3.2 Surface water monitoring results

The monitoring data for the surface water sites are examined in this section. These include summaries of the monitoring between May 2019 and April 2020, with comparison against the ANZECC and other applicable guidelines.

The 20th and 80th percentile concentrations of the data for each parameter have been calculated. Typically these constitute the baseline period for the project, comparison against data gathered for the reporting presented here to be used in subsequent reporting periods as determined by ARTC.

The applicable ANZECC trigger value (guideline) and the numbers of results greater than the upper ANZECC guideline and less than the lower ANZECC guideline (where applicable) are summarised. This provides context as to what results for that parameter would ideally be achieved in a minimally-disturbed waterway.

The ANZECC guidelines for some parameters vary depending on whether a site is a waterway or a lake. The monitoring sites presented in this report have all been compared against waterway guideline values. The lake guideline values are noted so as to provide some context.

For each parameter, all of the current study period data are compared in a figure. The routine (dry weather) data are presented as lines, whilst the wet weather data are separate and presented as single points. The ANZECC guideline thresholds for flowing waterways are shown as red lines, so as to provide further context.

3.2.1 pH

Most of the adverse effects of pH in water are associated with low pH values (acidic), effectively when pH of less than 6.5 is recorded. ANZECC (2000) states that almost all water quality guidelines around the world recommend that pH should be maintained in the range 6.5 to 9.0 to protect freshwater aquatic organisms. The ANZECC (2000) Guidelines for pH are 6.5 - 8.0 for freshwater lakes and reservoirs, and 6.5 – 8.5 for NSW lowland rivers.

The number of results is annotated as 'N'. The range, mean and median pH values observed in the dry weather sampling events are given in Table 3.2. Additionally, the results are summarised in Figure 3.2 to show the variations of measured values within each site.

The recorded pH data show this parameter to be quite stable over time, and within the ANZECC guideline range. One Upstream sample of pH 8.51 was above the ANZECC upper guideline value. The 20th and 80th percentile ranges of the three sites are between pH 7.0 and 7.9.

Wet weather did not result in observed changes to the pH at the sites.

Table 3.2 Measured pH (units) across sites

Site	N	Min	Max	Mean	Median	30th %ile	20th %ile	ANZECC upper guideline	#>ANZECC upper guideline	ANZECC lower guideline	#<ANZECC lower guideline	% outside guideline	Wet weather event 1
Upstream	12	6.91	8.51	7.44	7.45	7.63	7.06	8.5	1	6.5	0	8.33	7.46
Downstream	12	7.23	7.89	7.52	7.47	7.83	7.30	8.5	0	6.5	0	0	7.48
Georges River	12	7.29	7.81	7.59	7.67	7.73	7.41	8.5	0	6.5	0	0	7.61

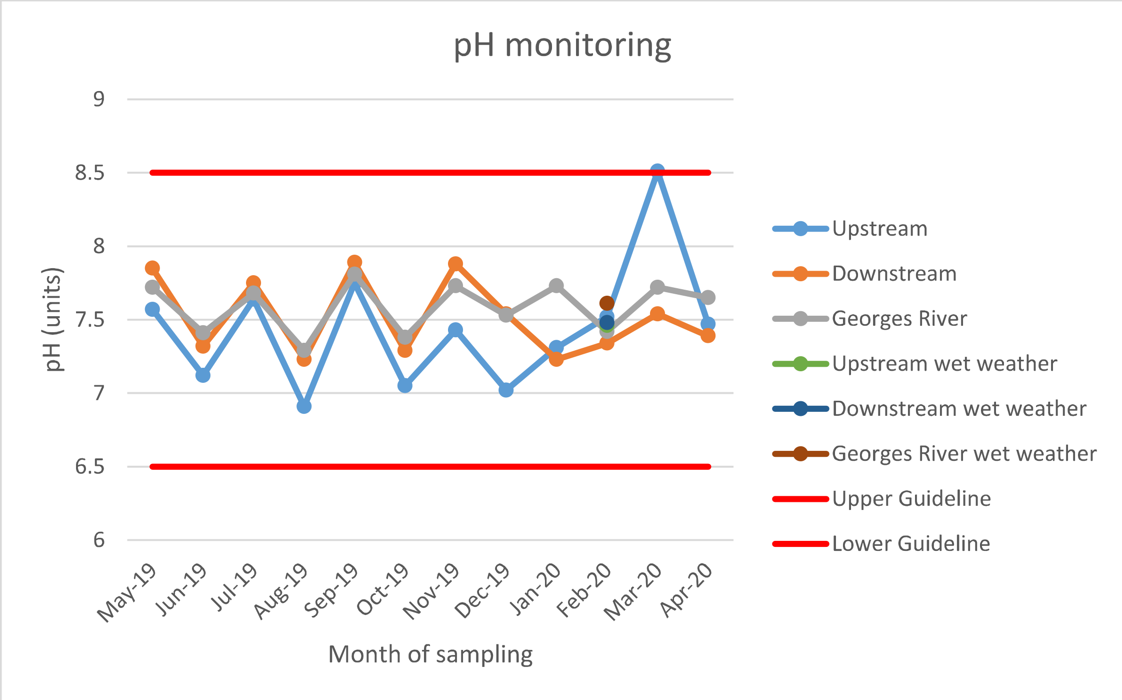


Figure 3.2 Measured pH across the monitored sites

3.2.2 Electrical Conductivity (EC)

EC is a measure of the types of salts (ions) in water, including anions: chlorides; sulphates; carbonates; phosphates and nitrates, as well as cations: sodium; calcium; magnesium and potassium. Concentrations of individual ions contributing to EC can vary. Metallic ions could also raise EC in water, which is affected by geology and soils; land use and catchment run-off, from agriculture, irrigation, urban and industrial development, including discharges of various effluents; and by groundwater inflows.

Sources of high EC include urban run-off containing salt, fertilisers, and organic matter. High levels of EC are also caused by clearing of vegetation and the resultant rise in the water table, excessive irrigation, and groundwater seepage.

Salinity in water ecosystems that is elevated towards marine concentrations is known to be harmful to freshwater aquatic organisms, as reflected in the ANZECC (2000) EC guidelines. Therefore, it is possible to predict that such high ionic contents in the waterbodies are likely to change the freshwater environment into a part-saline habitat. If such a change occurs, biotic communities may also change, over time, as a result.

Table 3.3 below presents the EC data for surface water, and Figure 3.3 shows the variations of measured values across the sites. The ANZECC (2000) guideline range for EC in NSW coastal lowland rivers is 200-300 µS/cm, and is applicable to flowing creeks. However, this guideline also state that Australia's east flowing lowland rivers could have EC as high as 2200 µS/cm and should be above 125 µS/cm, as noted in Table 2.2. The 2200 µS/cm threshold has been used as the upper guideline in the calculations in Table 3.3, and the 300 µS/cm upper guideline value is indicated in Figure 3.3.

The following observations can be made on the results tabulated in Table 3.3:

- Increased EC between upstream and downstream sites. Increased tidal influence further downstream. This is demonstrated by the results at the Georges River location where EC results were exceeded the guideline value for 9 of the 12 sampling events.

- Georges River showed substantially greater EC than the other sites – even greater tidal effect.
- Unlikely that these sites will influence EC in the Georges River, and some increase in EC is to be expected from Upstream to Downstream sites. However if substantial increases are seen during construction or post-construction phases, inputs other than tidal influences may still need consideration.
- The wet weather data showed clearly reduced EC at the sites, which can be attributed to dilution by stormwater flows.

Table 3.3 Measured EC (µS/cm) concentrations across sites

Site	N	Min	Max	Mean	Median	30^{th} %ile	20^{th} %ile	ANZECC upper guideline	#>ANZECC upper guideline	ANZECC lower guideline	#<ANZECC lower guideline	% outside guideline	Wet weather event 1
Upstream	12	480	833	637	645	746	516	2200	0	125	0	0	218
Down-stream	12	549	4530	1068	717	963	597	2200	1	125	0	8.3	228
Georges River	12	825	23400	10304	9680	17280	2940	2200	10	125	0	83.3	433

