# Featherston WWTP Discharge Consent Application - Water Quality Assessment

28 February 2017

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# Issue and Revision Record

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**Information class: Standard**

# Contents

# Executive Summary

## Introduction

South Wairarapa District Council ("SWDC") is legally responsible for the operation of wastewater treatment and disposal facilities throughout the District including the Featherston Wastewater Treatment Plant (WWTP). The Featherston WWTP's resource consent expired on 25 August 2012 and the site has been operating under a variation that allows continued operation until a new wastewater management approach is consented.

As part of the reconsenting process, work relating to discharge water quality and flow and receiving water quality and flow was undertaken by Mott MacDonald (MM). This work included:

- Review of Featherston WWTP discharge monitoring data and assessment of compliance with current consent conditions;
- A review of appropriate water quality guidelines for assessing surface water in Donald Creek;
- Assessment of current water quality in Donald Creek upstream and downstream of the discharge;
- Mass balance modelling to predict downstream load and concentrations of Total Nitrogen (TN), Dissolved Inorganic Nitrogen (DIN), Dissolved Reactive Phosphorus (DRP), Total Phosphorus (TP) and Total Biochemical Oxygen Demand ($TBOD_5$); and
- Monte Carlo mass balance modelling to better refine predictions of total ammoniacal nitrogen ($NH_4$-N) downstream of the discharge.

## Discharge Water Quality and Compliance

The measured flow and water quality of the Featherston WWTP discharge was assessed for compliance with current consent conditions.

Due to lack of definition of wet and dry discharge scenarios in the consent it was not possible to fully assess the discharge flow compliance. However, from March 2005 to May 2015 the site had flows below the consent limits over 99.5% of the time. During summertime there were five exceedances of the 9,000 $m^3$/day dry weather flow consent limit (out of 1872 days) and during winter there were four exceedances for the 12,000 $m^3$/day wet weather flow consent limit (out of 1937 days).

The site was fully compliant with all water quality consent limits for pH, $TBOD_5$, Total Suspended Solids (TSS), *E.Coli*, TN, Total Ammoniacal Nitrogen ($NH_4$-N), TP and DRP.

Assessment of the performance of the Featherston WWTP has been undertaken by g2e (2013). Based on analysis of the remaining water depth, pond volumes and the plant's remaining overall treatment capacity (confirmed following sludge surveys), the quality of treatment which should theoretically be achievable is close to what the plant is currently achieving, especially in respect to final effluent TSS and $BOD_5$ concentrations. Therefore, the plant is considered to be currently performing as would be expected.

## Receiving Water Quality Guidelines

A full review of available and relevant receiving water guidelines was undertaken as part of the assessment. The selection of the appropriate guidelines was undertaken in a hierarchical way with the statutory documents (Resource Management Act (1999), National Policy Statement for Freshwater Management (MfE, 2014) and Greater Wellington Regional Plans given precedence, followed by the effects based guidelines (ANZECC, 2000, and NIWA 2013 and 2014), with consideration given to other documents such as Aquanet (2013a and b). A full discussion of the guidelines used in this assessment is provided in the main body of this report (Section 3), a summary of the guidelines used for the assessment are provided Table 1.

**Table 1: Summary of selected water quality guidelines**

| Parameter | Limit | References |
|---|---|---|
| Temperature | No greater than a 3ºC change<br>Maximum of 25ºC | RMA (1999)/ FWP (2014)/ FWP (2014)/ PNRP (2015)<br>RMA (1999)/ FWP (2014) |
| pH | Between 6and 9<br><0.5 pH unit change | FWP (2014)<br>Aquanet (2013a)/ PNRP (2015) |
| Dissolved oxygen | >80% saturation<br>>5 g/m$^3$ | RMA (1999)/ FWP (2014)<br>NPS-FM (2014) Attribute B/ FWP (2014)/ PNRP (2015) |
| Visual clarity | >1.6 m<br>> 0.5 m<br><33% Change | MfE (1992)/ Aquanet (2013)<br>Aquanet (2013) Class C6c<br>PNRP (2015) Aquanet (2013) |
| Soluble carbonaceous BOD$_5$ | < 2 g/m$^3$ | Aquanet (2013) |
| Total Ammoniacal Nitrogen | pH dependant based on annual median and 95th percentile. | NPS-FM (2014) National bottom line<br>USEPA (2013) – Acute guidelines<br>NIWA (2014) – Chronic guidelines |
| Nitrate | <2.4 g/m$^3$ annual median<br><5.4 g/m$^3$ Annual 95th percentile | NIWA (2013)<br>NIWA (2013) |
| *E.Coli* | <260 cfu/100mL – “Green Mode”<br>>550 cfu/100mL – “Red Mode”<br><1000 cfu/100mL – median | MfE (2003)<br>MfE (2003)<br>PNRP (2015) |
| **Nutrients –guidelines (for reference only)** | | |
| Dissolved inorganic nitrogen | 0.63 g/m$^3$ | NIWA (2016) |
| Total phosphorus | 0.045 g/m$^3$ | NIWA (2016) |
| Dissolved reactive phosphorus | 0.011 g/m$^3$ | NIWA (2016) |

## Receiving Water Quality

The receiving water quality upstream and downstream of Donald Creek was assessed against the guidelines presented in Table 1 above and is summarised briefly below.

### Temperature

The temperature upstream and downstream of the discharge had a range of between 7ºC and 20ºC and the difference between upstream and downstream temperatures was consistently less than 3ºC, and there were no non-compliances with the temperature guidelines.

### pH

The pH in Donald Creek upstream and downstream of the discharge is typically between 6.5 and 8. There was one noncompliance (out of 99 measurements) with the lower pH guideline (of 6) at the upstream site in 2006 and 6 noncompliance’s with the lower pH limit guideline at the downstream site in 2006 and 2007. However, the pH of the discharge was within the 6 and 9 guideline on all occasions and the non-compliances were not likely to be as a result of the discharge.

### Suspended Solids

The suspended solids in Donald Creek upstream and downstream of the discharge were typically below 40 g/m$^3$. The downstream suspended solids concentrations were greater than the upstream concentrations 75% of the time, indicating that the discharge is increasing the suspended solids downstream of the site.

### Visual Clarity

The visual clarity of the upstream site was between 1.1 and 3.5 m, and was greater than the MfE recreational guideline (1.6m) 84% of the time and always above the Aquanet (2013) guideline for protection of aquatic ecosystems for a class C6c River (0.5m).

The downstream had lower visual clarity than upstream on all but one occasion with clarity of between 0.45 and 1.9m. The downstream site had clarity greater than 1.6 m 4% of the time and greater than the Aquanet guideline 90% of the time. The reduction in visual clarity downstream of the discharge was greater than 33% (the PNRP (2015) water quality standard) recommended change in clarity for a River class 5, 74% of the time.

### Dissolved Oxygen

The DO of the upstream site was consistently above the DO concentration guidelines with a minimum value of 6.3 g/m$^3$. The downstream DO concentration was consistently above the Natural Bottom Line value and PNRP guideline of 4 g/m$^3$ (NPS-FM, 2014, PNRP, 2015) but below the NPS-FM (2014) State B attribute value of 5 g/m$^3$ on one occasion out of 71 measurements.

The percentage saturation was calculated based on the measured temperature and calculated theoretical 100% saturation value. The upstream DO saturation was below the RMA and Freshwater Plan guideline of 80% saturation 14% of the time. The downstream DO saturation was typically lower than upstream, but the differences were typically less than 10%. The downstream DO was below 80% for 24% of the time.

### BOD$_5$

The routine monitoring at the site analyses Total BOD$_5$ in the discharge and receiving water, however, water quality guidelines for BOD use the soluble carbonaceous fraction (scBOD$_5$).

The concentration of Total BOD was 3 g/m$^3$ or below in all upstream samples. The concentration of Total BOD downstream of the discharge was highly variable with concentrations between <1 g/m$^3$ and 17 g/m$^3$ with all but one sample having a concentration of less than 9 g/m$^3$.

In order to fill the gap in the monitoring data a series of grab samples were made in 2016 and 2017 (Table 9), based on this data scBOD$_5$ was between 8% and 16% of the TBOD$_5$ in the discharge and between 3 and 25% at the downstream site. Based on this the scBOD$_5$ concentration downstream of the site would at times exceed the guideline value of 2 g/m$^3$ and there would be potential for heterotrophic growths.

### *E.Coli*

The number of *E.coli* upstream of the discharge was elevated above the Green Mode guideline 53% of the time, the Red Mode guideline 23% of the time but achieved compliance with the PNRP secondary contact recreation objective of <1000 *E.Coli* / 100mL as a median.

The number of *E.Coli* upstream of the discharge and downstream of the discharge was highly elevated prior to 2011. Since 2011, following installation of the UV treatment plant, the *E.Coli* numbers have decreased both in the discharge and downstream of the discharge. After 2011 the discharge exceeded the “Green Mode” guideline on 3 occasions (out of 21 samples) and the “Red Mode” guideline twice. Of the three exceedances of the Green Mode guideline only one exceedance resulted in an exceedance of Red Mode guideline downstream of the discharge (12th April 2013, 7000 *E.Coli* cfu/100mL). On the other two occasions the *E.Coli* numbers downstream of the discharge were lower than upstream which exceeded the Green Mode guideline.

### Total Ammoniacal Nitrogen

The upstream concertation was in the range <0.01 g/m$^3$ to 0.20 g/m$^3$, while downstream was more variable and usually elevated above upstream concentrations (due to evaluated concentrations of ammoniacal nitrogen in the effluent) with a range of between <0.01 g/m$^3$ and 3.18 g/m$^3$.

The assessment of the Total Ammoniacal Nitrogen ($NH_4$-N) concentration was undertaken using indicative guidelines derived by NIWA (2014) and the National Bottom Line described in the NPS-FM (2014). The NIWA (2014) guidelines require comparison of the median and 95th percentile concentration of the monitoring data and are pH adjusted. In addition, the NIWA (2014) guideline that would be protective of the Fingernail Clam (known to be present in Donald Creek) and protective of the more species Freshwater Mussels (not known to be present in Donald Creek) were considered.

The total ammoniacal nitrogen concentration upstream of the site was below the median and 95th percentile guideline concentrations for all years assessed for both levels of protection, and all values were below the national bottom line guidelines.

The downstream annual median total ammoniacal nitrogen concentration exceeded the pH dependant median guideline protective of Freshwater Mussels in 6 of the 10 years and exceeded the 95th percentile pH dependant guideline in 9 of the 10 years assessed. The ammonia concentration at the downstream site exceeded the pH dependant guidelines protective of the Fingernail Clam in 2007 and 2014 (i.e. 2 out of 10 years).

### Nitrate

The concentration of nitrate and total oxidised nitrogen upstream and downstream of the site was consistently below the nitrate-nitrogen guidelines for both the annual median (2.4 g/m$^3$) and annual 95th percentile (3.5 g/m$^3$) and there were no observed non-compliances during the monitoring. There was a minor increase in nitrate downstream of the discharge 73% of the time, however, 85% of the increased concentrations were less than 0.15 g/m$^3$.

### Dissolved Inorganic Nitrogen

The upstream DIN concentrations were typically in the range 0.3 g/m$^3$ to 1.2 g/m$^3$, while the downstream concentrations were elevated, due to elevated DIN concentrations in the discharge, with concentrations typically in the range 0.6 g/m$^3$ to 1.9 g/m$^3$.

The upstream DIN concentration was above the DIN periphyton guideline (“good” water quality for angling, NIWA, 2016) 73% of the time, while the downstream DIN concentration was above the guideline 90% of the time. Given the upstream concentrations are frequently above the guideline, these guideline values are only useful to provide context but cannot be used to measure compliance.

### Total Phosphorus

The TP upstream of the site is typically in the range 0.02 g/m$^3$ to 0.4 g/m$^3$, while downstream concentrations were typically between 0.1 g/m$^3$ and 1.0 g/m$^3$. The TP concentration is almost always below the TP periphyton guideline (based on “good” water quality for angling, NIWA 2016) at the upstream site, while it is almost always above the indicative guideline at the downstream site due to elevated TP in the discharge.

### Dissolved Reactive Phosphorus

The concentration of DRP upstream of the site was typically between 0.005 g/m$^3$ and 0.03 g/m$^3$, while downstream concentrations were elevated, due to elevated concentrations in the discharge, with concentrations typically in the range of 0.05 g/m$^3$ and 0.55 g/m$^3$.

The upstream DRP concentration was above the DRP periphyton guideline (based on “good” water quality for angling) approximately 50% of the time, while the downstream DRP concentration was above the indicative guideline 100% of the time. Given the upstream concentrations are frequently above the guideline, the guideline value is only useful to provide context but cannot be used to measure compliance.

## Flow and Discharge MS Excel Modelling Results

### MS Excel Mass Balance Modelling Approach

The water quality of key conservative parameters were modelled by a mass balance approach for the Project’s staged development. The parameters modelled were $TNH_4$-N, TON, TN, DRP, TP and $TBOD_5$. A full description of the modelling approach, input values, assumptions and limitations can be found in the main body of this report (Section 5).

The Project will be staged in the following way, with each stage resulting in an increasing reduction in volume and load of the effluent discharged to Donald Creek, these scenarios were modelled for the assessment:

**Stage 1A:** Minor treatment pond improvements and irrigation to land starting with an area of 8Ha of land allowing for approximately 3-5% of the current average annual wastewater discharge volume. Stage 1a will be operational 2 years from the commencement of the consent.

**Stage 1B:** Irrigation area expanded to 78 Ha allowing for irrigation of approximately 44% of the current average annual wastewater discharge volume. At this stage the majority of discharges occur in winter months. Stage 1B will be developed in parallel with Stage 1A and will be operational 2 years after the commencement of the consent.

**Stage 2A:** The **i**nfiltration and inflow into the pipe sewage reticulation network is reduced by upgrading of the pipe network (known as I&I reduction), resulting in a reduction of an annual average daily inflow of approximately 35%. The area of irrigation is further increased allowing for irrigation of approximately 68% of the current average annual waste water discharge. During this Stage almost all effluent discharged to Donald Creek occurs during winter. Stage 2A will be operational 10 years after the commencement of the consent.

**Stage 2B**: A large storage pond is constructed to defer flows and provide additional storage. The buffering allows for approximately 94% of the average annual wastewater discharge volume to be irrigated. During this Stage discharge to Donald Creek occurs infrequently and in winter only with discharges targeting, in order of priority, 3 x median and 2 x median stream flow where practicable. Stage 2B will be operational 20 years after the commencement of the consent.

### Discharge flow analysis

The discharge flows predicted by LEI (2017) have been analysed. The overall discharge volume decreases as the staged development occurs. At Stage 1B the discharge to Donald Creek is approximately 56% of the current discharge, dropping to 32% in Stage 2A and only 6% in Stage 2B.

Under all scenarios more discharge occurs in winter than summer. As the development proceeds the percentage of flow discharging in winter increases. By Stage 1B the majority of the discharge occurs in June, July and August. Once the development reaches Stage 2B discharge only occurs during July and August and will not discharge in some years.

### River flow vs discharge frequency

The modelled discharge and Donald Creek data were assessed to determine the Creek flow regimes occurring when the WWTP is discharging to the Creek. As the project progresses the frequency of the discharge to the Creek decreases and the proportion of time the discharge occurs during elevated Creek flows (2 x and 3 x median flow) increases, and the potential for nuisance growths such as periphyton and sewage fungus decreases.

Under the current scenario and Stage 1A the WWTP discharges 99% of the time with the discharge occurring 13% of the time above 3 x median flow and 23% above 2 x the median flow. At Stage 1B the frequency of discharge to the Creek reduces to 51% of the time with discharge occurring 25% of the time above 3 x median flow and 46% of the time above 2 x median flow.

Once Stage 2B is operational the WWTP discharges to the Creek less than 5% of the time, 75% of discharges occur while the Creek is above 3 x the median flow and over 90% of the discharges occur at 2 x median flow.

### Predicted Nitrate Concentrations

The model was used to predict the nitrate concentration downstream of the site under the different scenarios for the different years modelled. The model predicts that under all scenarios the median concentration downstream of the discharge would be less than 1 g/m$^3$ and the 95th percentile concentration would be less than 2 g/m$^3$. Therefore, the concentration of nitrate downstream of the site is predicted to comply with the NIWA (2013) guidelines at all times.

### Total Nitrogen

Stage 1A is not predicted to result in any significant reduction of load or concentration of TN. When Stage 1B is operational there will be very little discharge to the Creek during summer and the median TN concentration will be similar to background concentrations. During winter, median TN concentrations are estimated to decrease from the current concentration (1.9 g/m$^3$) to 1.6 g/m$^3$. Stage 1B is predicted to result in a significant (42%) reduction in TN load discharged to the river compared to the existing scenario.

Stage 2A will result in a minor decrease in winter median TN concentration compared to Stage 1B and a 47% reduction of TN load compared to the existing scenario. Further improvement occurs in Stage 2B at which time it is predicted that the median winter TN concentration will be similar to background concentrations and there will be approximately a 79% reduction in annual TN load to the Creek.

