolved	µg/L	5	414.8	332.0	318.4		275.6	
Ni-Dissolved	µg/L	1	41.8	36.0	18.4		16.0	
Pb-Dissolved	µg/L	1	11.6	7.5	3.8		3.0	
Se-Dissolved	µg/L	1	4.0	3.5	2.4		2.0	
Zn-Dissolved	µg/L	1	409.8	357.0	261.0		255.0	
Hg-Dissolved	µg/L	0.05	0.50	0.50	0.50		0.50	
Total Nitrogen	mg/L	0.1	6.05	4.35	0.85		0.81	
Nitrite	mg/L	0.005	0.003	0.003	0.004		0.005	
Nitrate	mg/L	0.005	0.008	0.005	0.022		0.047	
Ammonia	mg/L	0.005	0.751	0.641	0.475		0.393	
Total Phosphorus	mg/L	0.05	0.12	0.12	0.12		0.12	
Phosphate	mg/L	0.005	0.016	0.009	0.026		0.035	
Temp	C	0.01	21.53	19.93	21.99		21.90	
pH		0.01	5.33	5.13	8.11		8.05	
EC	mS/cm	0.01	2.03	1.90	1.23		1.22	
TSS	mg/L	5	118.2	106.8	118.2		115.0	
TDS	mg/L	1	1289.60	1294.00	1289.60		1289.60	
Bicarbonate	mg/L CaCO3	1	31.0	18.8	93.8		86.6	
Sodium	mg/L	1	321.0	285.0	196.2		192.6	
Potassium	mg/L	1	2.85	2.66	16.48		16.14	
Calcium	mg/L	1	4.01	3.38	26.20		25.50	
Magnesium	mg/L	1	41.84	36.25	17.20		16.40	
Chloride	mg/L	1	566.8	504.5	310.0		301.0	
Sulfate	mg/L	1	33.8	28.0	35.4		35.2	

Red shading – Indicates a result of interest.

Table B.6 Pre-construction, combined pre-construction/construction and operational phase summary groundwater quality results for approximate chainage 78500

Parameter	*Units*	*PQL*	*U/G* *pre P80* *36600.1*	*D/G* *pre med* *36600.2*	*U/G* *pre/con P80* *36600.1*	*D/G* *con med* *36600.2*	*U/G* *pre/con/op P80* *36600.1*	*D/G* *op med* *36600.2*
TRH C6 - C9	µg/L	10	10	10	10	10	10	10
TRH C6 - C10	µg/L	10			10	10	10	10
TRH C10-C14	µg/L	50	50	50	50	50	50	50
TRH C15-C28	µg/L	100	100	100	100	100	100	100
TRH C29-C36	µg/L	100	100	100	100	100	100	100
TRH >C10-C16	µg/L	50	50	50	50	50	50	50
TRH >C16-C34	µg/L	100	100	100	100	100	100	100
TRH >C34-C40	µg/L	100	100	100	100	100	100	100
Ag-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	1.0
Al-Dissolved	µg/L	10	70.0	8.5	67.0	14.5	67.0	220.0
As-Dissolved	µg/L	1	7.4	3.0	10.0	4.0	10.0	5.0
Cd-Dissolved	µg/L	0.1	1.4	1.0	1.0	1.0	1.0	0.1
Cr-Dissolved	µg/L	1	7.4	1.5	3.0	1.0	3.0	1.0
Cu-Dissolved	µg/L	1	10.2	1.0	5.0	1.0	5.0	1.0
Fe-Dissolved	µg/L	10	816.8	9.5	620.0	37.0	620.0	1700.0
Mn-Dissolved	µg/L	5	2020.4	506.0	2201.0	458.0	2201.0	450.0
Ni-Dissolved	µg/L	1	99.6	15.0	105.3	16.9	105.3	14.0
Pb-Dissolved	µg/L	1	1.0	1.0	1.0	1.0	1.0	1.0
Se-Dissolved	µg/L	1	50.2	1.0	28.0	2.0	28.0	1.0
Zn-Dissolved	µg/L	1	101.8	57.5	140.0	33.0	140.0	34.0
Hg-Dissolved	µg/L	0.05	0.50	0.50	0.50	0.50	0.50	0.05
Total Nitrogen	mg/L	0.1	1.21	0.17	0.46	0.12	0.46	0.23
Nitrite	mg/L	0.005	0.011	0.006	0.004	0.003	0.004	0.005
Nitrate	mg/L	0.005	0.146	0.008	0.175	0.023	0.175	0.030
Ammonia	mg/L	0.005	0.050	0.025	0.123	0.020	0.123	0.097
Total Phosphorus	mg/L	0.05	1.58	0.92	1.64	0.86	1.64	1.10
Phosphate	mg/L	0.005	1.388	0.577	1.577	0.649	1.577	0.537
Temp	C	0.01	21.54	21.80	21.30	20.40	21.30	21.30
pH		0.01	6.03	6.06	6.11	6.43	6.11	6.18
EC	mS/cm	0.01	2.79	1.12	3.07	1.23	3.07	1.24
TSS	mg/L	5	30.6	106.0	30.6		30.6	44.0
TDS	mg/L	1	1904.00	760.00	1904.00		1904.00	
Bicarbonate	mg/L CaCO3	1	106.0	80.0	100.0	71.9	100.0	75.0
Sodium	mg/L	1	539.0	203.0	580.0	230.5	580.0	238.0
Potassium	mg/L	1	3.84	1.09	2.24	0.80	2.24	1.06
Calcium	mg/L	1	12.04	4.55	4.33	4.60	4.33	3.55
Magnesium	mg/L	1	31.44	11.20	38.70	13.05	38.70	12.80
Chloride	mg/L	1	518.0	213.5	700.0	256.0	700.0	243.0
Sulfate	mg/L	1	457.2	102.7	399.0	102.3	399.0	108.0

Red shading – Indicates a result of interest.