Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Construction Water Quality Monitoring Report

Roads and Maritime Services | September 2018

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Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Construction Phase Water Quality Monitoring Report – September 2018

Report Prepared for:

Pacifico and NSW Roads and Maritime Services

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Prepared By:

Aquatic Science and Management

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1 Introduction

1.1 Introduction and Background

The Pacific Highway upgrade between Warrell Creek and Nambucca Heads (WC2NH upgrade) is operational. Surface water and groundwater monitoring has been ongoing in the pre-construction and construction phases according to the Surface Water Monitoring Program (GeoLINK 2013a) and the Groundwater Monitoring Program (GeoLINK 2013b).

This document presents a summary of the surface water and groundwater monitoring results obtained during the entire period of construction phase monitoring, between February 2015 and June 2018.

1.1.1 Aims and Objectives

The objective of this report is to provide a summary of the surface water and groundwater quality monitoring activities and results for the construction phase of the WC2NH upgrade. 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 Warrell Creek to Nambucca Heads and to comply with the Department of Planning and Environment (DP&E) Ministers conditions of approval (RTA 2011) for the Warrell Creek to Urunga section of the Pacific Highway upgrade (including the WC2NH upgrade and the Nambucca Heads to Urunga section).

The condition of approval that relates to water quality is the *Ministers Condition of Approval (MP 07_0112) B17 – Water Quality*, which requires 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 construction phase period (February 2015 – June 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) 2004) 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 gathered data.

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.

2 Methods

2.1 Locations

2.1.1 Surface Water Monitoring Sites

There are five surface water locations (11 sites) where ongoing surface water monitoring is required. Maps of the site locations are presented in **Illustrations 2.1** and **2.2** (GeoLINK 2013a). A key to the site names used over time and in this report is presented in **Table 2.1**.

Table 2.1 Surface water monitoring locations and sites

Waterway	*Site Names*	*New Chainage*	*Old Chainage*
Upper Warrell Creek	SW01 (upstream) SW02 (downstream)	Ch 41565 Ch 42565	Ch -200 Ch 700
Stony Creek	SW03 (upstream) SW04 (downstream)	Ch 45465 Ch 45665	Ch 3700 Ch 3900
Lower Warrell Creek	SW05 (upstream) SW06 (downstream)	Ch 48165	Ch 6400
Unnamed Drainage Line	SW07 (upstream west) SW08 (upstream east) SW09 (downstream)	Ch 50215	Ch 8450
Nambucca River	SW10 (upstream) SW11 (downstream)	Ch 52065	Ch 10300

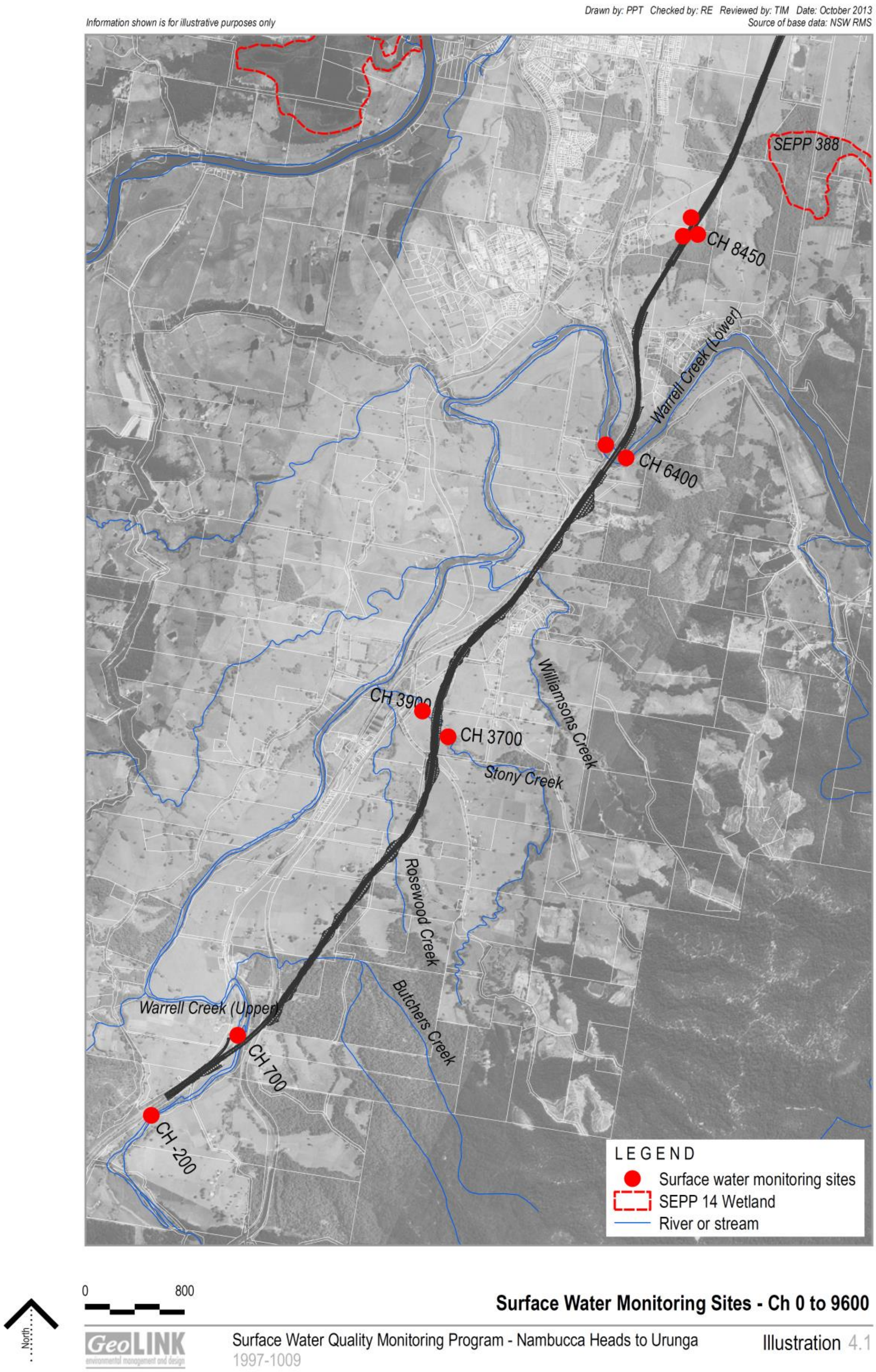

Illustration 2.1 Surface water monitoring sites – Ch 41765 to 51365 (Ch conversion +41765) (GeoLINK 2013a)

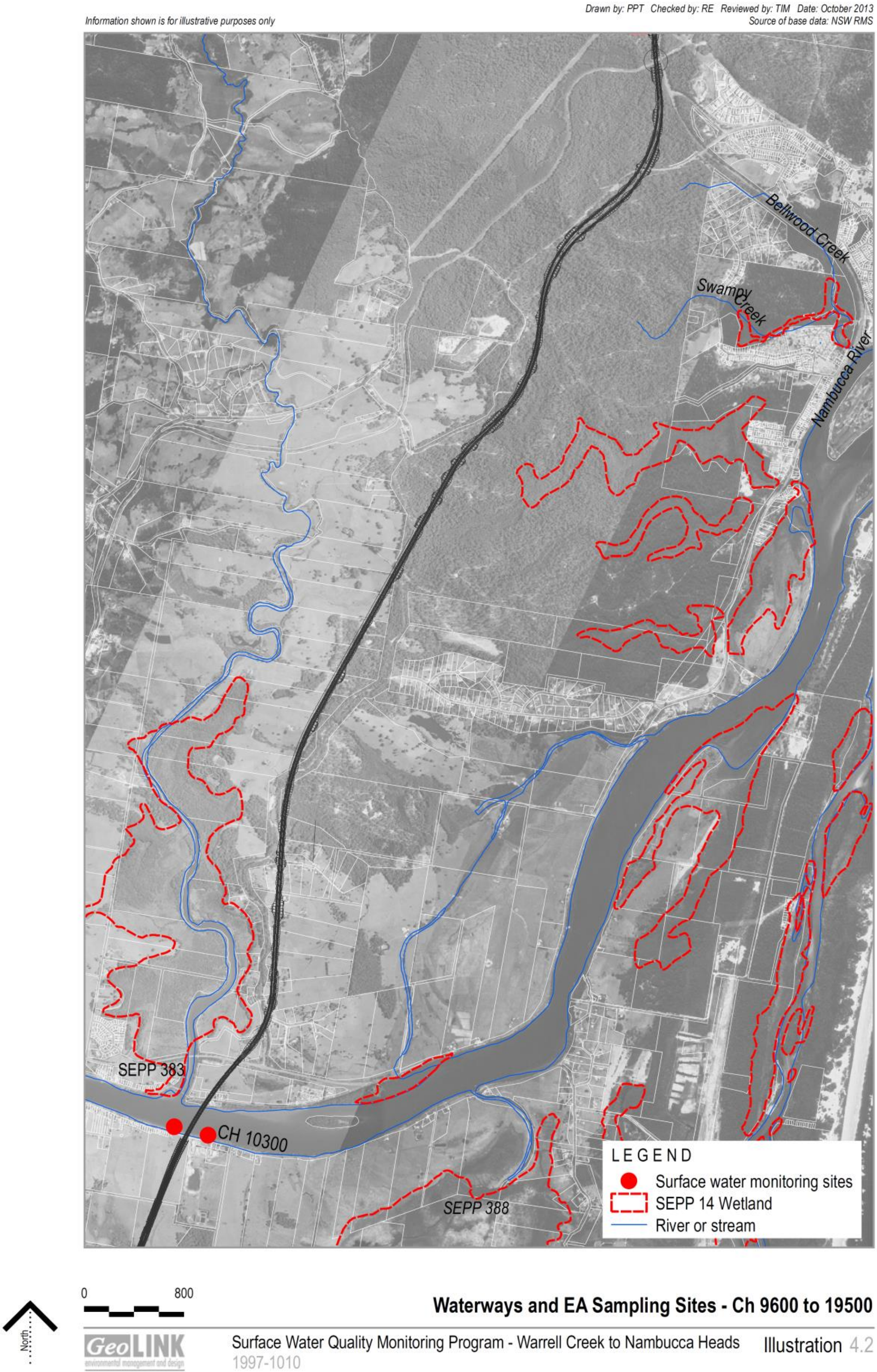

Illustration 2.2 Surface water monitoring sites – Ch 51365 to 71265 (Ch conversion +41765) (GeoLINK 2013a)

2.1.2 Groundwater Monitoring Sites

There are five locations (8 piezometers) where ongoing groundwater monitoring is required. Maps of the site locations are presented in **Illustrations 2.3** and **2.4** (GeoLINK 2013b). The locations (from south to north) are as follows:

- Cutting No. 1.11 on the west of the alignment, approximate chainage 49365, site Cut 12W.
- Embankment fill adjacent to Gumma Wetland, approximate chainage 50965, sites Fill 15E (upgradient) and Fill 15W (downgradient).
- Cutting No. 2.5 on the east and west of the alignment, approximate chainage 54065, sites Cut 15E (upgradient) and Cut 15W (downgradient)

Monitoring at several other sites where monitoring was undertaken in the pre-construction phase ceased prior to or during the construction phase (see GeoLINK 2013b and Coffey 2015).

Table 2.2 Groundwater monitoring locations and sites

Location	*Site Names*	*New Chainage*	*Old Chainage*
Cutting No. 1.5	Cut 6W (downgradient)	Ch 45165	Ch 3400
Cutting No. 1.10	Cut 11E (upgradient) Cut 11W (downgradient)	Ch 48665	Ch 6900
Cutting No. 1.11	Cut 12 W (downgradient)	Ch 49365	Ch 7600
Embankment Fill Gumma Wetland	Fill 15E (upgradient) Fill 15W (downgradient)	Ch 50965	Ch 9200
Cutting No. 2.5	Cut 15E (upgradient) Cut 15W (downgradient)	Ch 54065	Ch 12300

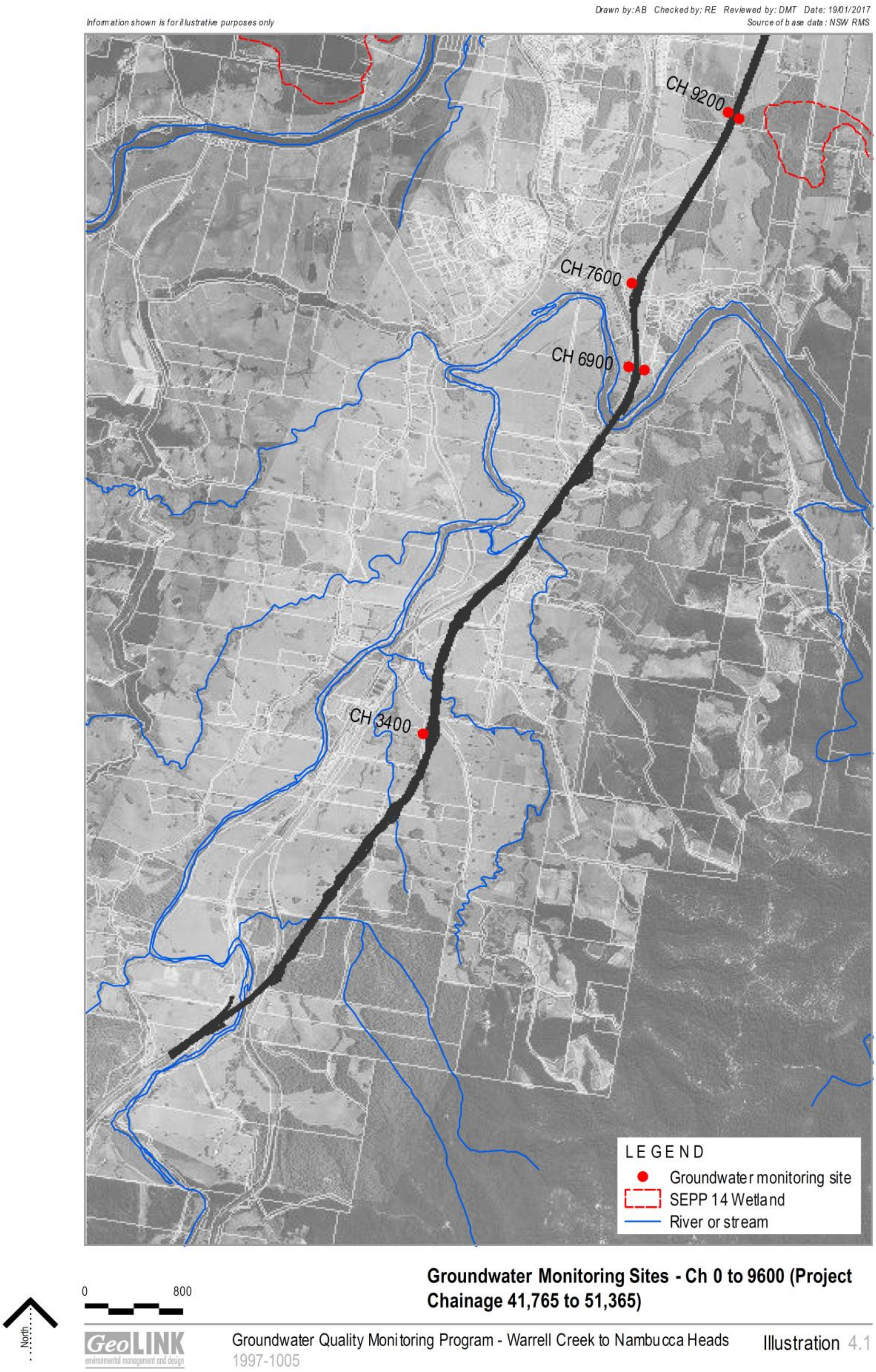

Illustration 2.3 Groundwater monitoring sites – Ch 41765 to 51365 (GeoLINK 2013b)

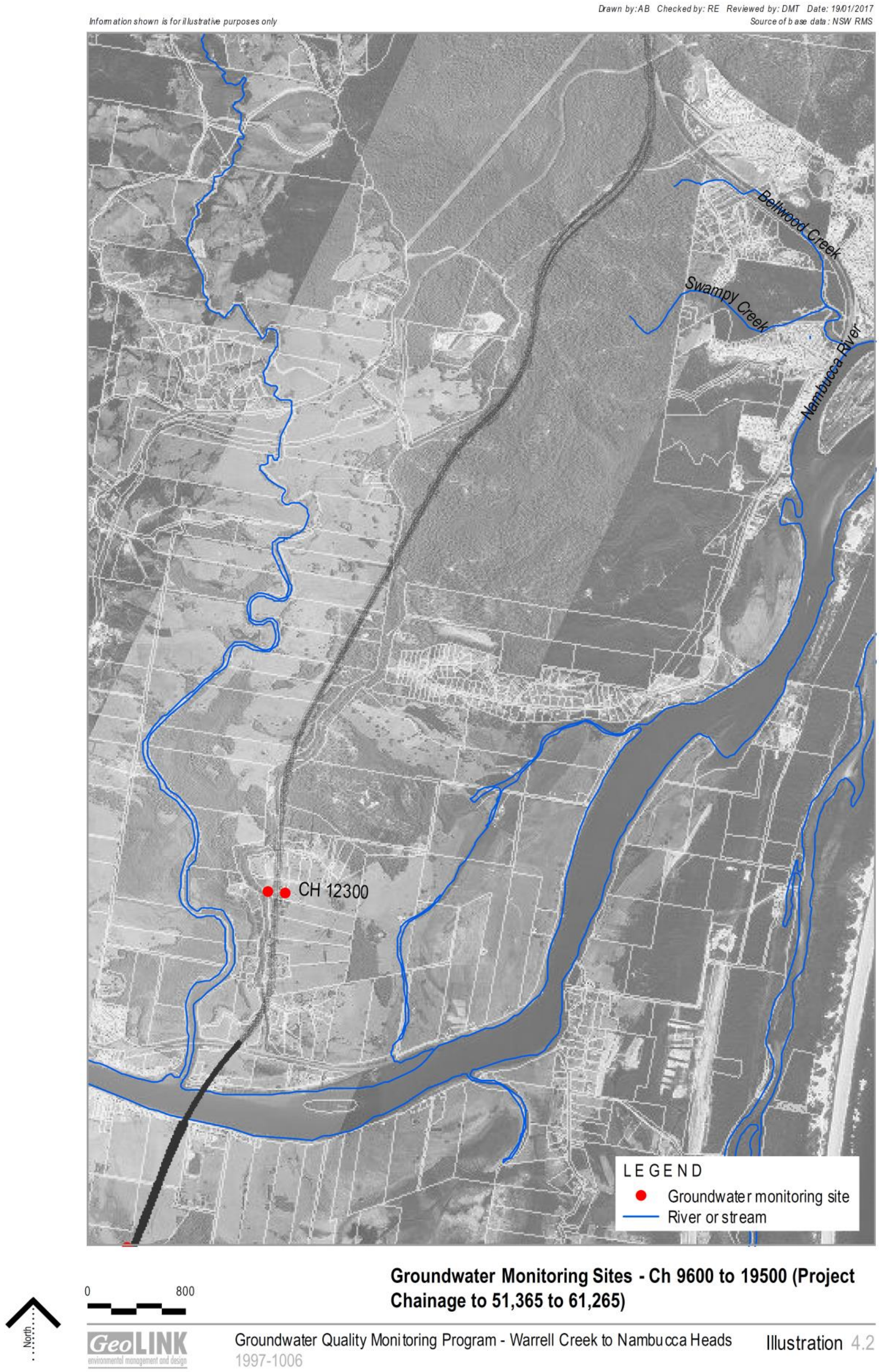

Illustration 2.4 Groundwater monitoring sites – Ch 51365 to 61265 (GeoLINK 2013b)

2.2 Sampling and Analysis

2.2.1 Surface Water Quality Monitoring

The SWMP outlines the parameters required for monitoring in the construction phase of the project. The complete list of parameters monitored is presented in **Table 2.3**.

Table 2.3 Surface water parameters for construction phase monitoring

Group	*Analytes*	*Method of Analysis*
Physicochemical	Temperature	Field measurement – Handheld Probe
	Electrical Conductivity (EC)	Field measurement – Handheld Probe
	pH	Field measurement – Handheld Probe
	Dissolved Oxygen (DO)	Field measurement – Handheld Probe
	Turbidity	Field measurement – Handheld Probe
	Total Dissolved Solids (TDS)	Field measurement – Handheld Probe
	Total Suspended Solids (TSS)	Laboratory Analysis
Hydrocarbons (if visual assessment confirms presence)	TRH C6 - C10	Laboratory Analysis
	TRH >C10 - C16	Laboratory Analysis
	TRH >C16 - C34	Laboratory Analysis
	TRH >C34 - C40	Laboratory Analysis
	Benzene	Laboratory Analysis
	Toluene	Laboratory Analysis
	Ethylbenzene	Laboratory Analysis
	Xylene	Laboratory Analysis
Metals	Aluminium (Al)	Laboratory Analysis
	Arsenic (As)	Laboratory Analysis
	Cadmium (Cd)	Laboratory Analysis
	Chromium (Cr)	Laboratory Analysis
	Copper (Cu)	Laboratory Analysis
	Lead (Pb)	Laboratory Analysis
	Manganese (Mn)	Laboratory Analysis
	Nickel (Ni)	Laboratory Analysis
	Selenium (Se)	Laboratory Analysis
	Silver (Ag)	Laboratory Analysis
	Zinc (Zn)	Laboratory Analysis
	Iron (Fe)	Laboratory Analysis
	Mercury (Hg)	Laboratory Analysis
Nutrients	Total Nitrogen (TN)	Laboratory Analysis
	Total Phosphorus (TP)	Laboratory Analysis
	Nitrate (NO_3)	Laboratory Analysis
	Nitrite (NO_2)	Laboratory Analysis
	Ammonia (NH_4)	Laboratory Analysis
	Phosphate	Laboratory Analysis

The SWMP also defines the sampling frequency for operational monitoring. This is presented in **Table 2.4**.

Table 2.4 Construction phase sample frequency (GeoLINK 2013a)

Period	*Dates*	*Parameters*	*Sample Frequency*
Construction Phase	February 2015 – June 2018	Physicochemical	2 wet samples monthly and 1 dry sample monthly
		Hydrocarbons, Metals, Nutrients and Solids	1 wet sample monthly and 1 dry sample bi-monthly

The dates of surface water quality monitoring sampling for the construction phase monitoring are presented in **Table 2.5**.