#### Dissolved Inorganic Nitrogen

The change in DIN concentration and load is predicted to be similar to that of TN, with no significant improvement in Stage 1A. Stage 1B is predicted to have summer median concentrations similar to the medium background concentration, and winter concentrations will reduce compared to the existing scenario. A 35% reduction in DIN load, compared to the existing scenario is predicted for Stage 1B. Stage 2A will result in a minor decrease in DIN concentrations compared to stage 1B. The annual load of DIN discharging to the Creek is predicted to decease by 70% under Stage 2B.

At Stage 2B both the summer and winter median DIN concentration is predicted to be similar to background concentrations. The annual DIN load to the river is estimated to be reduced to70% of the existing scenario.

As the median upstream input DIN concentrations are above the guideline of 0.63 g/m$^3$ (NIWA, 2016: “good water quality for angling”) improvement in compliance cannot be assessed, but it is likely that median DIN concentration downstream of the WWTP will exceed the guideline most of the time.

#### Dissolved Reactive Phosphorus

Implementation of Stage 1A results in no significant change in DRP concentration or load compared to the existing scenario. Once Stage 1B is operational the median summer concentration is predicted to be similar to the background median concentration (0.013 g/m$^3$) and a 53% reduction in DRP load is predicted. During Stage 1B the median winter DRP concentration is predicted to decrease from the existing scenario (0.094 g/m$^3$) to 0.061 g/m$^3$. The model predicts that the DRP concentration will exceed the DRP guideline (0.011 g/m$^3$) (NIWA, 2016: “good water quality for angling”) 95% of the time.

Once Stage 2A is operational the median winter DRP concentration will decrease slightly from that of Stage 1B (0.061 g/m$^3$ to 0.053 g/m$^3$). At Stage 2A a load reduction of 60% compared to the existing load is predicted. The model predicts that during Stage 2A the indicative DRP guideline will be exceeded 88% of the time.

Further improvement occurs under Stage 2B at which time both summer and winter median DRP concentrations are predicted to be similar to background concentrations and with a 92% reduction in load. The compliance with the guideline (0.011 g/m$^3$) (NIWA, 2016: “good water quality for angling”) improves in Stage 2B with an estimated frequency of exceedance of 53%, this is in a similar range to the current upstream exceedance frequency of 49%.

### Ammonia Monte Carol Mass Balance Modelling Results

#### Monte Carlo Mass Balance Modelling Approach

Elevated concentrations of total ammoniacal nitrogen is one of the key concerns of the current and future discharges to Donald Creek. The conservative mass balance modelling described in Section 5 is highly conservative and therefore further work was undertaken using Monte Carlo simulation to get a better idea of the likely compliance with the relevant guidelines. Monte Carlo mass balance modelling was undertaken using the River Quality Planning (RQP) model (MB v2.5) from the United Kingdom Environment Agency. Monte Carlo simulation allows for distributions (assuming a log-normal distribution) to be used as inputs and randomly combines the distributions in a statistically valid way to generate a statistical output.

## Predicted Total Ammoniacal Nitrogen Concentrations

*Stage 1B*

As development of Stages 1A and 1B will occur in parallel and will be complete within two years of a consent being granted only the Stage 1B scenario (which includes the effect of Stage 1A), was modelled. The model predicts a significant decrease in median and 95th percentile concentrations of $TNH_4$-N downstream of the WWTP discharge, with no exceedances of the NPS-FM national bottom line.

Comparison of the modelled concentrations with NIWA (2014) guideline that would be protective of the Fingernail Clam indicates the median guideline would be complied with in all modelled years. The model predicts that the annual 95th percentile NIWA guideline would be exceeded in only 2008 out of the 11 years modelled. Comparison to the model run on the full dataset complies with both the median and 95th percentile guideline.

It should be noted that the 2008 year had one of the highest discharge flows, which occurred predominately in winter, and one of the lower summer low flows in Donald Creek. Further analysis of the 2008 year by undertaking seasonal modelling indicates that the 2008 year would be compliant with the guideline.

Comparison of the model results to the more stringent guidelines, that would be protective of Freshwater Mussels, indicates that at Stage 1B there would be some exceedances of the median $TNH_4$-N guideline (5/11 years modelled) and the downstream concentration would consistently exceed the annual 95th percentile guideline.

*Stage 2A*

Implementation of Stage 2A will further reduce the frequency and volume of summer discharges and this will further reduce $TNH_4$-N concentrations downstream of the discharge.

The level of compliance with the NIWA (2014) guideline protective of the Fingernail Clam will remain the same as Stage 1B with an exceedance of the 95th percentile guideline in 2008. As with Stage 1B this is most likely an over estimate by the model.

The level of compliance will improve in relation to the median NIWA (2014) guideline protective of the Freshwater Mussels with exceedances in 3 out of ten years predicted compared to 5 out of 10 as in Stage 1B

*Stage 2B*

Under Stage 2B no summer discharge occurs and discharge is only predicted to occur in July and August, thereby eliminating any potential summer effects from $TNH_4$-N toxicity.

The model predicts a significant decrease in 95th percentile and median $TNH_4$-N concentrations downstream of the WWTP, with no exceedances of the NIWA (2014) guideline protective of the Fingernail Clam, and only 1 exceedance of the NIWA 95th percentile guideline that would be protective of Freshwater Mussels. This exceedance is predicted to occur in 2008, when as discussed above (under Stage 1B) the model will be predicting some summer time discharges, when flow in Donald Creek is lower. At Stage 2B there will be no summer time discharges and seasonal modelling indicates that the 2008 year would comply with the NIWA guideline protective of Freshwater Mussels.

# 1 Introduction

South Wairarapa District Council ("SWDC") is legally responsible for the operation of wastewater treatment and disposal facilities throughout the District including the Featherston Wastewater Treatment Plant (WWTP). The Featherston WWTP's resource consent expired on 25 August 2012 and the site has been operating under a variation that allows continued operation until a new wastewater management approach is consented.

The Featherston WWTP currently discharges water into Donald Creek which converges with Abbot Creek 2km downstream and ultimately discharges into Lake Wairarapa (Figure 1).

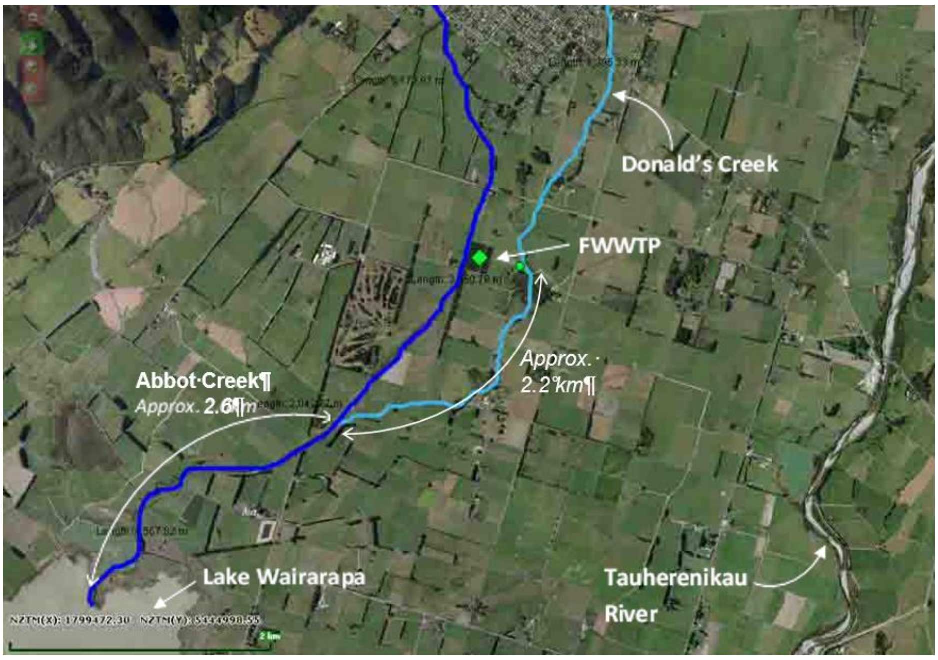
SWDC proposes to undertake staged upgrades to the Featherston WWTP to an irrigation based land treatment regime, including upgrades to the Featherston underground sewerage network. This will significantly reduce the discharge of wastewater to Donald Creek, and ultimately wastewater will only be discharged during winter. The staging of the Project is further described in Section 5 of this report (Water Quality Modelling).

As part of the Assessment of Environmental Effects (AEE), required for a new resource consent application, an assessment of effects on water quality is required, the assessments made in this report supports the assessment of effects on water quality presented in Section 6 of the Main AEE document (Mott MacDonald, 2017). This report provides the following:

- A summary of the current wastewater flows and quality and comparison to the current consent conditions;
- An assessment of the current effects on the water quality in Donald Creek, upstream and downstream of the discharge; and
- A description and summary of modelling of water quality under the proposed staged improvements to wastewater management.

The assessment of effects on water quality due to the Featherston WWTP on Donald Creek, Abbot Creek and Lake Wairarapa is presented in Section 6 of the Main AEE.

**Figure 1: Location of the Featherston WWTP and associated water ways**



# 2 Wastewater Flows and Quality

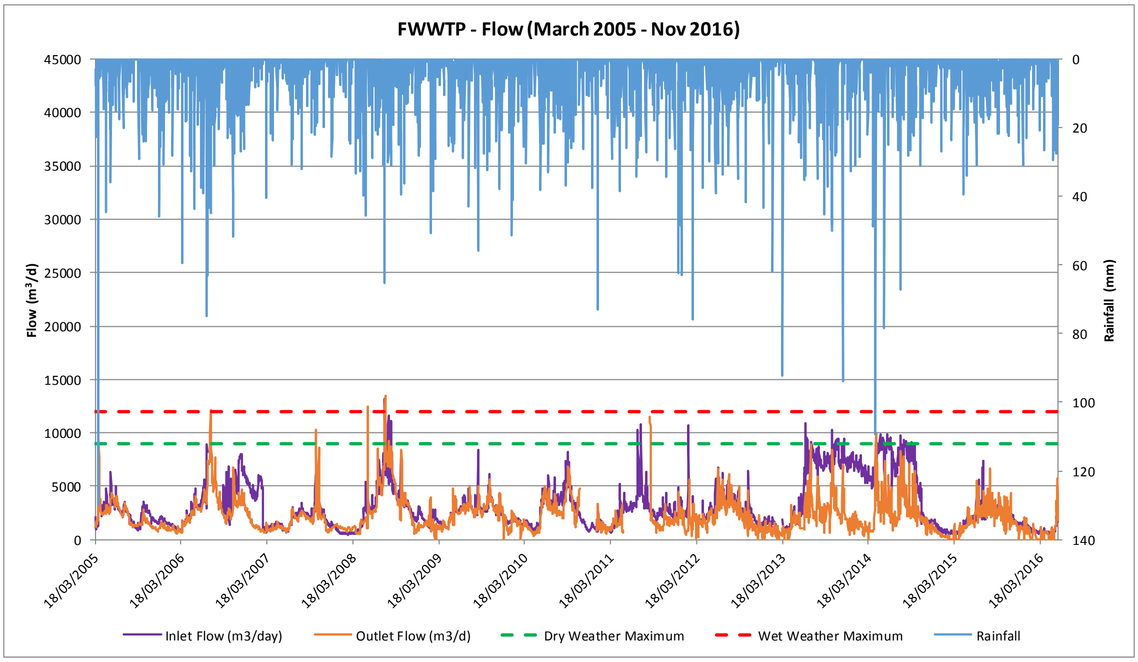
## 2.1 Introduction

The Featherston WWTP discharge flow and water quality are routinely monitored. The discharge flows are measured daily while the water quality monitored weekly or monthly. The current consent conditions for the site are presented in Table 2 and Table 3 for flow and water quality respectively. The following sections assess the compliance of the wastewater discharge with current consent conditions for the period 2005 to 2016.

## 2.2 Discharge flow volumes

The existing discharge consent allows the discharge of up to 9,000m$^3$ per day (dry weather flow) and up to 12,000m$^3$ per day (wet weather flow) to Donald Creek (Table 2). Influent and effluent flow volumes are monitored continuously by the operator. Flow volumes recorded between March 2005 and May 2016 are presented in Figure 2 below.

**Figure 2: Treated effluent Flow volumes between March 2005 and May 2016**



Source: *Rainfall used in the above figure has been sourced from the NIWA weather station at Woodside (approx. 6km north of Featherston).

On review of the data and annual compliance reports, there were a number of periods where faulty outflow meter readings were noted. These included a period toward the end of 2010 (8 November 2010 to 15 January 2011) and middle of 2011 (11 May 2011 to 1 September 2011) which have been removed from the dataset. Also we note the inflow meter appeared to be faulty or removed for service in early 2013 (1 March 2013 to 18 March 2013). During the middle of 2011 there may have been some exceedances in the 12,000m$^3$/d wet weather limit, however it is difficult to say whether the meter was reading correctly during this time. The outflow meter was subsequently replaced, and there have been no further issues in meter readings. The influent flow meter readings in 2013 appeared erroneous and as a result the meter was replaced by SWDC at the end of 2014. Data collected from June 2013 to the date of the meter replacement is therefore unreliable.

**Table 2: FWWTP Flow monitoring data March 2005 - May 2016 (N = 3809)**

| | Actual | Consent limit | Compliance achieved? |
|---|---|---|---|
| | | m3/d | |
| Average daily discharge | 2,271 | N/A | N/A |
| Median Daily Discharge | 1,911 | N/A | N/A |
| 90th %ile | 4,146 | | |
| Max daily discharge | 13,432 | N/A | N/A |
| Summer Average Daily Discharge | 1,495 | | |
| Summer Maximum | 10,076 | 9,000 | No |
| Winter Average Daily Discharge | 3,021 | | |
| Winter Maximum | 13,432 | 12,000 | No |

We note that a true dry weather and wet weather analysis has not been undertaken. To do this daily rainfall data should be evaluated to determine whether outflows are corresponding to dry and wet weather events. Instead a seasonal analysis has been undertaken. From March 2005 to May 2016 the site had flows below the consent limits over 99.5% of the time. During summertime there were five exceedances of the 9,000 $m^3$/day dry weather flow consent limit (out of 1872 days) and during winter there were four exceedances for the 12,000 $m^3$/day wet weather flow consent limit (out of 1937 days).

## 2.3 Wastewater Quality

### 2.3.1 Consent Conditions

Condition 16 of the consent outlines the effluent quality requirements, prior to discharge to the Donald Creek and is presented below in Table 3.

**Table 3: Effluent quality consent limits**

| Parameter | Standard Type | Standard | Frequency |
|---|---|---|---|
| pH (pH units) | Acceptable range | 6 – 9.5 | quarterly |
| Total carbonaceous BOD5 (g/$m^3$) | Maximum | 40 | quarterly |
| Total suspended solids (g/$m^3$) | Maximum | 175[a] | quarterly |
| Escherichia coli (cfu/100mL) | Maximum | 100,000[b] | quarterly |
| Ammoniacal nitrogen (g/m3) | Maximum | 18 | quarterly |
| Total nitrogen (g/m3) | Maximum | 25 | quarterly |
| Dissolved reactive phosphorus (g/$m^3$) | Maximum | 8 | quarterly |
| Total Phosphorus (g/$m^3$) | Maximum | 10 | quarterly |
| Temperature (°C) | | N/A | Weekly |
| Dissolved Oxygen (gO/$m^3$) | | N/A | Weekly |
| pH | | See above | Weekly |
| Electrical Conductivity (µS/cm) | | N/A | Weekly |
| Colour | Visual inspection | N/A | Weekly |
| Foam and Scum | Visual inspection | N/A | Weekly |

Notes:

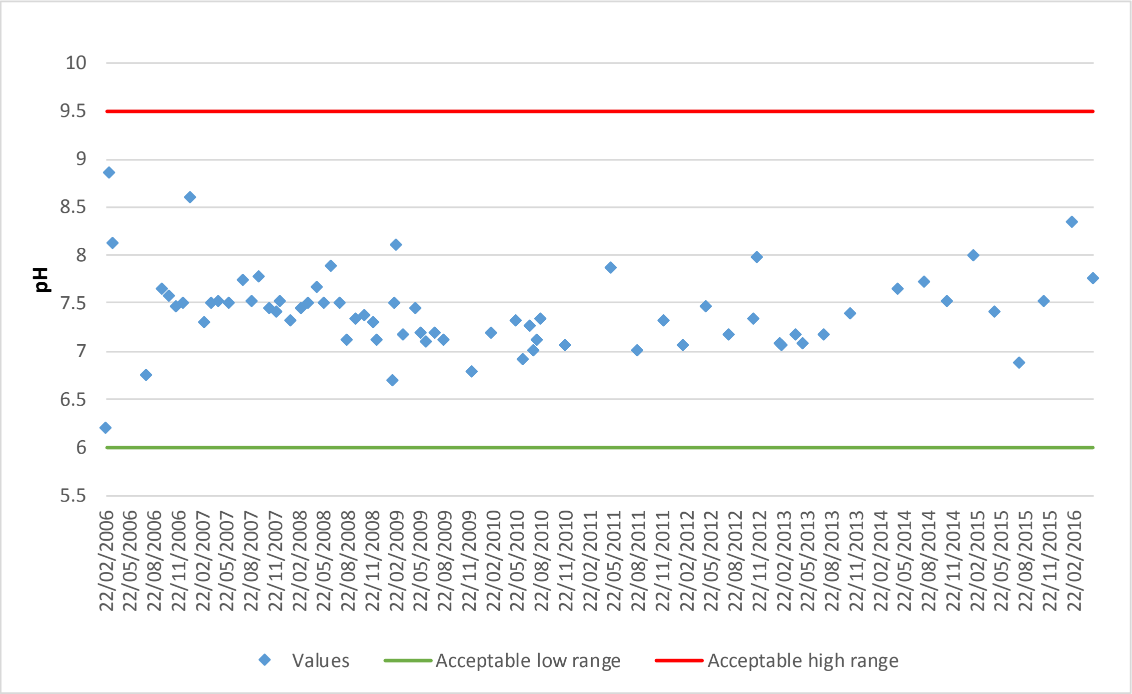
a. This standard may be exceeded where the permit holder can demonstrate that it was a result of increased algal growth in the new maturation cells
b. Note that the target maximum concentration once the new maturation cells are operative shall be 15,000 cfu/100mL

Effluent quality information has been reviewed in the following sections for key parameters of importance for the assessment of the effects of the discharge to land and water, and to assess compliance with consent conditions. The time periods assessed were February 2006 to May 2016 for monthly monitored parameters and April 2010 to June 2016 for weekly monitored parameters.