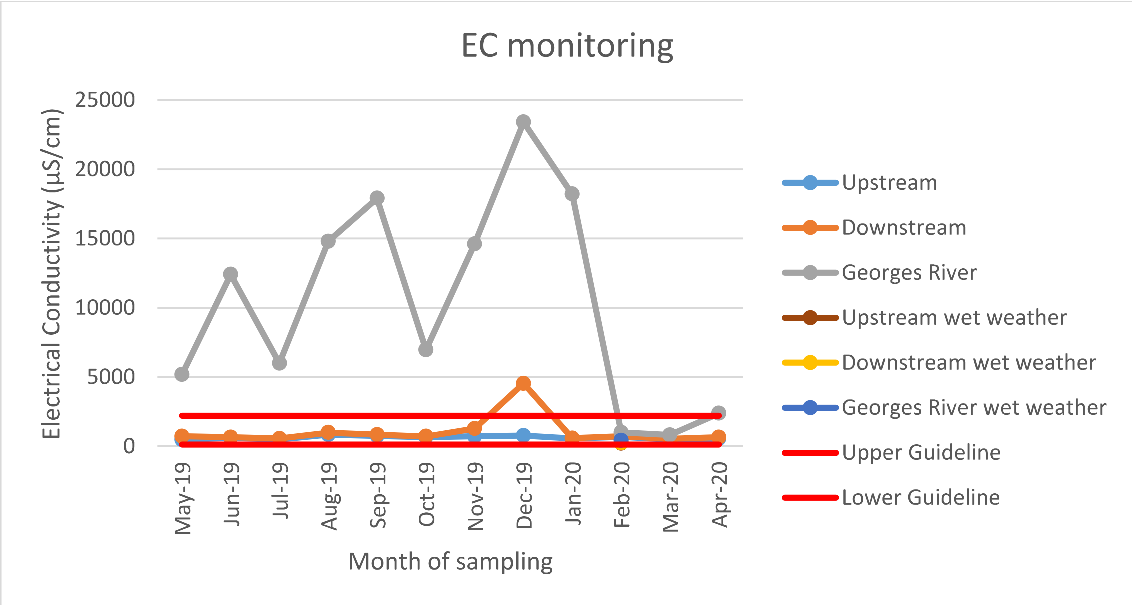


Figure 3.3 Measured EC (µS/cm) across the monitored sites

3.2.3 Turbidity

Turbidity, directly measured *in situ* by the water quality probe, provides readings which express how light is scattered by suspended particulate material in the water. These results, given in *Nephelometric Turbidity Units* (NTU), generally provide a good correlation with the concentration of particles in the water that affect water clarity and phytoplankton productivity.

Although high turbidity is often a sign of poor water quality and land management, crystal clear water does not always guarantee healthy water. Extremely clear water can signify very acidic conditions, or high levels of salinity. The ANZECC (2000) Freshwater Guidelines give a trigger value of 6-50 NTU for turbidity in lowland rivers.

The turbidity recorded at all sites in dry weather was below the 50 NTU ANZECC upper guideline. A number of samples at all sites were below the 5 NTU lower guideline, this was attributed to the salinity of the sites as recorded in the EC present. Whilst these samples are regarded as outside the guideline range, the low turbidity can be expected due to natural processes present at the sites.

The measured wet weather turbidities were greater than the maximum dry weather results for this parameter. This could be attributed to turbid inflows resulting from wet weather, as well as the dilution of the site salinities from stormwaters. Table 3.4 and Figure 3.4 below presents the turbidity data for surface water, and Figure 3.4 shows the variations of measured values across the sites.

Table 3.4 Measured Turbidity (NTU) across sites

Site	N	Min	Max	Mean	Median	80th %ile	20th %ile	ANZECC upper guideline	#>ANZECC upper guideline	ANZECC lower guideline	#<ANZECC lower guideline	% outside guideline	Wet weather event
Upstream	12	2.2	19.0	8.9	7.5	12.0	5.6	50	0	6	4	33.3	38.9
Downstream	12	1.0	10.1	5.1	5.2	6.6	3.2	50	0	6	8	66.7	41.3
Georges River	12	2.3	24.7	8.0	5.5	10.4	4.3	50	0	6	7	58.3	27.4

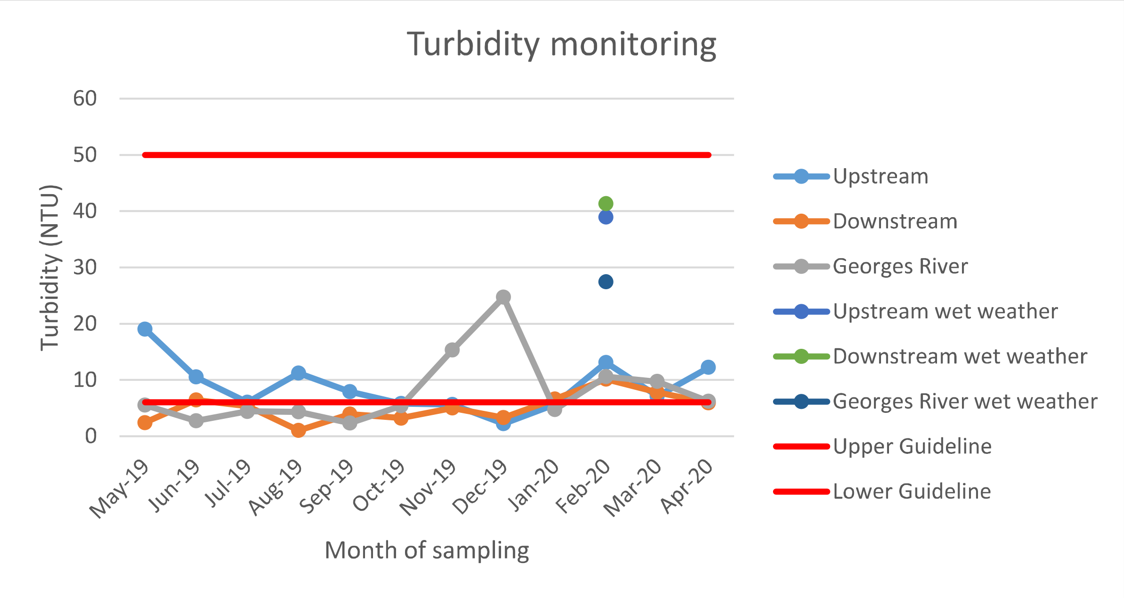


Figure 3.4 Measured Turbidity (NTU) across the monitored sites

3.2.4 Total Suspended Solids (TSS)

Suspended solids consist of an inorganic fraction (silts, clays, etc.) and an organic fraction (algae, zooplankton, bacteria, and detritus) that are carried along by water as it runs off the land. When suspended particles settle to the bottom of a water body, they become sediments or 'silt'. The inorganic portion is typically considerably higher than the organic fraction. Turbidity is correlated with the force of moving water, which keeps the particles suspended.

Suspended solids reduce sunlight penetration, reducing algal photosynthesis, thereby controlling phytoplankton abundance and the abundance of animals that feed on algae. Suspended solids also clog fish gills, either killing them or reducing their growth rate. When suspended sediment settles out and drops to the bottom, this causes the water to clear, but as the silt or sediment settles, it may change the nature of the lake bottom. The silt may be unfavourable to bottom-dwelling organisms, as it may cover breeding areas, and smother eggs.

Indirectly, suspended solids affect other water quality parameters, such as temperature and dissolved oxygen. Because of the greater heat absorbency of the particulate matter, the surface water becomes warmer and this tends to stabilize the stratification (layering) in lakes. This, in turn, interferes with mixing, decreasing the dispersion of oxygen and nutrients to deeper layers. Siltation (sediment deposition), may eventually fill up the water body converting it into a wetland.

A positive effect of the presence of suspended solids in water is that toxic chemicals, such as pesticides and metals tend to adsorb to them, or become complexed with them, which makes the toxins less available to be absorbed by living organisms.

There are no quantitative criteria for TSS in ANZECC (2000) Guidelines; however, in USA, Kentucky Water Quality Standards for aquatic life state that suspended solids "…*shall not be changed to the extent that the indigenous aquatic community is adversely affected*…" and "…*the addition of settleable solids that may adversely alter the stream bottom is prohibited*..."

The US National Academy of Sciences has recommended that the concentration of TSS should not reduce light penetration by more than 10%. In a study in which TSS concentrations were increased to 80 mg/L, the macroinvertebrate population was decreased by 60 % (http://kywater.org/ww/ramp/rmtss.htm). In the absence of any other guideline, a TSS concentration of 80 mg/L could be used as the uppermost level, not to be exceeded.

The observed range, mean and median TSS concentrations are shown in Table 3.5 below. The variation of measured values across the monitored sites is also shown in Figure 3.5.

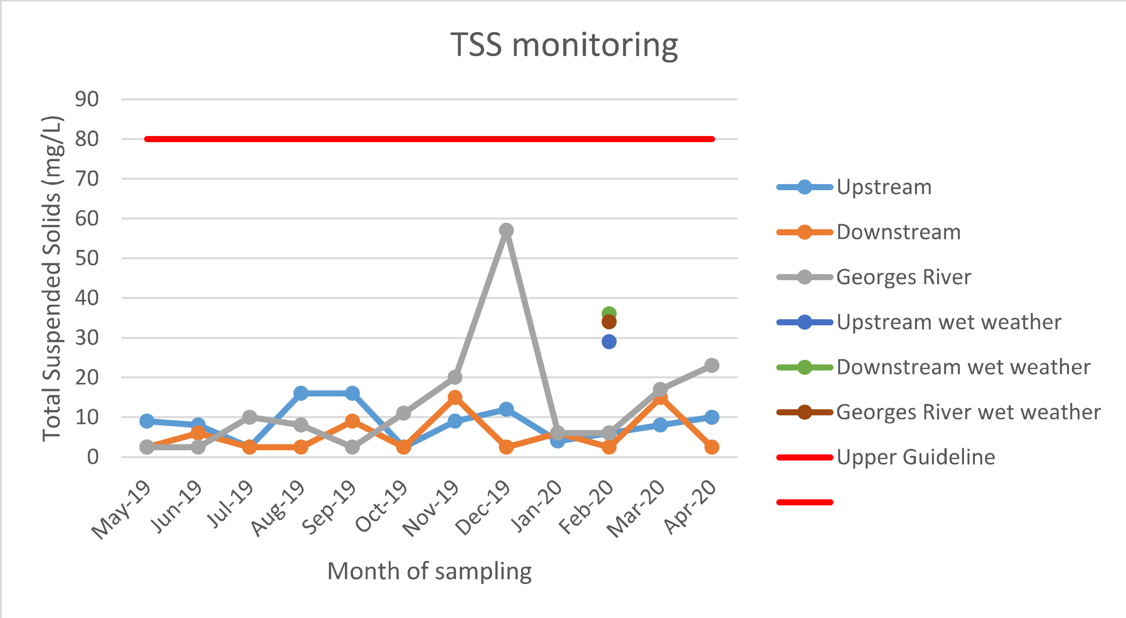
The TSS concentrations at the sites were uniformly below the adopted guideline concentration of 80 mg/L. TSS concentrations were usually greater at the Georges River site than the other two sites.