Table 2.5 Construction phase sampling dates

Date	*Sample Type*	*Parameters*				*Notes*
		Physicochemical	*Hydrocarbons*	*Metals*	*Nutrients*	
23/02/15	Wet	Y		Y	Y	No Access SW07
17/03/15	Dry	Y		Y	Y	
24/03/15	Wet	Y		Y	Y	
17/04/15	Dry	Y				
30/04/15	Wet	Y		Y	Y	
5/05/15	Wet	Y		Y	Y	
20/05/15	Dry	Y		Y	Y	
3/06/15	Dry	Y				
23/07/15	Dry	Y	Y	Y	Y	
26/08/15	Wet	Y	Y	Y	Y	
31/08/15	Dry	Y	Y	Y	Y	
18/09/15	Wet	Y		Y	Y	
26/09/15	Wet	Y		Y	Y	
29/09/15	Dry	Y				
8/10/15	Dry	Y		Y	Y	
23/10/15	Wet	Y		Y	Y	
5/11/15	Wet	Y		Y	Y	
16/11/15	Wet	Y				
25/11/15	Dry	Y				SW09 Dry
3/12/15	Wet	Y		Y	Y	
9/12/15	Dry	Y		Y	Y	
24/12/15	Wet	Y				
6/01/16	Wet	Y		Y	Y	
20/01/16	Dry	Y				
25/01/16	Wet	Y				
5/02/16	Wet	Y		Y	Y	

Date	Sample Type	Parameters				Notes
		Physicochemical	Hydrocarbons	Metals	Nutrients	
22/02/16	Wet	Y				
26/02/16	Dry	Y		Y	Y	
16/03/16	Dry	Y				
4/04/16	Wet	Y		Y	Y	
14/04/16	Wet	Y				
28/04/16	Dry	Y		Y	Y	
11/05/16	Dry	Y				
6/06/16	Wet	Y		Y	Y	
16/06/16	Dry	Y				
20/06/16	Wet	Y				
14/07/16	Dry	Y		Y	Y	
5/08/16	Wet	Y		Y	Y	SW09 Dry
26/08/16	Wet	Y				
30/08/16	Dry	Y				
7/09/16	Dry	Y		Y	Y	
16/09/16	Wet	Y		Y	Y	
17/10/16	Dry	Y				
10/11/16	Wet	Y		Y	Y	
23/11/16	Dry	Y		Y	Y	
15/12/16	Dry	Y				
10/01/17	Dry	Y		Y	Y	
16/01/17	Wet	Y		Y	Y	
10/02/17	Wet	Y		Y	Y	
20/02/17	Wet	Y				
23/02/17	Dry	Y				
6/03/17	Wet	Y		Y	Y	SW09 Dry
21/03/17	Wet	Y				
27/03/17	Dry	Y		Y	Y	
5/04/17	Dry	Y				
10/05/17	Dry	Y		Y	Y	SW09 Dry
15/05/17	Wet	Y		Y	Y	SW09 Dry
2/06/17	Dry	Y				SW09 Dry
19/06/17	Wet	Y		Y	Y	
30/6/17	Wet	Y				
12/07/17	Dry	Y		Y	Y	
8/08/17	Dry	Y				
6/09/17	Dry	Y		Y	Y	
3/10/17	Wet	Y		Y	Y	
12/10/17	Wet	Y				
25/10/17	Dry	Y				
10/11/17	Dry	Y		Y	Y	SW09 Dry
18/11/17	Wet	Y		Y	Y	
6/12/17	Wet	Y		Y	Y	

Date	Sample Type	Parameters				Notes
		Physicochemical	Hydrocarbons	Metals	Nutrients	
8/12/17	Dry	Y				
22/12/17	Wet	Y				
17/01/18	Dry	Y		Y	Y	SW09 Dry
3/01/18	Wet	Y		Y	Y	
2/02/18	Dry	Y				
21/02/18	Wet	Y		Y	Y	
7/03/18	Wet	Y		Y	Y	
16/03/18	Dry	Y		Y	Y	
22/03/18	Wet	Y				
4/04/18	Wet	Y		Y	Y	
18/04/18	Dry	Y				
24/04/18	Wet	Y				
4/05/18	Dry	Y		Y	Y	
6/06/18	Wet	Y		Y	Y	
12/06/18	Dry	Y				

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

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. A variety of sample vessels were used, depending upon the suite of parameters being analysed.

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

Where laboratories reported results as lower than the limits of detection, these results were incorporated into databases as the level of detection for the calculation of summary statistics and graphing.

2.2.2 Groundwater Quality Monitoring

The GMP outlines the parameters required for monitoring in the operational phase of the project. The complete list of parameters monitored is presented in **Table 2.6**).

Table 2.6 Surface water parameters for construction phase monitoring

Group	***Analytes***	***Method of Analysis***
Physicochemical	Temperature	Field measurement – Handheld Probe
	Electrical Conductivity (EC)	Field measurement – Handheld Probe
	pH	Field measurement – Handheld Probe
	Total Dissolved Solids (TDS)	Field measurement – Handheld Probe
Hydrocarbons	Total Recoverable Hydrocarbons (TRH) C6 - C10	Laboratory Analysis
	TRH >C10 - C16	Laboratory Analysis
	TRH >C16 - C34	Laboratory Analysis
	TRH >C34 - C40	Laboratory Analysis
	Benzene	Laboratory Analysis
	Toluene	Laboratory Analysis
	Ethylbenzene	Laboratory Analysis
	Xylene	Laboratory Analysis
Metals	Aluminium (Al)	Laboratory Analysis
	Arsenic (As)	Laboratory Analysis
	Cadmium (Cd)	Laboratory Analysis
	Chromium (Cr)	Laboratory Analysis
	Copper (Cu)	Laboratory Analysis
	Lead (Pb)	Laboratory Analysis
	Manganese (Mn)	Laboratory Analysis
	Nickel (Ni)	Laboratory Analysis
	Selenium (Se)	Laboratory Analysis
	Silver (Ag)	Laboratory Analysis
	Zinc (Zn)	Laboratory Analysis
	Iron (Fe)	Laboratory Analysis
	Mercury (Hg)	Laboratory Analysis
Nutrients	Total Nitrogen (TN)	Laboratory Analysis
	Total Phosphorus (TP)	Laboratory Analysis
	Nitrate (NO_3)	Laboratory Analysis
	Nitrite (NO_2)	Laboratory Analysis
	Ammonia (NH_4)	Laboratory Analysis
	Phosphate (PO_3)	Laboratory Analysis
Major Anions	Chloride (Cl^-)	Laboratory Analysis
	Sulfate (SO_4^{2-})	Laboratory Analysis
	Bicarbonate (HCO_3^-)	Laboratory Analysis
	Nitrate (NO_3^-)	Laboratory Analysis
Major Cations	Sodium (Na^+)	Laboratory Analysis
	Potassium (K^+)	Laboratory Analysis
	Calcium (Ca^{2+})	Laboratory Analysis
	Magnesium (Mg^{2+})	Laboratory Analysis

The frequency of groundwater monitoring is also defined by the GMP. This is presented in **Table 2.7**. The dates of groundwater measurements collected during the construction phase are presented in **Table 2.8**.

Table 2.7 Operational phase sample frequency (GeoLINK 2013b)

Period	*Dates*	*Parameters*	*Sample Frequency*
Construction Phase	February 2015 – June 2018	Physicochemical	1 sample every month
		Hydrocarbons, Metals, Nutrients, Solids, Anions and Cations	1 sample every three months

Table 2.8 Construction phase groundwater sampling dates

Date	*Parameters*					*Notes*
	Physicochemical	*Hydrocarbons*	*Metals*	*Nutrients*	*Major Ions*	
4/05/15	Y	Y	Y	Y	Y	No sample Fill 15W
30/05/15	Y	Y	Y	Y	Y	No sample Fill 15W
18/06/15	Y					No sample Fill 15W
16/07/15	Y	Y	Y	Y	Y	No sample Fill 15W
17/08/15	Y	Y	Y	Y	Y	No sample Cut 12W, Fill 15W
29/09/15	Y					No sample Cut 6W, Fill 15W
26/11/15	Y	Y	Y	Y	Y	
16/12/15	Y	Y	Y	Y	Y	
28/01/16	Y	Y	Y	Y	Y	
25/02/16	Y					No sample Cut 15E
24/03/16	Y					No sample Cut 15E
27/04/16	Y	Y	Y	Y	Y	No sample Cut 11E, Cut 15E, Cut 15W
26/05/16	Y					No sample Cut ^W, Cut 15E, Cut 15W
17/06/16	Y					No sample Cut 15E, Cut 15W
25/07/16	Y	Y	Y	Y	Y	No sample Cut 11E, Cut 15E, Cut 15W
19/08/16	Y					No sample Cut 15W, Fill 15E
26/09/16	Y					No sample Cut 15W, Fill 15E
25/10/16	Y	Y	Y	Y	Y	No sample Cut 12W, Cut 15W, Fill 15E

Date	*Parameters*					*Notes*
	Physicochemical	*Hydrocarbons*	*Metals*	*Nutrients*	*Major Ions*	
29/11/16	Y					No sample Cut 12W, Cut 15W, Fill 15E
8/12/16	Y					No sample Cut 12W, Cut 15W, Fill 15E
20/01/17	Y	Y	Y	Y	Y	No sample Cut 6W, Cut 12W, Cut 15W, Fill 15E
24/02/17	Y					No sample Cut 6W, Cut 12W, Cut 15W, Fill 15E
23/03/17	Y					No sample Cut 15W
20/04/17	Y	Y	Y	Y	Y	No sample Cut 12W, Cut 15W
12/05/17	Y		Y	Y	Y	No sample Cut 15W
7/06/17	Y					No sample Cut 15W
20/07/17	Y	Y	Y	Y	Y	No sample Cut 15W
4/08/17	Y					No sample Cut 12W, Cut 15W
12/09/17	Y					No sample Cut 12W, Cut 15W
24/10/17	Y	Y	Y	Y	Y	No sample Cut 12W, Cut 15W
22/11/17	Y					No sample Cut 12W, Cut 15W
14/12/17	Y					No sample Cut 12W, Cut 15W
10/01/18	Y	Y	Y	Y	Y	No sample Cut 12W, Cut 15W
14/02/18	Y					No sample Cut 12W, Cut 15W
8/03/18	Y					No sample Cut 12W, Cut 15W
18/04/18	Y	Y	Y	Y	Y	No sample Cut 12W, Cut 15W
10/5/18	Y					No sample Cut 12W, Cut 15W
20/6/18	Y					No sample Cut 12W, Cut 15W

Where laboratories reported results as lower than the limits of detection, these results were incorporated into databases as the level of detection for the calculation of summary statistics and graphing.

2.2.3 Groundwater Level Monitoring

Groundwater levels were monitored using HOBO data loggers and physical measurements during the construction phase monitoring. Data loggers were deployed at all sites although there were some gaps in the collected datasets, due to changes in the piezometers at some locations. The HOBO loggers were deployed at various depths and appear to have been redeployed at different levels on some occasions. Manual measurements, undertaken when data was downloaded from the HOBO loggers, provide a reference for changed deployments. The logged data has not been corrected for atmospheric pressure fluctuations. Logged groundwater data from the construction phase reporting period was retrieved on several occasions, with the final data retrieval occurring on 18/04/2018.

Some of the groundwater piezometers used for monitoring in the pre-construction and early construction monitoring phases were decommissioned during the construction phase and new piezometers constructed.

Manual measurements of groundwater levels were collected during every time groundwater quality samples were collected. Measurements were taken as depth to standing water from the top of the piezometer column. Manual measurements have not been translated into relative levels. The manual measurements collected were used to calibrate the logged data.

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. Rainfall data from the Bureau of Meteorology (BOM) station at Stuarts Island and Utungun (the nearest stations to the project), is presented in **Figure 3.1**.

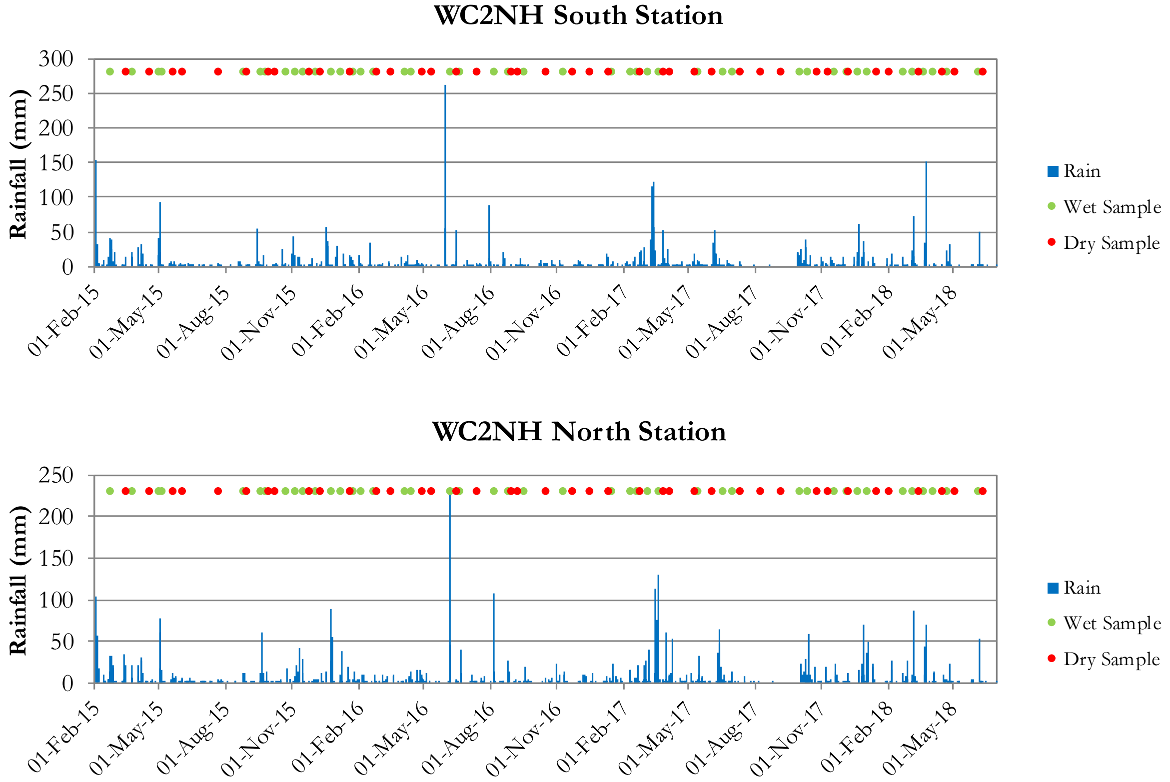

Figure 3.1 Daily rainfall at the WC2NH south and north weather stations for the reporting period plotted against sampling events.

Note: The data presented after 10 January 2018 is from the Utungun (south) and Stuarts Island (north) Bureau of Meteorology weather stations

Rainfall was relatively consistent across the construction phase. There were 7 rainfall events greater than 100 mm over the 3 years and 4 months of construction. The wettest months of the reporting period were February 2015, March 2017 and March 2018. The driest periods were between June and August 2015 and between July and September 2017.

3.2 Surface Water

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

Sampling dates for all surface water samples collected during the construction phase reporting period are displayed in **Table 2.3**.

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 construction phase monitoring period from each site is presented in **Appendix A** with the upstream P80 values. To provide historical context the summary data from the pre-construction phase, where published, is also presented.

A summary of relevant statistics for each waterway is presented in **Tables A.1** to **A.6**. A brief description of the summary results from each waterway follows. For the purposes of analysing the results of operational phase monitoring results of interest are defined as those where the construction phase downstream median is greater than the construction phase upstream P80.

3.2.1 Upper Warrell Creek

There were no results of interest from the Upper Warrell Creek monitoring sites (**Table A.1**). Turbidity and TSS measurements during the construction phase were relatively consistent (**Figures 3.2** and **3.3**). The highest turbidity and TSS measurements were collected upstream of the crossing, indicating that elevated measurements did not originate in the construction area. The pH measurements from the construction phase monitoring (**Figure 3.4**) were also relatively consistent and did not indicate any issues originating from construction activities.

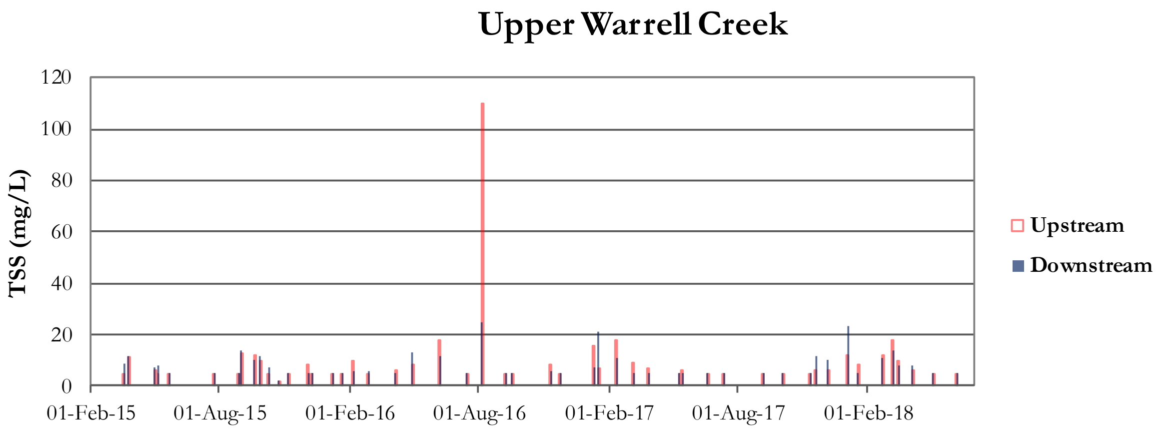

Figure 3.2 TSS concentrations from Upper Warrell Creek during the construction phase monitoring

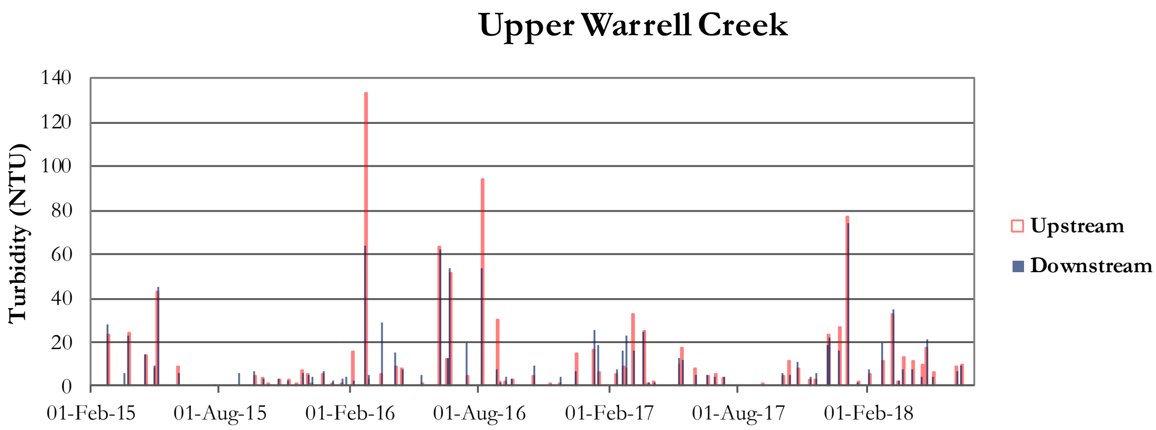

Figure 3.3 Turbidity measurements from Upper Warrell Creek during the construction phase monitoring

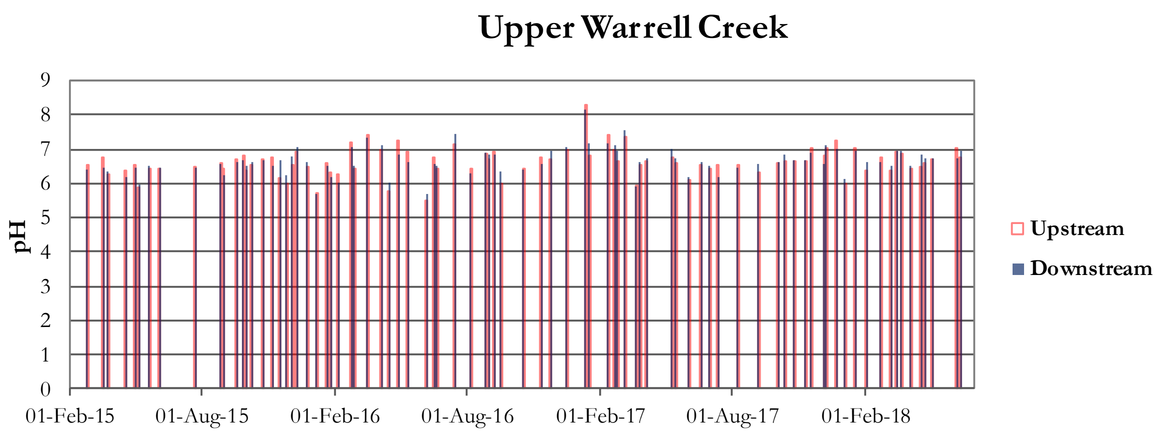

Figure 3.4 pH measurements from Upper Warrell Creek during the construction phase monitoring

Comparisons with the published data from the preconstruction monitoring phase are favourable for Upper Warrell Creek. Whilst the downstream maximum measurements from the construction phase exceeded the downstream maximum measurements from preconstruction for Al, As, Cu, Ni, Zn, Hg, PO_3, NO_3, NH_4, pH and turbidity, the upstream maximum construction phase measurements were greater than the downstream maximum construction phase measurements for all of these parameters with the exception of Ni and NH_4. This indicates that the source of most of the elevated measurements was upstream of the construction area.

Summary for Upper Warrell Creek – No results of interest for the construction phase. Downstream maximum construction phase measurements exceeded both downstream maximum pre-construction phase measurements and upstream maximum construction phase measurements for Ni and NH_4 only.

3.2.2 Stony Creek

There were no results of interest from the Stony Creek monitoring sites (**Table A.2**). Turbidity and TSS measurements during the construction phase were variable (**Figures 3.5** and **3.6**). The highest turbidity and TSS measurements were collected upstream of the crossing, although there were several occasions where downstream turbidity and TSS measurements exceeded upstream turbidity and TSS measurements. The pH measurements from the construction phase monitoring (**Figure 3.7**) were relatively consistent and did not indicate any issues originating from construction activities.