### 2.3.2 pH

Monitoring results for pH (Figure 3) indicate that the effluent is near neutral and has consistently complied with the minimum and maximum consent limits (6 and 9.5)

**Figure 3: Effluent pH**

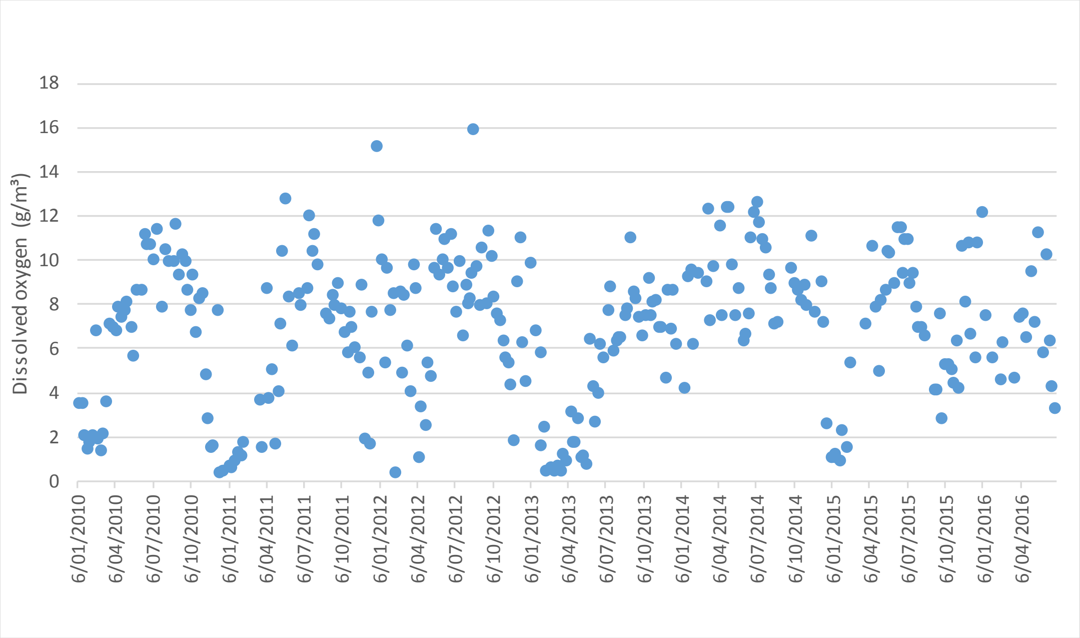


Source: SWDC monitoring data

### 2.3.3 Dissolved Oxygen

Currently there are no consent limits for DO. The DO of the effluent was between 0.5 g/m$^3$ and 16 g/m$^3$ for the last five years (Figure 4). Seasonal trends are evident in the data with high DO concentrations occurring in winter when concentrations are typically between 6 g/m$^3$ and 12 g/m$^3$, and lower DO concentrations recorded in summer typically between 0.5 g/m$^3$ and 4 g/m$^3$. This relationship is expected as the solubility of DO is higher in colder temperatures.

**Figure 4: Effluent dissolved oxygen concentration**

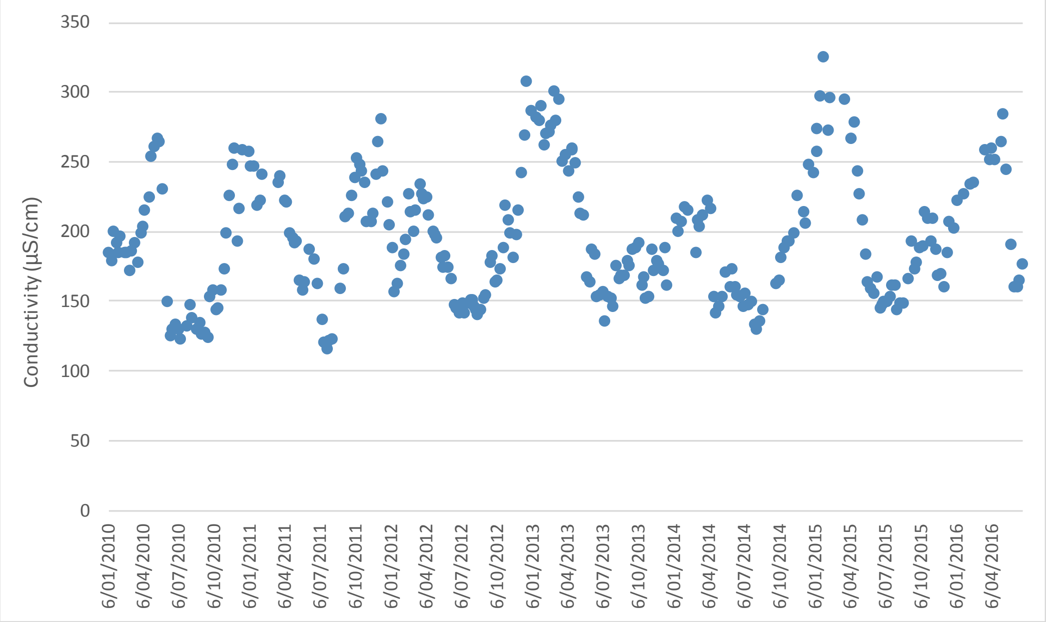


Source: SWDC monitoring data

### 2.3.4 Electrical Conductivity

The Electrical Conductivity (EC) in the effluent is presented in Figure 5. The EC of the effluent showed a strong seasonal trend with EC typically between 130 µS/cm and 150 µS/cm in winter and between 200 µS/cm and 300 µS/cm in summer.

**Figure 5: Effluent electrical conductivity**

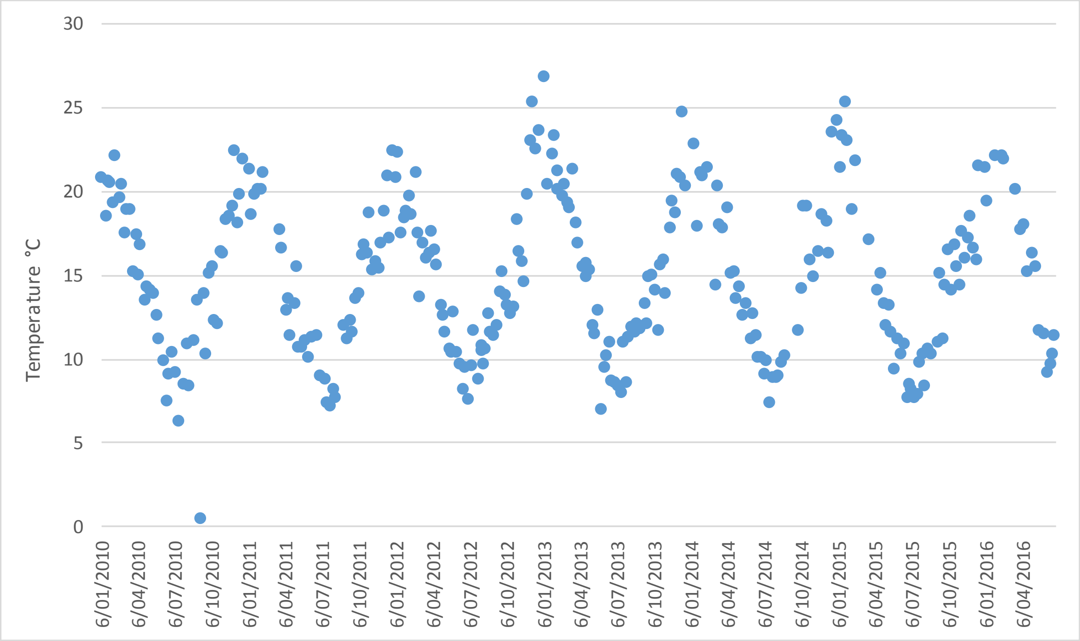


Source: SWDC monitoring data

### 2.3.5 Temperature

The temperature of the wastewater discharge shows a strong seasonal relationship with temperatures below 10ºC being measured in winter and temperatures above 18ºC being measured in summer (Figure 6).

**Figure 6: Effluent Temperature**

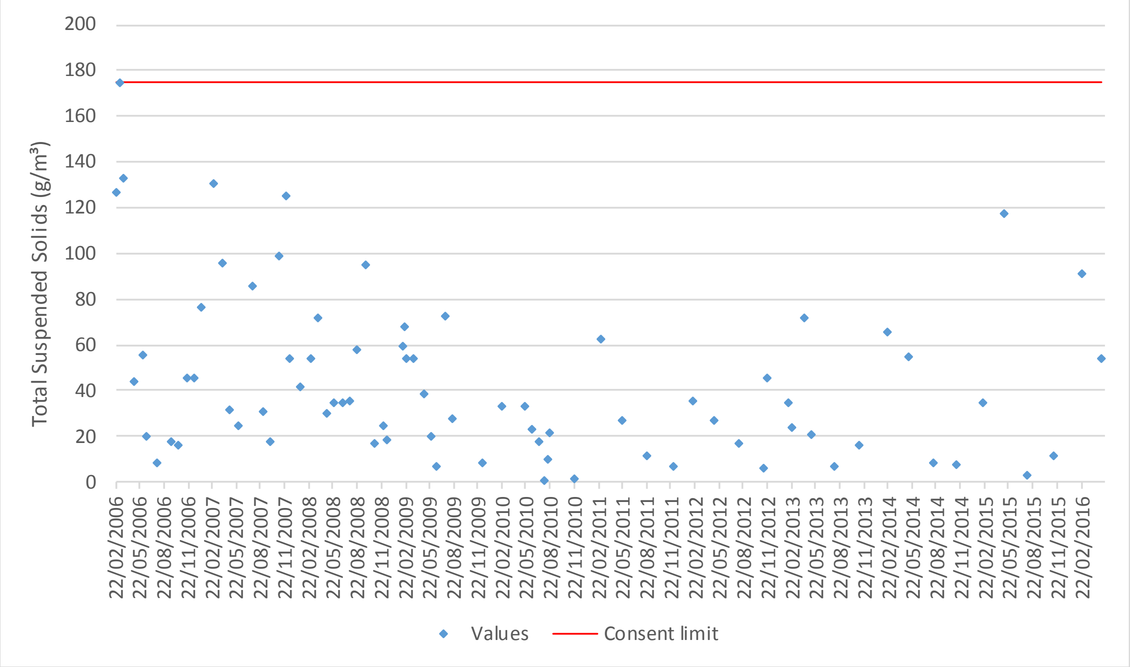


Source: SWDC monitoring data

### 2.3.6 Suspended Solids

Monitoring results for TSS indicate full compliance with the consent limit (175 g/m$^3$) with a maximum of 175 g/m$^3$ recorded in 2006 (Figure 7). The TSS of the effluent was typically below 100 g/m$^3$ during the monitoring period.

**Figure 7: TSS in the Effluent**

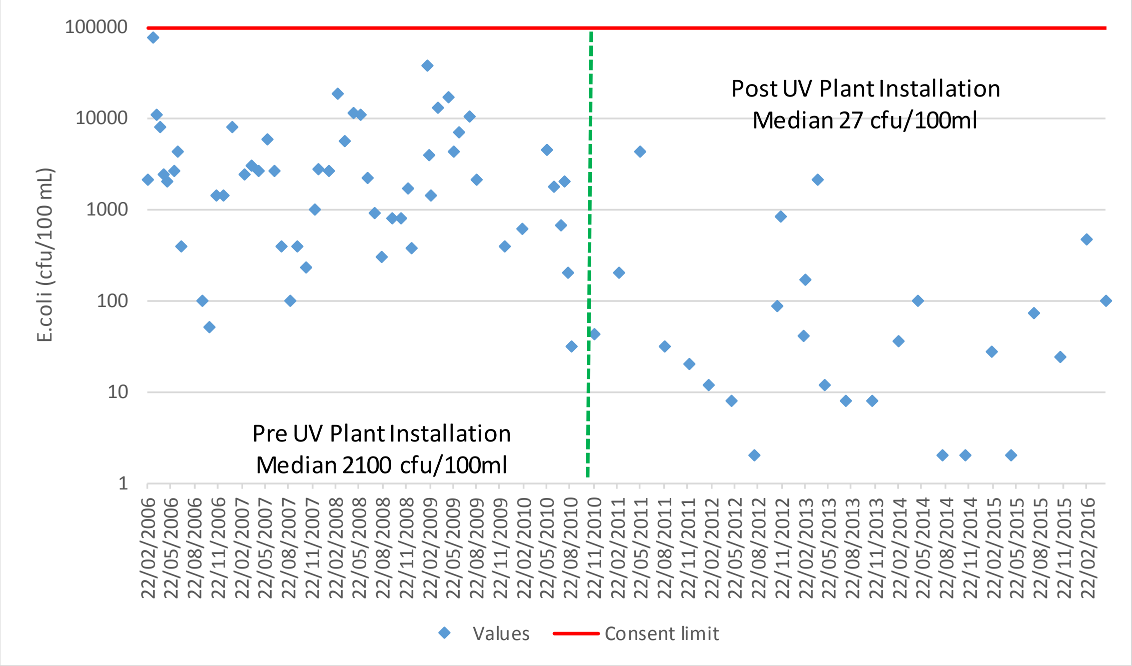


Source: SWDC Monitroing data

### 2.3.7 *E.Coli*

SWDC installed an ultraviolet (UV) disinfection unit in December 2011 resulting in a notable reduction in *E.Coli* number in the discharge (Figure 8). Monitoring results from 2006-2011 give a median of 2050 cfu/100ml, which has decreased to 27 cfu/100ml since 2011. All results are well within the consented 100,000cfu/100ml limit. The *E.Coli* numbers in the discharge exceeded the MfE (2003) recreational guideline (Green Mode) of 260 *E.Coli* cfu/100mL on four occasions since the installation of the UV plant in 2011 (4,300 *E.Coli* cfu/100mL), 2012 (820 *E.Coli* cfu/100mL), 2013 (2,100 *E.Coli* cfu/100mL) and 2016 (470 *E.Coli* cfu 100mL), however have achieved compliance with the PNRP secondary contact recreation objective of median <1,000 cfu/100ml.

**Figure 8: Effluent *E.Coli* numbers**

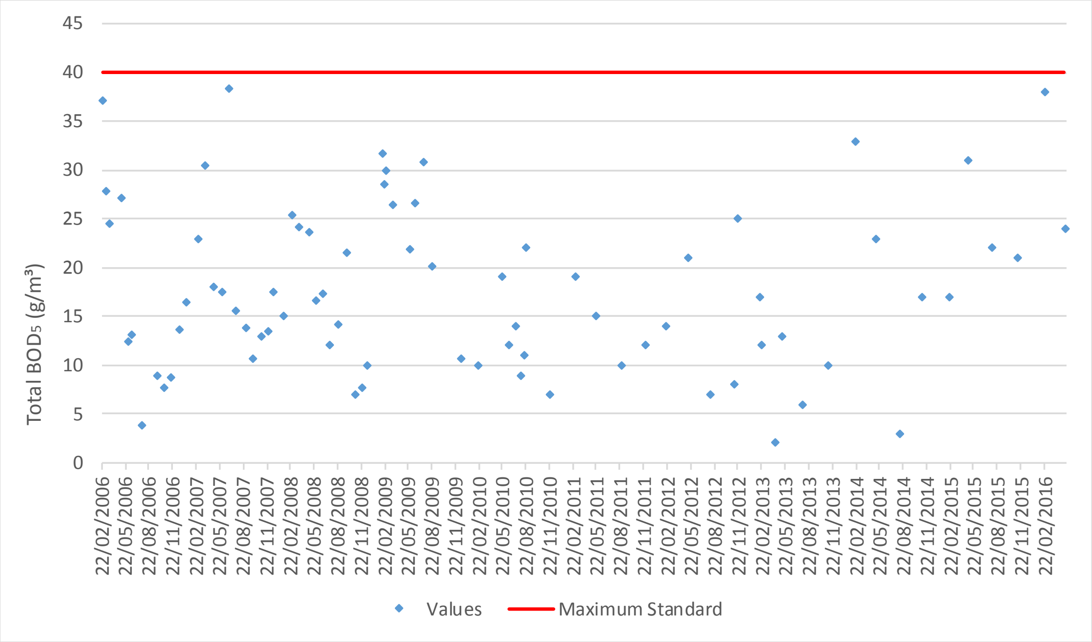


Source: SWDC Monitoring data

### 2.3.8 Total Biochemical Oxygen Demand

Monitoring results for $TBOD_5$ indicate full compliance with the consent limit ($40g/m^3$) with a maximum of $38g/m^3$ recorded over the past 10 years (Figure 9). The concentrations of $TBOD_5$ in the discharge have typically been between 5 $g/m^3$ and 30 $g/m^3$.