Wet weather resulted in somewhat elevated TSS concentrations at all sites, however these were still less than 80 mg/L. Some increases can be expected with wet weather inflows to waterways.

Table 3.5 Measured total suspended solids (mg/L) across sites*

Site	N	Min	Max	Mean	Median	80th %ile	20th %ile	Adopted upper guideline	#>Adopted upper guideline	Lower guideline	#<Lower guideline	% outside guideline	Wet weather event
Upstream	12	2.5	16.0	8.6	8.5	11.6	4.4	80	0	N/A	-	0	29
Downstream	12	2.5	15.0	5.7	2.5	8.4	2.5	80	0	N/A	-	0	36
Georges River	12	2.5	57.0	13.8	9.0	19.4	3.2	80	0	N/A	-	0	34

* US EPA Guideline 80 mg/L adopted.



Note: The red line indicates the adopted guideline (80 mg/L, see text for details)

Figure 3.5 Measured TSS (mg/L) across sites

It should be noted that TSS is an important parameter to be measured in waterways that may be impacted by construction activities. Elevated TSS, which is often transient, may not always be ecologically significant for biota. However, it is generally considered a good indicator of how effective the sediment and runoff controls and other mitigation measures might be, which are taken to reduce adverse impacts on downstream waterways.

To enable some comparison between turbidity and TSS data, these have been presented on the same chart in Figure 3.6. Please note that the axes are changed from the earlier figures so as to allow a comparison of these two parameters. As can be seen, there are some similarities between the patterns of these parameters, such as the concentration spikes for the Georges River site in December 2019 for both turbidity and TSS. Other smaller variations are not always corresponding in both parameters, which can be expected due to the different effects on the parameters by different suspended materials.

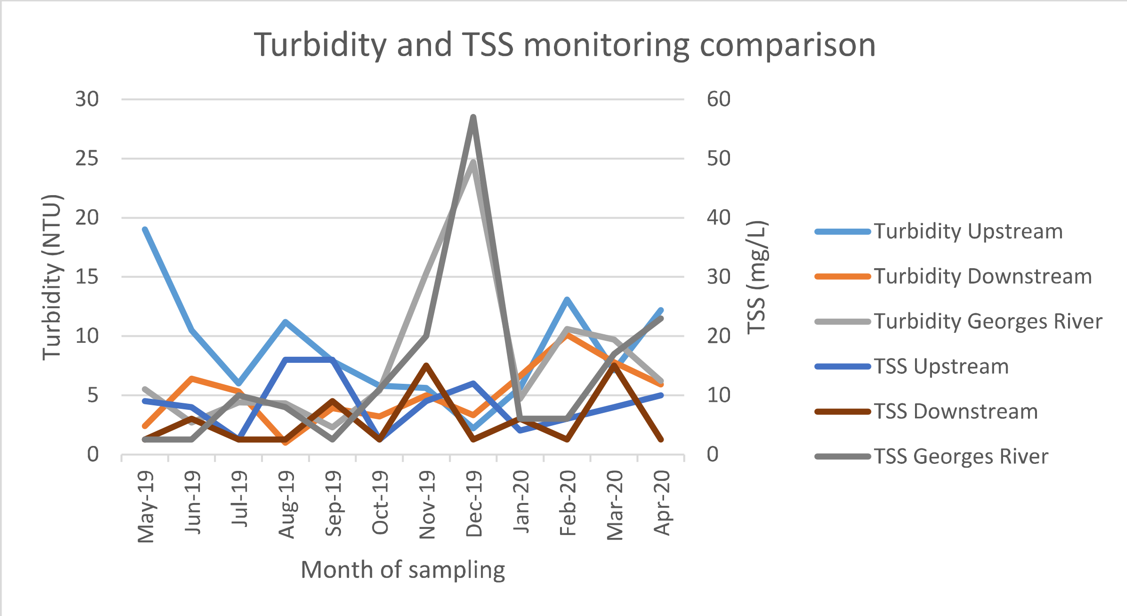


Figure 3.6 Measured turbidity and TSS monitoring data

3.2.5 Enterococci and *E. coli*

The bacterial contamination of water has been tested by the abundance of enterococci and *E. coli*. These bacteria are present specifically in the gut and feces of warm-blooded animals. As a consequence, enterococci and *E. coli* counts are considered an accurate indicator of animal or human waste contamination of waterbodies or water supplies. The ANZECC guideline concentrations for primary contact recreation (a median concentration of ≤35 CFU/100 mL enterococci, and ≤150 faecal coliform CFU/100 mL) and secondary contact recreation (≤230 enterococci CFU/100 mL, and ≤1000 faecal coliform CFU/100 mL) have been used here to provide comparative context for these results. *E. coli* are a sub-group of faecal coliforms, and make up the overwhelming majority of faecal coliforms present in faecal contamination, and have been used as a functionally equivalent measure of faecal coliforms here. Whilst these guideline values are intended to be compared against the median values of ongoing monitoring, they have been used here as a measure of how frequently elevated concentrations occur.

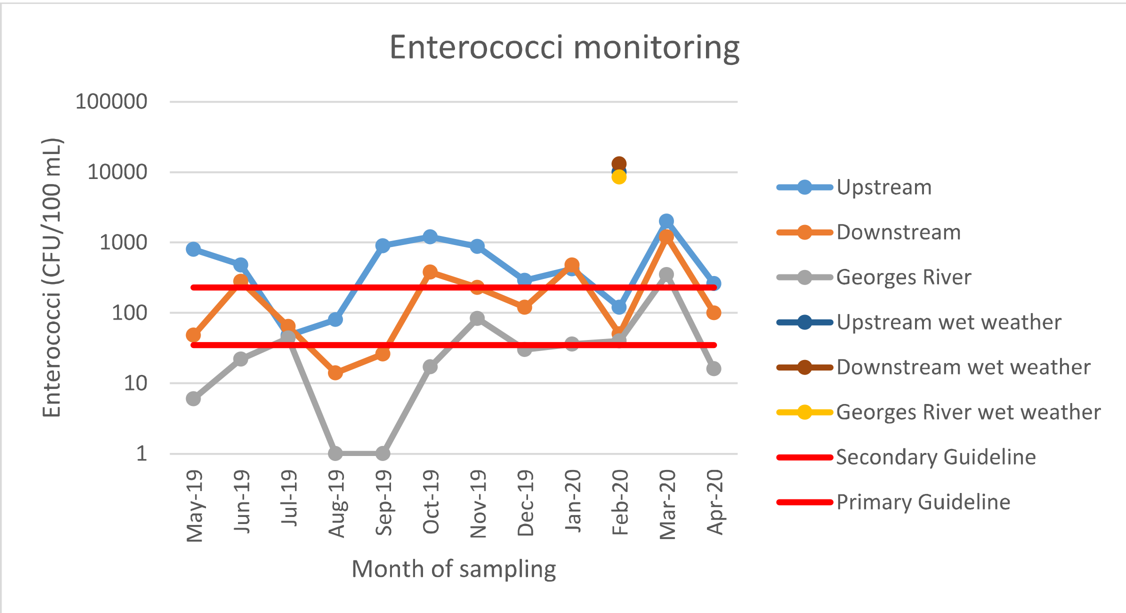
From the dry weather sampling, the Upstream and Downstream sites recorded greater concentrations than the Georges River site, typically by approximately an order of magnitude. Additionally, the Upstream site usually recorded greater concentrations than the Downstream site. This can be attributed to upstream inputs of faecal contamination, with progressive downstream dilution. The Upstream site recorded nine of 12 samples with enterococci concentrations greater than the ANZECC secondary contact recreation guideline, compared to four of 12 samples from the Downstream site, and one of 12 samples from the Georges River site.

All three sites recorded substantially increased enterococci concentrations following wet weather, of more than an order of magnitude at the Downstream and Georges River sites. This indicates the potential for wet weather flows to transport faecal contamination to all of these waterway sites. Table 3.6 and Figure 3.7 below presents the enterococci data for surface water, and Note: Red lines indicate the ANZECC Guidelines (35 CFU/100 mL for primary contact, and 230 CFU/100/mL for secondary contact recreation)

Figure 3.7 shows the variations of measured values across the sites.