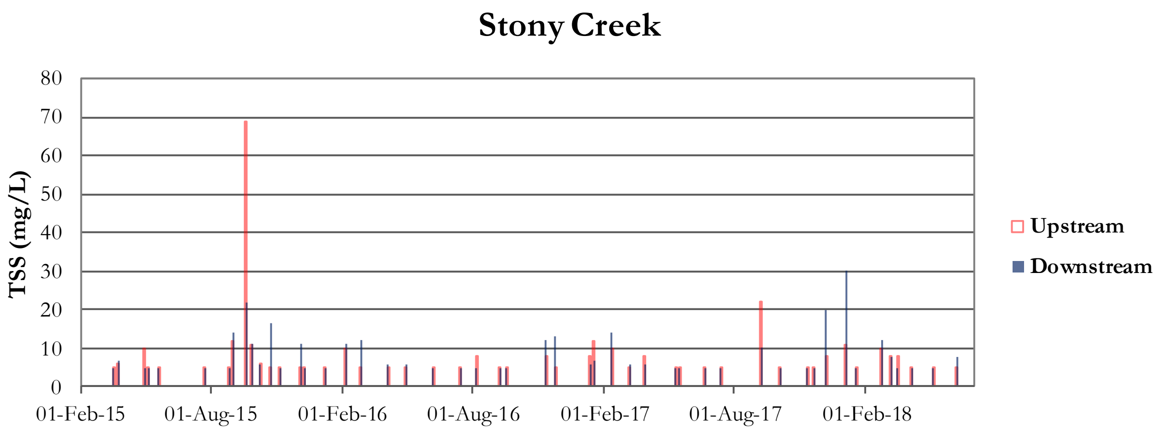

Figure 3.5 TSS concentrations from Stony Creek during the construction phase monitoring

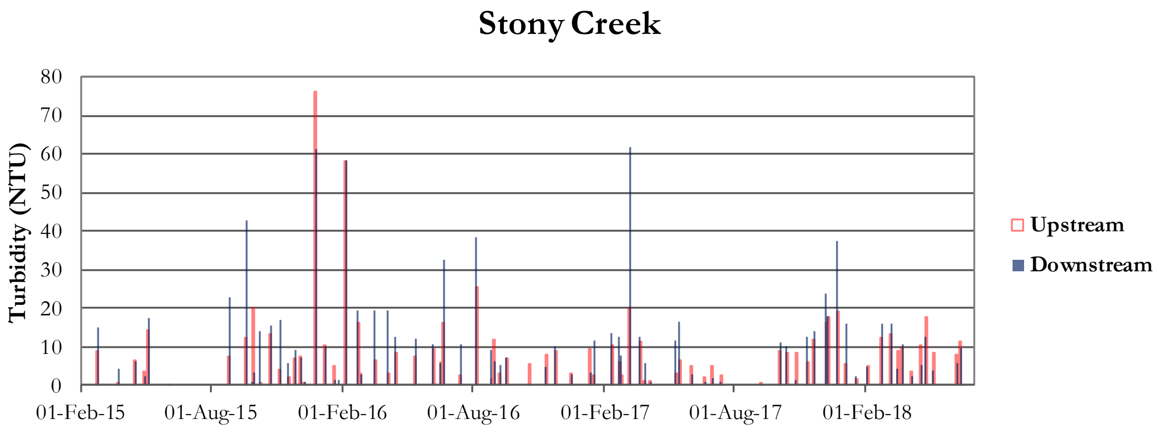

Figure 3.6 Turbidity measurements from Stony Creek during the construction phase monitoring

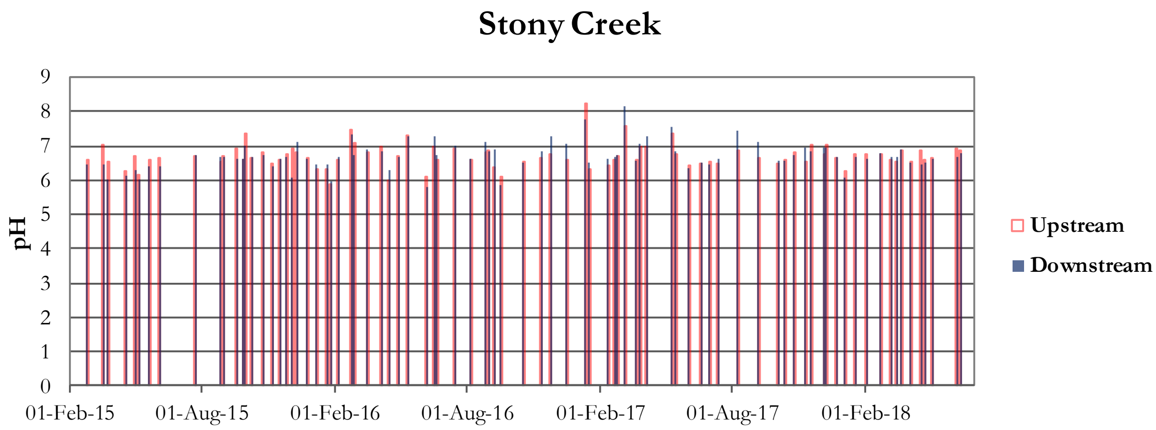

Figure 3.7 pH measurements from Stony Creek during the construction phase monitoring

Comparisons with the published data from the preconstruction monitoring phase are moderately favourable for Stony Creek. Whilst the downstream maximum measurements from the construction phase exceeded the downstream maximum measurements from preconstruction for Al, Cr, Cu, Mn, Ni, Se, Zn, Fe, Hg, PO_3, TN, NO_3, NH_4, TSS, pH and turbidity, the upstream maximum construction phase measurements were greater than the downstream maximum construction phase measurements for all of these parameters with the exception of Al, Se and NH_4. This indicates that the source of most of the elevated measurements was upstream of the construction area.

Summary for Stony Creek – No results of interest for the construction phase. Downstream maximum construction phase measurements exceeded both downstream maximum pre-construction phase measurements and upstream maximum construction phase measurements for Al, Se and NH_4 only.

3.2.3 Lower Warrell Creek

There were no results of interest from the Lower Warrell Creek monitoring sites (**Table A.3**). Turbidity and TSS measurements during the construction phase were variable (**Figures 3.8** and **3.9**). The highest turbidity and TSS measurements were collected upstream of the crossing, and elevated downstream turbidity and TSS measurements were generally accompanied by elevated upstream turbidity and TSS measurements. The pH measurements from the construction phase monitoring (**Figure 3.10**) were relatively consistent and did not indicate any issues originating from construction activities.

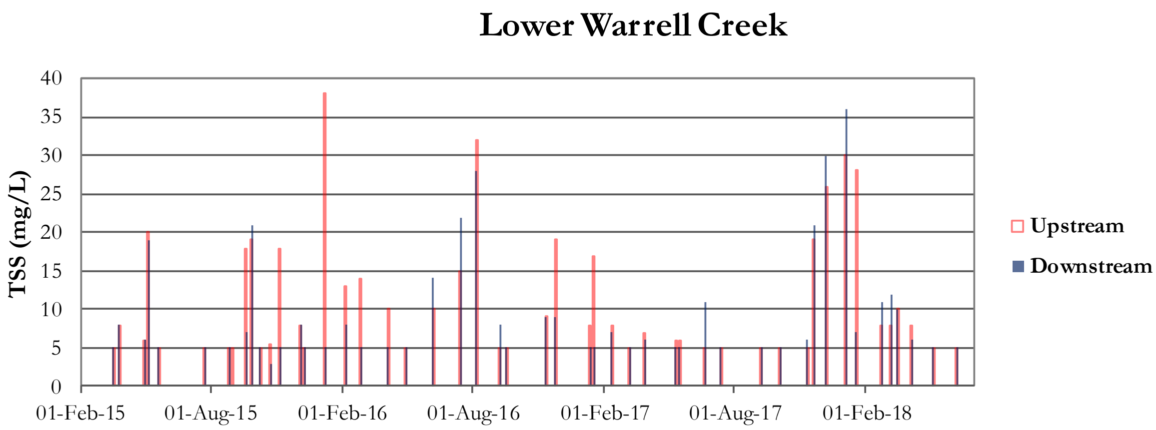

Figure 3.8 TSS concentrations from Lower Warrell Creek during the construction phase monitoring

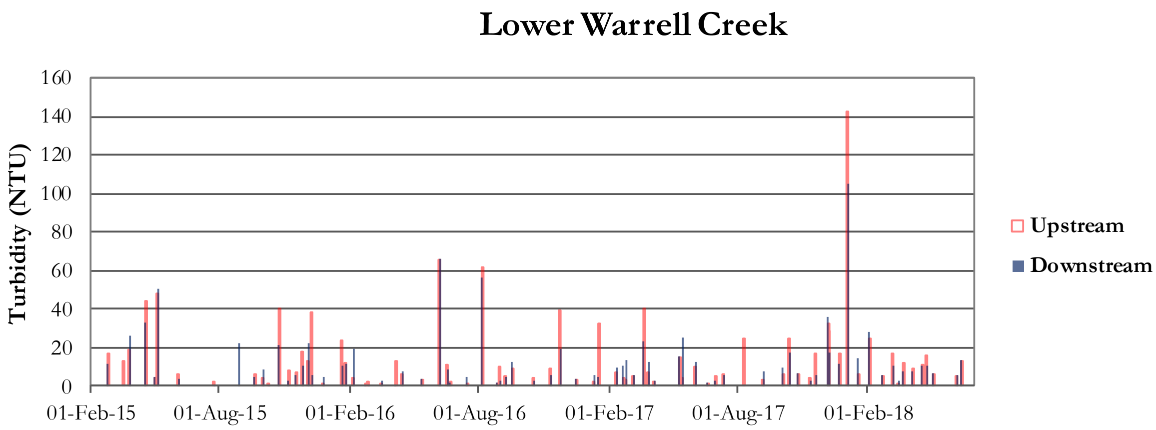

Figure 3.9 Turbidity measurements from Lower Warrell Creek during the construction phase monitoring

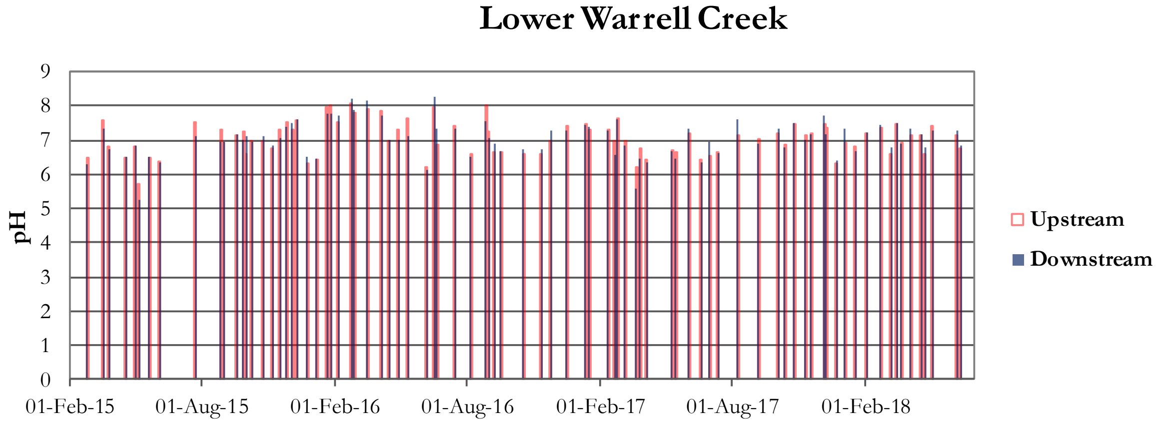

Figure 3.10 pH measurements from Lower Warrell Creek during the construction phase monitoring

Comparisons with the published data from the preconstruction monitoring phase are not possible for Lower Warrell Creek because the pre-construction summary data published was prepared from the combined upstream and downstream monitoring sites.

Summary for Lower Warrell Creek – No results of interest for the construction phase.

3.2.4 Unnamed Creek Gumma West

There was one result of interest from the Unnamed Creek Gumma West monitoring sites (**Table A.4**). The downstream median Ni concentration exceeded the upstream p80 Ni concentration. There were several occasions during the construction phase when the downstream Ni concentration exceeded the upstream Gumma West Ni concentration (**Figure 3.14**). However, on most of these occasions the upstream Gumma East Ni concentrations were elevated, indicating that the source was not related to construction activity (**Figure 3.19**). Turbidity and TSS measurements during the construction phase were variable (**Figures 3.11** and **3.12**). The highest TSS measurement was collected upstream of the crossing but the highest turbidity measurement was collected downstream of the crossing (on the same date). Elevated downstream turbidity and TSS measurements were accompanied by elevated upstream turbidity and TSS measurements with few exceptions. The pH measurements from the construction phase monitoring (**Figure 3.13**) were relatively consistent and did not indicate any issues originating from construction activities.

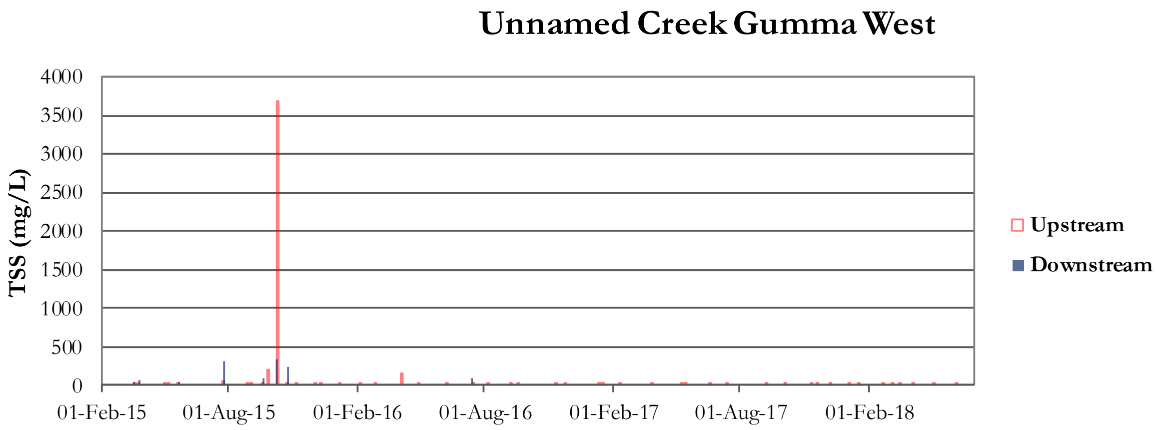

Figure 3.11 TSS concentrations from Unnamed Creek Gumma West during the construction phase monitoring

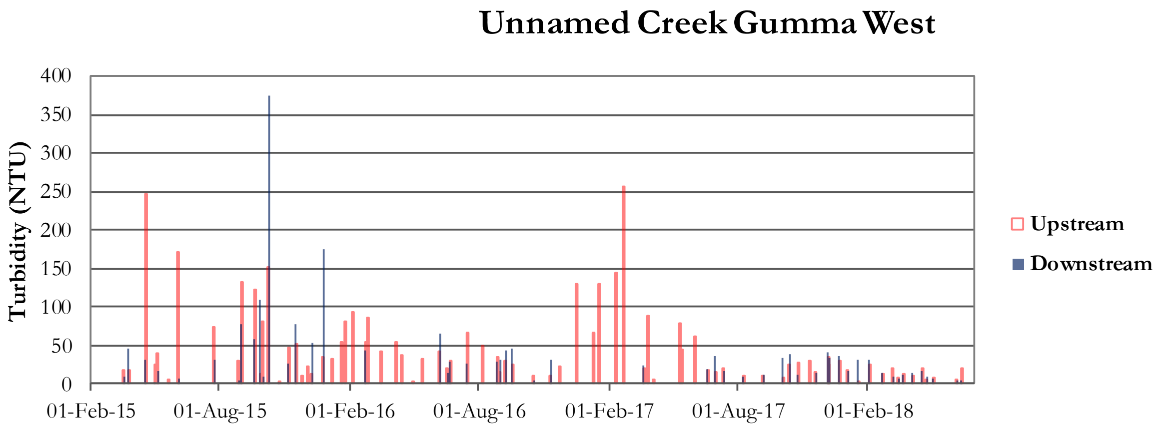

Figure 3.12 Turbidity measurements from Unnamed Creek Gumma West during the construction phase monitoring

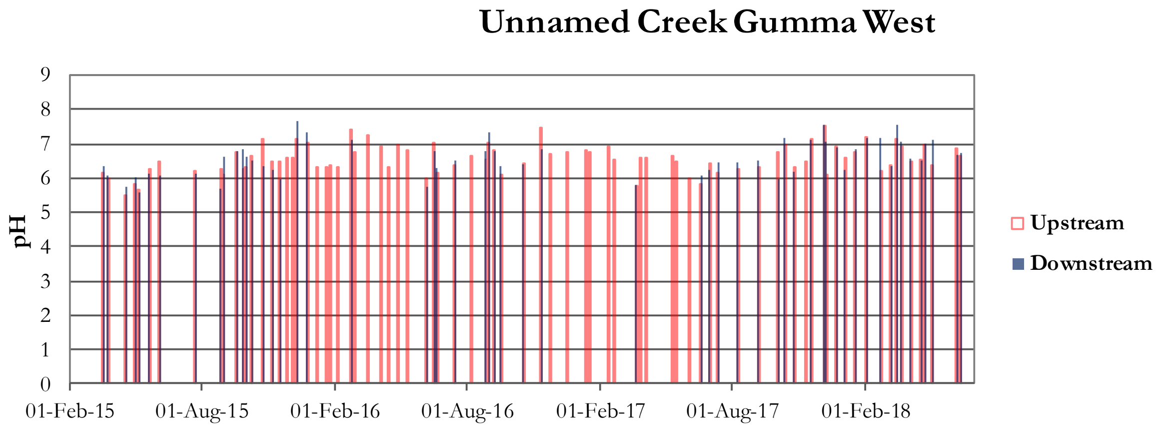

Figure 3.13 pH measurements from Unnamed Creek Gumma West during the construction phase monitoring

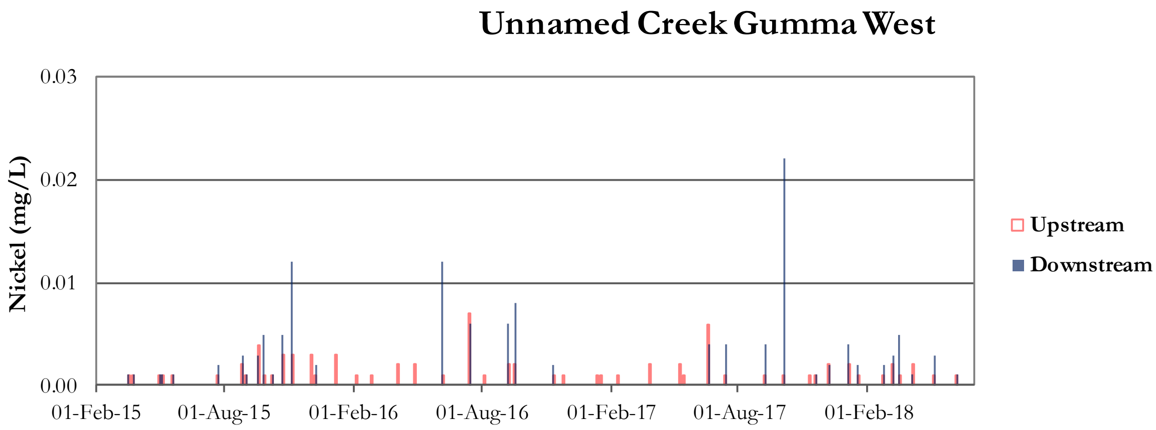

Figure 3.14 Nickel measurements from Unnamed Creek Gumma West during the construction phase monitoring

Comparisons with the published data from the preconstruction monitoring phase are not possible for the unnamed Creek at Gumma Wetlands West because the pre-construction summary data published was prepared from the combined upstream and downstream monitoring sites.

Summary for Unnamed Creek Gumma West – One result of interest for the construction phase which was unlikely to be related to construction activity. There were many occasions during the construction phase monitoring when there was not a suitable water level at the downstream sample site to enable sampling.

3.2.5 Unnamed Creek Gumma East

There was one result of interest from the Unnamed Creek Gumma East monitoring sites (**Table A.5**). The downstream median conductivity measurement exceeded the upstream p80 conductivity measurement. However, the increased downstream conductivity measurements are highly likely to be related to tidal influence from the Nambucca River, not to construction activity. Turbidity and TSS measurements during the construction phase were variable (**Figures 3.15** and **3.16**). The highest TSS measurement was collected upstream of the crossing but the highest turbidity measurement was collected downstream of the crossing (on the same date). Elevated downstream turbidity and TSS measurements were accompanied by elevated upstream turbidity and TSS measurements with few exceptions. The pH measurements from the construction phase monitoring (**Figure 3.17**) were relatively consistent and did not indicate any issues originating from construction activities.

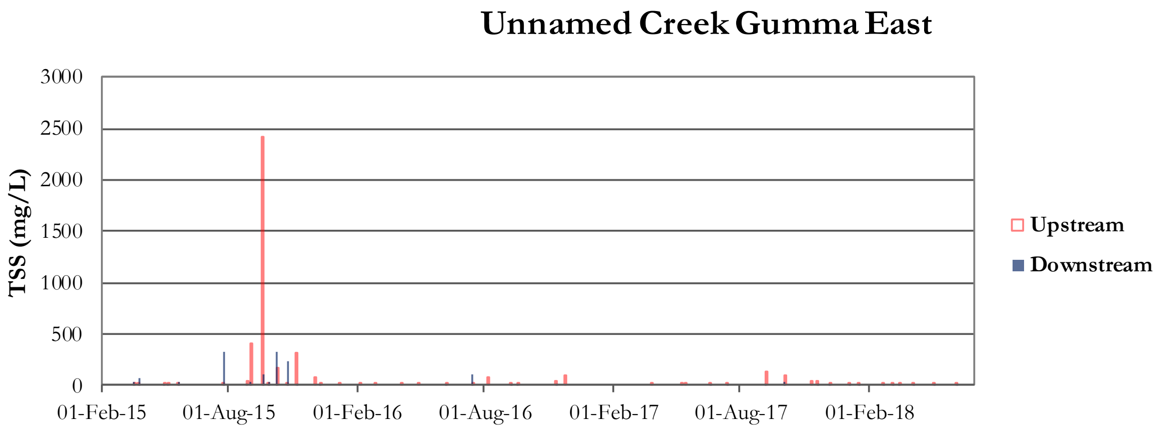

Figure 3.15 TSS concentrations from Unnamed Creek Gumma East during the construction phase monitoring

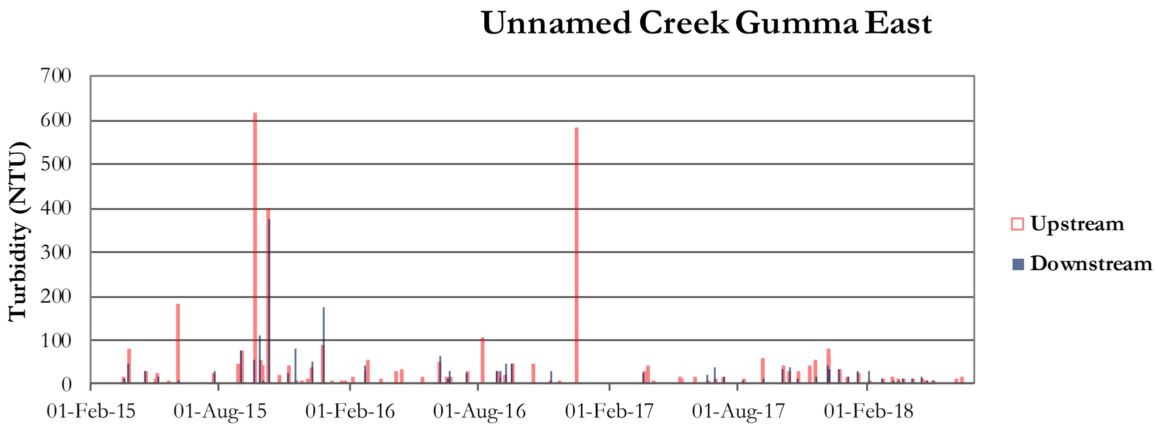

Figure 3.16 Turbidity measurements from Unnamed Creek Gumma East during the construction phase monitoring

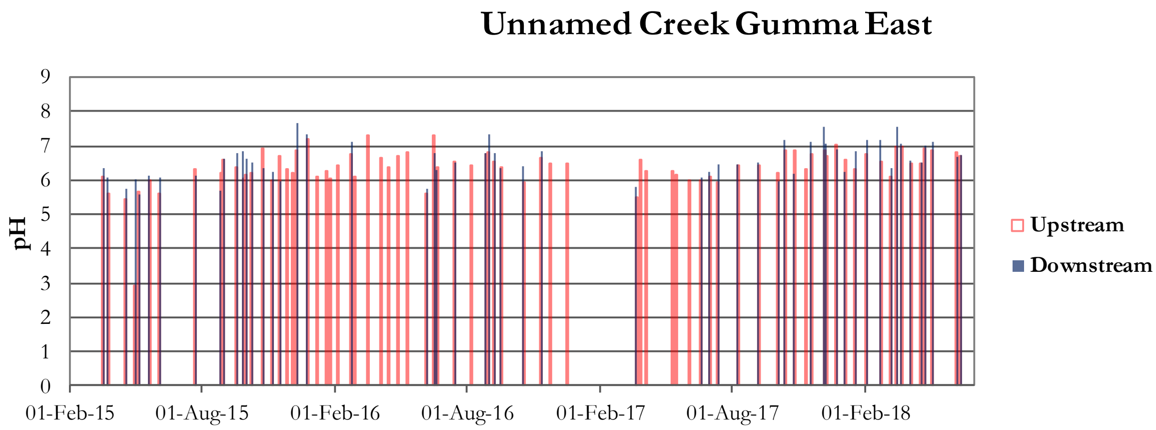

Figure 3.17 pH measurements from Unnamed Creek Gumma East during the construction phase monitoring