**Figure 9: Total biochemical oxygen demand in the effluent**

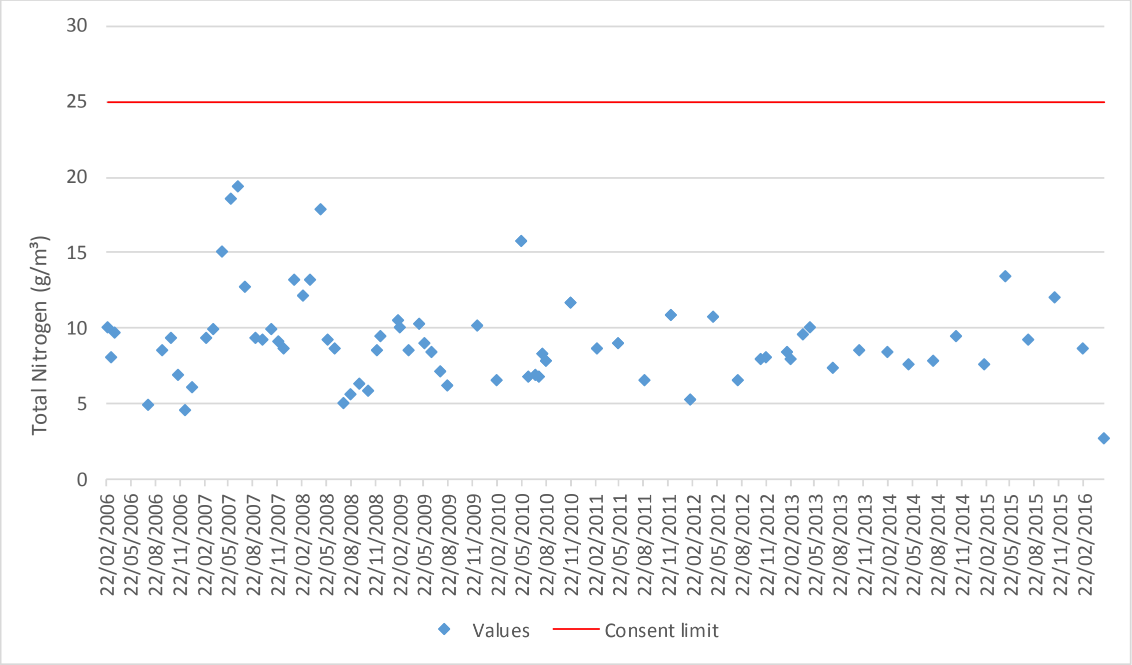


Source: SWDC monitoring data

### 2.3.9 Total Nitrogen

Monitoring results for TN indicate full compliance with the consent limit (25mg/L) with a maximum of 19 g/m³ recorded in 2007 and concentrations typically between 5 g/m³ and 15 g/m³. There has been no noticeable change in TN concentration over this period, and no seasonal variation indicated (Figure 10).

**Figure 10: Total nitrogen in the effluent**

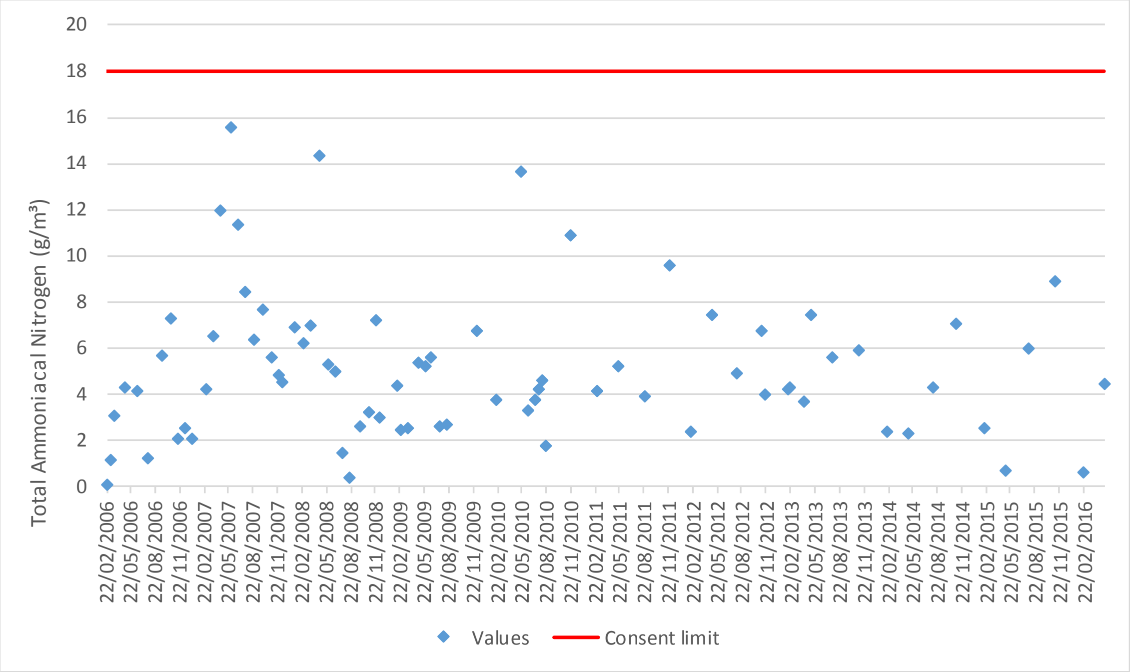


Source: SWDC Monitoring Data

### 2.3.10 Total Ammoniacal Nitrogen

Monitoring results for total ammoniacal nitrogen indicate full compliance with the consent limit (18 g/m³) with a maximum of 15.6 g/m³ recorded in 2007 and a median of 4.4 g/m³ (Figure 11). There total ammonical nitrogen concentration of the effluent was typically between 2 g/m³ and 10 g/m³ with no obvious seasonal variation indicated.

**Figure 11: Total ammoniacal nitrogen in the effluent**

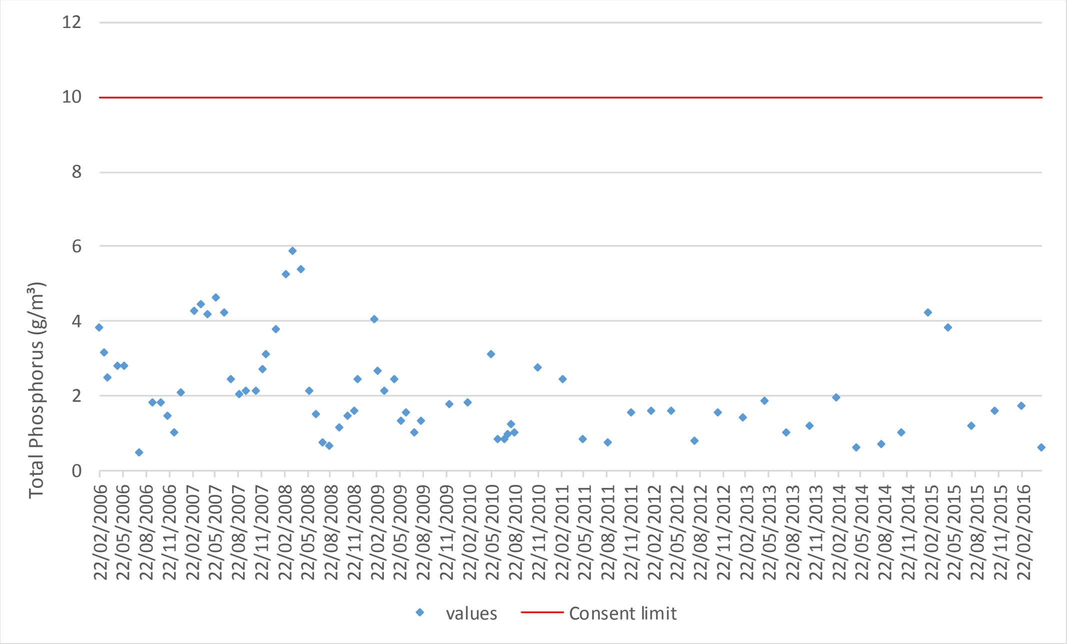


Source: SWDC monitoring data

### 2.3.11 Total Phosphorus (TP)

Monitoring results for TP indicate full compliance with the consent limit (10 g/m³) with a maximum of 5.9 g/m³ recorded in 2008 and a median of 1.8g/m³, (Figure 12) with concentrations typically between 1 g/m³ and 3 g/m³. There has been no noticeable change in TP concentration over this period, with some seasonal variation indicated (i.e. lower values measured in winter).

**Figure 12: Total phosphorus in the effluent**

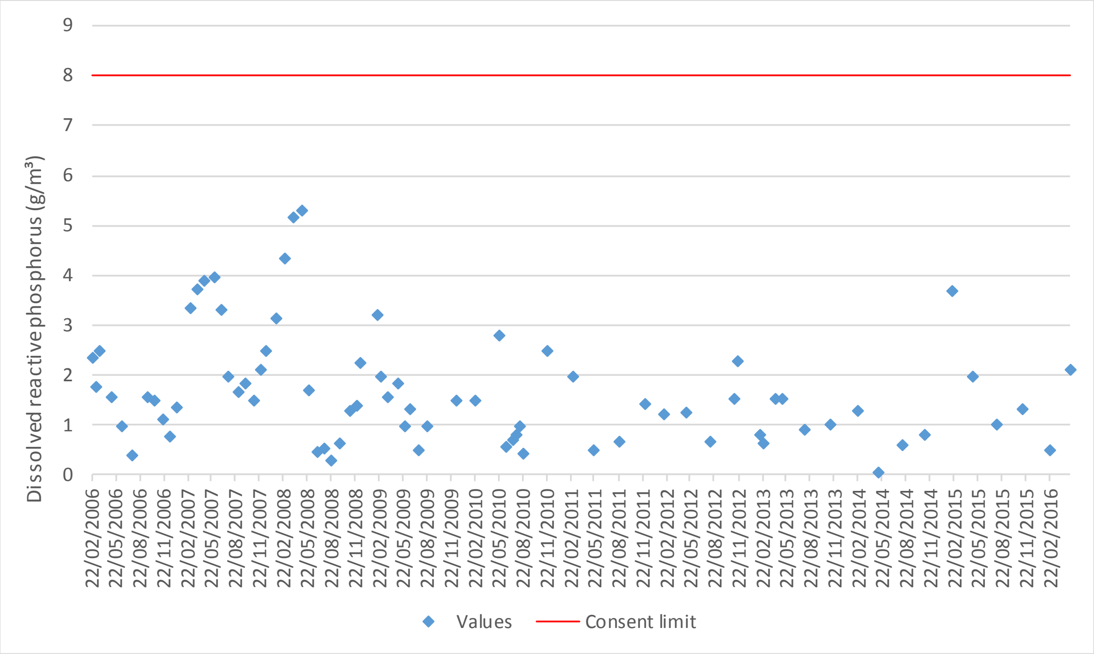


Source: SWDC monitoring data

## 2.3.12 Dissolved Reactive Phosphorus

Monitoring results for DRP indicate full compliance with the consent standard (8 g/m³) with a maximum of 5.3 g/m³ recorded in 2008 and a median of 1.5 g/m³ (Figure 13). The DRP concentrations in the effluent have typically been between 0.5 g/m³ and 2.5 g/m³ and no seasonal variation is discernible.

**Figure 13: Dissolved reactive phosphorus in the effluent**

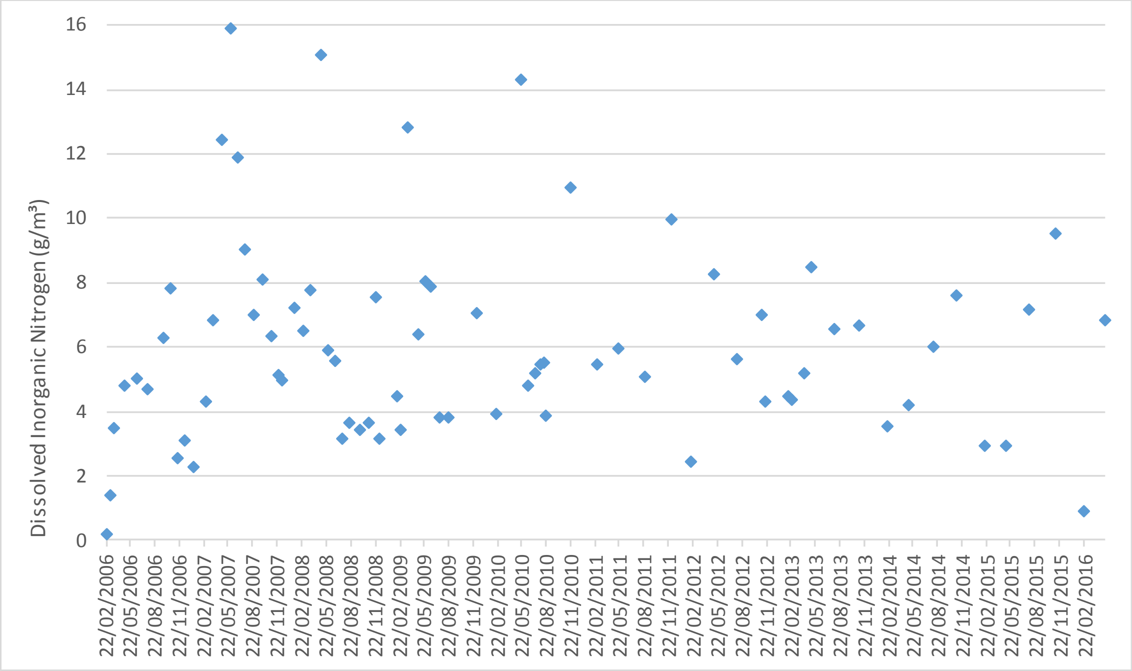


Source: SWDC monitoring data

## 2.3.13 Dissolved inorganic nitrogen

There are currently no consent conditions for DIN. The DIN in the wastewater discharge is variable with typical concentrations between 15.9 g/m³ and 0.19 g/m³ (Figure 14) with values typically between 2 g/m³ and 9 g/m³. There is no obvious seasonal variation in DIN concentrations.

**Figure 14: Dissolved inorganic nitrogen**



Source: SWDC Monitoring data

# 3 Receiving Water Quality Guidelines

## 3.1 Background

A number of different guidelines were considered for the assessment these are summarised in Table 4. The selection of the appropriate guidelines was undertaken in a hierarchical way with the statutory documents (RMA (RMA, 1999), National Policy Statement for Freshwater Management (NPS-FM, 2014) and Greater Wellington Regional Plans given precedence, followed by the effects based guidelines (ANZECC, 2000, and NIWA 2013 and 2014), with consideration given to the other documents such as MfE (2003), Aquanet (2013 a and b) and NIWA (2016).

Due to the elevated concentrations of nutrients upstream of the site (particularly DIN and DRP, see Section 4.12 of this report) it is not considered appropriate to measure compliance downstream based on currently available nutrient guidelines and the guidelines presented are for reference only.

Consideration of the Aquanet (2013a and b) documents for protection of aquatic ecosystem health, recreation and visual amenity requires definition of a river class. For the purpose of this assessment it has been assumed that Donald Creek is a C6c[1] river.

The sections below discuss the rationale for selecting the guidelines used for the assessment for the key parameters.

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[1] This river classification system has been since superseded with that presented in the PNRP.