Table 3.6 Measured Enterococci (CFU/100 mL) across sites

Site	N	Min	Max	Mean	Median	80th %ile	20th %ile	ANZECC primary contact guideline	#>ANZECC primary contact guideline	ANZECC secondary contact guideline	#<ANZECC secondary contact guideline	% outside secondary contact guideline	Wet weather event
Upstream	12	48	2000	623	450	896	148	35	12	230	9	75.0	10000
Down-stream	12	14	1200	249	110	360	48.4	35	10	230	4	33.3	13000
Georges River	12	1	350	54	26	43.2	8	35	5	230	1	8.3	8500



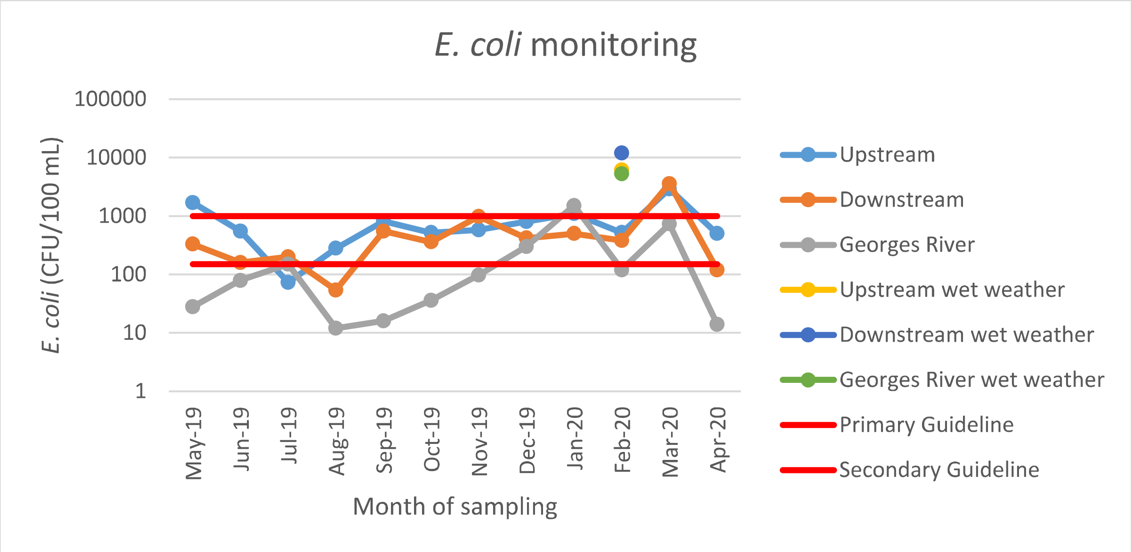
Note: Red lines indicate the ANZECC Guidelines (35 CFU/100 mL for primary contact, and 230 CFU/100/mL for secondary contact recreation)

Figure 3.7 Measured enterococci (CFU/100 mL) across sites

The *E. coli* concentrations at the tested sites were similar to those observed for enterococci, with the same samples showing elevated concentrations. Fewer samples were elevated above the secondary contact guideline concentration than was the case with enterococci concentrations, which may be attributed to decreased survival times of *E. coli* in saline waters. This differential survival has led to enterococci being the preferred indicator of faecal contamination of marine and estuarine waters (NHMRC, 2008).

Table 3.7 Measured *E. coli* (CFU/100 mL) across sites

Site	N	Min	Max	Mean	Median	80th %ile	20th %ile	ANZECC primary contact guideline	#>ANZECC primary contact guideline	ANZECC secondary contact guideline	#<ANZECC secondary contact guideline	% outside secondary contact guideline	Wet weather event
Upstream	12	73	2900	861.9167	565	1044	504	150	11	1000	3	25.0	12
Down-stream	12	54	3600	637.8333	370	540	168	150	10	1000	1	8.3	12
Georges River	12	12	1500	256.8333	88	270	18.4	150	3	1000	1	8.3	12



Note: Red lines indicate the ANZECC Guidelines (150 CFU/100 mL for primary contact, and 1000 CFU/100/mL for secondary contact recreation)

Figure 3.8 Measured *E. coli* (CFU/100 mL) across sites

3.2.6 Nutrients

Of the range of parameters monitored as aquatic ecosystem health indicators in the monitoring program, algal growth nutrients (nitrogen, N; and phosphorus, P) are the most significant. The concentrations of N and P provide useful information on the changes that are occurring in the waterways and waterbodies of the project area.

The discussion below provides the context for the monitoring of aquatic ecosystem health indicators that are relevant to managing the construction impacts of the project.

Nitrogen relationships

Nitrogen is the most abundant element and about 80% of the air we breathe is nitrogen. It is found in the cells of all living things, as a major component of proteins. Inorganic nitrogen may exist in the free-state as gaseous nitrogen (N_2); or ammonia (NH_3); or as oxides (nitrate (NO_3^-); nitrite (NO_2^-). Organic N is found in proteins, and is continually recycled by plants and animals.

Concentrations of these N species and total nitrogen (TN) are major indicators of aquatic ecosystem health (ANZECC, 2000). TN is the sum of organic nitrogen, NOx and ammonia:

$$\textbf{TN} = (\textbf{organic nitrogen}) + (NO_3^-) + (NO_2^-) + (NH_3)$$

By definition, Total Kjeldahl Nitrogen (TKN), a component of TN, is the sum of organic nitrogen and ammonia. Therefore, the above equation may be re-written as:

$$\textbf{TN} = (\textbf{TKN}) + (NO_3^-) + (NO_2^-)$$

Ammonia

High levels of ammonia in water indicate poor water quality, as ammonia is a waste product and at high concentrations is toxic to most aquatic life, including fish. Ammonia toxicity to aquatic life increases as pH decreases, and as temperature decreases. Plants are more tolerant of ammonia than animals, and invertebrates are more tolerant than fish. High concentrations adversely affect structural development, hatching and growth rates of fishes.

Most of the ammonia produced in Australia is used in fertilizers - as ammonium sulfate, nitrate and urea. It is also used in the production of ice and in refrigerating plants, and in household cleaning products. Since ammonia is a decomposition product from urea and protein, it is found in domestic wastewater. Aquatic life and fish also contribute to ammonia levels in a water body.

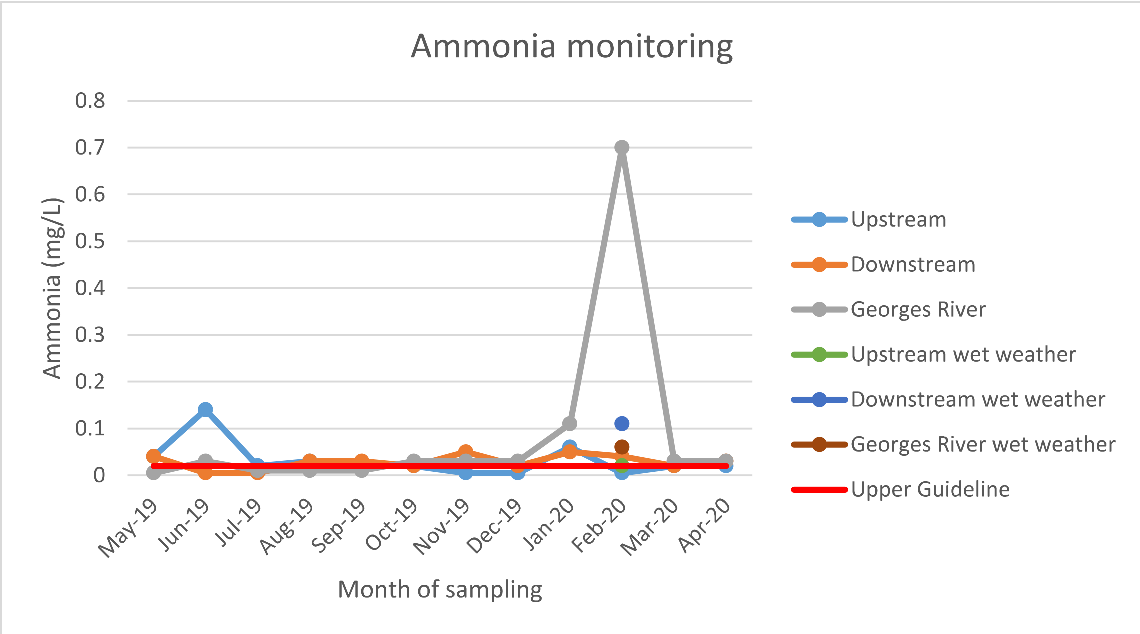
Summary statistics for ammonia concentrations measured at the monitored sites are given in Table 3.8 and the variation of measured values in ammonia concentrations across the sites shown in Figure 3.9.

Ammonia concentrations exceeded the ANZECC guideline (0.02 mg/L) in several samples at all sites. This included 4 of 12 samples from the Upstream site, 7 of 12 samples Downstream, and 8 of 12 samples from the Georges River site. The maximum concentrations for the Upstream (0.14 mg/L) and Downstream (0.05 mg/L) sites were relatively similar to the guideline threshold, in contrast the Georges River site maximum concentration (0.7 mg/L) was markedly greater.

The wet weather ammonia concentrations were similar to the dry weather medians for the Upstream and Georges River sites, contrasting with a higher concentration than the dry weather maximum in the Downstream site. This is attributed to wet weather inflows of nutrients at the Downstream site, that had not yet wash through via stormwater flows.