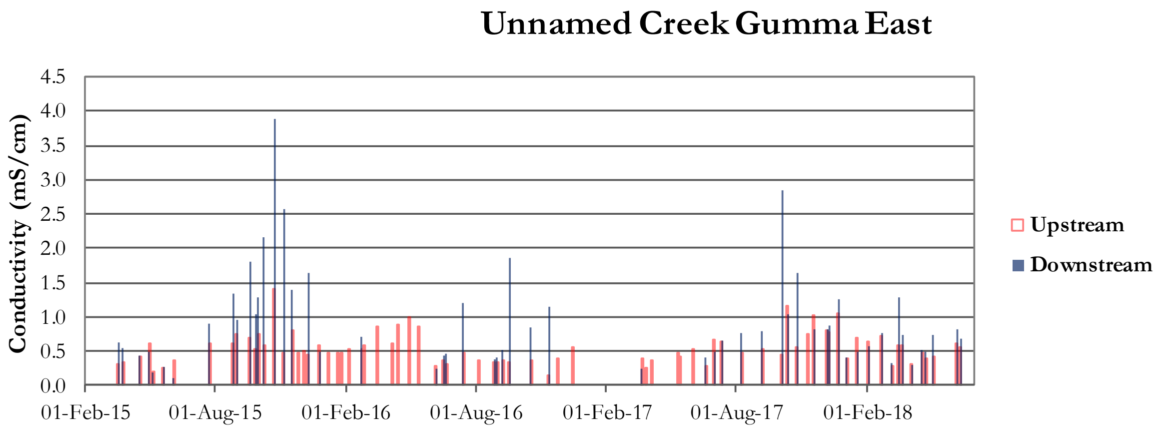

Figure 3.18 Conductivity measurements from Unnamed Creek Gumma East during the construction phase monitoring

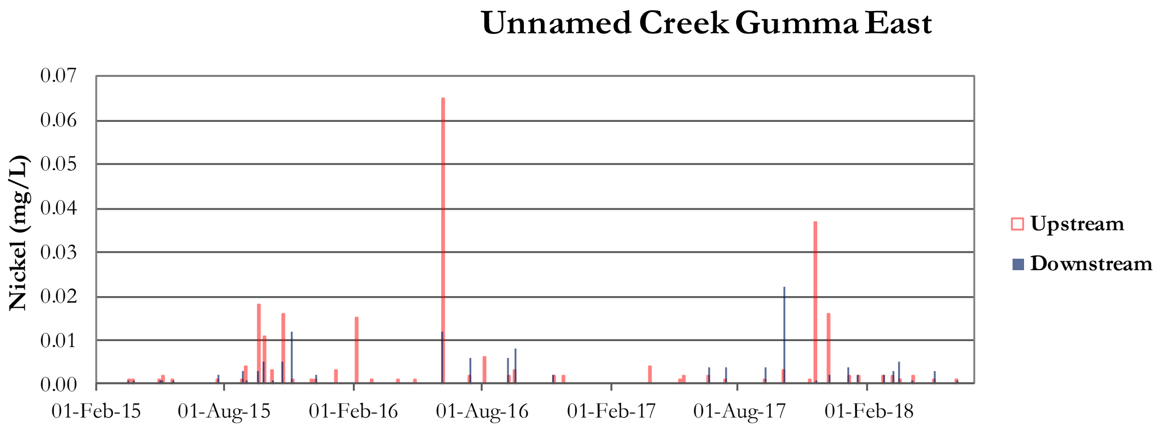

Figure 3.19 Nickel measurements from Unnamed Creek Gumma East during the construction phase monitoring

Comparisons with the published data from the preconstruction monitoring phase are not possible for the unnamed Creek at Gumma Wetlands east because the pre-construction summary data published was prepared from the combined upstream and downstream monitoring sites.

Summary for Unnamed Creek Gumma East – One result of interest for the construction phase which was unlikely to be related to construction activity. There were many occasions during the construction phase monitoring when there was not a suitable water level at the downstream sample site to enable sampling.

3.2.6 Nambucca River

There were no results of interest from the Nambucca River monitoring sites (**Table A.6**). Turbidity and TSS measurements during the construction phase were variable (**Figures 3.20** and **3.21**). The highest TSS measurements were collected upstream of the crossing, and elevated downstream turbidity and TSS measurements were all accompanied by elevated upstream turbidity and TSS measurements. The pH measurements from the construction phase monitoring (**Figure 3.22**) were consistent and did not indicate any issues originating from construction activities.

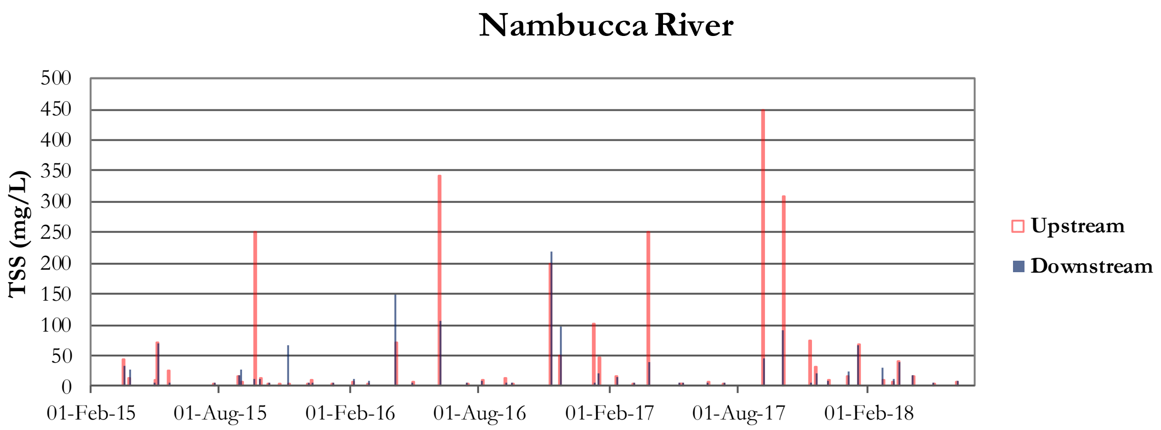

Figure 3.20 TSS concentrations from the Nambucca River during the construction phase monitoring

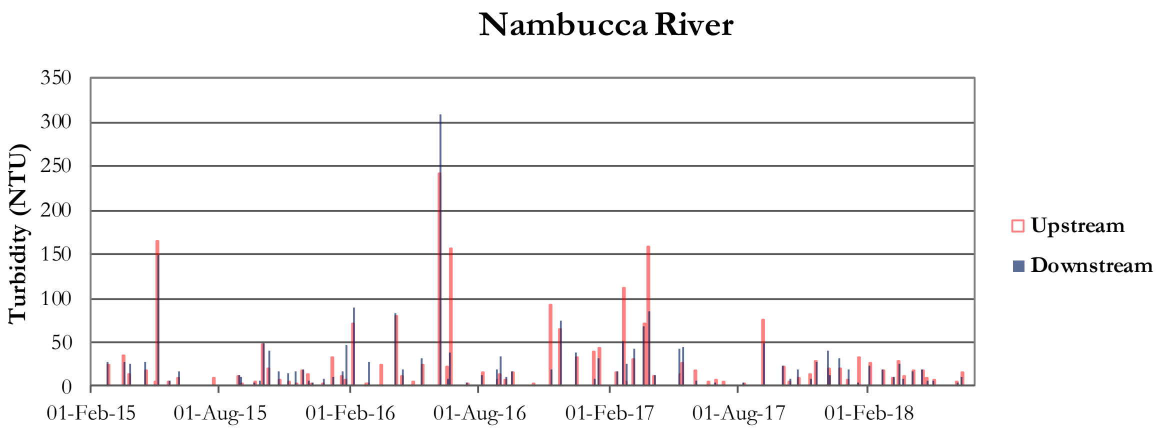

Figure 3.21 Turbidity measurements from the Nambucca River during the construction phase monitoring

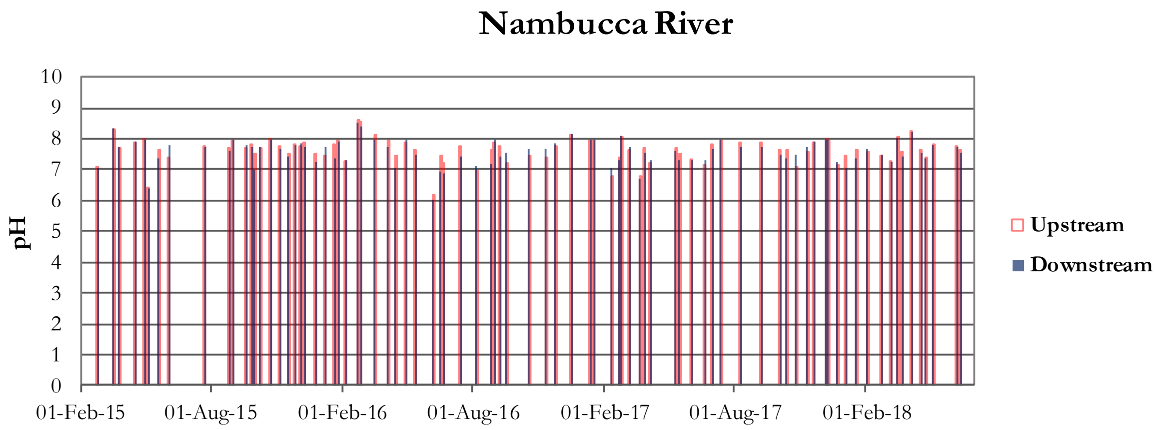

Figure 3.22 pH measurements from the Nambucca River during the construction phase monitoring

Comparisons with the published data from the preconstruction monitoring phase are not possible for the Nambucca River because the pre-construction summary data published was prepared from the combined upstream and downstream monitoring sites.

Summary for the Nambucca River – No results of interest for the construction phase.

3.3 Groundwater

3.3.1 Groundwater Quality

A summary of groundwater quality results from the construction phase monitoring is provided in **Appendix B**.

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 downgradient site is presented in **Appendix B** with the upgradient P80 values from the construction phase

The relevant summary statistics for each groundwater site are presented in **Tables B.1** to **B.5**. 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 construction phase downgradient median is greater than the construction phase upgradient P80.

3.3.2 Ch 45165 – Cut 6

There were no results of interest from Ch 45165 (**Table B.1**). The upgradient piezometer at Ch 45165 was dry for the entire construction monitoring phase. As a result, there is no upgradient data for a comparison. Total dissolved solids (TDS) measurements were relatively consistent throughout the monitoring period (**Figure 3.23**). The pH measurements were variable at the beginning of the monitoring period but were stable for the last year of monitoring (**Figure 3.24**).

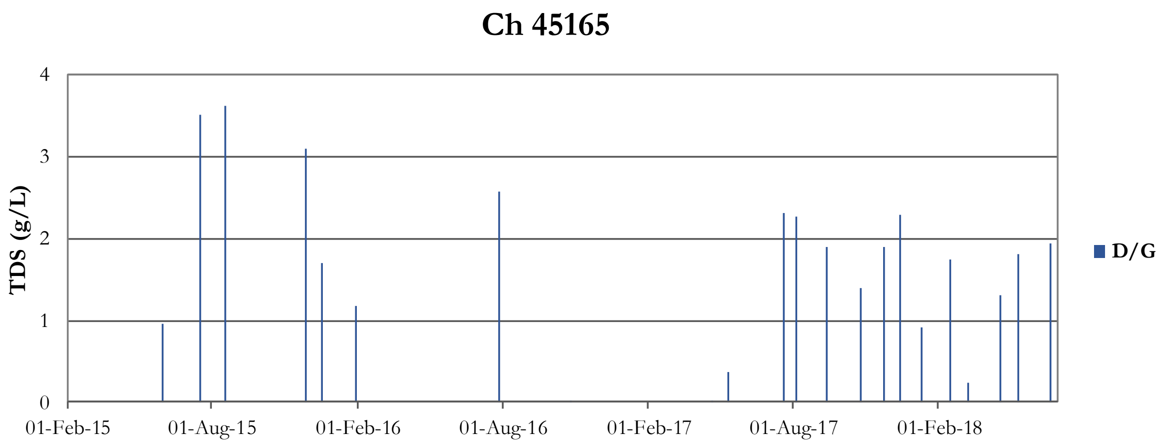

Figure 3.23 Total dissolved solids concentrations from Ch 45165 since February 2015

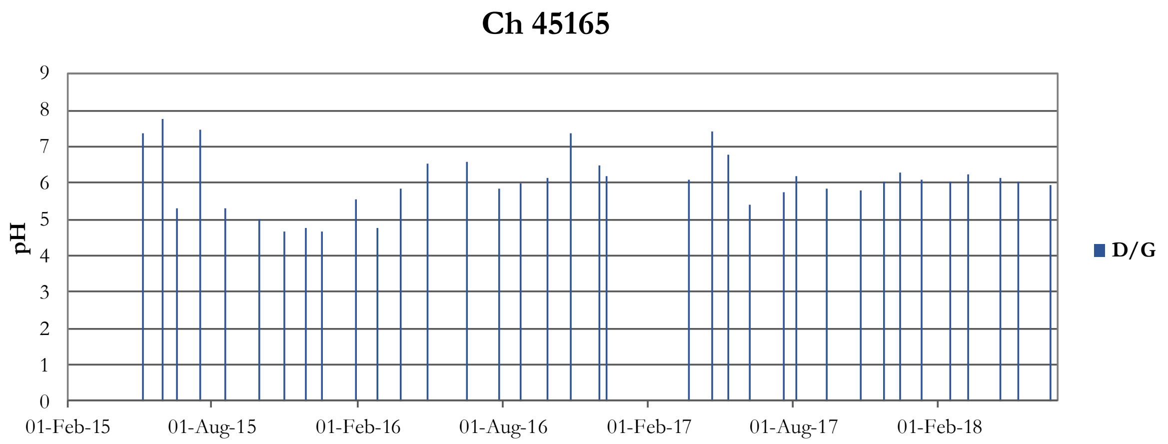

Figure 3.24 pH measurements from Ch 45165 since February 2015

Summary for Ch 45165: No results of interest, no upgradient data available for the construction monitoring period.

3.3.3 Ch 48665 – Cut 11

Results were no results of interest from Ch 48665 (**Table B.2**). Downgradient total dissolved solids (TDS) measurements were relatively consistent throughout the monitoring period but upgradient concentrations increased significantly in April 2017 before reducing steadily throughout the rest of the monitoring period (**Figure 3.25**). The pH measurements were relatively consistent throughout the construction phase with few exceptions (**Figure 3.26**).

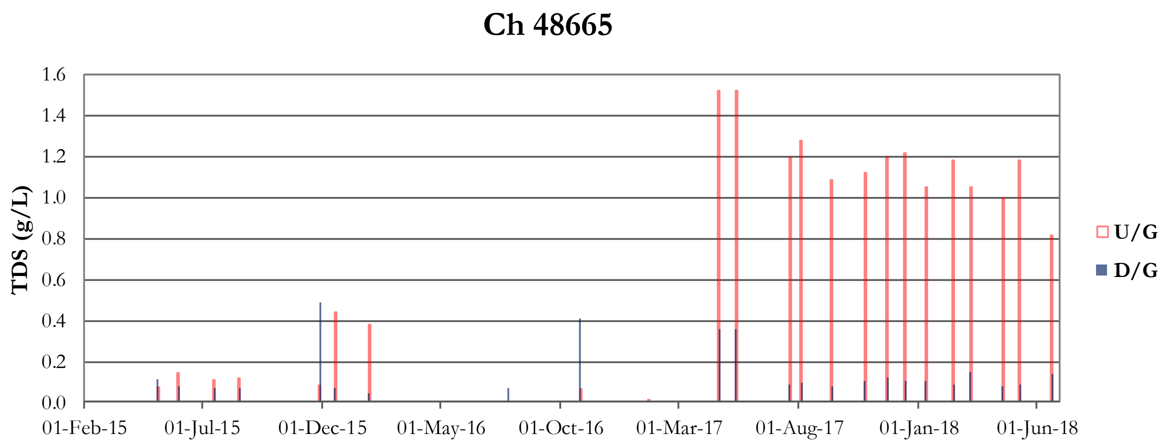

Figure 3.25 Total dissolved solids concentrations from Ch 48665 since February 2015

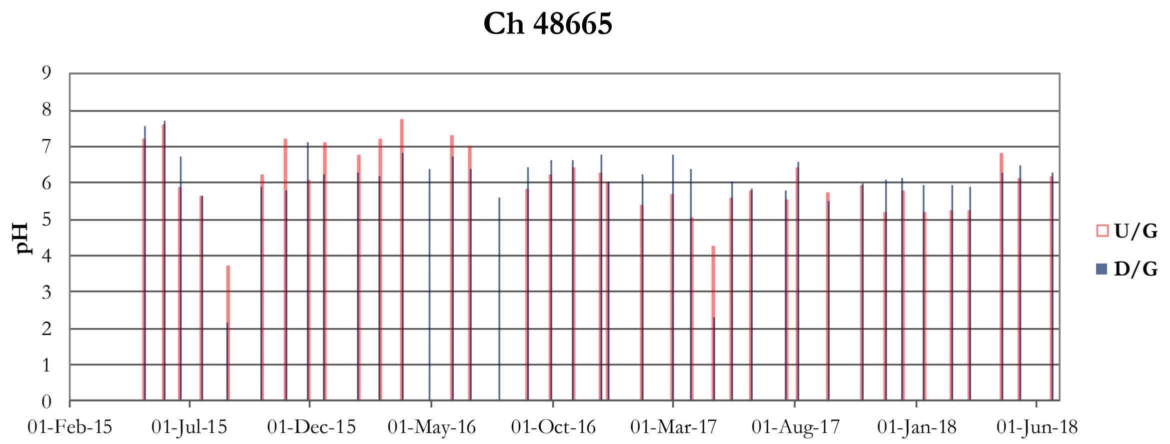

Figure 3.26 pH measurements from Ch 48665 since February 2015

Summary for Ch 48665: No results of interest, a new upgradient monitoring bore was constructed in August 2016.

3.3.4 Ch 49365 – Cut 12

There were no results of interest from Ch 49365 (**Table B.3**). The upgradient piezometer at Ch 45165 was dry for the entire construction monitoring phase. As a result, there is no upgradient data for a comparison. Total dissolved solids (TDS) measurements were relatively consistent throughout the monitoring period with one exception (**Figure 3.27**). The pH measurements were relatively stable throughout the construction phase (**Figure 3.28**).

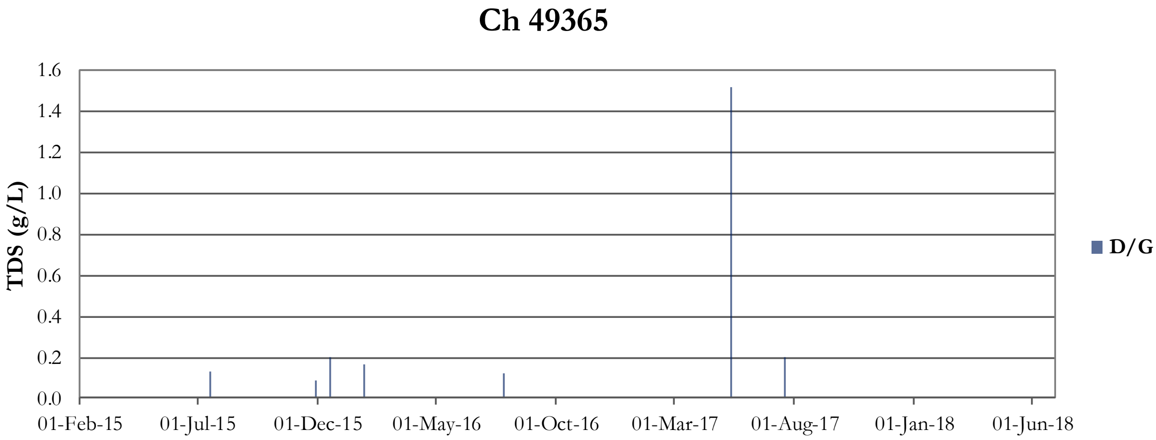

Figure 3.27 Total dissolved solids concentrations from Ch 49365 since February 2015

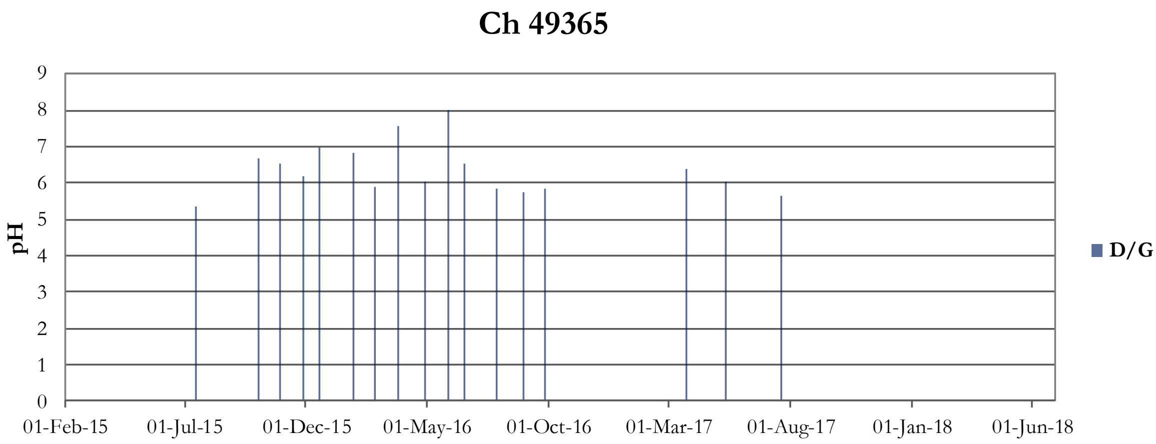

Figure 3.28 pH measurements from Ch 49365 since February 2015

Summary for Ch 49365: No results of interest, no upgradient data available for the construction monitoring period. A new downgradient monitoring bore was constructed in July 2017 and the bore was dry from August 2017 until the end of the construction monitoring phase.

3.3.5 Ch 54065 – Cut 15

Results of interest from Ch 54065 (**Table B.4**) were the downgradient median Mn, Fe, SO_4^{2-}, HCO_3^-, K^+, Ca^{2+} and Mg^{2+} measurements. There was no water in the downgradient piezometer from February 2016 until the end of the construction phase monitoring, limiting the capacity to draw conclusions about groundwater quality. For each of Mn, K^+, Ca^{2+} and Mg^{2+} a spike in the concentrations occurred in November 2015, December 2015 and January 2016 (**Figures 3.31**, **3.35**, **3.36** and **3.37**). For Fe, SO_4^{2-} and HCO_3^- there is no pattern to the variation. The TDS measurements were relatively stable for most of the construction phase, with a moderate spike registered in upgradient and downgradient piezometers in November and December 2015 and January 2016 (**Figure 3.29**). The pH measurements were variable throughout the monitoring period but there was no detectable trend (**Figure 3.30**).