## Table 4: Summary of water quality documents reviewed

| Reference | Name | Type | Relevant parameters | Comment |
|---|---|---|---|---|
| RMA (1999) | Resource Management Act | Operative statuary document | Temperature | The RMA is the principal document for environmental management in New Zealand and all numerical guidelines will be applied to the assessment of water quality. |
| NPS-FM (2014) | National Policy Statement for Freshwater Management (2014) | Operative statuary document | DO, nitrate, ammonia, *E.Coli* | The NPS defines objectives for regional councils to manage and improve water quality in their region. The NPS also defines minimum acceptable guidelines for freshwaters in New Zealand (known as the national bottom line). It should be noted that these values do not need to be immediately achieved and in some instances less stringent values may be appropriate. |
| FWP (2014) | Regional Freshwater Plan for the Wellington Region (2014) | Operative statuary document | Temperature, pH, DO | The FWP defines objectives and rules relating to the management freshwater in the Wellington region. |
| ANZECC (2000) | Australian and New Zealand Guidelines for Fresh and Marine Water Quality | Non-statutory but accepted New Zealand water quality guidelines for protection of aquatic life and stock drinking water. | Ammonia, nitrate, DO, pH, nutrients | Parameters for nutrients, DO and pH are not effects based. The effects based values for total ammoniacal nitrogen and nitrate-nitrogen have been updated by NIWA (see below). |
| NIWA (2014) | Updating nitrate toxicity effects on freshwater aquatic species | Non-statutory updated guideline value currently gaining acceptance in New Zealand. | Nitrate - nitrogen | Updated guideline values for nitrate toxicity derived according to the ANZECC (2000) method to correct errors in the ANZECC (2000) derivation and add additional data for relevant species. |
| NIWA (2013) | Derivation of the indicative total ammoniacal nitrogen guidelines for the National Objectives Framework | Non-statutory updated indicative guideline value currently gaining acceptance in New Zealand. | Total ammoniacal nitrogen | Updated guideline values for ammonia toxicity derived according to the ANZECC (2000) method to include sensitive species such as mussels. Values are pH dependant but temperature dependence is not considered. |
| Aquanet (2013a) | Recommended water quality limits for rivers and streams managed for Aquatic Ecosystem Health in the Wellington Region | Non-statutory providing recommended guidelines for incorporation into the greater wellington regional plan. | Temperature, pH, DO, clarity, E.*Coli*, | Guidelines dependant on the river class. Guidelines for pH, DO are not effects based, but instead represent percentiles of monitoring data at background sites. |
| Aquanet (2013b) | Recommended water quality limits for rivers and streams managed for contact recreation, | Non-statutory providing recommended guidelines for | Temperature, pH, DO, clarity, E.*Coli*, cBOD, total ammonia-N | Guidelines dependant on the river class. Guidelines for pH, DO are not effects based, but instead represent percentiles of monitoring data at background sites |

| Reference | Name | Type | Relevant parameters | Comment |
|---|---|---|---|---|
| | amenity and stock drinking in the Wellington region. | incorporation into the greater wellington regional plan. | | |
| MfE (2003) | Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas | Non-statutory guidelines to help water managers control the public health risk from microbial contamination. | *E.Coli* | Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas and provide triggers for action and monitoring. |
| PNRP (2015) | Proposed Natural Resources Plan (PNRP) for the Wellington Region. | Proposed statutory document, notified and given legal affect but not yet operative. Some weighting must be given to the plan objectives and policies | pH, DO, clarity, *E.Coli* | Proposed plan developed to manage natural resources in the Wellington region. |
| Quinn (2009) | Section 42A report of John Martin Quinn on behalf of Horizons Regional Council | Non-statutory document. Evidence presented at a hearing relating to water quality. | Soluble $cBOD_5$ | Evidence presents professional opinion regarding the fraction and concentration of BOD required to protect river systems from growth of sewage fungus. |
| NIWA (2000) | New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams | Non-statutory document defining guidelines for managing nuisance periphyton growth in streams | Nutrients/ periphyton | Defines concentrations of DIN and DRP required to prevent different levels of periphyton cover. Dependant on accrual periods, shading and other factors. Specific to cobble stream beds. |
| NIWA (2016) | Instream plant and nutrient guidelines: Review and development of an extended decision-making framework Phase 3 | Non-statutory undertaking a review of existing nutrient guidelines. | Nutrients/ periphyton | Defines issues with existing guidelines for nutrients and makes recommendations for some less conservative more achievable guidelines compared with NIWA (2000) |

## 3.2 Selected Receiving Water Guidelines

The following sections describe the rationale behind selecting the receiving water guidelines for the assessment, the selected guidelines are summarised in Table 5: Summary of selected Table 5.

**Table 5: Summary of selected guidelines**

| Parameter | Limit | References |
|---|---|---|
| Temperature | No greater than a 3°C change<br>Maximum of 25°C | RMA (1999)/ FWP (2014) )/ FWP (2014)/ PNRP (2015)<br>RMA (1999)/ FWP (2014) |
| pH | Between 6.5 and 9<br><0.5 pH unit change | FWP (2014)<br>Aquanet (2013a) / PNRP (2015) |
| Dissolved oxygen | >80% saturation<br>>5 $g/m^3$ | RMA (1999)/ FWP (2014)<br>NPS-FM (2014) Attribute B/ FWP (2014)/ PNRP (2015) |
| Visual clarity | >1.6 m<br>> 0.5 m<br><33% Change | MfE (1992)/ Aquanet (2013)<br>Aquanet (2013) Class C6c<br>PNRP (2015) Aquanet (2013) |
| Soluble carbonaceous $BOD_5$ | < 2 $g/m^3$ | Aquanet (2013) |
| Total Ammoniacal Nitrogen | pH dependant based on annual median and 95th percentile, see Table 6 and Table 7 below for details | NPS-FM (2014) National bottom line<br>USEPA (2013) – Acute guidelines<br>NIWA (2014) – Chronic guidelines |
| Nitrate | <2.4 $g/m^3$ annual median<br><5.4 $g/m^3$ Annual 95th percentile | NIWA (2013)<br>NIWA (2013) |
| *E.Coli* | <260 cfu/100mL "Green Mode"<br>>550 cfu/100 mL<br><1000 cfu/100mL – median | MfE (2003)<br>MfE (2003)<br>PNRP (2015) |
| **Nutrients –guidelines (for reference only)** | | |
| Dissolved inorganic nitrogen | 0.63 $g/m^3$ | NIWA 2016 "Good" water quality for angling |
| Total phosphorus | 0.045 $g/m^3$ | NIWA (2016) "Good" water quality for angling |
| Dissolved reactive phosphorus | 0.011 $g/m^3$ | NIWA (2016) "Good" water quality for angling |

### 3.2.1 Temperature

Changes in temperature, due to discharges to surface water, can cause stress to aquatic species and need to be controlled. The RMA and FWP prescribe that a discharge should not result in the receiving water exceeding 25°C or result in a change of temperature of 3°C between upstream and downstream sites. The latter is also prescribed in Policy 71 of the PNRP. These guidelines were selected for the temperature assessment in the current study.

### 3.2.2 pH

The RMA states that for water being managed for aquatic ecosystems that a discharge should not result in a change in pH that has an adverse impact on aquatic life but does not provide a numerical guideline.

The FWP (2014) states that, after reasonable mixing a discharge should not result in the pH of surface waters to be outside the range of 6 to 9.

Aquanet 2013b recommend a pH range of between 6 and 9 is suitable to protect the water for stock drinking and guideline of 5.8 to 8.7 for protection of a C6c River, such as Donald Creek (Aquanet, 2013a).

The PNRP (2015) and Aquanet (2013a) indicate that a discharge should not result in a greater than 0.5 pH unit change downstream of the discharge. However, the rationale for this guideline is not clear.

The ANZECC 2000 guidelines for pH were not considered appropriate as they are based on measured 20th and 80th percentiles in New Zealand lowland and upland streams and are not effects based values.

Therefore, the statutory guidelines from the FWP (2014) and PNRP (2015) of between 6.0 and 9 and no change in pH more than +0.5 were selected for the pH assessment.

### 3.2.3 Dissolved Oxygen

Depleted dissolved oxygen (DO) in waterways can impact negatively on aquatic species. The RMA (1999) and FWP (2014) states for water being managed for aquatic ecosystems that the dissolved oxygen saturation in the water should exceed 80%.

The Aquanet (2013a and b) documents recommend 60% as the minimum oxygen saturation for C6c Rivers and is therefore less conservative than the RMA and FWP.

In addition to percentage saturation, the concentration of dissolved oxygen in the water is also of importance. The FWP (2014) states that after reasonable mixing, no contaminant is to result in the DO of the receiving surface water to drop below 5 g/m$^3$. This is in line with the NPS-FM that presents a National Bottom Line of 4 g/m$^3$ as a minimum and a DO above 5 g/m$^3$ for an attribute B river. The PNRP also states that a discharge shall not result in the DO of the receiving water dropping below a daily minimum of 4 g/m$^3$.

As a conservative measure, a minimum of 5 g/m$^3$ was selected for this assessment, this is in-line with the NPS-FM and more conservative than the proposed limit in the PNRP. In addition, the minimum oxygen saturation value (80%) in the RMA and FWP (2014) was also used for the assessment.

### 3.2.4 Visual Clarity

Visual clarity of a water body is of importance for water bodies that are used extensively for bathing, and the MfE (1994): *"Water Quality Guidelines No. 2: Guidelines for the Management of Water Colour and Clarity"* recommend a guideline for clarity of greater than 1.6 m (as measured using a black disc) for waters used for recreational purposes. The MfE guidelines also indicate that a change in clarity by 30% or more is typically detectable by most people.

Aquanet (2013a) also provide guidance with respect to water clarity for protection of aquatic ecosystems. For a Class C6c water body, such as Donald Creek, Aquanet (2013a) recommends the visual clarity remain above 0.5 m with a less than 33% change downstream of a discharge. A decrease in water clarity of no more than 33% is also prescribed within Policy 71 of the PNRP for water quality standards which are to apply downstream of a point source discharge in River Classes 2 to 6 (Donald Creek is classified as a River 5).

Although the above guidelines have been used in the assessment it should be noted that Donald Creek is not known to be a common location for bathing and the MfE guideline may not be suitable for assessment of future compliance.

### 3.2.5 BOD

Elevated concentrations of Biochemical Oxygen Demand (BOD) can result in heterotrophic growths (sewage fungus) in surface water. Limited guidelines are available for BOD and all are based on work carried out on the Manatawu River (Quinn 1988, 2009), where a maximum limit of 2 g/$m^3$ of soluble carbonaceous BOD is recommended as a guideline. Aquanet (2013a & b) also recommend this as a suitable guideline for rivers in the Wellington Region.

Therefore, a guideline value of less than 2 g/$m^3$ soluble carbonaceous five day BOD ($scBOD_5$) has been used for this assessment.

### 3.2.6 Ammonia

Ammoniacal Nitrogen ($NH_4$-N) is present in human and animal wastes and is therefore present in sewage discharges. In surface water ammonia occurs as two species, the unionised form $NH_3$ and the ionised form $NH_4^+$. The ionised species is the predominant species in surface waters at typical pH and temperature ranges (pH 6-8, temperature 12 to 25 $^oC$) and it usually accounts for between 99% and 80% of the total $NH_4$-N (T $NH_4$-N). The relative proportion of unionised to ionised $NH_4$-N is pH and temperature dependant with the unionised species increasing in concentration as pH and temperature increases. This is of importance to water quality assessments as the unionised species is more toxic than the ionised form as it is capable of crossing cell membranes more effectively (ANZECC, 2000).

In order to assess the potential effects of $TNH_4$-N on a receiving environment it is important to consider two potential toxic effects. That is acute and chronic toxicity, acute toxicity refers to the ability of a chemical or element to cause mortality or an adverse effect in an organism from a single or short−term exposure to a chemical compound or element. Chronic toxicity refers to the ability of a chemical or element to cause an adverse effect in an organism which results from exposure to a chemical or element for a time period representing that significant portion of the natural life expectancy of that organism.

#### Acute and Statutory Guidelines

There are no New Zealand guidelines relating to acute toxicity as it is assumed that management of a water body for chronic effects will protect against acute effects.

*United States Protection Agency*

The United States Protection Agency (USEPA) provides both acute and chronic guidelines (USEPA, 2013). The pH dependant acute guidelines from the USEPA for protection of sensitive species are presented in Table 6 assuming a temperature of 20 $^oC$. The acute guidelines are provided for pH range typically measured downstream of the discharge in Donald Creek (pH 6.7 to 8.3).

**Table 6: USEPA acute criteria for $TNH_4$-N**

| pH | USEPA Acute Criteria (g/$m^3$) | NPS Bottom Line Median (g/$m^3$) | NPS Bottom Line Maximum (g/$m^3$) |
|---|---|---|---|
| 6.7 | 21 | 3.43 | 5.8 |
| 6.8 | 20 | 3.37 | 5.7 |
| 6.9 | 18 | 3.26 | 5.5 |
| 7.0 | 17 | 3.15 | 5.3 |
| 7.1 | 15 | 3.00 | 5.1 |
| 7.2 | 14 | 2.87 | 4.9 |
| 7.3 | 12 | 2.72 | 4.6 |
| 7.4 | 11 | 2.52 | 4.3 |
| 7.5 | 9.2 | 2.33 | 3.9 |

| pH | USEPA Acute Criteria ($g/m^3$) | NPS Bottom Line Median ($g/m^3$) | NPS Bottom Line Maximum ($g/m^3$) |
|---|---|---|---|
| 7.6 | 7.9 | 2.12 | 3.6 |
| 7.7 | 6.7 | 1.91 | 3.2 |
| 7.8 | 5.6 | 1.70 | 2.9 |
| 7.9 | 4.7 | 1.48 | 2.5 |
| 8.0 | 3.9 | 1.30 | 2.2 |
| 8.1 | 3.2 | 1.13 | 1.9 |
| 8.2 | 2.7 | 0.95 | 1.6 |
| 8.3 | 2.2 | 0.81 | 1.4 |

Source: USEPA (2013) and NPS-FW (2014)

*National Policy Statement for Freshwater Management – Nation Bottom Line*

Objective A1 of the NPS-FM aims to safeguard the life supporting capacity of freshwater and safeguard human health at least to a level safe for secondary contact. Objective A2 is committed to improving the quality of fresh water in water bodies that have been degraded by human activities to the point of being over-allocated. Part of the NPS-FM process was to develop National Bottom Lines for various attributes.

The NPS-FM states National Bottom lines are the minimum acceptable state for freshwater system. The NPS-FM defines a National Bottom Line for $TNH_4$-N, in lakes or rivers, of 1.2 $g/m^3$ for comparison to the annual median and 2.2 $g/m^3$ as an annual maximum, based on a pH of 8 (see Table 6, for pH adjusted guidelines). However, NPS states that these are not standards that must be achieved immediately. But where water bodies exceed national bottom lines, they will need to be improved to at least the national bottom lines over time.

### Chronic Guidelines

New Zealand based guidelines for $TNH_4$-N are chronic guidelines derived to protect species from long term exposure. These include the ANZECC (2000) guidelines and a set of indicative guidelines derived by NIWA (2014).

*ANZECC*

In 2000 ANZECC released an updated set of water quality guidelines with the purpose of assisting water managers and communities to sustainably use and manage of water resources in an environmental, economic and social context. These guidelines include trigger values for toxicants such as $TNH_4$-N. These trigger values were not intended to be simplistic threshold numbers above which a toxic effect is likely, rather they represent values below which there is a low risk that adverse biological effects will occur, and are therefore considered chronic guidelines. If exceeded, these values trigger a management response such as the incorporation of additional information or further investigation to determine if a real risk to the ecosystem exists and, where possible, to adjust the trigger values into regional, local or site-specific guidelines.

It is important to note that exceedance of an ANZECC trigger value (or other guidelines) does not necessarily mean toxic effects will be occurring in the water body as numerous factors such as exposure time, species present and habitat type influence if toxic effects will be observed.

In New Zealand the ANZECC (2000) $TNH_4$-N trigger values are often used for water quality assessments. ANZECC (2000) provides trigger values, with pH adjustment, for different levels of protection with a 99% level of protection for pristine environments, a 95% level of protection for slightly to moderately disturbed environments and an 80% level of protection for highly degraded environments. The default level of protection is the 95% level, the pH adjusted trigger values for the 95% level of protection are summarised in Table 7.

*NIWA (2014)*

As part of the development of the NPS the Ministry for the Environment is developing National Objectives Frameworks (NOF) for freshwaters which include a National Bottom Line for $TNH_4$-N and different attribute states for lakes and rivers. Attributes are measurable characteristics of fresh water, including physical, chemical and biological properties, which supports particular values. For potentially toxic compounds such as $TNH_4$-N, these attribute states are ranges of concentrations developed to manage surface waters such that the water is protected from $TNH_4$-N toxicity.

As part of the development of the NPS and NOF, NIWA (2014) have derived ammoniacal nitrogen attribute states for lakes and rivers according to the ANZECC method. NIWA updated the ANZECC $TNH_4$-N toxicity dataset with data for the highly sensitive species of North American fresh water mussels from the USEPA's updated guideline values (USEPA, 2013). These species which have a similar sensitivity as New Zealand Freshwater Mussels. The toxicity data relating to these species represent the lowest in the dataset with No Observable Effects Concentration (NOEC) of between 0.24 g/m$^3$ to 0.59 g/m$^3$. In addition to freshwater mussels the Fingernail Clam (*Sphaerium novaezelandiae*) is commonly found in New Zealand low land streams and is known to be sensitive to $TNH_4$-N concentrations with a measured NOEC (mortality) of 0.59 g/m$^3$. The Freshwater Clam also was considered in the NIWA assessment.