Table 3.8 Measured ammonia (mg/L) concentrations across sites

Site	N	Min	Max	Mean	Median	80th %ile	20th %ile	ANZECC upper guideline	#>ANZECC upper guideline	ANZECC lower guideline	#<ANZECC lower guideline	% outside guideline	Wet weather event
Upstream	12	0.005	0.14	0.032	0.02	0.038	0.008	0.02	4	N/A		33.3	0.02
Down-stream	12	0.005	0.05	0.028	0.03	0.04	0.02	0.02	7	N/A		58.3	0.11
Georges River	12	0.005	0.7	0.085	0.03	0.03	0.01	0.02	8	N/A		66.7	0.06



Note: The red line indicates the ANZECC Guideline for lowland rivers (0.02 mg/L)

Figure 3.9 Measured ammonia (mg/L) across sites

Nitrogen Oxides (NOx)

Nitrate [NO_3^-] and nitrite [NO_2^-] are related N compounds, which occur naturally in soil, water, plants and food. They are formed when microorganisms break down organic materials, such as plants, animal manure, and sewage. Nitrate is found in chemical fertilizers. Nitrite is used as a preservative and as a curing agent for meat. Nitrate is more commonly found in water than nitrite. The occurrence of high levels of both points to the contamination of water by various sources of N, such as fertilizer and wastewater (in runoff, or leaking septic tanks); manure from livestock, animal wastes (eg fish and birds); and discharges from car exhausts.

Bacteria in water readily convert nitrites to nitrates in an aerobic process called nitrification, which consumes dissolved oxygen. Because of the rapid conversion, nitrites in water are relatively short-lived. In poorly aerated water or water overloaded with organic contamination, low oxygen levels can inhibit nitrification, leaving most of the nitrogen as ammonia or nitrite. Both of these are relatively toxic to organisms.

The major impact of NOx on freshwater is nutrient enrichment, stimulating the growth of phytoplankton, which provides food for higher organisms (invertebrates and fish). An excess of nitrogen often results in over-production of phytoplankton, and as they die and decompose, they use up oxygen, causing oxygen-depletion and death of other oxygen-dependent organisms.

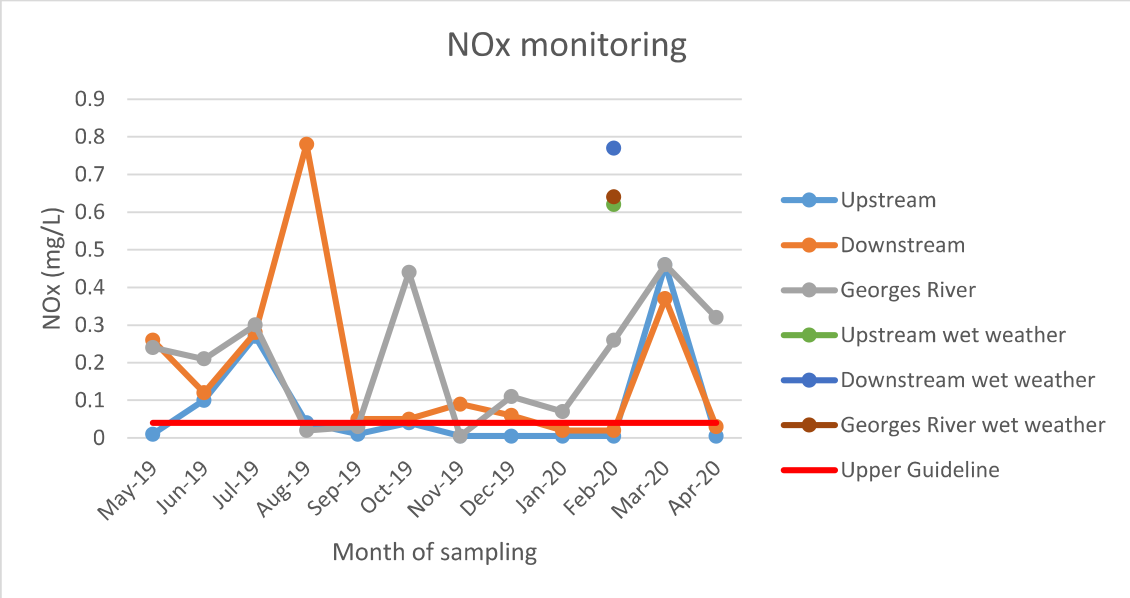
The ANZECC (2000) Freshwater Guideline for NOx is a concentration of 0.04 mg/L for lowland rivers. The summary results for NOx data observed in the sampling are tabulated in Table 3.9 below, and the variation of measured values shown in Figure 3.10.

The ANZECC guideline concentration for NOx was exceeded by 3 of 12 samples for the Upstream site, and 9 of 12 samples for each of the downstream and Georges River sites. When combined with the substantially greater NOx concentrations evident in the mean, median and 80th and 20th percentile concentrations of these latter sites, it appears that they are more frequently affected by nutrient inflows containing NOx than the Upstream site. Such inflows can be expected to occur at the three sites, as shown by the elevated maximum concentrations recorded (0.46 mg/L for Upstream and Georges River, and 0.78 for Downstream), however there are differences in the frequency as described..

Wet weather NOx concentrations were similar to or greater than the dry weather maximum concentrations for each of the sites. This is consistent with increased nutrient mobilisation and transport to the waterway during wet weather.

Table 3.9 Measured NOx (mg/L) concentrations across sites

Site	N	Min	Max	Mean	Median	80th %ile	20th %ile	ANZECC upper guideline	#>ANZECC upper guideline	ANZECC lower guideline	#<ANZECC lower guideline	% outside guideline	Wet weather event
Upstream	12	0.005	0.46	0.080	0.01	0.088	0.005	0.04	3	N/A	-	25	0.62
Down-stream	12	0.02	0.78	0.178	0.075	0.276	0.034	0.04	9	N/A	-	75	0.77
Georges River	12	0.005	0.46	0.205	0.225	0.316	0.038	0.04	9	N/A	-	75	0.64



Note: The red line indicates the ANZECC Guideline for NOx in lowland rivers (0.04 mg/L)

Figure 3.10 Measured NOx (mg/L) across the monitored sites

Total Nitrogen (TN)

The ANZECC (2000) Freshwater Guidelines outline a default TN concentration trigger value of 0.35 mg/L for freshwater lakes and reservoirs, and for east flowing coastal rivers in NSW.

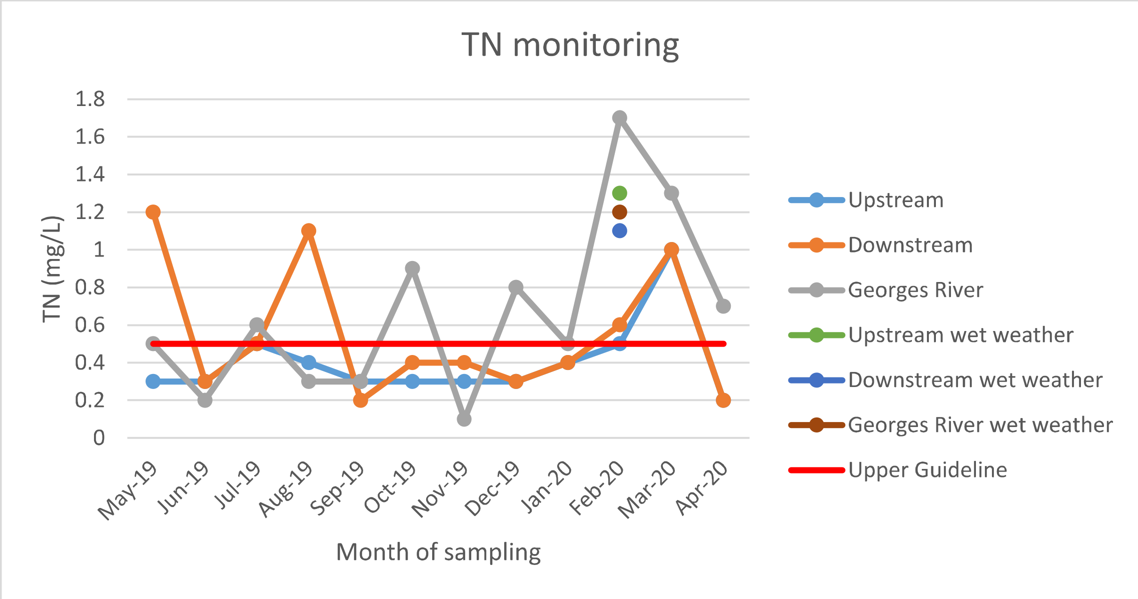
The range, mean and median TN concentrations observed in the first six months of sampling rounds are tabulated in Table 3.10 and the variation of measured values shown in Figure 3.11.

The Upstream site infrequently exceeded the ANZECC TN guideline concentration, with 1 of 12 samples greater than 0.5 mg/L TN. The guideline was more frequently exceeded at the Downstream (4 of 12 samples) and Georges River (6 of 12 samples) sites. The TN maxima for all sites ranged between 1.0 and 1.7 mg/L, indicating that all sites can be affected by inflows containing similar TN concentrations. The pattern of the Downstream and Georges River sites more frequently exceeding the guideline threshold was also observed with the NOx monitoring results.