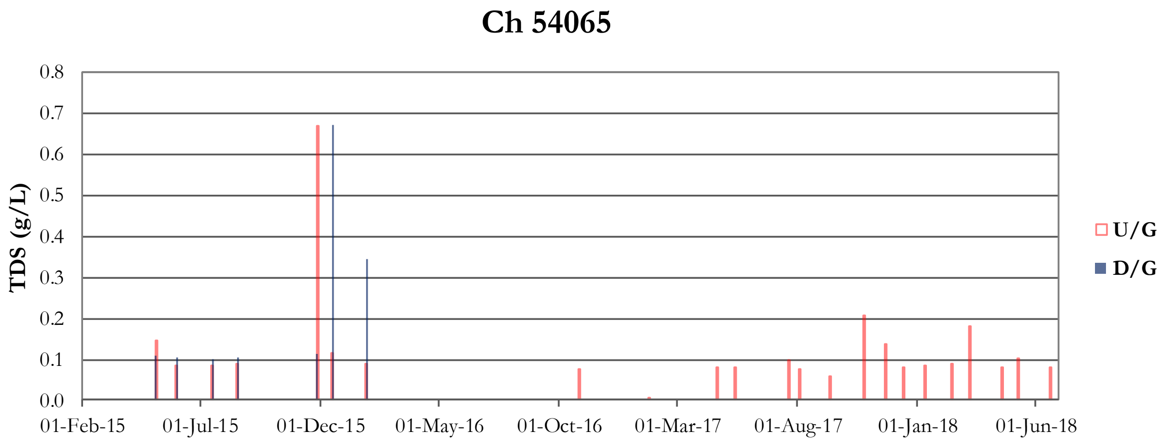

Figure 3.29 TDS measurements from Ch 54065 since February 2015

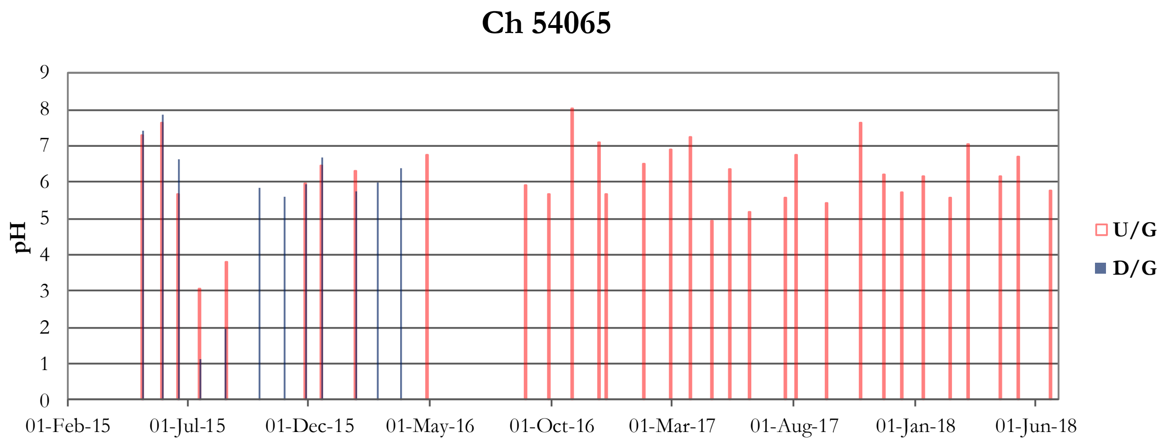

Figure 3.30 pH measurements from Ch 54065 since February 2015

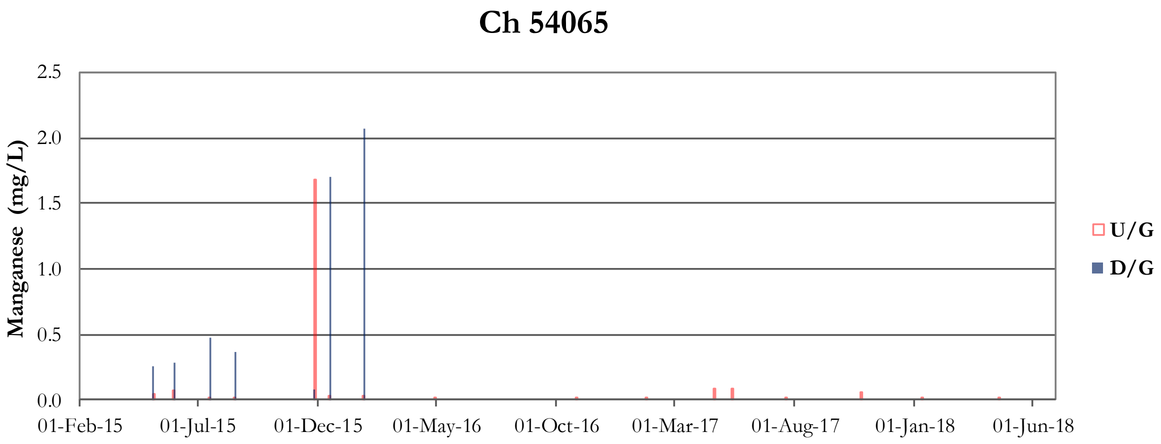

Figure 3.31 Manganese measurements from Ch 54065 since February 2015

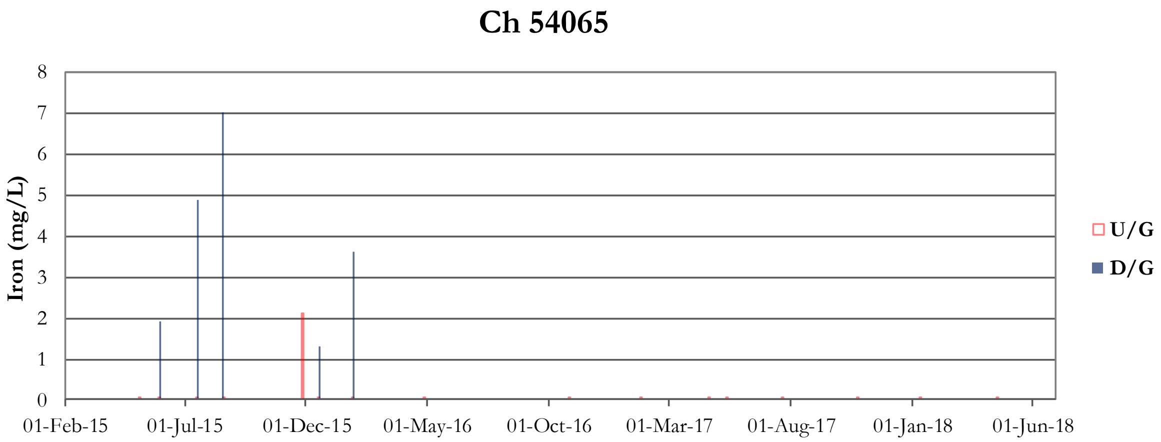

Figure 3.32 Iron measurements from Ch 54065 since February 2015

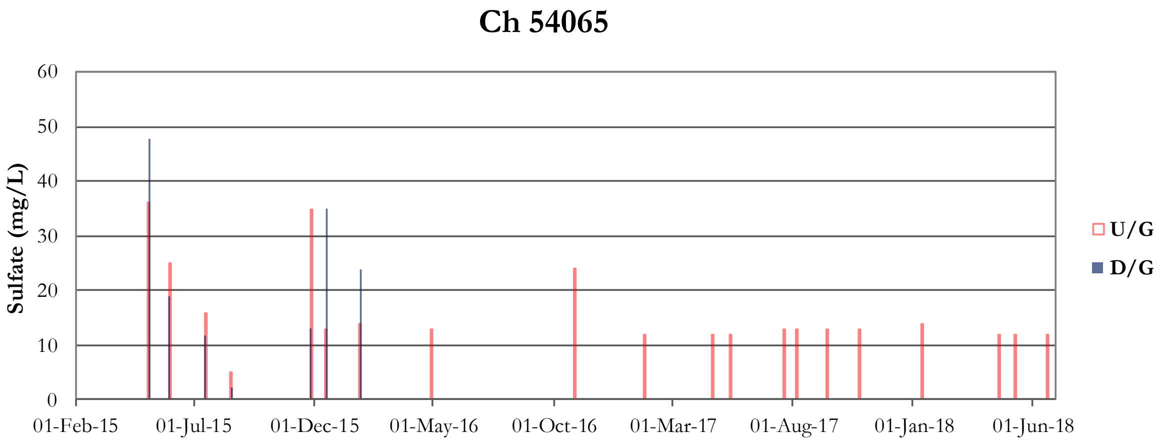

Figure 3.33 Sulfate measurements from Ch 54065 since February 2015

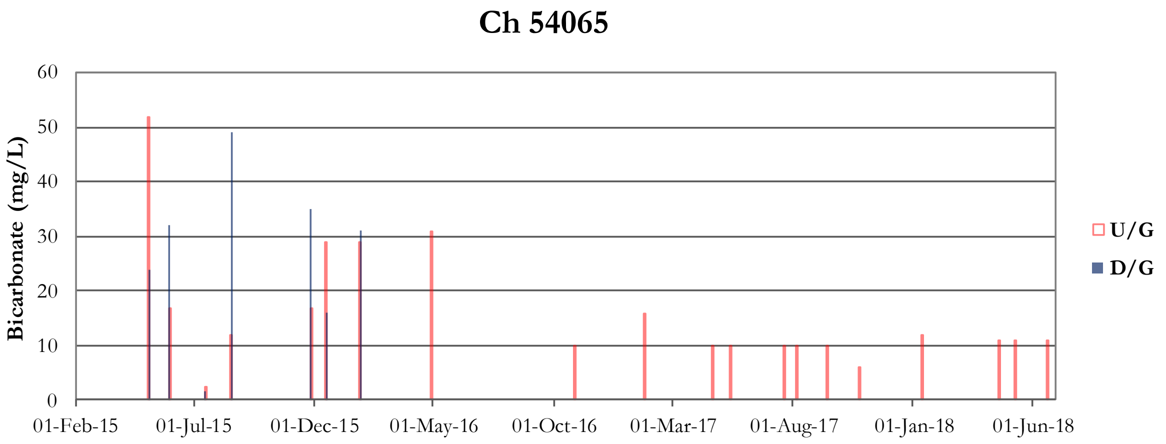

Figure 3.34 Bicarbonate measurements from Ch 54065 since February 2015

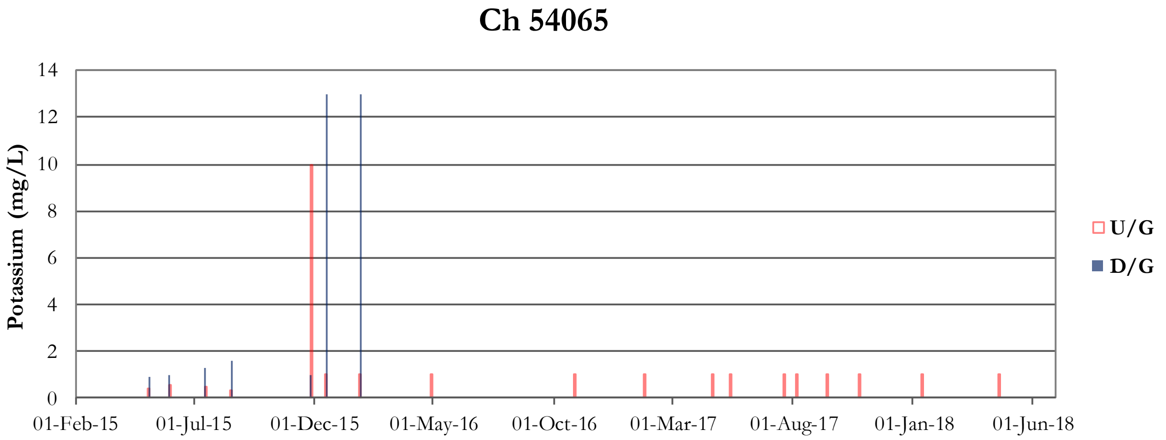

Figure 3.35 Potassium measurements from Ch 54065 since February 2015

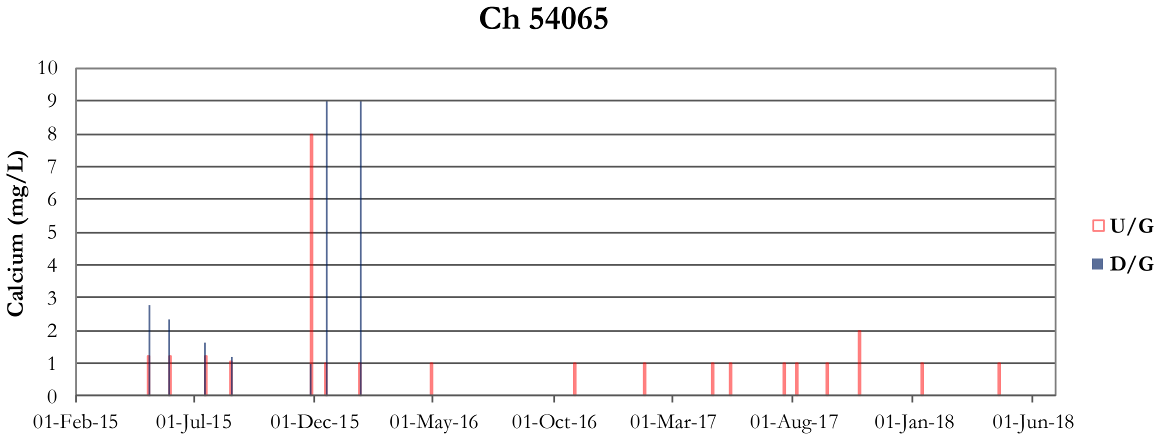

Figure 3.36 Calcium measurements from Ch 54065 since February 2015

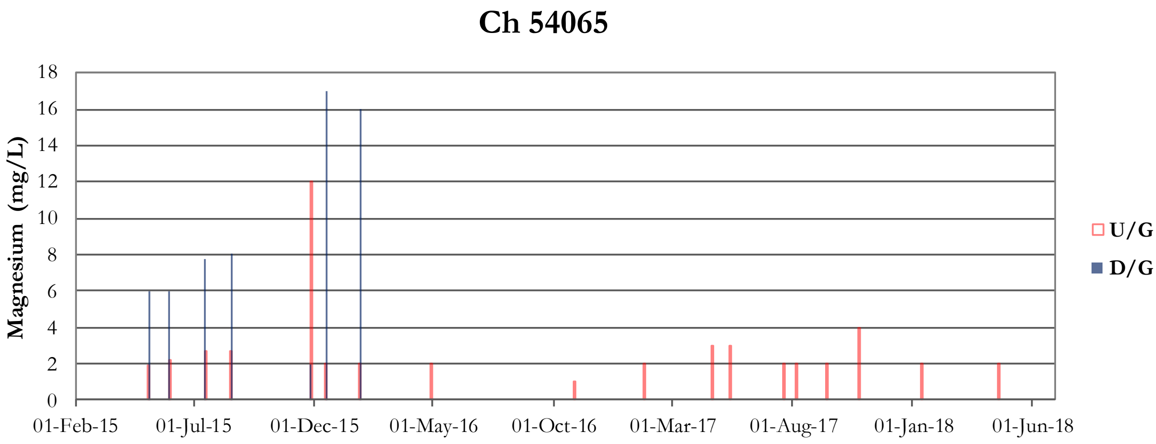

Figure 3.37 Magnesium measurements from Ch 54065 since February 2015

Summary for Ch 54065: Several results of interest were generated, mostly among the major cations and anions. A number of the results of interest appear related to an isolated spike in the concentrations between November 2015 and January 2016. The capacity to draw conclusions from the available data is limited by the fact that the downgradient bore was dry from February 2016 until the end of the construction phase monitoring. A new upgradient bore was constructed in September 2016. There appears to have been a change in the downgradient monitoring bore utilised in January 2017, though the new bore remained dry from that time until the end of the construction phase monitoring.

3.3.6 Ch 50965 – Fill 15

The results of interest from Ch 50965 (**Table B.5**) were the downgradient median Mn, Fe, TN, TKN, NH_4, SO_4^{2-}, Ca^{2+} and Mg^{2+} measurements. For each of Mn, SO_4^{2-}, Ca^{2+} and Mg^{2+} the highest measurement occurred in the upgradient piezometer in July 2015 and the downgradient measurements were relatively consistent, indicating that there was no clear impact from construction activities. a spike in the concentrations occurred in November 2015, December 2015 and January 2016 (**Figures 3.40**, **3.45**, **3.46** and **3.47**). For Fe, TN, TKN and NH_3 there was a steady increase in downgradient concentrations over several months prior to a steady decrease, indicating a potential link with construction activities (**Figures 3.41** to **3.44**). The TDS and pH measurements were moderately variable for most of the construction phase but there was no detectable trend (**Figures 3.38** and **3.39**).