It should be noted that NIWA derivation did not include full review of the ANZECC dataset or literature review of new $TNH_4$-N toxicity data. Given that only new toxicity data for highly sensitive species was added to the dataset with no additional data for less sensitive species, the new NIWA guidelines would be considered highly conservative. Although the NIWA guidelines are provided for different levels of protection in line with the ANZECC method (i.e. 99%, 95% 90% and 80%), as they are conservative they may not directly relate to the levels of protection discussed in ANZECC. Therefore, it is more relevant to consider the species that the guidelines protect, with consideration of most sensitive species protected by the guideline. It is noted that the NIWA document states:

*"[the 90th percentile guideline values] are protective of the native fingernail clam, though some effects are indicated for the North American juvenile mussels, which are not resident in New Zealand."*

Therefore the:

- NIWA (2014) trigger for 95% level of protection would protect the most sensitive species found in lakes in rivers, that is Freshwater Mussels; and
- NIWA (2014) 90% level of protection would protect the next most sensitive species found in lakes and rivers, the Fingernail Clam.

A summary of the NIWA indicative guidelines are also summarised in Table 7. It should be noted that the ANZECC (2000) guidelines are similar to the NIWA surveillance guidelines that would be protective of the fingernail clam.

The NIWA (2014) guidelines have been used for the assessment of potential chronic toxicity rather than the ANZECC (2000) guidelines, as they are; at least or more conservative than the ANZECC (2000) guidelines, account for the protection of Freshwater Mussels and the Fingernail Clam, and provide a value for an annual median and annual 95th percentile.

**Table 7: Comparison of TNH$_4$-N Guidelines**

| pH | NIWA Indicative Guideline for protective of Mussels (g/m$^3$) | | NIWA Indicative Guideline for protective of fingernail (g/m$^3$) | | ANZECC (2000) 95% level of protection (g/m$^3$) |
|---|---|---|---|---|---|
| Type | Grading[1] | Surveillance[2] | Grading[1] | Surveillance[2] | |
| 6.7 | 0.63 | 1.06 | 1.43 | 2.43 | 2.38 |
| 6.8 | 0.62 | 1.04 | 1.40 | 2.38 | 2.33 |
| 6.9 | 0.60 | 1.00 | 1.36 | 2.31 | 2.26 |
| 7.0 | 0.58 | 0.97 | 1.31 | 2.23 | 2.18 |
| 7.1 | 0.55 | 0.92 | 1.25 | 2.13 | 2.08 |
| 7.2 | 0.53 | 0.88 | 1.19 | 2.03 | 1.99 |
| 7.3 | 0.50 | 0.84 | 1.13 | 1.92 | 1.88 |
| 7.4 | 0.47 | 0.78 | 1.05 | 1.78 | 1.75 |
| 7.5 | 0.43 | 0.72 | 0.97 | 1.65 | 1.61 |
| 7.6 | 0.39 | 0.65 | 0.88 | 1.50 | 1.47 |
| 7.7 | 0.35 | 0.59 | 0.79 | 1.35 | 1.32 |
| 7.8 | 0.31 | 0.52 | 0.71 | 1.21 | 1.18 |
| 7.9 | 0.27 | 0.46 | 0.62 | 1.05 | 1.03 |
| 8.0 | 0.24 | 0.40 | 0.54 | 0.92 | 0.90 |
| 8.1 | 0.21 | 0.35 | 0.47 | 0.80 | 0.78 |
| 8.2 | 0.18 | 0.29 | 0.39 | 0.67 | 0.66 |
| 8.3 | 0.15 | 0.25 | 0.33 | 0.57 | 0.56 |

Notes: [1]Grading guidelines are for comparison to annual median. [2]Surveillance guidelines are for comparison to annual 95th percentile.

### 3.2.7 Nitrate

Elevated concentrations for nitrate can be toxic to aquatic species. According to NIWA (2013) the derivation of the ANZECC (2000) trigger value for nitrate contained errors. In 2009 NIWA recalculated the trigger value for nitrate (based on Nitrate – nitrogen) to resolve the errors and include additional toxicity data. In 2013, NIWA refined the trigger value based on the ANZECC method and included further toxicity data for additional species. The trigger values from NIWA (2013) were lower than those calculated in 2009 and have been selected for the current assessment. The 95% level of protection values were selected, these are 2.4 g/m$^3$ based on an annual average and 5.4 g/m$^3$ based on the annual 95th percentile.

It should be noted that the NPS-FM defines national bottom line concentrations of 6.9 g/m$^3$ and 9.8 g/m$^3$ for the annual median and annual 95th percentile respectively. Therefore, the guidelines used in this study are considerably more conservative than the NPS-FM national bottom line values.

In addition ANZECC (2000) defines values for protection of stock drinking and these guidelines are considerably higher than those used in this study.

### 3.2.8 *E.Coli*

Pathogens from treated sewage discharges have potential to impact on human health. As detection of pathogens is difficult indicator species are used to assess microbial contamination in water bodies. For freshwater systems, MfE (2003) recommend the use of *E.Coli* for assessment of pathogens. MfE (2003) define monitoring and action values for recreational waters. Although, Donald Creek is not considered to be used for primary contact recreation a conservative approach has been used and *E.Coli* numbers in the receiving water have been compared to the “green” surveillance mode (the level at which the water is safe for swimming) of *260 E.Coli* cfu/100 mL, and the “Red Mode” for action (>550 *E.Coli* cfu/100 mL).

The NPS-FM national bottom line and PNRP Objective for secondary contact recreation is a median of <1000 *E.Coli*/ 100mL. Aquanet (2013) also recommend a guideline of <550 *E.Coli*/100mL for protection of stockwater.

### 3.2.9 Nutrients

Elevated nutrient concentrations in surface water bodies can cause eutrophication of the system and result in the development of nuisance aquatic plant growths (such as periphyton). These growths can have impacts on aesthetics and ecological health. However, the development of nuisance growths is dependent on a number of factors including nutrient concentrations, the time period between flood events (known as the accrual period), the amount of sunlight irradiation, type of river bed (cobble vs silt bottom) and shading of the environment. As a result it is difficult to define appropriate nutrient concentrations to protect the system from eutrophication and nuisance growths. In addition, many streams and rivers in New Zealand currently have concentrations of nutrients that would frequently exceed any of the available guideline values.

A number of nutrient values were considered as part of the current study with guidance taken from the NIWA review of instream plant and nutrient guidelines (NIWA, 2016 and 2012). The NIWA documents highlight the following issues with respect to using currently available numerical guidelines for nutrients (nitrogen and phosphorous species) to assess water quality:

- The ANZECC (2000) guidelines for nutrients are based on the 20th and 80th percentiles of nitrogen and phosphorus species measured in New Zealand lowland and highland streams and are therefore not effects based; and
- The New Zealand periphyton guidelines (NIWA, 2000) were developed to determine conditions required to prevent excessive growth of periphyton cover. According to NIWA (2016) these guidelines are considered to be worst case and are highly conservative.

In the NIWA review document (NIWA, 2016), less conservative nutrient guidelines were developed. These guidelines were developed to provide >85% compliance with the existing MfE (2000) periphyton guidelines based on both coverage during the growth season and angler acceptability.

As previously stated, Donald Creek upstream of the site has elevated nutrient concentrations frequently above guideline levels (see Section 4.12 below). Therefore, for comparative purposes only, the DIN, DRP and TP guidelines corresponding to less than 120 mg/m$^2$ periphyton cover representing “good” water quality for angling have been used in the assessment (Table 8).

**Table 8: Nutrient criteria used for comparative purposes**

| Parameter | Good water quality for angling <100 mg/m$^2$ periphyton cover 80% of the time |
|---|---|
| DIN | 0.63 |
| DRP | 0.011 |
| TP | 0.045 |

Source: NIWA (2016)

# 4 Receiving Water Quality Results

## 4.1 Introduction

The receiving water quality, both upstream (approximately 20 m upstream of the discharge) and downstream (approximately 150 m downstream of the discharge) of the site in Donald Creek, has been monitored quarterly or weekly for a number of years and is currently ongoing for most parameters. It should be noted that there are some gaps in the data and at times the site monitors upstream, downstream and effluent water quality on different days in the quarter. This limits the ability to make direct upstream and downstream comparisons for some sampling rounds, however, the majority of the data can be compared.

The receiving water data has been compared to relevant water quality guidelines where possible. A discussion regarding the selection of appropriate water quality guidelines is presented in section 3 above. In the case of nutrients, currently available guidelines are not suitable for future compliance monitoring as the upstream site frequently exceeds the guidelines. A summary of the water quality monitoring data is provided in Appendix A.

## 4.2 Temperature

The temperature of Donald Creek upstream and downstream of the discharge and the difference between upstream and downstream temperatures are presented in Figure 15. The temperature had a range of between 7$^{o}$C and 20$^{o}$C and the difference between upstream and downstream temperatures was consistently less than 3$^{o}$C and the sites have been fully compliant with the temperature guidelines.

## 4.3 pH

The pH upstream and downstream of the discharge is presented in Figure 15. The pH in Donald Creek upstream and downstream of the discharge is typically between 6 and 8. There was one noncompliance (out of 99 measurements) with the lower pH guideline at the upstream site in 2006 and 6 noncompliance's with the lower pH limit at the downstream site in 2006 and 2007. However, the pH of the discharge was within the 6 and 9 guideline on all occasions and the non-compliances were not likely to be as a result of the discharge.

In 2007 and 2006 some low pH values downstream of the site were measured with 4 samples having pH less than of 5 and one less than pH of 2. The reason for these low pH values is unknown but it is possible that they were due to issues with the measuring equipment, as these very low pH values do not fit with the rest of the data and pH below 5 would be unusual for surface waters unless they were receiving a low pH discharge.

The difference between upstream and downstream pH is also presented in Figure 15 (presented as downstream – upstream). The difference in pH between upstream and downstream pH was greater than 0.5 (the guidelines presented in the PNRP and Aquanet (2013a)), 19% of the time. Thirteen percent of the time the downstream pH was higher than the upstream pH and 6% of the time the upstream pH was higher than the downstream pH.

## 4.4 Suspended Solids

The suspended solids upstream and downstream from the discharge are presented in Figure 16. The upstream and downstream suspended solids concentration sites were typically below 40 g/m$^3$. The downstream suspended solids concentrations were greater than the upstream concentrations 75% of the time, indicating that the discharge is increasing the suspended solids downstream of the site.

## 4.5 Turbidity

The turbidity at both the upstream and downstream sites was consistently below 12 NTU, with the majority of values below 8 NTU (Figure 16). Turbidity exhibited the same relationship as suspended solids, with the majority of downstream samples exceeding those of the upstream samples on the same day. However, the difference in upstream and downstream turbidity was typically small with differences of less than 2 NTU occurring 70% of the time.

## 4.6 Visual Clarity

The visual clarity of the upstream site was between 1.1 and 3.5 m, and was greater than the MfE recreational guideline (1.6m) 84% of the time and always above the Aquanet (2013) guideline for protection of aquatic ecosystems for a class C6c River (0.5m) (Figure 16).

The downstream had lower visual clarity than upstream on all but one occasion, with clarity of between 0.45 and 1.9m. The downstream site had clarity greater than 1.6 m 4% of the time and greater than the Aquanet guideline 90% of the time.

The reduction in visual clarity downstream of the discharge was greater than 33% (the PNRP and Aquanet recommended change in clarity for a Class 5 or C6c River) 74% of the time.

## Figure 15: Receiving water quality: Temperature and pH

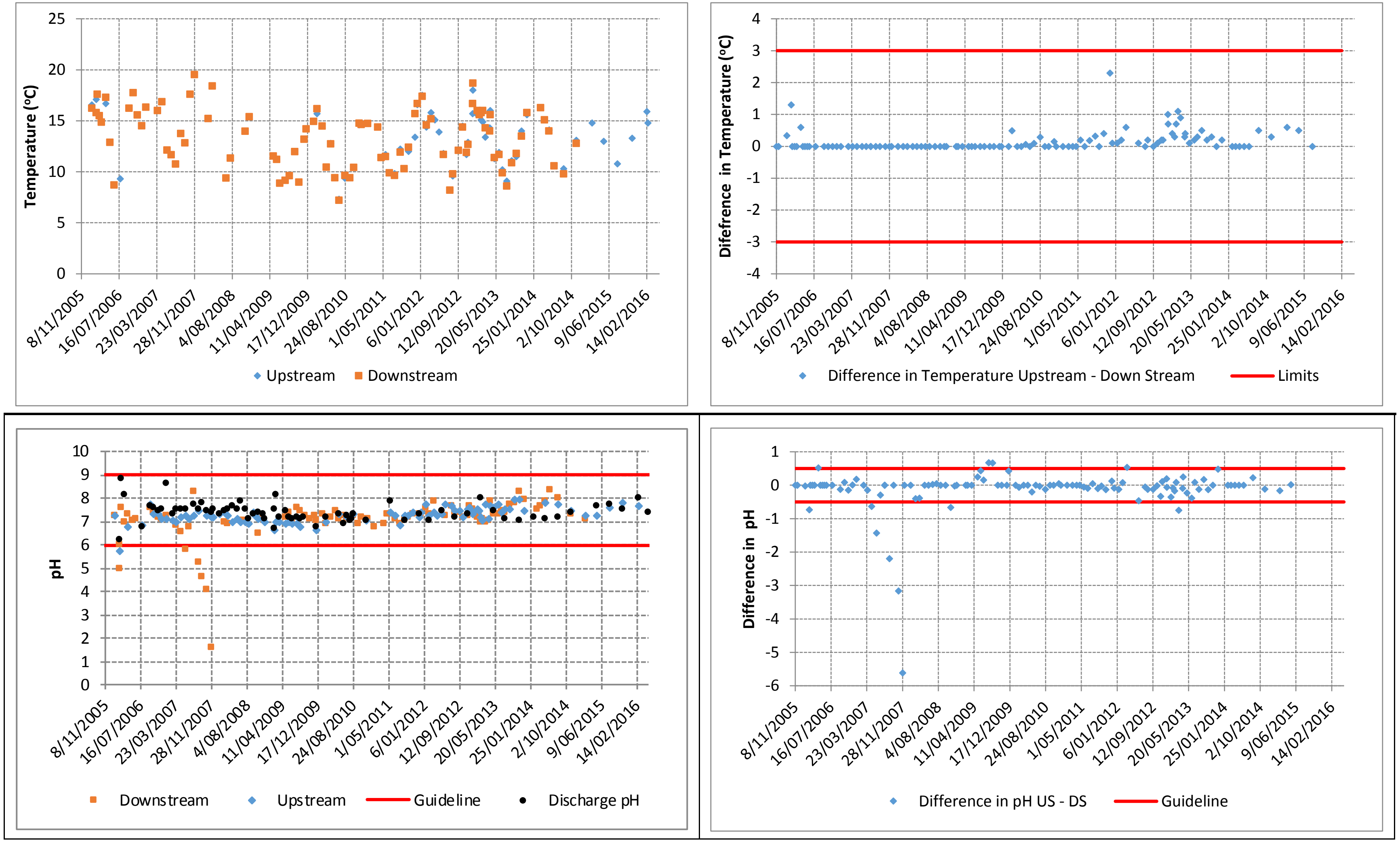
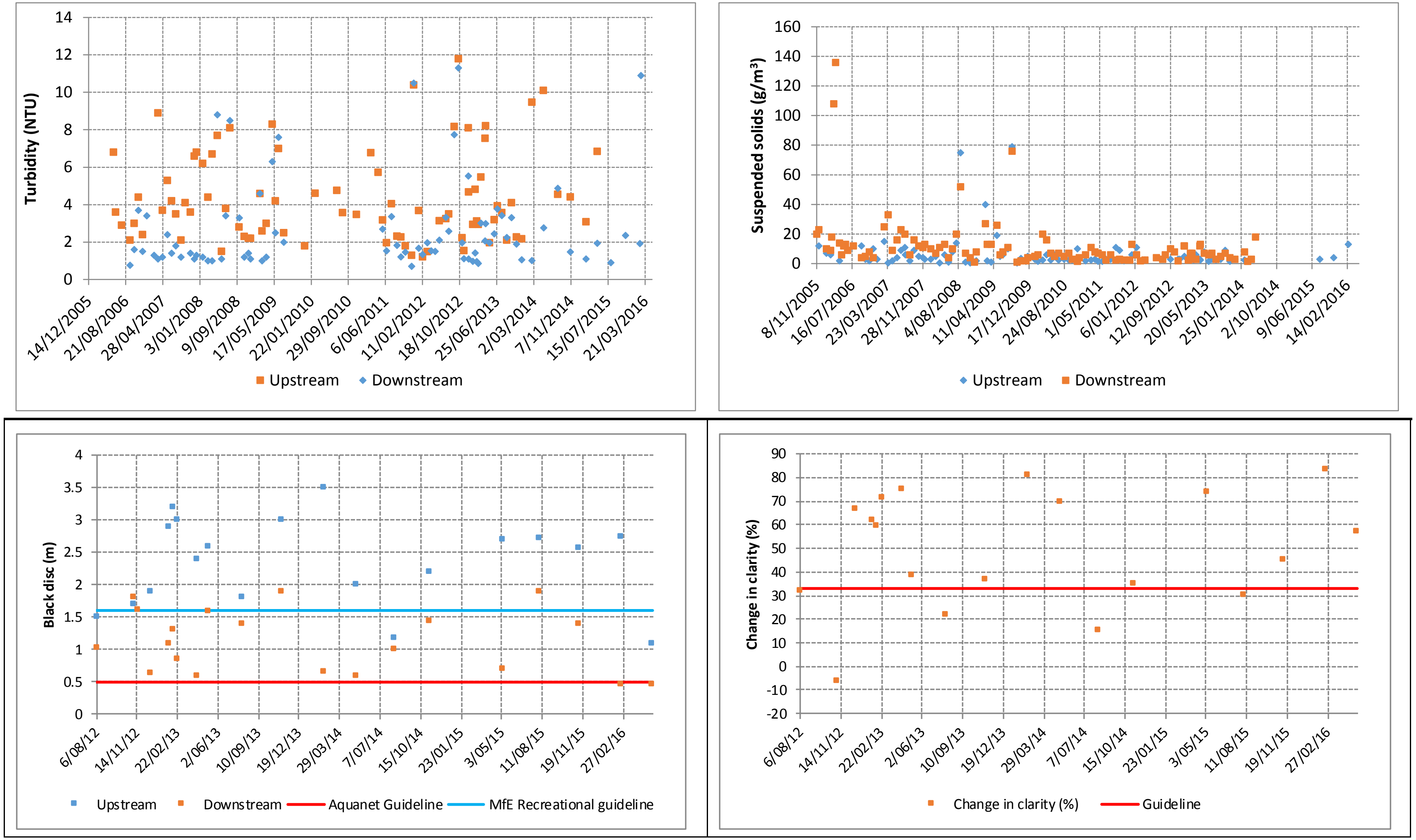


**Figure 16: Receiving water turbidity, suspended solids and visual clarity**



## 4.7 Dissolved Oxygen

The DO of the upstream site was consistently above the DO concentration guidelines with a minimum value of 6.3 g/m$^3$ (Figure 17). The downstream DO concentration was consistently above the National Bottom Line value and PNRP guideline of 4 g/m$^3$ but below the State B attribute value of 5 g/m$^3$ (NPS-FM, 2014) on one occasion out of 71 measurements.