The wet weather concentrations at all sites were similar to the maximum dry weather concentrations.

Table 3.10 Measured TN (mg/L) concentrations across sites

Site	N	Min	Max	Mean	Median	80th %ile	20th %ile	ANZECC upper guideline	#>ANZECC upper guideline	ANZECC lower guideline	#<ANZECC lower guideline	% outside guideline	Wet weather event
Upstream	12	0.2	1	0.4	0.3	0.48	0.3	0.5	1	N/A	-	8.3	1.3
Downstream	12	0.2	1.2	0.55	0.4	0.92	0.3	0.5	4	N/A	-	33.3	1.1
Georges River	12	0.1	1.7	0.66	0.55	0.88	0.3	0.5	6	N/A	-	50	1.2



Note: The red line indicates the ANZECC freshwater guideline for TN in lowland rivers (0.5 mg/L)

Figure 3.11 Measured TN (mg/L) across the monitored sites

Phosphorus - Soluble Reactive Phosphorus (SRP) and Total (TP)

Phosphorus is a key element necessary for growth of all plants and animals. Phosphates can exist in three forms: orthophosphate, meta-phosphate (or polyphosphate) and organically bound phosphate. Each compound contains phosphorus in a different chemical formula. Ortho forms are produced by natural processes and are found in sewage. Poly forms are used for treating boiler waters and in detergents. In water, they change into the ortho form. Organic phosphates result from the breakdown of organic pesticides, which contain phosphates. All forms of P may exist in solution, as particles, loose fragments or in the bodies of aquatic organisms.

Rainfall can cause varying amounts of phosphates to wash from farm soils into waterways. Phosphates stimulate the growth of plankton and aquatic plants, which provide food for fish. This may cause an increase in the fish population and improve the overall water quality.

However, under excess concentrations of P, algae and aquatic plants could grow wildly, choke up the waterways and consume large amounts of dissolved oxygen. This condition is known as ***eutrophication*** or over-fertilization of receiving waters. The excessive growth of aquatic vegetation eventually dies, and as it decays, it uses up oxygen. This process in turn causes the death of aquatic life, because of the lowering of oxygen levels.

Soluble Reactive Phosphorus (SRP)

The ANZECC (2000) Guidelines for the readily-available, soluble P concentrations are 0.005 mg/L for freshwater lakes and reservoirs, and 0.02 mg/L for flowing rivers.

As shown in Table 3.11, the majority of dry weather samples recorded SRP concentrations lower than the ANZECC guideline threshold. Exceedances included 2 of 12 Upstream samples, 0 of 12 Downstream samples, and 4 of 12 Georges River samples. The maximum SRP concentration recorded for the Georges River site (0.16 mg/L) was substantially greater than for the other sites (0.04 mg/L Upstream and 0.02 mg/L Downstream), suggesting that this site may receive inflows containing phosphorus from other inflows, and be more susceptible to subsequent algal growth.

As seen with other nutrients, the wet weather SRP concentrations increased at the Upstream and Downstream sites, and were greater than the dry weather maxima for those sites. For the

Georges River site, the wet weather concentration was greater than the dry weather mean, but less than the dry weather maximum. Table 3.11and Figure 3.12 below presents the SRP data for surface water, and Figure 3.12 shows the variations of measured values across the sites.

Table 3.11 Measured SRP (mg/L) concentrations across sites*

Site	N	Min	Max	Mean	Median	80th %ile	20th %ile	ANZECC upper guideline	#>ANZECC upper guideline	ANZECC lower guideline	#<ANZECC lower guideline	% outside guideline	Wet weather event
Upstream	12	0.005	0.04	0.013	0.01	0.018	0.005	0.02	2	N/A	-	16.7	0.15
Down-stream	12	0.005	0.02	0.008	0.005	0.01	0.005	0.02	0	N/A	-	0	0.05
Georges River	12	0.005	0.16	0.028	0.015	0.03	0.005	0.02	4	N/A	-	33.3	0.06

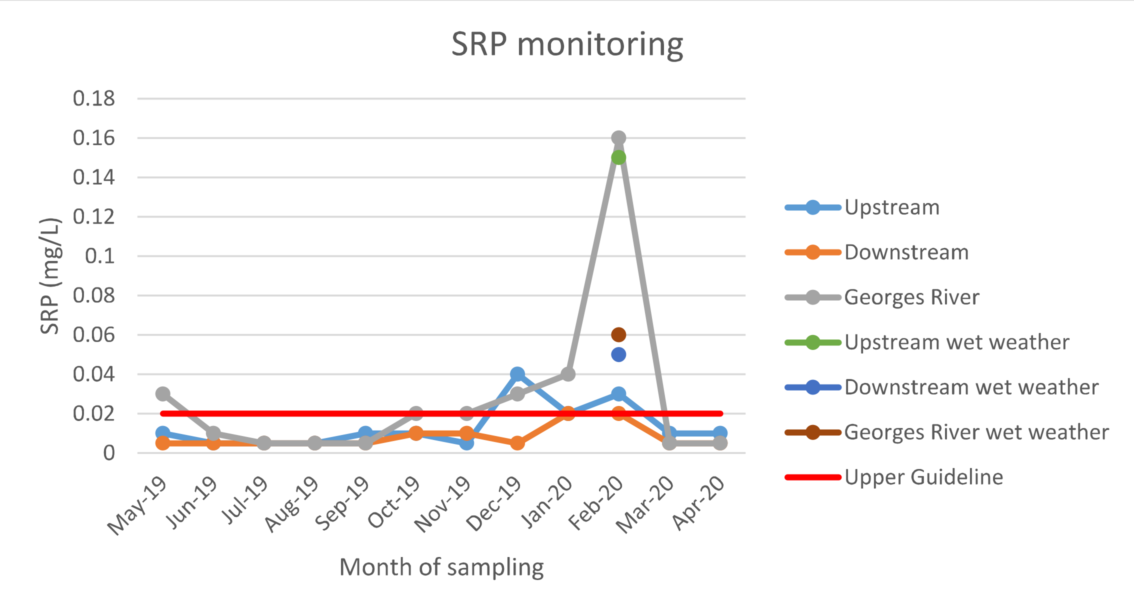


Figure 3.12 Measured SRP (mg/L) across the monitored sites

Total Phosphorus (TP)

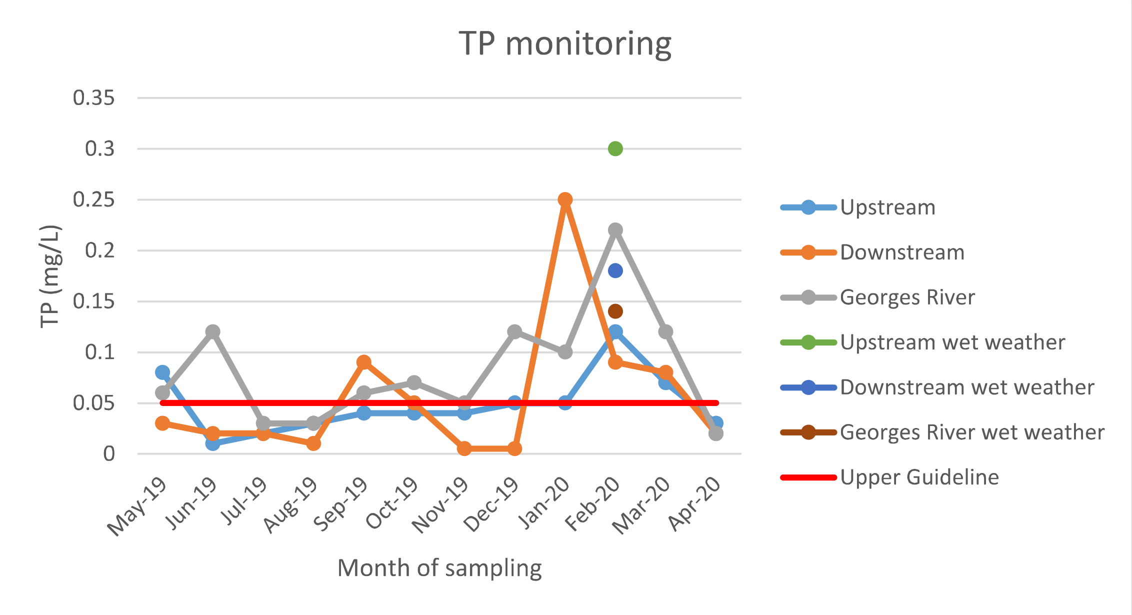
The ANZECC (2000) Guidelines for TP concentrations are 0.01 mg/L for freshwater lakes and reservoirs, and 0.05 mg/L for east-flowing rivers. The range, mean and median TP concentrations recorded in the first six months are shown in Table 3.12 below and in Figure 3.13.

The Upstream site recorded 3 of 12 dry weather samples that exceeded the 0.05 mg/L ANZECC guideline, and similarly 4 of 12 samples from the Downstream site exceeded the guideline. These contrasted with 8 of 12 exceedances at the Georges River site. These results indicated a similar pattern to the other nutrient results, with the Georges River site more frequently exceeding guideline thresholds. The maximum TP concentrations recorded at the three sites were similar, and ranged between 0.12 and 0.25 mg/L.