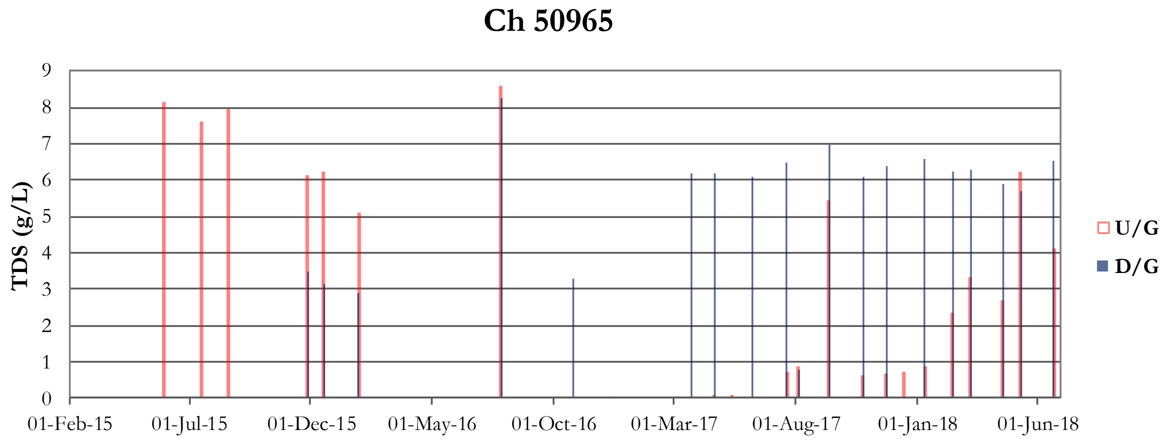

Figure 3.38 TDS measurements from Ch 50965 since February 2015

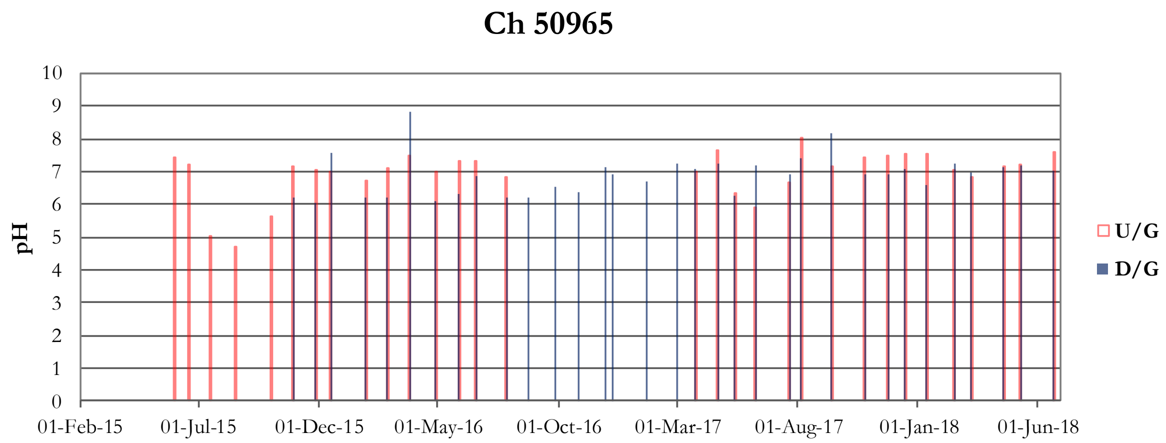

Figure 3.39 pH measurements from Ch 50965 since February 2015

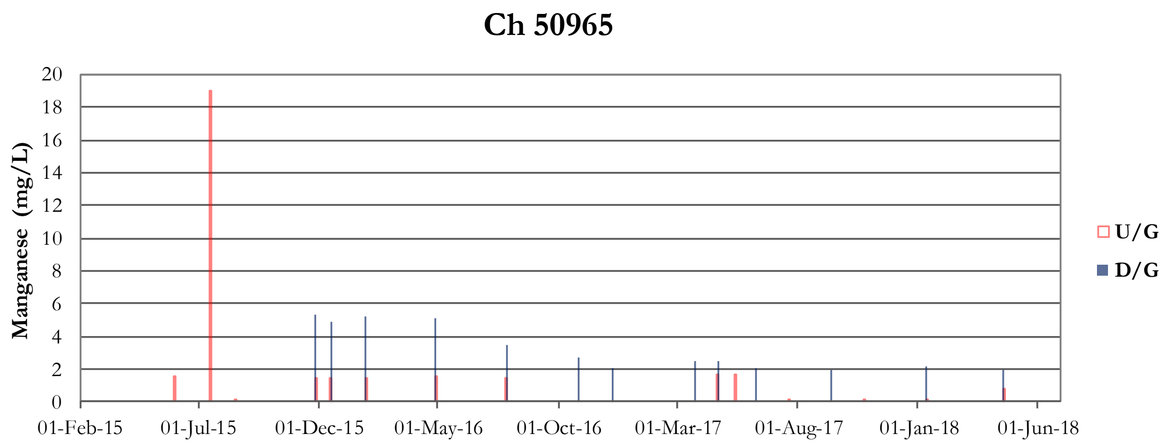

Figure 3.40 Manganese measurements from Ch 50965 since February 2015

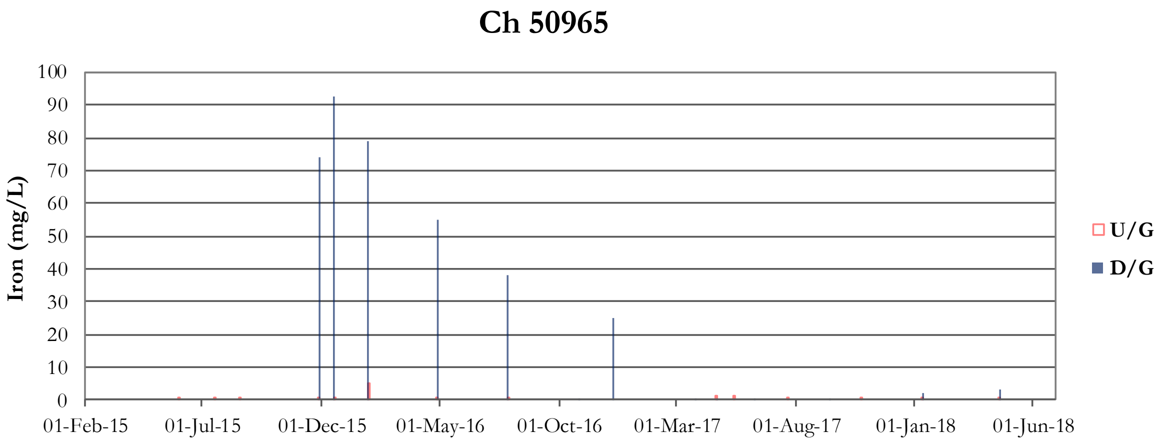

Figure 3.41 Iron measurements from Ch 50965 since February 2015

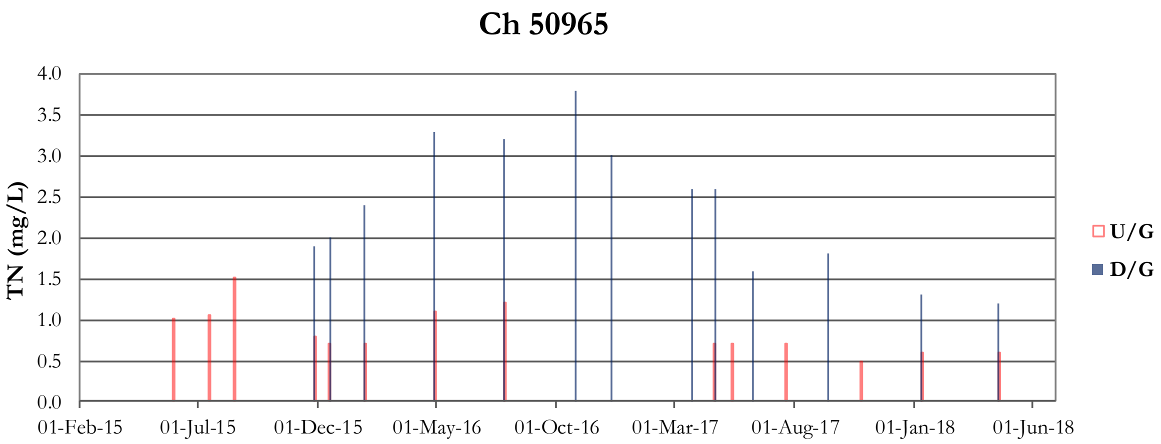

Figure 3.42 TN measurements from Ch 50965 since February 2015

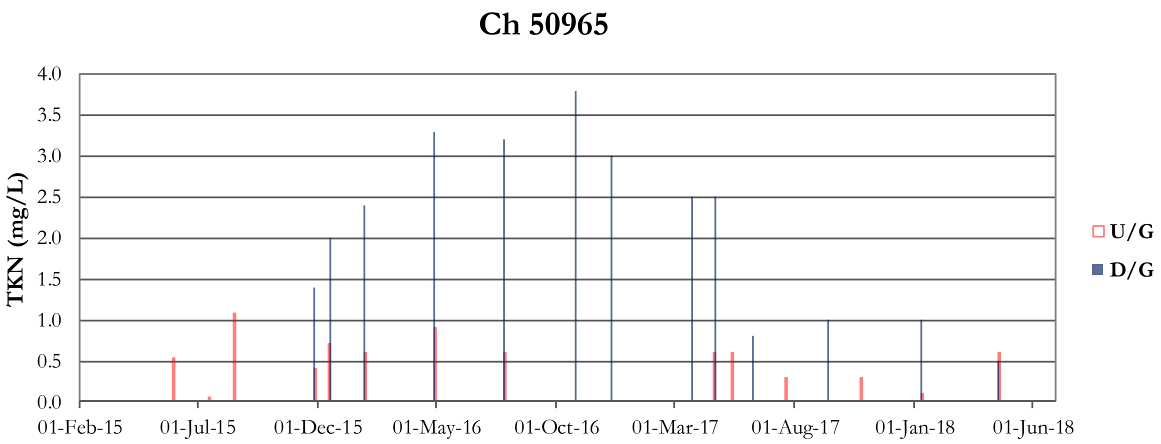

Figure 3.43 TKN measurements from Ch 50965 since February 2015

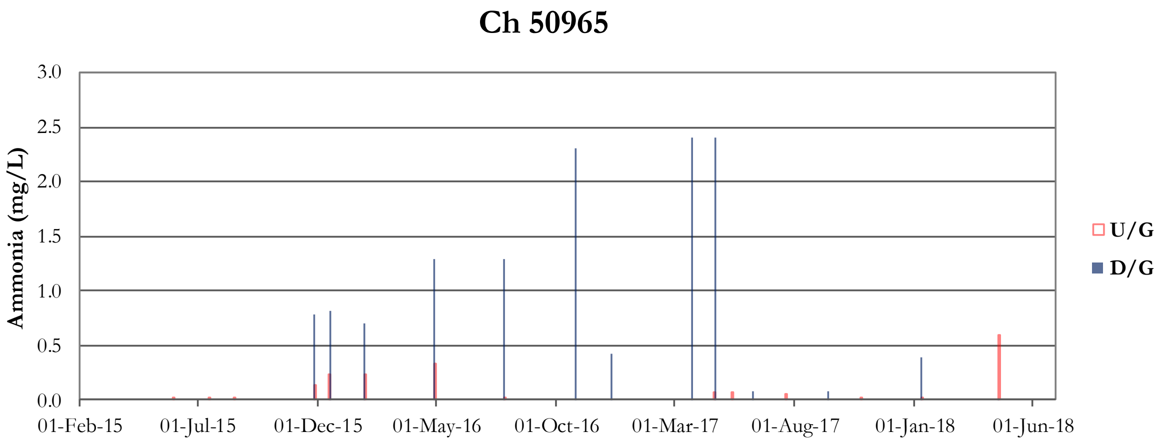

Figure 3.44 Ammonia measurements from Ch 50965 since February 2015

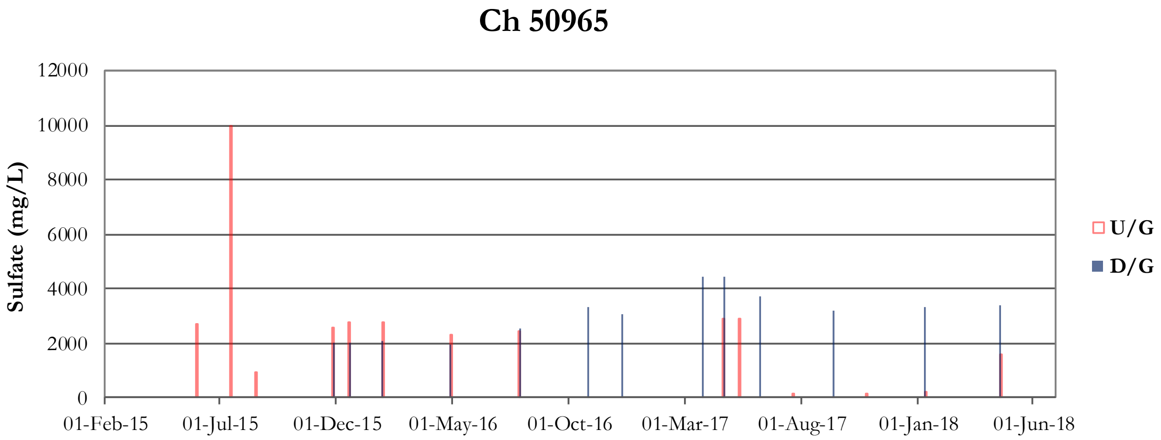

Figure 3.45 Sulfate measurements from Ch 50965 since February 2015

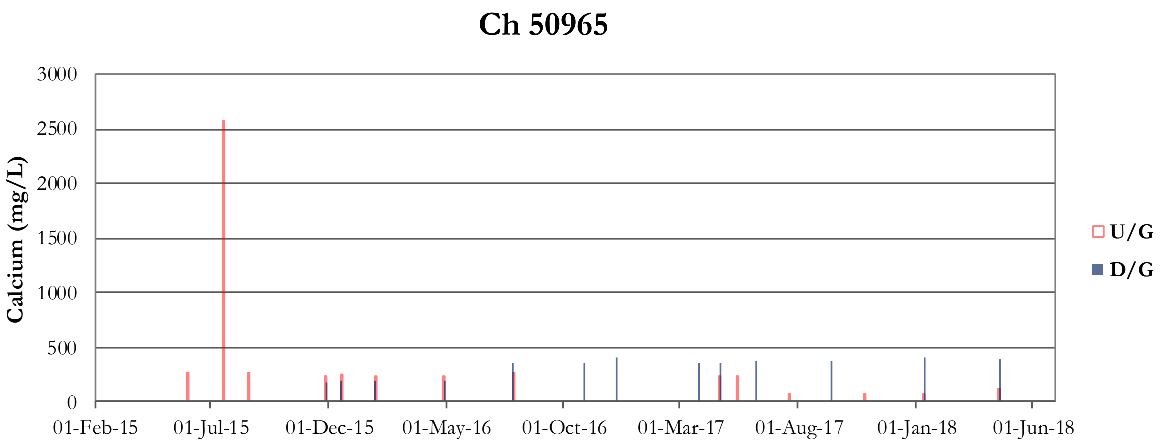

Figure 3.46 Calcium measurements from Ch 50965 since February 2015

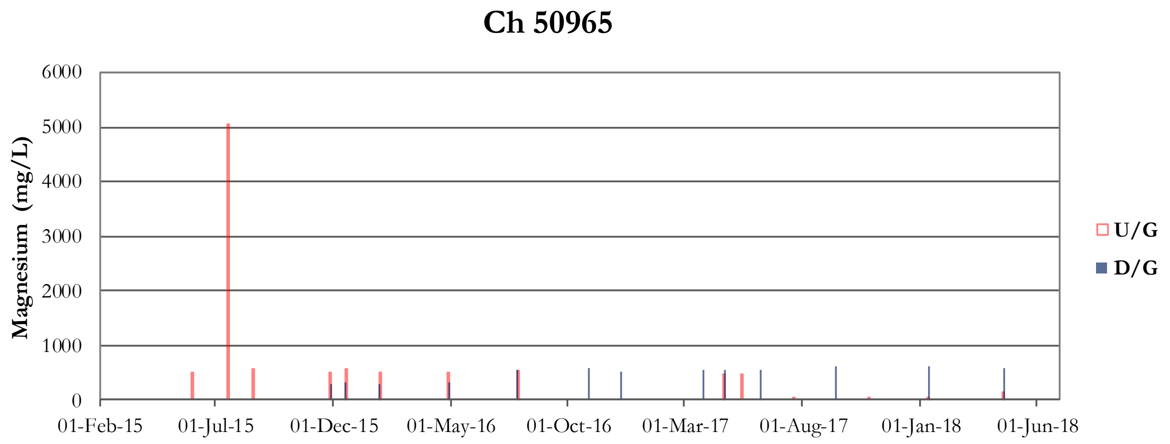

Figure 3.47 Magnesium measurements from Ch 50965 since February 2015

Summary for Ch 54065: Several results of interest were generated among the metals, nutrients and major cations and anions. There is a possible link between construction activities and the Fe, TN, TKN and NH_4 concentrations measured. Of the other parameters that generated results of interest the highest measurements were collected from the upgradient site, indicating that the elevated concentrations were not related to construction activities.

3.3.7 Groundwater Level

The logged groundwater level data collected during the construction monitoring phase is displayed in **Figures 3.48 to 3.52**.

The upgradient piezometer at Ch 45165 (Cut 6) was dry for the entire construction phase monitoring period. The water level in the downgradient piezometer fluctuated upwards and downwards throughout the construction phase. There was no indication of impacts of construction upon the groundwater level at Ch 45165 (**Figure 3.48**).

The upgradient water levels at Ch 48665 (Cut 11) fluctuated regularly during the construction monitoring period. The location of the upgradient piezometer changed during the construction monitoring phase and the new upgradient piezometer was in a position where the groundwater table was much closer to the surface of the ground. Whilst the level fluctuations at the new upgradient piezometer were less responsive than at the old piezometer, the groundwater levels upgradient and downgradient of the highway construction appear to have maintained a relatively consistent response to groundwater recharge and discharge events throughout construction (**Figure 3.49**).

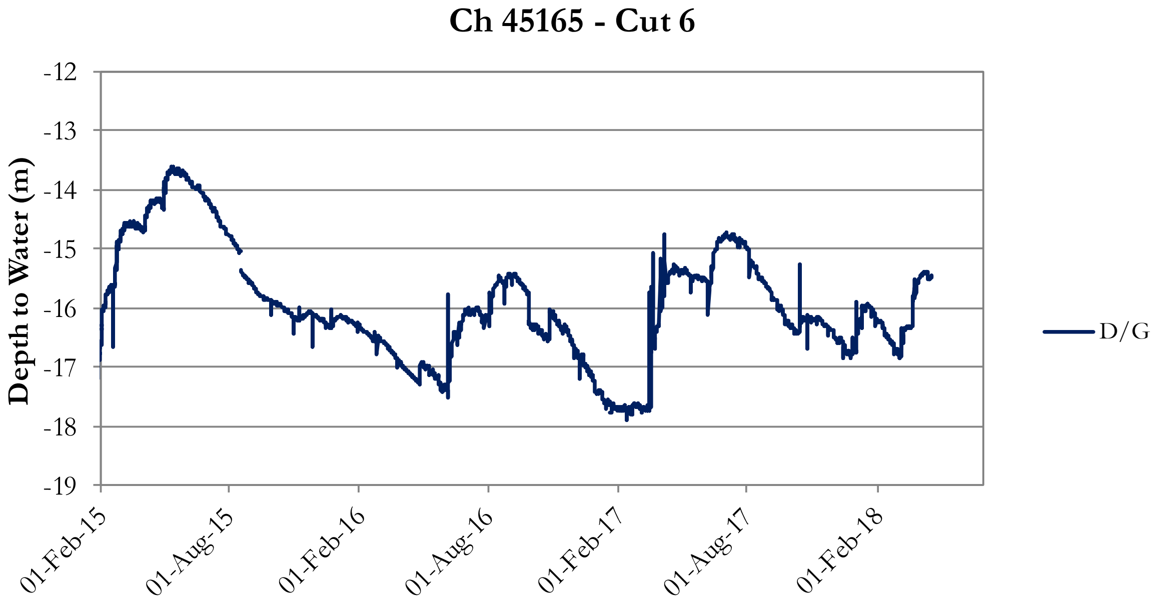

Figure 3.48 Groundwater levels at chainage 45165

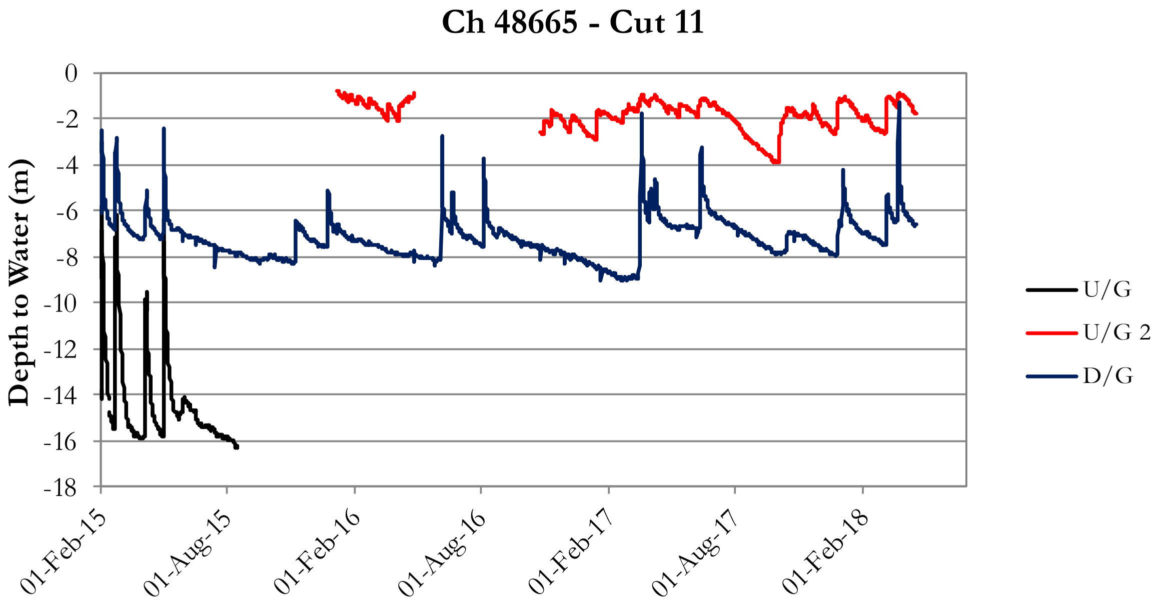

Figure 3.49 Groundwater levels at chainage 48665

The upgradient piezometer at Ch 49365 (Cut 12) was dry for the entire construction monitoring period. The location of the downgradient piezometer was changed during the construction monitoring period and the available information is limited due to gaps in, and problems with the quality of, the logged data. The water level in the downgradient piezometer fluctuated both upwards and downwards throughout the construction phase. There was no indication of impacts of construction upon the groundwater level at Ch 45165 (**Figure 3.50**)

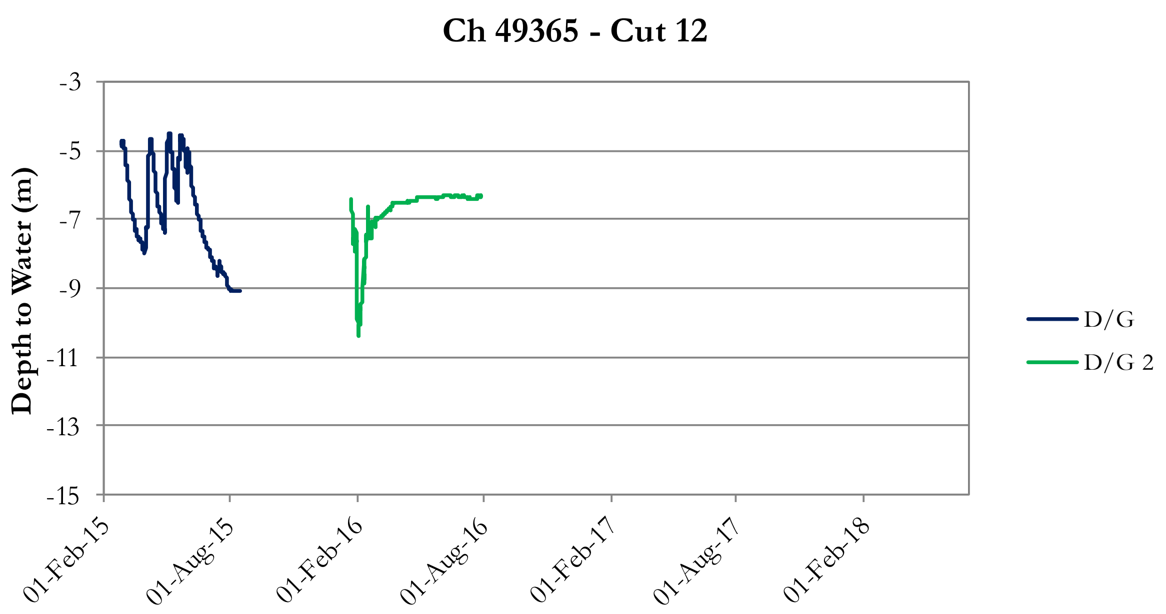

Figure 3.50 Groundwater levels at chainage 49365

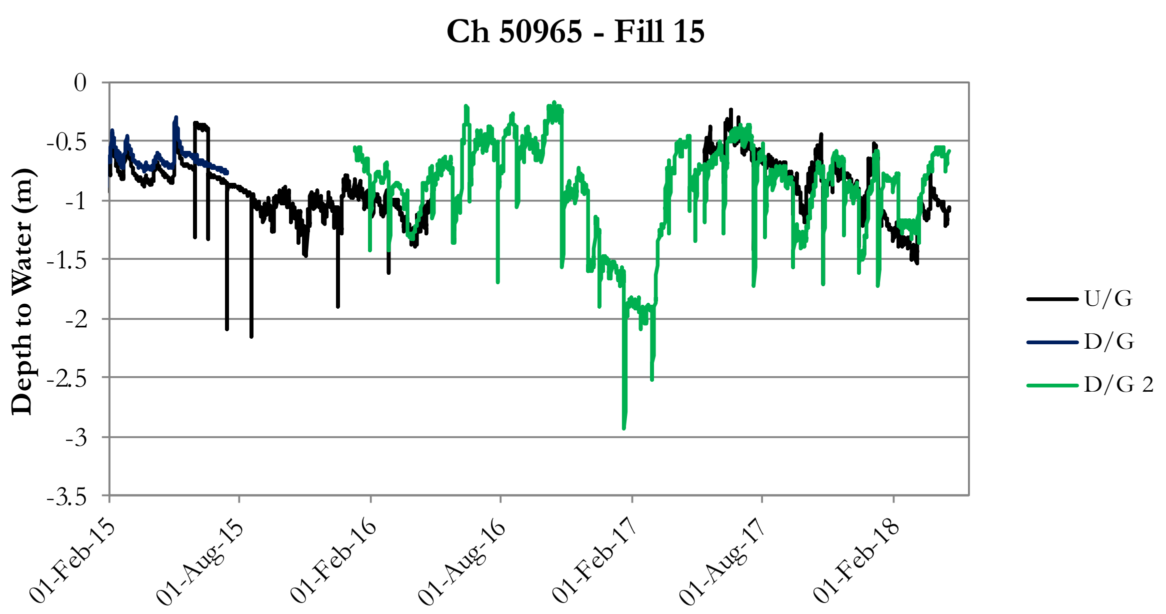

Figure 3.51 Groundwater levels at chainage 50965

At Ch 50965 (Fill 15) there are some gaps in the logged groundwater level data in both upgradient and downgradient piezometers. However, the available data shows clearly that groundwater levels upgradient and downgradient fluctuated in a similar way in response to groundwater recharge and discharge events for most of the construction monitoring period and that the groundwater level difference between the upgradient and downgradient piezometers remained relatively consistent. (**Figure 3.51**).

There are several gaps in the logged data from both the upgradient and downgradient piezometers at Ch54065 (Cut 15) due to changes in the location of the piezometers and problems with logger deployment and data quality. Two successive downgradient groundwater piezometers dried out during the construction monitoring phase. In the latter part of the construction monitoring phase the water level in the downgradient piezometer did not respond to recharge events that showed clearly in the logged dataset from the upgradient piezometer. This indicates that there may have been some impact of construction on groundwater levels at Ch 54065 (**Figure 3.52**).

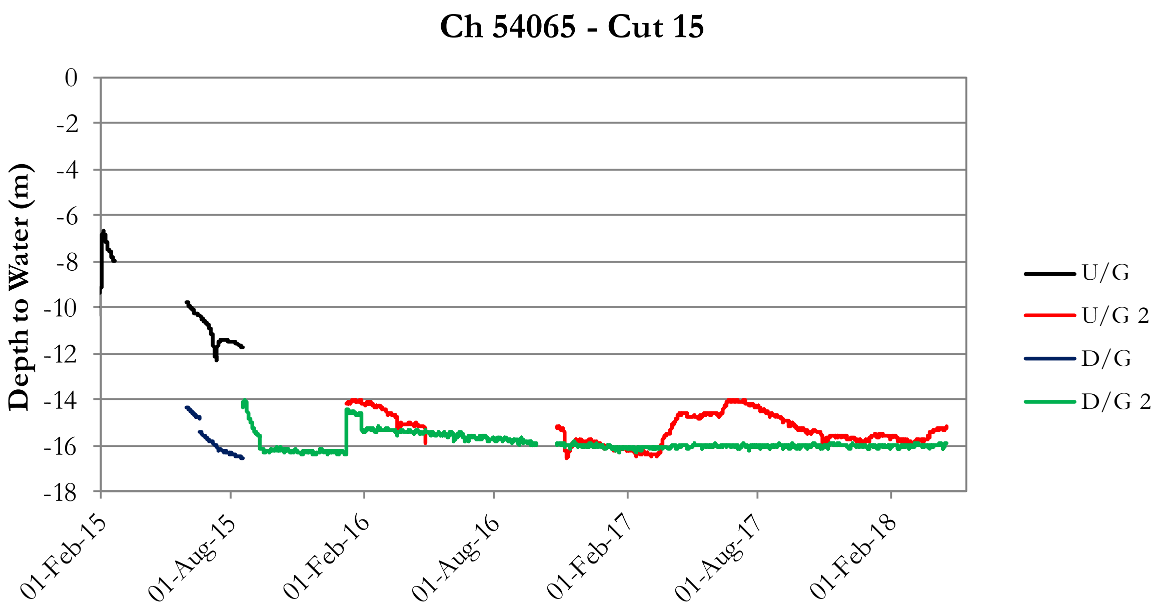

Figure 3.52 Groundwater levels at chainage 54065

4 Conclusions

Between February 2015 and June 2018 the surface water and groundwater monitoring program along the WC2NH upgrade met the requirements of the SWMP and GMP. The following general conclusions can be drawn from the collected construction phase surface water and groundwater monitoring data:

Surface Water Quality

- The majority of results from surface water monitoring indicate that water quality protection measures implemented during construction have been successful, and that there has not been a significant, long term impact from the construction of the WC2NH upgrade upon surface water quality.