The percentage saturation was calculated based on the measured temperature and calculated theoretical 100% saturation value. The upstream DO saturation was below the RMA and Freshwater Plan guideline of 80% saturation 14% of the time (Figure 17). The downstream DO saturation was typically lower than upstream, but the differences were typically less than 10%. The downstream DO was below 80% saturation for 24% of the time.

## 4.8 TBOD$_5$

The concentration of total BOD was 3 g/m$^3$ or below in all upstream samples (Figure 17). The concentration of total BOD downstream of the discharge was highly variable with concentrations between <1 g/m$^3$ and 17 g/m$^3$ with all but one sample having a concentration of less than 9 g/m$^3$. As the guideline for BOD is based on the soluble carbonaceous fraction (scBOD$_5$) of less than 2 g/m$^3$, compliance against guideline cannot be assessed.

In order to fill the gap in the monitoring data a series of grab samples were made in 2016 and 2017 (Table 9). Soluble cBOD$_5$ was found to be between 8% and 16% of the TBOD$_5$ in the discharge and between 3 and 25% at the downstream site. Based on this the scBOD$_5$ concentration downstream of the site would at times exceed the guideline value of 2 g/m$^3$ and there would be potential for heterotrophic growths.

**Table 9: Comparison of BOD fractions in the discharge, upstream and downstream of the site**

| Sample/ Date | TBOD$_5$ (g/m$^3$) | sBOD$_5$ (g/m$^3$) | cBOD$_5$ (g/m$^3$) | scBOD$_5$ (g/m$^3$) | Fraction of scBOD of TBOD$_5$ (%) |
|---|---|---|---|---|---|
| **Discharge** | | | | | |
| 26/10/2016 | 22 | <3 | NA | NA | |
| 27/10/2016 | 21 | <3 | NA | NA | |
| 6/12/2016 | 37 | <6 | 25 | 6 | 16 |
| 30/01/2017 | 32 | 3 | 20 | 3 | 9.4 |
| 31/01/2017 | 36 | 3 | 20 | 3 | 8.3 |
| 1/02/2017 | 26 | 3 | 25 | 3 | 12 |
| **Upstream** | | | | | |
| 24/11/2016 | <1 | <1 | <1 | <1 | |
| 30/01/2017 | <1 | <1 | <1 | <1 | |
| 31/01/2017 | 1 | <1 | 1 | <1 | |
| 1/02/2017 | <1 | <1 | <1 | <1 | |
| **Downstream** | | | | | |
| 24/11/2016 | 4 | <1 | 4 | 1 | 25 |
| 30/01/2017 | 7 | 2 | 5 | 1 | 14 |
| 31/01/2017 | 34 | 1 | 20 | 1 | 2.9 |

## 4.9 *E.Coli*

The number of *E.coli* upstream of the discharge was elevated above the Green Mode guideline 53% of the time and the Red Mode guideline 23% of the time (Figure 17). The upstream site did however meet the PNRP secondary contact recreational median guideline of 1<000 *E.Coli*/100 mL.

The number of *E.Coli* upstream of the discharge and downstream of the discharge was highly elevated prior to 2011. Since 2011, following installation of the UV treatment plant, the *E.Coli* numbers have decreased both in the discharge and downstream of the discharge (Figure 17). After 2011 the discharge exceeded the "Green Mode" guideline on 3 occasions (out of 21 samples),the "Red Mode" guideline twice (Table 10). Of the three exceedances of the Green Mode guideline only one exceedance resulted in an exceedance of "Red Mode" guideline and stock drinking guideline downstream of the discharge (12th April 2013, 7000 *E.Coli* cfu/100mL). On the other two occasions the *E.Coli* numbers downstream of the discharge were lower than upstream which exceeded the Green Mode guideline. The PNRP secondary contact recreation guideline has been complied with downstream.

**Table 10: Summary of discharge exceedances of E.Coli**

| Date | Discharge | Upstream | Downstream |
|---|---|---|---|
| 19 November 2012 | **820** | 550 | 320 |
| 12 April 2013 | **2100** | 400 | **7000** |
| 22 February 2016 | 470 | 380 | 320 |

Source: SWDC Monitoring data

## 4.10 Nitrate and Total Oxidised Nitrogen

The concentration of nitrate and total oxidised nitrogen upstream and downstream of the site was consistently below the nitrate-nitrogen guidelines. The downstream site had (an annual median 0.90 g/m$^3$ compared to a guideline of 2.4 g/m$^3$ and annual maximum of 2.25 g/m$^3$ compared to a 95th percentile guideline 3.5 g/m$^3$, and there were no observed non-compliances during the monitoring. There was a minor increase in nitrate downstream of the discharge 73% of the time, however, 85% of the increased concentrations were less than 0.15 g/m$^3$.

## 4.11 Total Ammoniacal Nitrogen

The total ammoniacal nitrogen of Donald Creek upstream and downstream of the discharge is presented in Figure 18. The upstream concentration was in the range <0.01 g/m$^3$ to 0.2 g/m$^3$, while downstream was more variable and usually elevated above upstream concentrations (due to elevated concentrations of ammoniacal nitrogen in the discharge) with a range of between <0.01 g/m$^3$ and 2.6 g/m$^3$.

The two indicative guideline values in Figure 18 are presented for reference, these values represent the annual median and annual 95th percentile guidelines from NIWA (2014), based on a conservative scenario of pH 8. These values are highly conservative as they assume the presence of highly sensitive species and an elevated pH of 8. A more thorough assessment is discussed below.

It should be noted that the spring ecological survey (Hamill, 2017) identified the presence of the New Zealand Fingernail Clam downstream of the site, hence the conservative NIWA (2014) values have been used for assessment. However, given the species was found downstream of the site the species may be less sensitive to ammonia concentrations than indicated by the toxicity data.

The assessment using the NIWA (2014) values require determination of the 95th percentile pH to determine the annual median and annual 95th percentile guideline value (Table 7**),** followed by comparison of that value with the instream annual median and 95th percentile concentrations. This assessment is presented in Table 11 (upstream) and Table 12 (downstream) below. Two NIWA (2014) guidelines have been used for the assessment, that is the guidelines that would be protective of the Fingernail Clam and the more stringent guideline that would be protective of Freshwater Mussels (note no Freshwater Mussels have been observed in Donald Creek upstream or downstream of the discharge).

The total ammoniacal nitrogen concentration upstream of the site was below the median and 95th percentile guideline concentrations for all years assessed for both levels of protection, and all values were below the national bottom line guidelines.

The downstream annual median total ammoniacal nitrogen concentration exceeded the pH dependant median guideline for protective of Freshwater Mussels in 6 of the 10 years and exceeded the 95th percentile pH dependant guideline in 9 of the 10 years assessed. The downstream total ammoniacal nitrogen concentration downstream site exceeded the NIWA (2014) median and 95th guideline protective of the Fingernail Clam in 2 of the 10 years (2007 and 2014).

The downstream ammonia concentration was below the pH adjusted national bottom line for all years.

## Table 11: Upstream total ammoniacal nitrogen assessment

| Year | Measured pH | Measured $NH_4$-N (g/m$^3$) | Measured $NH_4$-N (g/m$^3$) | Measured $NH_4$-N (g/m$^3$) | NIWA (2014) $NH_4$-N Guideline protective of Freshwater Mussels (g/m$^3$) | NIWA (2014) $NH_4$-N Guideline protective of Freshwater Mussels (g/m$^3$) | NIWA (2014) $NH_4$-N Guideline protective of Fingernail Clam (g/m$^3$) | NIWA (2014) $NH_4$-N Guideline protective of Fingernail Clam (g/m$^3$) | Number of ammonia samples |
|---|---|---|---|---|---|---|---|---|---|
| Statistic | 95th percentile | Median | 95th Percentile | Maximum | For comparison to Median | For comparison to 95th Percentile | For comparison to Median | For comparison to 95th Percentile | |
| 2006 | 7.6 | 0.37 | 0.066 | 0.070 | 0.39 | 0.65 | 0.88 | 1.5 | 4 |
| 2007 | 7.4 | 0.040 | 0.073 | 0.086 | 0.47 | 0.78 | 1.05 | 1.78 | 12 |
| 2008 | 7.4 | 0.035 | 0.12 | 0.199 | 0.47 | 0.78 | 1.05 | 1.78 | 11 |
| 2009 | 7.0 | 0.041 | 0.24 | 0.043 | 0.58 | 0.97 | 1.31 | 2.23 | 8 |
| 2010 | 7.3 | 0.025 | 0.041 | 0.043 | 0.50 | 0.84 | 1.13 | 1.92 | 4 |
| 2011 | 7.4 | <0.01 | 0.014 | 0.020 | 0.47 | 0.78 | 1.05 | 1.78 | 9 |
| 2012 | 7.7 | <0.01 | 0.024 | 0.030 | 0.35 | 0.89 | 0.79 | 1.05 | 14 |
| 2013 | 7.9 | <0.01 | 0.033 | 0.040 | 0.27 | 0.46 | 0.62 | 1.05 | 15 |
| 2014 | 7.8 | <0.01 | 0.018 | 0.020 | 0.31 | 0.52 | 0.71 | 1.21 | 4 |
| 2015 | 7.4 | <0.01 | <0.01 | 0.005 | 0.47 | 0.78 | 1.05 | 1.78 | 4 |