The wet weather TP concentrations for the three sites ranged between 0.14 and 0.3 mg/L, similar to the dry weather maxima.

Table 3.12 Measured TP (mg/L) concentrations across sites

Site	N	Min	Max	Mean	Median	80th %ile	20th %ile	ANZECC upper guideline	#>ANZECC upper guideline	ANZECC lower guideline	#<ANZECC lower guideline	% outside guideline	Wet weather event
Upstream	12	0.01	0.12	0.048	0.04	0.066	0.03	0.05	3	N/A	-	25	0.3
Downstream	12	0.005	0.25	0.056	0.025	0.088	0.012	0.05	4	N/A	-	33.3	0.18
Georges River	12	0.02	0.22	0.083	0.065	0.12	0.034	0.05	8	N/A	-	66.7	0.14



Note: The red lines indicate the ANZECC guidelines for TP in lowland rivers (0.05 mg/L)

Figure 3.13 Measured TP (mg/L) across the monitored sites

3.3 Metals

The samples were examined for a suite of eight metals, the concentrations of which were compared against the NHMRC (2008) and the ANZECC (2000) Guideline values. The thresholds and instances where the detected concentrations exceeded the guidelines are summarised in Table 3.13. With many of the metals concentration results below analytical detection limits, these data have been presented differently to the previous parameters, with description instead of maximum concentrations and the frequency of results exceeding the ANZECC (2000) default guideline concentrations.

Table 3.13 Metals exceedances, all sites, May 2019 to April 2020

Parameter	NHMRC Recreation Guidelines	ANZECC Recreation Guideline	ANZECC Guidelines Freshwater*	Comments
Arsenic (mg/L)	0.07	0.05	0.013	Maximum concentration of 0.002 mg/L recorded in 3 samples (Georges River December 2019, and Upstream and Georges River February 2020). Wet weather maximum concentration 0.001 mg/L.
Cadmium (mg/L)	0.02	0.005	0.0002	Maximum concentration of 0.0002 mg/L recorded in 2 samples (Upstream and Georges River March 2020). Not detected in wet weather samples.
Chromium (mg/L)	0.5	0.05	0.001	Maximum concentration of 0.002 mg/L recorded in 3 samples (Georges River August 2019, Upstream December 2019, and Georges River February 2020). Maximum wet weather concentration 0.002 mg/L, Upstream site.
Copper (mg/L)	20	1	0.0014	Detected at concentrations above ecosystem guideline value in 3 samples Upstream, 5 samples Downstream, and 6 samples Georges River. Maximum concentrations of 0.004 mg/L (Upstream), 0.003 mg/L (Downstream), and 0.005 mg/L (Georges River). Wet weather concentrations of 0.004 mg/L (Upstream and Downstream), and 0.007 mg/L (Georges River).
Lead (mg/L)	0.1	0.05	0.0034	Maximum concentration of 0.002 mg/L recorded in one sample (Georges River December 2019). Maximum wet weather concentration 0.003 mg/L.
Nickel (mg/L)	0.2	0.1	0.011	Maximum concentration of 0.003 mg/L recorded in 6 samples (two each from Upstream, Downstream and Georges River). Not detected in wet weather samples.

Parameter	NHMRC Recreation Guidelines	ANZECC Recreation Guideline	ANZECC Guidelines Freshwater*	Comments
Zinc (mg/L)	30	5	0.008	Detected at concentrations above ecosystem guideline value in 7 samples Upstream,11 samples Downstream, and 3 samples Georges River. Maximum concentrations of 0.05 mg/L (Upstream) and 0.053 mg/L (Downstream) during January 2020 were substantially greater than other recorded results. Wet weather concentrations of 0.026 mg/L (Upstream), 0.03 mg/L (Downstream), and 0.023 mg/L (Georges River).
Mercury (mg/L)	0.01	0.001	0.0006	Not detected at any of the sites during dry or wet weather sampling (LOR 0.0001 mg/L).

* For 95% species protection in South-East Australian waterways.

The following observations about the metals results to-date can be made:

- Cadmium, Lead and Nickel were not detected at concentrations greater than the ANZECC ecosystem protection guidelines during dry weather sampling.
- Arsenic and Chromium were infrequently detected at concentrations slightly greater than the ANZECC ecosystem protection guidelines at the Upstream and Georges River sites.
- Copper was infrequently detected at concentrations slightly greater than the ANZECC ecosystem protection guidelines at the three sites.
- Zinc was frequently detected at concentrations slightly greater than the ANZECC ecosystem protection guidelines at the Upstream and Downstream sites, and infrequently at the Georges River site. The Upstream and Downstream sites both recorded greater zinc concentrations (~0.05 mg/L) in the January 2020 samples.

These data indicate that, under pre-construction conditions and inflows, the concentrations of some metals can sometimes be expected to exceed guideline concentrations at the three monitored sites. In particular, Zinc concentrations can be expected to regularly exceed the ANZECC guideline threshold at the Upstream and Downstream sites, in the absence of construction activities.

3.4 Other urban pollutants

Testing for a range of other analytical parameters was performed for all samples, including organochlorine (OC) and organophosphate (OP) pesticides, PAH and phenolic substances, semi-volatile total recoverable hydrocarbons (TRH), and volatile TRM including BTEXN (benzene, toluene, ethylbenzene, xylene and naphthalene). The results for these analyses were negative (below the limit of reporting) for all samples, including dry and wet weather monitoring.

3.5 Wet weather event monitoring

One wet weather event was sampled during the reporting period; on 7 February 2020. Commentary about the wet weather data has been included with each of the analytical parameters, and is summarised as follows:

- Of the monitored physico-chemical parameters, pH was not noticeably affected by wet weather, EC was reduced, and turbidity and TSS were increased. These changes can be attributed to the dilution of salinity and the effect of stormwater inflows containing suspended material on the waterway.
- Enterococci concentrations were greatly increased following wet weather. This can be attributed to stormwater inflows mobilising and transporting faecal material to the waterway (ie Sewage overflows).
- For nutrients, wet weather ammonia concentrations were similar to dry weather median data, whilst for other nutrients the wet weather concentrations were similar to dry weather maxima.
- Of the monitored rmetals; cadmium, nickel and mercury were not detected in wet weather samples. The other metals were similar to dry weather concentrations.
- The other tested contaminants (pesticides and hydrocarbons) were not detected in dry or wet weather sampling.

3.6 Summary of surface water quality sites

A summary of the water quality obtained from the surface water monitoring is presented in Table 3.14. These data indicate that:

- pH was almost always within the ANZECC guideline range, with one Upstream sample outside of the range.
- EC was almost always within the ANZECC guideline range, with the exception of the Georges River site, which has marine influences.
- Turbidity was sometimes greater than the ANZECC guideline threshold, more frequently at the Downstream and Georges River sites than the Upstream site.
- TSS was always less than the adopted guideline threshold.
- Enterococci concentrations were frequently above the secondary contact recreation threshold at the Upstream site, and progressively less frequently above this threshold at the Downstream and Georges River sites. E. coli concentrations were not compared here due to the increased die-off of this organism under saline conditions.
- Nutrient concentrations were frequently above the ANZECC guideline thresholds at the Downstream and Georges River sites, and less frequently elevated at the upstream site.
- Seasonal variations where generally not observed, during the wet weather event sampled, increases in faecal material was noted in the analysis.

Table 3.14 Summary of water quality data (May 2019 – April 2020) – exceedance of default ANZECC guideline values (% of samples)

Site	pH	EC	Turbidity	TSS	Enterococci	Ammonia	NOx	TN	SRP	TP
Upstream	8.3	0	33.3	0	75.0	33.3	25	8.3	16.7	25
Downstream	0	8.3	66.7	0	33.3	58.3	75	33.3	0	33.3
Georges River	0	83.3	58.3	0	8.3	66.7	75	50	33.3	66.7

Note: Results are summarised from the values presented in the previous tables in this report, of the percentage of results outside of guideline ranges.

The following observations summarise the water quality characteristics of the monitored sites:

3.6.1 Upstream

- Small amount of tidal influence on EC.
- Some effects of turbid inflows.
- Enterococci concentrations usually above the secondary contact recreational guideline, indicating ongoing effect from faecal contamination during dry weather.
- A substantial increase in enterococci concentrations during wet weather.
- Nutrient concentrations sometimes above ANZECC guidelines, although less frequently than observed at the other monitored sites.
- Some metals infrequently recorded above ANZECC ecological guidelines (As, Cr, Cu). Zn was frequently recorded above ANZECC guidelines.
- No pesticides or hydrocarbons detected.

3.6.2 Downstream

- More elevated EC than Upstream, attributed to tidal effects.
- Turbidity more frequently elevated than Upstream.
- Enterococci concentrations sometimes above the secondary contact recreational guideline, indicating some effect from faecal contamination during dry weather.
- A substantial increase in enterococci concentrations during wet weather.
- Nutrient concentrations frequently above ANZECC guidelines, particularly the nitrogenous nutrients.
- Some metals infrequently recorded above ANZECC ecological guidelines (Cu). Zn was frequently recorded above ANZECC guidelines.
- No pesticides or hydrocarbons detected.