- Measuring results of interest as those where the construction phase downstream median result was greater than the construction phase upstream p80 result, the only results of interest generated from the construction phase surface water monitoring dataset were:

  - The downstream median concentration of nickel at the unnamed Creek west of the highway at Gumma Swamp. However, the downstream concentration of nickel was found to be related to the upstream concentration from the unnamed creek ***east*** of the highway at Gumma Swamp, which flows into the same downstream waterway. In addition, the median downstream concentration (0.003 mg/L) was close to limit of detection for the analyses used (0.001 mg/L).

  - The downstream median conductivity measurement at the unnamed Creek east of the highway at Gumma Swamp. However, this result is highly likely to be related to the tidal influence of the Nambucca River and not construction activity. Additionally, the highest downstream measurements indicated moderately brackish conditions (less than 10% seawater) and were unlikely to be of unusual environmental significance in the Gumma Swamp landscape.

- No hydrocarbons were detected in any surface water samples during the construction phase monitoring, though only approximately 10% of samples were analysed for hydrocarbons.

Groundwater Quality

- At two of the groundwater monitoring locations, Ch 45165 (Cut 6) and Ch 49365 (Cut 12), the upgradient piezometers were dry for the entire construction phase monitoring period, limiting the capacity to draw conclusions about the impacts of construction works upon downgradient groundwater quality and levels.
- At many of the groundwater monitoring sites new piezometers were constructed during the construction phase monitoring period to replace piezometers that had dried out, had become inaccessible or were otherwise damaged or not functioning.
- The concentrations of several groundwater parameters indicate a potential impact arising from the construction of the WC2NH upgrade at the Cut 15 and Fill 15 locations. The results of interest were:
    - The downgradient median manganese and iron concentrations from Ch 50965 (Fill 15) and Ch 54065 (Cut 15).
    - The downgradient median total dissolved solids, sulfate ion, potassium ion and calcium ion concentrations from Ch 50965 (Fill 15) and Ch 54065 (Cut 15).
    - The downgradient median total nitrogen and total kjeldahl nitrogen concentrations from Ch 50965 (Fill 15).
    - The downgradient median bicarbonate ion and magnesium ion concentrations from Ch 54065 (Cut 15).
- The majority of the results of interest at Ch 54065 (Cut 15) were associated with piezometers drying out, new piezometers being installed and/or spikes in the upgradient concentrations. Because two successive downgradient piezometers have dried out it is not possible to provide an accurate assessment of impacts to groundwater quality at Ch 54065.
- Results of interest from groundwater quality monitoring in the construction phase that indicated potential impacts associated with construction activities were limited to the iron, total nitrogen and ammonia concentrations from Ch 50965 (Fill 15). However, these results were associated with a change in the downgradient piezometer in December 2015 or January 2016 and possibly indicated impacts associated with piezometer

construction rather than highway construction. Ongoing monitoring during the operational phase should clarify the extent of these potential impacts.

Groundwater levels

Groundwater levels were logged at 8 sites over the construction phase monitoring period. However, the available logged groundwater level data is patchy due to a combination of technical problems, piezometers drying out and data quality. The following conclusions have been drawn from the available logged groundwater level data:

- Groundwater levels declined at some sites and fluctuated at other sites between February 2015 and 30 June 2018.
- Where upgradient and downgradient data are available, the data indicates that there has not been a significant change in the relationship between the groundwater levels upgradient and downgradient of the highway, except for at Ch 54065 (Cut 15).
- At Ch 54065 (Cut 15) the groundwater levels reduced in all four piezometers utilised during the construction phase monitoring period (two of which were decommissioned during the construction phase) and both of the downgradient piezometers used dried out during the construction phase monitoring period. The decline in groundwater levels at Ch 54065 (Cut 15) may indicate an impact of construction activities upon groundwater levels but could alternatively indicate that construction activities resulted in damage to the groundwater piezometers. In order to provide accurate groundwater quality and level information at Ch 54065 a new downgradient piezometer will need to be constructed.
- In general, drawing conclusions about groundwater levels and quality is restricted by the fact that several piezometers were decommissioned during construction, new piezometers were located in different areas and other piezometers ran dry.

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

- In general, the interpretation of the results presented here would benefit from the inclusion of pre-construction results into the dataset or the comparison of preconstruction summary statistics on a site by site basis.

- Where laboratories reported results as lower than the limits of detection, these results were incorporated into databases as the level of detection for the calculation of summary statistics and graphing.
- Monitoring for the operational phase is ongoing. The results collected in operational phase monitoring may clarify some of the conclusions from construction phase monitoring and, where potential impacts have been detected, determine the extent and time-frame of potential impacts during the construction phase.

References

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Appendix A
Surface Water – Summary Monitoring Data

Table A.1 Construction (Con) phase downstream median surface water results, upstream 80th percentile (P80) results and sample numbers (No.) for Upper Warrell Creek

Parameter	PQL	U/S SW01 No.	D/S SW02 No.	U/S SW01 Con P80	D/S SW02 Con Med	U/S SW01 Con Max	D/S SW02 Con Max
Aluminium-Total (µg/L)	0.01	52	52	0.05	0.02	1.456	1.298
Arsenic-Total (µg/L)	0.001	52	52	0.001	0.001	0.006	0.005
Cadmium-Total (µg/L)	0.0001	52	52	0.0001	0.0001	0.001	0.001
Chromium-Total (µg/L)	0.001	52	52	0.001	0.001	0.002	0.001
Copper-Total (µg/L)	0.001	52	52	0.001	0.001	0.02	0.012
Lead-Total (µg/L)	0.001	52	52	0.001	0.001	0.001	0.001
Manganese-Total (µg/L)	0.001	52	52	0.2972	0.0915	1.02	0.486
Nickel-Total (µg/L)	0.001	51	51	0.001	0.001	0.003	0.015
Selenium-Total (µg/L)	0.01	51	51	0.01	0.01	0.01	0.01
Silver-Total (µg/L)	0.001	51	51	0.001	0.001	0.001	0.001
Zinc-Total (µg/L)	0.005	51	51	0.006	0.005	0.064	0.045
Iron-Total (µg/L)	0.05	51	51	0.72	0.3	1.44	1.14
Mercury-Total (µg/L)	0.0001	51	51	0.0001	0.0001	0.0005	0.0005
Napthalene (µg/L)	5	3	3	5	5	5	5
TRH C6 - C10 (µg/L)	20	3	3	20	20	20	20
TRH C6 - C10 less BTEX (µg/L)	20	3	3	20	20	20	20
TRH >C10 - C16 (µg/L)	100	3	3	100	100	100	100
TRH >C16 - C34 (µg/L)	100	3	3	100	100	100	100
TRH >C34 - C40 (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C40 sum (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C16 less Napthalene (µg/L)	100	3	3	100	100	100	100
Benzene (µg/L)	1	3	3	1	1	1	1
Toluene (µg/L)	2	3	3	2	2	2	2
Ethylbenzene (µg/L)	2	3	3	2	2	2	2
m&p-Xylenes (µg/L)	2	3	3	2	2	2	2
o-Xylene (µg/L)	2	3	3	2	2	2	2
Xylenes – Total (µg/L)	2	3	3	2	2	2	2
Sum of BTEX (µg/L)	1	3	3	1	1	1	1
Total Phosphorus (mg/L)	0.01	51	51	0.05	0.02	0.2	0.2
Phosphate (mg/L)	0.01	51	51	0.01	0.01	0.03	0.03
Total Nitrogen (mg/L)	0.1	51	51	0.9	0.5	1.9	1.1
Total Kjeldahl Nitrogen (mg/L)	0.1	49	49	0.74	0.4	1.7	0.9
Nitrate (mg/L)	0.01	51	51	0.14	0.05	1.38	0.59
Nitrite (mg/L)	0.01	51	51	0.01	0.01	0.07	0.06
Ammonia (mg/L)	0.01	51	51	0.04	0.02	0.1	0.18
Total Suspended Solids (mg/L)	5	50	50	10.2	5	110	25
Total Dissolved Solids (g/L)	0.001	84	84	0.1864	0.164	81	84
Temperature (°C)	0.01	83	83	23.454	21.51	29.68	28.43
pH	0.01	84	84	6.92	6.64	8.27	8.15
Conductivity (mS/cm)	0.001	84	84	0.2816	0.2485	0.434	0.365
Turbidity (NTU)	0.1	84	84	17.02	6.25	133	74.2
Dissolved Oxygen (mg/L) (P20)*	0.01	83	83	2.306	3.81	11.91	12.79

Red shading – Indicates a result of interest.

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

Table A.2 Construction (Con) phase downstream median surface water results, upstream 80th percentile (P80) results and sample numbers (No.) for Stony Creek

Parameter	*PQL*	*U/S SW03 No.*	*D/S SW04 No.*	*U/S SW03 Con P80*	*D/S SW04 Con Med*	*U/S SW03 Con Max*	*D/S SW04 Con Max*
Aluminium-Total (µg/L)	0.01	51	51	0.04	0.01	1.298	1.8
Arsenic-Total (µg/L)	0.001	51	51	0.001	0.001	0.005	0.003
Cadmium-Total (µg/L)	0.0001	51	51	0.0001	0.0001	0.001	0.001
Chromium-Total (µg/L)	0.001	51	51	0.001	0.001	0.002	0.002
Copper-Total (µg/L)	0.001	51	51	0.001	0.001	0.007	0.006
Lead-Total (µg/L)	0.001	51	51	0.001	0.001	0.001	0.001
Manganese-Total (µg/L)	0.001	51	51	0.096	0.081	1.07	0.398
Nickel-Total (µg/L)	0.001	50	50	0.001	0.001	0.004	0.003
Selenium-Total (µg/L)	0.01	50	50	0.01	0.01	0.01	0.02
Silver-Total (µg/L)	0.001	50	50	0.001	0.001	0.001	0.001
Zinc-Total (µg/L)	0.005	50	50	0.006	0.005	0.211	0.036
Iron-Total (µg/L)	0.05	50	50	0.626	0.1	2.7	2.66
Mercury-Total (µg/L)	0.0001	50	50	0.0001	0.0001	0.0005	0.0005
Napthalene (µg/L)	5	3	3	5	5	5	5
TRH C6 - C10 (µg/L)	20	3	3	20	20	20	20
TRH C6 - C10 less BTEX (µg/L)	20	3	3	20	20	20	20
TRH >C10 - C16 (µg/L)	100	3	3	100	100	100	100
TRH >C16 - C34 (µg/L)	100	3	3	100	100	100	100
TRH >C34 - C40 (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C40 sum (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C16 less Napthalene (µg/L)	100	3	3	100	100	100	100
Benzene (µg/L)	1	3	3	1	1	1	1
Toluene (µg/L)	2	3	3	2	2	2	2
Ethylbenzene (µg/L)	2	3	3	2	2	2	2
m&p-Xylenes (µg/L)	2	3	3	2	2	2	2
o-Xylene (µg/L)	2	3	3	2	2	2	2
Xylenes – Total (µg/L)	2	3	3	2	2	2	2
Sum of BTEX (µg/L)	1	3	3	1	1	1	1
Total Phosphorus (mg/L)	0.01	51	50	0.03	0.02	0.2	0.12
Phosphate (mg/L)	0.01	51	50	0.01	0.01	0.03	0.03
Total Nitrogen (mg/L)	0.1	51	50	0.6	0.3	1100	2.3
Total Kjeldahl Nitrogen (mg/L)	0.1	49	48	0.4	0.2	100	0.8
Nitrate (mg/L)	0.01	51	50	0.13	0.06	999	1.72
Nitrite (mg/L)	0.01	51	50	0.01	0.01	0.13	0.09
Ammonia (mg/L)	0.01	50	50	0.03	0.02	0.09	0.14
Total Suspended Solids (mg/L)	5	49	49	8.8	5	69	30
Total Dissolved Solids (g/L)	0.001	84	84	0.1764	0.157	114	139
Temperature (°C)	0.01	83	83	22.978	20.88	26.73	25.6
pH	0.01	84	84	6.93	6.68	8.22	8.18
Conductivity (mS/cm)	0.001	84	84	0.263	0.241	0.329	0.411
Turbidity (NTU)	0.1	84	84	11.74	8.65	76	61.7
Dissolved Oxygen (mg/L) (P20)*	0.01	83	83	3.14	4.69	9.26	9.81

Red shading – Indicates a result of interest.

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

Table A.3 Construction (Con) phase downstream median surface water results, upstream 80th percentile (P80) results and sample numbers (No.) for Lower Warrell Creek

Parameter	*PQL*	*U/S*	*D/S*	*U/S*	*D/S*	*U/S*	*D/S*
		SW05	*SW06*	*SW05*	*SW06*	*SW05*	*SW06*
		No.	*No.*	*Con P80*	*Con Med*	*Con Max*	*Con Max*
Aluminium-Total (µg/L)	0.01	51	49	0.08	0.02	1.266	1.228
Arsenic-Total (µg/L)	0.001	51	49	0.001	0.001	0.008	0.01
Cadmium-Total (µg/L)	0.0001	51	49	0.0001	0.0001	0.001	0.0014
Chromium-Total (µg/L)	0.001	51	49	0.001	0.001	0.001	0.002
Copper-Total (µg/L)	0.001	51	49	0.001	0.001	0.042	0.044
Lead-Total (µg/L)	0.001	51	49	0.001	0.001	0.001	0.001
Manganese-Total (µg/L)	0.001	51	49	0.272	0.165	1.54	2.85
Nickel-Total (µg/L)	0.001	50	49	0.0032	0.002	0.048	0.073
Selenium-Total (µg/L)	0.01	50	49	0.01	0.01	0.01	0.01
Silver-Total (µg/L)	0.001	50	49	0.001	0.001	0.001	0.001
Zinc-Total (µg/L)	0.005	50	49	0.0164	0.006	0.08	0.145
Iron-Total (µg/L)	0.05	50	49	0.552	0.12	1.08	2.35
Mercury-Total (µg/L)	0.0001	50	49	0.0001	0.0001	0.0005	0.0005
Napthalene (µg/L)	5	3	2	5	5	5	5
TRH C6 - C10 (µg/L)	20	3	2	20	20	20	20
TRH C6 - C10 less BTEX (µg/L)	20	3	2	20	20	20	20
TRH >C10 - C16 (µg/L)	100	3	2	100	100	100	100
TRH >C16 - C34 (µg/L)	100	3	2	100	100	100	100
TRH >C34 - C40 (µg/L)	100	3	2	100	100	100	100
TRH >C10 - C40 sum (µg/L)	100	3	2	100	100	100	100
TRH >C10 - C16 less Napthalene (µg/L)	100	3	2	100	100	100	100
Benzene (µg/L)	1	3	2	1	1	1	1
Toluene (µg/L)	2	3	2	2	2	2	2
Ethylbenzene (µg/L)	2	3	2	2	2	2	2
m&p-Xylenes (µg/L)	2	3	2	2	2	2	2
o-Xylene (µg/L)	2	3	2	2	2	2	2
Xylenes – Total (µg/L)	2	3	2	2	2	2	2
Sum of BTEX (µg/L)	1	3	2	1	1	1	1
Total Phosphorus (mg/L)	0.01	50	49	0.042	0.02	0.3	0.39
Phosphate (mg/L)	0.01	50	49	0.01	0.01	0.04	0.03
Total Nitrogen (mg/L)	0.1	50	49	0.8	0.5	2.6	2.7
Total Kjeldahl Nitrogen (mg/L)	0.1	48	47	0.6	0.5	1.8	1.6
Nitrate (mg/L)	0.01	50	49	0.14	0.06	1.56	1.43
Nitrite (mg/L)	0.01	50	49	0.01	0.01	0.09	0.55
Ammonia (mg/L)	0.01	50	49	0.08	0.06	0.32	0.51
Total Suspended Solids (mg/L)	5	49	48	18	6	38	36
Total Dissolved Solids (g/L)	0.001	84	84	6.76	2.625	134	138
Temperature (°C)	0.01	83	83	27.924	23.58	31.38	31.23
pH	0.01	84	84	7.48	7.09	8.08	8.27
Conductivity (mS/cm)	0.001	84	84	10.088	3.78	29.1	29.6
Turbidity (NTU)	0.1	84	84	18.06	6.75	143	105
Dissolved Oxygen (mg/L) (P20)*	0.01	83	83	3.00	4.43	7.78	10.6

Red shading – Indicates a result of interest.
* - Upstream dissolved oxygen results are P20, not P80.

Table A.4 Construction (Con) phase downstream median surface water results, upstream 80th percentile (P80) results and sample numbers (No.) for the Unnamed Creek at Gumma Wetland west

		U/S	*D/S*	*U/S*	*D/S*	*U/S*	*D/S*
		SW07	*SW09*	*SW07*	*SW09*	*SW07*	*SW09*
Parameter	*PQL*	*No.*	*No.*	*Con P80*	*Con Med*	*Con Max*	*Con Max*
Aluminium-Total (µg/L)	0.01	48	33	0.066	0.04	0.29	0.64
Arsenic-Total (µg/L)	0.001	48	33	0.0026	0.001	0.007	0.007
Cadmium-Total (µg/L)	0.0001	48	33	0.0001	0.0001	0.0005	0.0018
Chromium-Total (µg/L)	0.001	48	33	0.001	0.001	0.001	0.002
Copper-Total (µg/L)	0.001	48	33	0.0016	0.001	0.005	0.006
Lead-Total (µg/L)	0.001	48	33	0.001	0.001	0.001	0.001
Manganese-Total (µg/L)	0.001	48	33	0.3466	0.195	0.929	2.07
Nickel-Total (µg/L)	0.001	48	33	0.002	0.003	0.007	0.022
Selenium-Total (µg/L)	0.01	48	33	0.01	0.01	0.01	0.01
Silver-Total (µg/L)	0.001	48	33	0.001	0.001	0.001	0.001
Zinc-Total (µg/L)	0.005	48	33	0.0126	0.008	0.285	0.267
Iron-Total (µg/L)	0.05	48	33	1.228	0.36	5.91	7.16
Mercury-Total (µg/L)	0.0001	48	33	0.0001	0.0001	0.0001	0.0001
Napthalene (µg/L)	5	3	3	5	5	5	5
TRH C6 - C10 (µg/L)	20	3	3	20	20	20	20
TRH C6 - C10 less BTEX (µg/L)	20	3	3	20	20	20	20
TRH >C10 - C16 (µg/L)	100	3	3	100	100	100	100
TRH >C16 - C34 (µg/L)	100	3	3	100	100	100	100
TRH >C34 - C40 (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C40 sum (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C16 less Napthalene (µg/L)	100	3	3	100	100	100	100
Benzene (µg/L)	1	3	3	1	1	1	1
Toluene (µg/L)	2	3	3	2	2	2	2
Ethylbenzene (µg/L)	2	3	3	2	2	2	2
m&p-Xylenes (µg/L)	2	3	3	2	2	2	2
o-Xylene (µg/L)	2	3	3	2	2	2	2
Xylenes – Total (µg/L)	2	3	3	2	2	2	2
Sum of BTEX (µg/L)	1	3	3	1	1	1	1
Total Phosphorus (mg/L)	0.01	48	33	0.086	0.03	1.1	5.4
Phosphate (mg/L)	0.01	48	33	0.01	0.01	0.05	0.04
Total Nitrogen (mg/L)	0.1	48	33	2.02	1.1	10.6	8.7
Total Kjeldahl Nitrogen (mg/L)	0.1	46	31	1.8	1	9.6	8.3
Nitrate (mg/L)	0.01	48	33	0.09	0.03	8.76	3.74
Nitrite (mg/L)	0.01	48	33	0.01	0.01	0.05	0.05
Ammonia (mg/L)	0.01	48	33	0.066	0.03	0.28	0.9
Total Suspended Solids (mg/L)	5	48	33	23.6	14	3690	332
Total Dissolved Solids (g/L)	0.001	81	56	0.522	0.4845	164	2.49
Temperature (°C)	0.01	80	56	25.562	21.08	31.05	33.21
pH	0.01	81	56	6.91	6.555	7.51	652
Conductivity (mS/cm)	0.001	81	56	0.816	0.7445	1.96	3.89
Turbidity (NTU)	0.1	81	56	67.9	25.25	256	376
Dissolved Oxygen (mg/L) (P20)*	0.01	80	56	1.32	3.41	9.95	10.79

Red shading – Indicates a result of interest.
* - Upstream dissolved oxygen results are P20, not P80.

Table A.5 Construction (Con) phase downstream median surface water results, upstream 80th percentile (P80) results and sample numbers (No.) for the Unnamed Creek at Gumma Wetland east

Parameter	*PQL*	*U/S SW08 No.*	*D/S SW09 No.*	*U/S SW08 Con P80*	*D/S SW09 Con Med*	*U/S SW08 Con Max*	*D/S SW09 Con Max*
Aluminium-Total (µg/L)	0.01	45	33	0.112	0.04	8.7	0.64
Arsenic-Total (µg/L)	0.001	45	33	0.003	0.001	0.011	0.007
Cadmium-Total (µg/L)	0.0001	45	33	0.0001	0.0001	0.008	0.0018
Chromium-Total (µg/L)	0.001	45	33	0.001	0.001	0.013	0.002
Copper-Total (µg/L)	0.001	45	33	0.003	0.001	0.029	0.006
Lead-Total (µg/L)	0.001	45	33	0.001	0.001	0.014	0.001
Manganese-Total (µg/L)	0.001	45	33	0.383	0.195	2.61	2.07
Nickel-Total (µg/L)	0.001	45	33	0.004	0.003	0.065	0.022
Selenium-Total (µg/L)	0.01	45	33	0.01	0.01	0.01	0.01
Silver-Total (µg/L)	0.001	45	33	0.001	0.001	0.001	0.001
Zinc-Total (µg/L)	0.005	45	33	0.018	0.008	0.432	0.267
Iron-Total (µg/L)	0.05	45	33	1.462	0.36	30.1	7.16
Mercury-Total (µg/L)	0.0001	45	33	0.0001	0.0001	0.0001	0.0001
Napthalene (µg/L)	5	3	3	5	5	5	5
TRH C6 - C10 (µg/L)	20	3	3	20	20	20	20
TRH C6 - C10 less BTEX (µg/L)	20	3	3	20	20	20	20
TRH >C10 - C16 (µg/L)	100	3	3	100	100	100	100
TRH >C16 - C34 (µg/L)	100	3	3	100	100	100	100
TRH >C34 - C40 (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C40 sum (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C16 less Napthalene (µg/L)	100	3	3	100	100	100	100
Benzene (µg/L)	1	3	3	1	1	1	1
Toluene (µg/L)	2	3	3	2	2	2	2
Ethylbenzene (µg/L)	2	3	3	2	2	2	2
m&p-Xylenes (µg/L)	2	3	3	2	2	2	2
o-Xylene (µg/L)	2	3	3	2	2	2	2
Xylenes – Total (µg/L)	2	3	3	2	2	2	2
Sum of BTEX (µg/L)	1	3	3	1	1	1	1
Total Phosphorus (mg/L)	0.01	45	33	0.142	0.03	1.5	5.4
Phosphate (mg/L)	0.01	45	33	0.01	0.01	0.05	0.04
Total Nitrogen (mg/L)	0.1	45	33	2.2	1.1	30.2	8.7
Total Kjeldahl Nitrogen (mg/L)	0.1	43	31	1.9	1	8.2	8.3
Nitrate (mg/L)	0.01	45	33	0.074	0.03	1.16	3.74
Nitrite (mg/L)	0.01	45	33	0.01	0.01	16.8	0.05
Ammonia (mg/L)	0.01	45	33	0.102	0.03	1.63	0.9
Total Suspended Solids (mg/L)	5	45	33	58.2	14	2410	332
Total Dissolved Solids (g/L)	0.001	77	56	0.4636	0.4845	254	2.49
Temperature (°C)	0.01	76	56	24.05	21.08	29.8	33.21
pH	0.01	77	56	6.806	6.555	7.33	652
Conductivity (mS/cm)	0.001	77	56	0.6976	0.7445	1.42	3.89
Turbidity (NTU)	0.1	77	56	45.04	25.25	614	376
Dissolved Oxygen (mg/L) (P20)*	0.01	76	56	0.47	3.41	8.37	10.79

Red shading – Indicates a result of interest.
* - Upstream dissolved oxygen results are P20, not P80.