3.6.3 Georges River

- More elevated EC than the other sites, attributed to tidal effects.
- Turbidity more frequently elevated than Upstream.
- Enterococci concentrations infrequently above the secondary contact recreational guideline, indicating some effect from faecal contamination during dry weather.
- A substantial increase in enterococci concentrations during wet weather.
- Nutrient concentrations frequently above ANZECC guidelines.

- Some metals infrequently recorded above ANZECC ecological guidelines (As, Cr, Cu, Zn).
- No pesticides or hydrocarbons detected.

3.7 Long term data comparison

Some long term monitoring data are available for this area. The GRCCC has generously shared their monitoring data for two sites on Cabramatta Creek (Cabramatta Creek Upper and Cabramatta Creek Lower), so as to allow a comparison of the described project data with a dataset gathered over a longer period. The Upper Cabramatta Creek sampling location is near 94 Bugong Road, Prestons well upstream of the project site. The Lower Cabramatta Creek sampling location is at the same location adjacent to Broomfield St as this project has noted as the 'downstream' sampling location. The GRCCC dataset includes other parameters that have not been summarised here. The dataset is comprised of samples taken between 1 November 2009 and 31 March 2020. Non-numeric data have been treated the same way as in the earlier data analysis (ie <x = x/2).

The GRCCC data have been summarised in Table 3.15 and Table 3.16. From a brief and non-systematic comparison, the datasets appear to be relatively similar. The concentrations of TN and TP in the 11-year dataset are more elevated than those recorded in the recent sampling, this may be due to different rainfall patterns and/or changes in catchment land use between the two study periods.

Table 3.15 GRCCC Cabramatta Creek Upper – data summary

Parameter	N	Min	Max	Mean	Median	80th %ile	20th %ile
pH (units)	17	5.98	8.11	7.09	7.15	7.39	6.84
EC (µS/cm)	19	542	3770	1582	1087.4	2470	950.8
Turbidity (NTU)	18	3.4	216	41.38	20.85	52.34	7.84
TSS (mg/L)	4	2.5	126	35	5.75	55.8	2.5
Enterococci	0	-	-	-	-	-	-
Ammonia (mg/L)	13	0.04	1	0.3	0.25	0.46	0.08
NOx (mg/L)	16	0.0025	0.34	0.1	0.04	0.23	0.01
TN (mg/L)	19	0.6	2.9	1.36	1.2	1.74	0.98
SRP (mg/L)	10	0.01	0.14	0.049	0.024	0.083	0.018
TP (mg/L)	19	0.03	0.8	0.25	0.18	0.34	0.12

Table 3.16 GRCCC Cabramatta Creek Lower – data summary

Parameter	N	Min	Max	Mean	Median	80th %ile	20th %ile
pH (units)	29	6.07	8.19	7.28	7.37	7.532	7.02
EC (µS/cm)	31	434	2800	1108	971	1625	559
Turbidity (NTU)	31	0	114	14.5	9.3	16.5	4.2
TSS (mg/L)	4	2.5	15	5.6	2.5	7.5	2.5
Enterococci	0	-	-	-	-	-	-
Ammonia (mg/L)	14	0.0025	0.06	0.02	0.02	0.024	0.0092
NOx (mg/L)	30	0.005	0.38	0.102	0.065	0.16	0.02
TN (mg/L)	31	0.2	6.9	0.76	0.55	0.8	0.4
SRP (mg/L)	10	0.004	0.027	0.014	0.012	0.023	0.005
TP (mg/L)	30	0.005	0.94	0.08	0.05	0.08	0.03

4. Discussion and recommendations

4.1 General observations

This reports builds on the data and information provided by Technical Report 7 – Surface Water and Groundwater Quality Impact Assessment. This describes, in detail, the existing environmental conditions in the project area, with regard to surface water.

The intention of the monitoring program seeks to establish baseline surface water quality conditions for the project area. Establishing this will enable the achievement of Level 2 of the credit Env-1 from the Infrastructure Sustainability Rating Scheme v2.0 by establishing pre-construction baseline surface water quality data which will subsequently be compared to construction and operational monitoring data. The available twelve month baseline monitoring period was defined by ARTC prior to the potential start of construction activities. Site specific guideline levels have been defined based on the existing conditions of the sites as measured by the baseline water quality monitoring program. These values are presented in section 3.2 and will be used to confirm whether the proposed water quality controls and management measures during and following construction will meet the water quality objectives (ARTC, 2019).

Whilst the overall amount of rainfall was similar to the long term average, the distribution of rainfall was different. Rainfall was extremely light throughout most of the reporting period, with the exception of two wet weather events in September 2019 and February 2020. Eight of the twelve months in the period were drier than the corresponding long-term median. Most of the rainfall recorded fell during the February 2020 event; 328 millimetres fell between 7 and 10 February, and 160 millimetres was recorded on 10 February alone. As described, one wet weather sampling event was performed in February 2020. Additional wet weather sampling would have been preferable to better establish wet weather water quality conditions, however such sampling is of course weather-dependent, and was not able to be performed in the monitoring timeframe.

Two notable characteristics of all of the sites are elevated enterococci levels, and nutrient enrichment, which are both closely related to land use. Elevated enterococci levels are indicative of potential faecal contamination from sources such as sewage overflows, urban runoff and agricultural inputs within the catchment draining to the creek (typical of a catchment of this nature). These were noted to greatly increase during sampling of the wet weather event on 7 February 2020. The enterococci levels found during sampling are infrequently above the recreational guideline value for secondary contact.

Nutrient enrichment of both standing pools and flowing waterways is common, indicated particularly by highly elevated concentrations of TP, TN, NOx and ammonia. Runoff of these nutrients can be expected from landscaped parks and recreational areas along with golf courses that may use nutrient rich fertilisers for lawns in these areas.

Some metals were detected infrequently at most sites, with only copper and zinc being more frequently recorded at concentrations greater than ANZECC ecosystem protection guidelines.

Hydrocarbons were not detected at the surface water sites. Of the other monitored potential pollutants, including OC/OP pesticides, PAHs, and phenolic substances, the analyses were negative for all samples, including dry and wet weather monitoring.

A brief and non-systematic comparison with the GRCCC long term water quality dataset 2009-2020 found that more elevated TN and TP concentrations have been recorded in Cabramatta Creek in the last 11 years, compared with what was recorded in the 12 month dataset for this project. This observation may be linked to differences in rainfall patterns between those time periods, and/or changes in land use in the creek catchment area. More detailed examination of the longer term dataset may be warranted if concentrations of water quality parameters during construction monitoring deviate significantly from those recorded in the pre-construction phase. This is to be determined whether necessary by ARTC during further phases of the proposed assets life cycle.

4.1.1 Rain events

Water quality monitoring was performed after a single rain event, following heavy rainfall on 7 February 2020. The results of the wet weather monitoring included:

- Decreased EC at the sites.
- Markedly increased turbidity and TSS for the wet weather event at the sites.
- Increased enterococci concentrations at most sites, this can be attributed to stormwater inflows mobilising and transporting faecal material to the waterway.
- For nutrients, wet weather ammonia concentrations were similar to dry weather median data, whilst for other nutrients the wet weather concentrations were similar to dry weather maxima.
- Of the monitored metals, cadmium, nickel and mercury were not detected in wet weather samples. The other metals were similar to dry weather concentrations.
- The other tested contaminants (pesticides and hydrocarbons) were not detected in dry or wet weather sampling.

These results are as expected in wet weather flows through areas where urbanisation through the catchment has occurred, as it has in much of the Cabramatta Creek catchment.

4.2 Summary and recommendations

The sampling and monitoring shall be undertaken as determined by ARTC, to allow the collection of data during the construction and operational phases that can be compared against the baseline data. Implementation of the monitoring program has enabled the collection of surface water quality data of the selected sites. Sampling was performed mostly under dry weather conditions, as well as the monitored rain event.

It is recommended that if sampling sites need to be moved, that this can occur in advance of access becoming restricted, and that it is to be described and considered in any subsequent reporting. Restricted access may occur as future construction progresses (namely around the sampling location downstream of the project site).

It is recommended that if potential water quality effects on the sites from nearby construction become known, that these are described and considered in subsequent reporting. Details of monitoring requirements of water discharge and receiving water quality is recommended to be included in relevant management plans for construction and operation.

5. References

ANZECC (2000) Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Australian Rail Track Corporation (2019), *Cabramatta Rail Loop Environmental Impact Statement: Technical Report 7 – Surface Water and Groundwater Quality Impact Assessment.*

Bewsher Consulting Pty Ltd(2004), *Georges River Floodplain Risk Management Study and Plan,* Georges River Floodplain Management Committee.

BOM (2018), Long-term Rainfall Data for Bankstown Aerodrome station 13667, Bureau of Meteorology. http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=066137.

Georges Riverkeeper (2020), Interactive map of the Georges River. https://georgesriver.org.au/learn-about-the-river/georges-river-map.

Georges River Combined Councils Committee Incorporated, 2018, *2016-2017 River Health Georges River Report Card.* NHMRC (2008). National Health & Medical Research Council. Guidelines for managing risk in recreational waters. Australian Government Publication.

NSW EPA (2004), *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales*. Department of Environment and Conservation (NSW).