Table A.6 Construction (Con) phase downstream median surface water results, upstream 80th percentile (P80) results and sample numbers (No.) for Nambucca River

Parameter	PQL	U/S SW10 No.	D/S SW11 No.	U/S SW10 Con P80	D/S SW11 Con Med	U/S SW10 Con Max	D/S SW11 Con Max
Aluminium-Total (µg/L)	0.01	50	50	0.1	0.1	0.922	0.907
Arsenic-Total (µg/L)	0.001	50	50	0.01	0.01	0.01	0.01
Cadmium-Total (µg/L)	0.0001	50	50	0.001	0.001	0.001	0.001
Chromium-Total (µg/L)	0.001	50	50	0.01	0.01	0.016	0.01
Copper-Total (µg/L)	0.001	50	50	0.01	0.01	0.082	0.062
Lead-Total (µg/L)	0.001	50	50	0.01	0.01	0.01	0.01
Manganese-Total (µg/L)	0.001	50	50	0.068	0.047	0.177	0.156
Nickel-Total (µg/L)	0.001	50	50	0.01	0.01	0.01	0.015
Selenium-Total (µg/L)	0.01	50	50	0.1	0.1	0.15	0.14
Silver-Total (µg/L)	0.001	50	50	0.01	0.01	0.01	0.01
Zinc-Total (µg/L)	0.005	50	50	0.05	0.05	0.118	0.057
Iron-Total (µg/L)	0.05	50	50	0.5	0.1	1.34	0.955
Mercury-Total (µg/L)	0.0001	50	50	0.0001	0.0001	0.0005	0.0005
Napthalene (µg/L)	5	3	3	5	5	5	5
TRH C6 - C10 (µg/L)	20	3	3	20	20	20	20
TRH C6 - C10 less BTEX (µg/L)	20	3	3	20	20	20	20
TRH >C10 - C16 (µg/L)	100	3	3	100	100	100	100
TRH >C16 - C34 (µg/L)	100	3	3	100	100	100	100
TRH >C34 - C40 (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C40 sum (µg/L)	100	3	3	100	100	100	100
TRH >C10 - C16 less Napthalene (µg/L)	100	3	3	100	100	100	100
Benzene (µg/L)	1	3	3	1	1	1	1
Toluene (µg/L)	2	3	3	2	2	2	2
Ethylbenzene (µg/L)	2	3	3	2	2	2	2
m&p-Xylenes (µg/L)	2	3	3	2	2	2	2
o-Xylene (µg/L)	2	3	3	2	2	2	2
Xylenes – Total (µg/L)	2	3	3	2	2	2	2
Sum of BTEX (µg/L)	1	3	3	1	1	1	1
Total Phosphorus (mg/L)	0.01	50	50	0.09	0.05	1.17	0.24
Phosphate (mg/L)	0.01	50	50	0.01	0.01	0.03	0.03
Total Nitrogen (mg/L)	0.1	50	50	0.7	0.5	3.2	1.6
Total Kjeldahl Nitrogen (mg/L)	0.1	48	48	0.66	0.5	3.2	1.2
Nitrate (mg/L)	0.01	50	50	0.088	0.03	0.43	0.66
Nitrite (mg/L)	0.01	50	50	0.01	0.01	0.05	0.05
Ammonia (mg/L)	0.01	50	50	0.09	0.05	0.16	0.18
Total Suspended Solids (mg/L)	5	49	49	69.2	11	449	220
Total Dissolved Solids (g/L)	0.001	84	84	26.74	22.3	7690	9610
Temperature (°C)	0.01	83	83	27.228	23.9	30.23	30.23
pH	0.01	84	84	7.92	7.64	8.61	8.5
Conductivity (mS/cm)	0.001	84	84	43.56	36.7	49.1	49.2
Turbidity (NTU)	0.1	84	84	32.42	17.5	241	309
Dissolved Oxygen (mg/L) (P20)*	0.01	83	83	4.18	5.58	10.97	10

Red shading – Indicates a result of interest.

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

Appendix B
Summary Groundwater Monitoring Data

Table B.1 Construction phase summary groundwater quality results for approximate chainage 45165 (Cut 6)

Parameter	*Units*	*PQL*	*U/G No.*	*D/G No.*	*U/G con P80*	*D/G con med*	*U/G con max*	*D/G con max*
				Cut 6W		*Cut 6W*		*Cut 6W*
Aluminium	mg/L	0.01		16		0.085		0.458
Arsenic	mg/L	0.001		16		0.001		0.003
Cadmium	mg/L	0.0001		16		0.0001		0.001
Chromium	mg/L	0.001		16		0.001		0.005
Copper	mg/L	0.001		16		0.009		0.301
Lead	mg/L	0.001		16		0.001		0.002
Manganese	mg/L	0.001		16		0.178		0.337
Nickel	mg/L	0.001		16		0.0045		0.025
Selenium	mg/L	0.01		16		0.01		0.01
Silver	mg/L	0.001		16		0.001		0.001
Zinc	mg/L	0.005		16		0.0175		0.086
Iron	mg/L	0.01		16		5.83		39.7
Mercury	mg/L	0.0001		16		0.0001		0.0005
C6-C9 Fraction	µg/L	20		10		20		20
C10-C14 Fraction	µg/L	50		14		50		280
C15-C28 Fraction	µg/L	100		14		100		120
C29-C36 Fraction	µg/L	100		14		50		100
C10-C36 Fraction (sum)	µg/L	50		10		50		280
C10-C16 Fraction	µg/L	50		4		61.5		100
C16-C34 Fraction	µg/L	100		4		100		110
C34-C40 Fraction	µg/L	100		4		100		100
Benzene	µg/L	1		12		1		1
Toluene	µg/L	1		12		2		2
Ethylbenzene	µg/L	1		12		2		2
m+p-Xylene	µg/L	2		12		2		2
o-Xylene	µg/L	1		12		2		2
Naphthalene	µg/L	5		11		5		5
Total Phosphorus	mg/L	0.01		16		0.026		0.16
Phosphate	mg/L	0.001		16		0.01		0.014
Total Nitrogen	mg/L	0.1		16		0.55		2.4
Total Kjeldahl Nitrogen	mg/L	0.1		16		0.55		2.2
Nitrate	mg/L	0.005		16		0.02		0.2
Nitrite	mg/L	0.001		16		0.01		0.019
Ammonia	mg/L	0.005		16		0.1		0.95
Total Dissolved Solids	g/L	0.01		22		1.78		3.61
Chloride	mg/L	0.1		16		1107.5		1862
Sulfate	mg/L	0.1		16		34.1		3285
Bicarbonate	mg/L	0.1		16		44		165
Sodium	mg/L	0.1		16		567		933.7
Potassium	mg/L	0.01		16		1.96		5
Calcium	mg/L	0.01		16		5		53
Magnesium	mg/L	0.1		16		86		137
Temperature	oC	0.01		36		21.74		30
pH	pH	0.01		36		6.045		7.77
Conductivity	mS/cm	0.01		36		3.3		5.33
Depth to standing water level	m	0.01		35		16.18		18.53

Red shading – Indicates a result of interest.

Table B.2 Construction phase summary groundwater quality results for approximate chainage 48665 (Cut 11)

Parameter	*Units*	*PQL*	*U/G No. Cut 11E*	*D/G No. Cut 11W*	*U/G con P80 Cut 11E*	*D/G con med Cut 11W*	*U/G con max Cut 11E*	*D/G con max Cut 11W*
Aluminium	mg/L	0.01	15	17	0.416	0.01	0.51	0.033
Arsenic	mg/L	0.001	15	17	0.001	0.001	0.001	0.005
Cadmium	mg/L	0.0001	15	17	0.0105	0.0001	0.0196	0.001
Chromium	mg/L	0.001	15	17	0.001	0.001	0.004	0.002
Copper	mg/L	0.001	15	17	0.0092	0.009	0.01	0.129
Lead	mg/L	0.001	15	17	0.001	0.001	0.003	0.002
Manganese	mg/L	0.001	15	17	2.506	0.007	3.32	0.019
Nickel	mg/L	0.001	15	17	0.152	0.003	0.197	0.006
Selenium	mg/L	0.01	15	17	0.01	0.01	0.01	0.01
Silver	mg/L	0.001	15	17	0.001	0.001	0.001	0.001
Zinc	mg/L	0.005	15	17	0.529	0.016	0.671	0.121
Iron	mg/L	0.01	15	17	0.212	0.05	4.802	0.434
Mercury	mg/L	0.0001	15	17	0.0005	0.0001	0.0005	0.0006
C6-C9 Fraction	µg/L	20	10	11	20	20	20	20
C10-C14 Fraction	µg/L	50	14	16	50	50	490	50
C15-C28 Fraction	µg/L	100	14	16	100	100	100	100
C29-C36 Fraction	µg/L	100	14	16	100	50	100	100
C10-C36 Fraction (sum)	µg/L	50	10	12	50	50	490	50
C10-C16 Fraction	µg/L	50	4	4	50	50	50	50
C16-C34 Fraction	µg/L	100	4	4	100	100	100	100
C34-C40 Fraction	µg/L	100	4	4	100	100	100	100
Benzene	µg/L	1	12	13	1	1	1	1
Toluene	µg/L	1	12	13	2	2	2	2
Ethylbenzene	µg/L	1	12	13	2	2	2	2
m+p-Xylene	µg/L	2	12	13	2	2	2	2
o-Xylene	µg/L	1	12	13	2	2	2	2
Naphthalene	µg/L	5	11	12	5	5	5	5
Total Phosphorus	mg/L	0.01	15	17	0.036	0.026	0.08	0.16
Phosphate	mg/L	0.001	15	17	0.015	0.01	0.02	0.025
Total Nitrogen	mg/L	0.1	15	17	3.28	0.3	4.2	2.4
Total Kjeldahl Nitrogen	mg/L	0.1	15	17	0.64	0.17	26.9	2.2
Nitrate	mg/L	0.005	15	17	3.142	0.14	26.9	0.99
Nitrite	mg/L	0.001	15	17	0.01	0.01	0.02	0.01
Ammonia	mg/L	0.005	15	17	0.1	0.04	0.168	0.42
Total Dissolved Solids	g/L	0.01	23	24	1.20	0.09	1.52	0.48
Chloride	mg/L	0.1	15	17	283.6	14	587	19.9
Sulfate	mg/L	0.1	15	17	699	8	834	46.5
Bicarbonate	mg/L	0.1	15	17	85.4	23	148	48
Sodium	mg/L	0.1	15	17	209.8	18	285	24
Potassium	mg/L	0.01	15	17	6.2	1	9	4
Calcium	mg/L	0.01	15	17	84.8	1	110	8.01
Magnesium	mg/L	0.1	15	17	93.8	2	123	3.73
Temperature	oC	0.01	37	39	25.07	21.47	28.58	26.79
pH	pH	0.01	37	39	6.97	6.23	7.74	7.71
Conductivity	mS/cm	0.01	37	39	1.90	0.14	3.4	0.76
Depth to standing water level	m	0.01	36	38	2.87	7.52	16.24	18.8

Red shading – Indicates a result of interest.

Table B.3 Construction phase summary groundwater quality results for approximate chainage 49365 (Cut 12)

Parameter	*Units*	*PQL*	*U/G No.*	*D/G No. Cut 12W*	*U/G con P80*	*D/G con med Cut 12W*	*U/G con max*	*D/G con max Cut 12W*
Aluminium	mg/L	0.01		8		0.015		0.44
Arsenic	mg/L	0.001		8		0.001		0.001
Cadmium	mg/L	0.0001		8		0.0001		0.0139
Chromium	mg/L	0.001		8		0.001		0.002
Copper	mg/L	0.001		8		0.001		0.034
Lead	mg/L	0.001		8		0.001		0.004
Manganese	mg/L	0.001		8		0.0055		3.01
Nickel	mg/L	0.001		8		0.001		0.197
Selenium	mg/L	0.01		8		0.01		0.01
Silver	mg/L	0.001		8		0.001		0.001
Zinc	mg/L	0.005		8		0.009		0.616
Iron	mg/L	0.01		8		0.05		0.05
Mercury	mg/L	0.0001		8		0.0001		0.0005
C6-C9 Fraction	µg/L	20		6		20		20
C10-C14 Fraction	µg/L	50		7		50		50
C15-C28 Fraction	µg/L	100		7		100		100
C29-C36 Fraction	µg/L	100		7		50		100
C10-C36 Fraction (sum)	µg/L	50		6		50		50
C10-C16 Fraction	µg/L	50		1		50		50
C16-C34 Fraction	µg/L	100		1		100		100
C34-C40 Fraction	µg/L	100		1		100		100
Benzene	µg/L	1		7		1		1
Toluene	µg/L	1		7		2		2
Ethylbenzene	µg/L	1		7		2		2
m+p-Xylene	µg/L	2		7		2		2
o-Xylene	µg/L	1		7		2		2
Naphthalene	µg/L	5		7		5		5
Total Phosphorus	mg/L	0.01		8		0.06		0.09
Phosphate	mg/L	0.001		8		0.01		0.02
Total Nitrogen	mg/L	0.1		8		0.7		4.2
Total Kjeldahl Nitrogen	mg/L	0.1		8		0.4		1.2
Nitrate	mg/L	0.005		8		0.35		3.79
Nitrite	mg/L	0.001		8		0.01		0.02
Ammonia	mg/L	0.005		8		0.035		0.16
Total Dissolved Solids	g/L	0.01		7		0.16		0.15
Chloride	mg/L	0.1		8		33.3		410
Sulfate	mg/L	0.1		8		5.5		834
Bicarbonate	mg/L	0.1		8		14		27
Sodium	mg/L	0.1		8		28.5		261
Potassium	mg/L	0.01		8		1		5
Calcium	mg/L	0.01		8		1		92
Magnesium	mg/L	0.1		8		1		109
Temperature	oC	0.01		17		21.8		28.61
pH	pH	0.01		17		6.19		8
Conductivity	mS/cm	0.01		17		0.193		0.351
Depth to standing water level	m	0.01		17		6.84		8.8

Red shading – Indicates a result of interest.

Table B.4 Construction phase summary groundwater quality results for approximate chainage 54065 (Cut 15)

Parameter	*Units*	*PQL*	*U/G*	*D/G*	*U/G*	*D/G*	*U/G*	*D/G*
			No.	*No.*	*con P80*	*con med*	*con max*	*con max*
			Cut 15E	*Cut 15W*	*Cut 15E*	*Cut 15W*	*Cut 15E*	*Cut 15W*
Aluminium	mg/L	0.01	16	7	0.01	0.005	0.01	0.01
Arsenic	mg/L	0.001	16	7	0.001	0.001	0.001	0.001279
Cadmium	mg/L	0.0001	16	7	0.001	0.001	0.001	0.001
Chromium	mg/L	0.001	16	7	0.001	0.001	0.001	0.001
Copper	mg/L	0.001	16	7	0.004	0.001	0.013	0.001
Lead	mg/L	0.001	16	7	0.001	0.001	0.024	0.02
Manganese	mg/L	0.001	16	7	0.08	0.363	1.69	2.07
Nickel	mg/L	0.001	16	7	0.003	0.003	0.01	0.012
Selenium	mg/L	0.01	16	7	0.01	0.01	0.01	0.01
Silver	mg/L	0.001	16	7	0.001	0.001	0.001	0.001
Zinc	mg/L	0.005	16	7	0.01	0.008	0.014	0.016
Iron	mg/L	0.01	16	7	0.05	1.91	2.12	7.02
Mercury	mg/L	0.0001	16	7	0.0005	0.0005	0.0006	0.0017
C6-C9 Fraction	µg/L	20	11	3	20	20	20	20
C10-C14 Fraction	µg/L	50	15	7	50	50	180	2160
C15-C28 Fraction	µg/L	100	15	7	100	100	570	200
C29-C36 Fraction	µg/L	100	15	7	100	100	150	100
C10-C36 Fraction (sum)	µg/L	50	11	3	50	50	180	2360
C10-C16 Fraction	µg/L	50	4	4	74	50	110	50
C16-C34 Fraction	µg/L	100	4	4	300	100	600	100
C34-C40 Fraction	µg/L	100	4	4	100	100	100	100
Benzene	µg/L	1	13	5	1	1	1	1
Toluene	µg/L	1	13	5	2	2	2	2
Ethylbenzene	µg/L	1	13	5	2	2	2	2
m+p-Xylene	µg/L	2	13	5	2	2	2	2
o-Xylene	µg/L	1	13	5	2	2	2	2
Naphthalene	µg/L	5	12	4	5	5	5	5
Total Phosphorus	mg/L	0.01	16	7	0.32	0.031	0.84	0.2
Phosphate	mg/L	0.001	16	7	0.01	0.01	0.01	0.01
Total Nitrogen	mg/L	0.1	16	7	1.3	0.245	2.5	4.2
Total Kjeldahl Nitrogen	mg/L	0.1	16	7	1.1	0.2	2.2	4.2
Nitrate	mg/L	0.005	15	7	0.348	0.04	0.39	0.32
Nitrite	mg/L	0.001	16	7	0.01	0.003	0.01	0.01
Ammonia	mg/L	0.005	16	7	0.07	0.04	0.16	0.17
Total Dissolved Solids	g/L	0.01	23	7	0.13	0.11	0.67	0.67
Chloride	mg/L	0.1	20	7	21.2	17.62	360	365
Sulfate	mg/L	0.1	20	7	17.36	18.84	36	47.7
Bicarbonate	mg/L	0.1	20	7	19.4	31	52	49
Sodium	mg/L	0.1	18	7	33.6	11.9	179	210
Potassium	mg/L	0.01	18	7	1	1.32	10	13
Calcium	mg/L	0.01	18	7	1.21	2.36	8	9
Magnesium	mg/L	0.1	18	7	2.89	7.73	12	17
Temperature	○C	0.01	32	14	25.08	21.37	29.49	30.82
pH	pH	0.01	32	14	7.00	6.06	8.01	7.83
Conductivity	mS/cm	0.01	32	14	0.26	0.18	2.18	72
Depth to standing water level	m	0.01	31	13	15.69	15.97	18.03	19.61

Red shading – Indicates a result of interest.

Table B.5 Construction phase summary groundwater quality results for approximate chainage 50965 (Fill 15)

Parameter	*Units*	*PQL*	*U/G*	*D/G*	*U/G*	*D/G*	*U/G*	*D/G*
			No.	*No.*	*con P80*	*con med*	*con max*	*con max*
			Fill 15E	*Fill 15W*	*Fill 15E*	*Fill 15W*	*Fill 15E*	*Fill 15W*
Aluminium	mg/L	0.01	14	13	0.01	0.01	0.037	0.02
Arsenic	mg/L	0.001	14	13	0.001	0.001	0.001	0.001
Cadmium	mg/L	0.0001	14	13	0.0007	0.0001	0.001	0.0002
Chromium	mg/L	0.001	14	13	0.001	0.001	0.002	0.002
Copper	mg/L	0.001	14	13	0.0024	0.001	0.005	0.004
Lead	mg/L	0.001	14	13	0.001	0.001	0.001	0.002
Manganese	mg/L	0.001	14	13	1.6292	2.5	19.02	5.29
Nickel	mg/L	0.001	14	13	0.0172	0.005	0.075	0.015
Selenium	mg/L	0.01	14	13	0.01	0.01	0.02	0.01
Silver	mg/L	0.001	14	13	0.001	0.001	0.003	0.001
Zinc	mg/L	0.005	14	13	0.0758	0.018	0.107	0.108
Iron	mg/L	0.01	14	13	1.068	3.05	4.99	92.6
Mercury	mg/L	0.0001	14	13	0.00026	0.0001	0.0005	0.0001
C6-C9 Fraction	µg/L	20	10	11	20	20	20	20
C10-C14 Fraction	µg/L	50	13	12	50	50	50	510
C15-C28 Fraction	µg/L	100	13	12	100	100	100	400
C29-C36 Fraction	µg/L	100	13	12	80	50	100	50
C10-C36 Fraction (sum)	µg/L	50	10	12	50	50	50	910
C10-C16 Fraction	µg/L	50	3	0	50	-	50	0
C16-C34 Fraction	µg/L	100	3	0	100	-	100	0
C34-C40 Fraction	µg/L	100	3	0	100	-	100	0
Benzene	µg/L	1	12	11	1	1	1	1
Toluene	µg/L	1	12	11	2	2	2	2
Ethylbenzene	µg/L	1	12	11	2	2	2	2
m+p-Xylene	µg/L	2	12	11	2	2	2	2
o-Xylene	µg/L	1	12	11	2	2	2	2
Naphthalene	µg/L	5	11	11	5	5	5	5
Total Phosphorus	mg/L	0.01	14	13	0.172	0.04	0.792	0.34
Phosphate	mg/L	0.001	14	13	0.034	0.01	0.045	0.05
Total Nitrogen	mg/L	0.1	14	13	1.073	2.4	1.524	3.8
Total Kjeldahl Nitrogen	mg/L	0.1	14	13	0.64	2.4	1.076	3.8
Nitrate	mg/L	0.005	14	13	0.4776	0.05	0.996	0.75
Nitrite	mg/L	0.001	14	13	0.01	0.01	0.04	0.81
Ammonia	mg/L	0.005	14	13	0.23	0.78	0.6	2.4
Total Dissolved Solids	mg/L	0.01	21	20	6.22	6.15	8.55	8.27
Chloride	mg/L	0.1	14	13	2370	1710	25719	1970
Sulfate	mg/L	0.1	14	13	2832	3200	10003	4430
Bicarbonate	mg/L	0.1	14	13	903.8	468	990	727
Sodium	mg/L	0.1	14	13	1772	1340	15156	1530
Potassium	mg/L	0.01	14	13	94.2	68	812	79
Calcium	mg/L	0.01	14	13	266.71	364	2571	414
Magnesium	mg/L	0.1	14	13	550.8	564	5048	636
Temperature	oC	0.01	31	33	24.57	22.34	30.1	29.07
pH	pH	0.01	31	33	7.5	6.94	8.03	8.81
Conductivity	mS/cm	0.01	31	33	10.7	9.42	12.3	11.3
Depth to standing water level	m	0.01	31	33	1.17	0.74	1.75	1.87

Red shading – Indicates a result of interest.