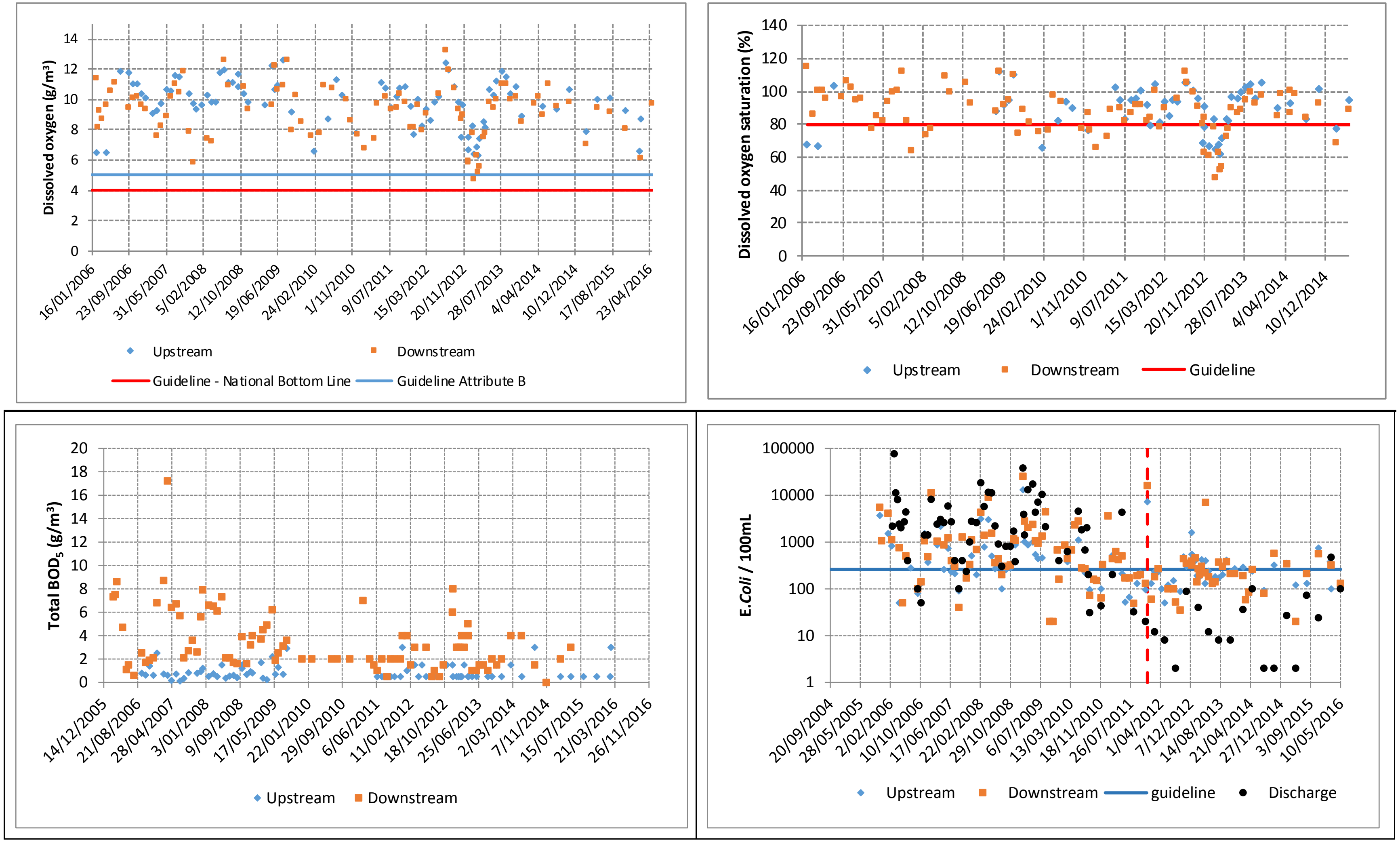
Source: SWDC monitoring data

## Table 12: Downstream total ammoniacal nitrogen assessment

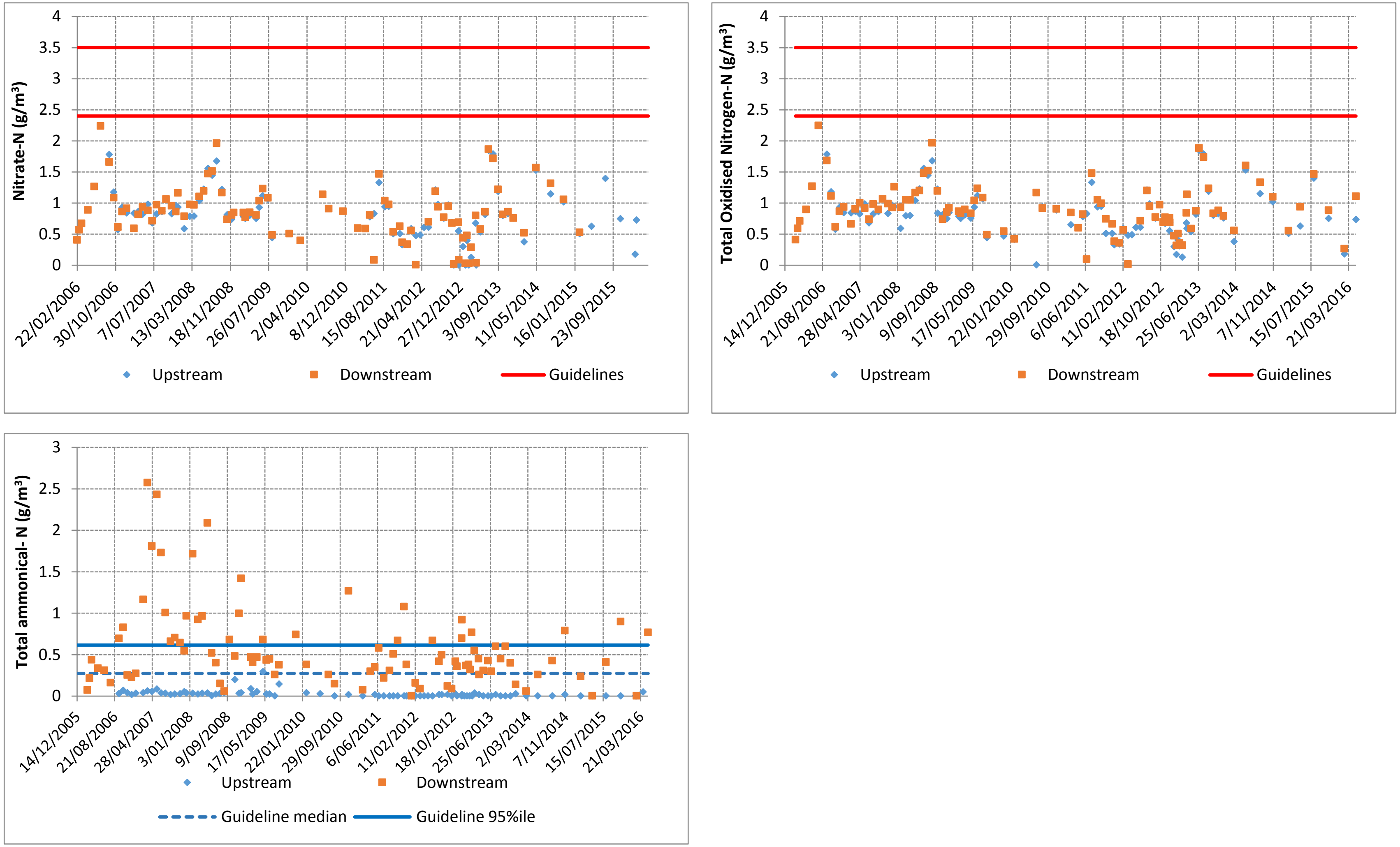
| Year | Measured pH | Measured $NH_4$-N (g/m$^3$) | Measured $NH_4$-N (g/m$^3$) | Measured $NH_4$-N (g/m$^3$) | NIWA (2014) $NH_4$-N Guideline protective of Freshwater Mussels (g/m$^3$) | NIWA (2014) $NH_4$-N Guideline protective of Freshwater Mussels (g/m$^3$) | NIWA (2014) $NH_4$-N Guideline protective of Fingernail Clam (g/m$^3$) | NIWA (2014) $NH_4$-N Guideline protective of Fingernail Clam (g/m$^3$) | Number of $TNH_4$-N samples |
|---|---|---|---|---|---|---|---|---|---|
| Statistic | 95th percentile | Median | 95th Percentile | Maximum | For comparison to Median | For comparison to 95th Percentile | For comparison to Median | For comparison to 95th Percentile | |
| 2006 | 7.6 | 0.28 | **0.77** | 0.83 | 0.39 | 0.65 | 0.88 | 1.5 | 10 |
| 2007 | 7.8 | **0.99** | **2.4** | **2.6** | 0.31 | 0.52 | 0.71 | 2.21 | 12 |
| 2008 | 7.1 | **0.80** | **1.9** | 2.09 | 0.55 | 0.92 | 1.25 | 2.13 | 12 |
| 2009 | 7.5 | 0.45 | 0.72 | 0.74 | 0.43 | 0.72 | 0.97 | 1.65 | 9 |
| 2010 | 7.4 | 0.32 | **1.1** | 1.27 | 0.47 | 0.78 | 1.05 | 1.78 | 4 |
| 2011 | 7.3 | 0.37 | **0.90** | 1.08 | 0.50 | 0.84 | 1.13 | 1.92 | 10 |
| 2012 | 7.8 | **0.39** | **0.80** | 0.92 | 0.31 | 0.52 | 0.71 | 1.21 | 12 |
| 2013 | 8.0 | **0.40** | **0.65** | 0.77 | 0.24 | 0.40 | 0.54 | 0.92 | 15 |
| 2014 | 8.3 | **0.35** | **0.74** | 0.79 | 0.15 | 0.25 | 0.33 | 0.57 | 4 |
| 2015 | 7.4 | 0.33 | **0.83** | 0.90 | 0.47 | 0.78 | 1.05 | 1.78 | 4 |
| 2016 | NA | NA | NA | **3.18** | NA | NA | NA | NA | 2 |

Note - Blue highlighted values exceed the NIWA (2014) guidelines that are protective of the Fingernail Clam. NPS -FW maximum national bottom line of 2.9 g/m$^3$ pH of 7.8 for 2007, and measured pH of 7.1, at the time of sampling in 2016, equating to a maximum bottom line of 5.1 g/m$^3$. **Bolded** values exceed values in the NIWA (2014) guidelines that are protective of Freshwater Mussels. NA – statistical values for the 2016 year are not applicable as at the time of writing only 2 samples were available for analysis, the maximum value measured in 2016 has been included as it is the highest measured value in the monitoring data.

**Figure 17: Receiving water dissolved oxygen, total BOD$_5$ and *E.Coli***



### Figure 18: Receiving water nitrate, total oxidised nitrogen and ammonia



## 4.12 Nutrients

### 4.12.1 Total Nitrogen

The TN concentrations downstream of the discharge are consistently elevated above upstream concentrations due to elevated total nitrogen concentrations in the discharge. The TN concentrations upstream of the discharge were typically between 0.5 g/m$^3$ and 1.5 g/m$^3$, while concentrations of TN downstream of the discharge were typically between 1 g/m$^3$ and 3 g/m$^3$.

### 4.12.2 Dissolved Inorganic Nitrogen

The upstream DIN concentrations were typically in the range 0.3 g/m$^3$ to 1.2 g/m$^3$, while the downstream concentrations were elevated, due to elevated DIN concentrations in the discharge, with concentrations typically in the range 0.6 g/m$^3$ to 1.9 g/m$^3$ (Figure 19).

The upstream DIN concentration was above the DIN periphyton guideline ("good" water quality for angling, NIWA, 2016) 73% of the time, while the downstream DIN concentration was above the guideline 90% of the time.

Given the upstream concentrations are frequently above the NIWA (2016) guidelines, these guideline values are only useful to provide context but cannot be used to measure compliance.

### 4.12.3 Total Phosphorus

The TP upstream of the site is typically in the range 0.02 g/m$^3$ to 0.4 g/m$^3$, while downstream concentrations were typically between 0.1 g/m$^3$ and 1.0 g/m$^3$ (Figure 19).

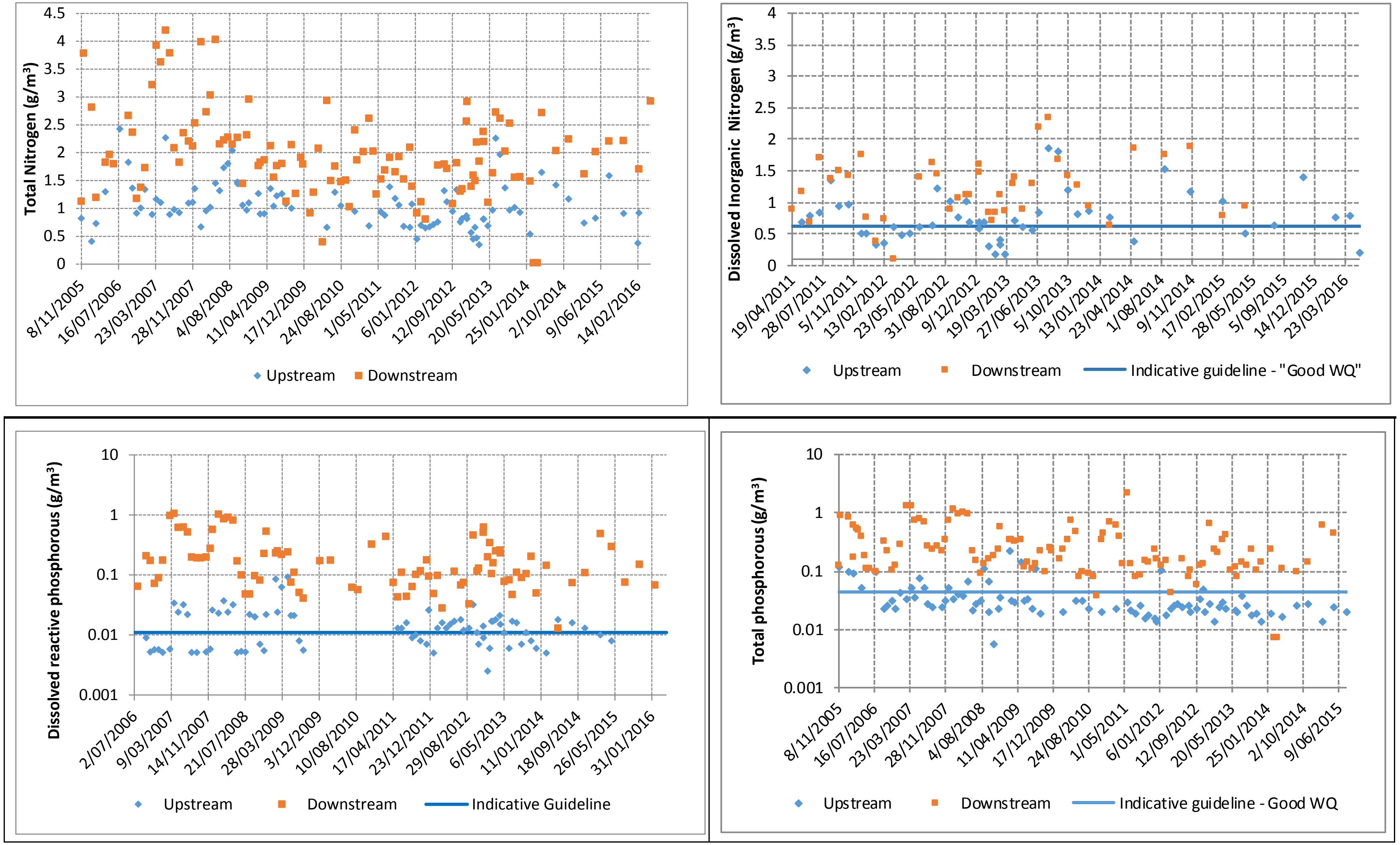
The TP concentration is almost always below the TP periphyton guideline (based on "good" water quality for angling, NIWA 2016) at the upstream site, while it is almost always above the guideline at the downstream site due to elevated TP in the discharge.

### 4.12.4 Dissolved Reactive Phosphorus

The concentration of DRP upstream of the site was typically between 0.005 g/m$^3$ and 0.03 g/m$^3$, while downstream concentrations were elevated, due to elevated concentrations in the discharge, with concentrations typically in the range of 0.05 g/m$^3$ and 0.55 g/m$^3$ (Figure 19).

The upstream DRP concentration was above the DRP periphyton guideline (based on "good" water quality for angling, NIWA 2016) approximately 50% of the time, while the downstream DRP concentration was above the indicative guideline 100% of the time. Given the upstream concentrations are frequently above the guideline, the guideline value is only useful to provide context but cannot be used to measure compliance.

**Figure 19: Receiving water total nitrogen, dissolved inorganic nitrogen, dissolved reactive phosphorus and total phosphorus**



# 5 Water Quality Modelling – Excel Based

## 5.1 Introduction

The water quality of key conservative parameters were modelled using a deterministic mass balance approach, in MS Excel, for the Project's staged development. The parameters modelled were $TNH_4$-N, TON, TN, DRP, TP and $TBOD_5$.

The Project will be staged in the following way, with each stage resulting in an increasing reduction in volume and load of the effluent discharged to Donald Creek, these scenarios were modelled for the assessment:

**Stage 1A:** Minor treatment pond improvements and irrigation to land starting with an area of 8Ha of land allowing for approximately 3-5% of the current average annual wastewater discharge volume. Stage 1a will be operational 2 years from the commencement of the consent.

**Stage 1B:** Irrigation area expanded to 78 Ha allowing for irrigation of approximately 44% of the current average annual wastewater discharge volume. At this stage the majority of discharges occur in winter months. Stage 1B will be developed in parallel with Stage 1A and will be operational 2 years after the commencement of the consent.

**Stage 2A:** The infiltration and inflow into the pipe sewage reticulation network is reduced by upgrading of the pipe network (known as I&I reduction), resulting in a reduction of an annual average daily inflow of approximately 35%. The area of irrigation is further increased allowing for irrigation of approximately 68% of the current average annual waste water discharge. During this stage almost all effluent discharged to Donald Creek occurs during winter. Stage 2A will be operational 10 years after the commencement of the consent.

**Stage 2B**: A large storage pond is constructed to defer flows and provide additional storage. The buffering allows for approximately 94% of the average annual wastewater discharge volume to be irrigated. During this stage discharge to Donald Creek occurs infrequently and in winter only with discharges targeting, in order of priority, 3 x median and 2 x median stream flow where practicable. Stage 2B will be operational 20 years after the commencement of the consent.

In addition to the above scenarios the existing scenario, where all wastewater is discharged to Donald Creek, was also modelled on a daily time step so comparisons to the current situation could be made.

### 5.1.1 Mass Balance Calculations

A mass balance model was developed based on a daily time step to predict the downstream concentrations and load of modelled parameters. The following calculations were used:

$$L_{DS} = (Q_{US} \times C_{US}) + (Q_E \times C_E)$$

$$C_{DS} = L_{DS} / (Q_{US} + Q_E)$$

Where:

- $L_{DS}$ = Downstream load (g/day)

- $Q_{US}$ = Upstream flow in Donald Creek ($m^3$/day)
- $Q_E$ = Discharge flow ($m^3$/day)
- $C_{US}$ = Upstream concentration ($g/m^3$)
- $C_E$ = Discharge concentration ($g/m^3$)
- $C_{DS}$ = Downstream concentration ($g/m^3$)

Two scenarios where modelled for each stage, these were the:

  - **Median model:** the median discharge and upstream concentration values were used as inputs. This model represents the likely average concentrations and loads of modelled parameters downstream of the site; and
  - **Conservative model:** the 95th percentile discharge and upstream concentrations were used as inputs. This model represents the worst case scenario, providing an indication of the potential maximum concentrations of modelled parameters downstream of the site.

## 5.2 Model Input Data

### 5.2.1 Donald Creek flow

Historically there was no continuous flow monitoring sites located in Donald Creek. In February 2016 Professional Ground Water and Environmental Services (PGWES) installed a temporary flow monitoring site upstream of the discharge.

Due to the lack of monitoring data a synthetic flow record was developed by PGWES (2016). The synthetic flow record was developed by correlating spot gauging's from Donald Creek with a number of continuous flow monitoring sites in the Wellington Region. The best correlation was achieved with Otukura Stream and this site was used to develop a synthetic flow record from 2000 to 2016. A full description of the development of the synthetic flow record is provided in PGWS (2016) (see Appendix 6A of the Main AEE). The synthetic flow record was compared to the monitoring data for 2016 by PGWS and a reasonable agreement between the synthetic flow record and the monitoring data was found (see Appendix 6C of the Main AEE).

### 5.2.2 Discharge flow data

The discharge flow is measured continuously using an online flow meter as part of the site's compliance monitoring program. The average daily discharge flow from 2005 to 2016 was used as modelled inputs.

The change in discharge flow volumes to Donald Creek for, the four development stages, was predicted by Lowe Environmental Impact (LEI, 2017) using a water balance model. The model predicts the amount of water that can be irrigated on a daily time step. To do this the model determines the soil moisture characteristics using rainfall, evaporation and evapotranspiration. If the soil has characteristics that are suitable for irrigation then wastewater is irrigated to land at an appropriate hydraulic loading and the remaining water is discharged to Donald Creek. In the case of Stage 2B the potential for storage in the deferred storage pond is considered and the discharge to Donald Creek only occurs when the pond volume exceeds 140,000 $m^3$. A full description of the water balance model can be found in LEI (2017) (see Appendix 7 of the Main AEE).

### 5.2.3 Water quality inputs

**Existing Scenario, Stages 1A and 1B – Before I/I reduction**

The input water quality values used in the model are presented in Table 13 and Table 14. The water quality inputs for the model for the Existing Scenario, Stages 1A and 1B were based on measured medians and 95th percentiles of upstream and discharge water quality from the sites water quality monitoring program from 2005 to 2016. As some parameters demonstrate a seasonal trend the input concentrations were divided into summer and winter values, with summer assumed to be November to April and winter assumed to be May to October.

It should be noted that as the discharge at times contains measurable concentrations of nitrite total oxidised nitrogen was modelled rather than nitrate, and the total oxidised nitrogen values were compared to the nitrate-nitrogen water quality guidelines.

**Stages 2A and 2B – After I/I reduction**

For stages 2A and 2B the upstream values are assumed to be the same as for Stages 1A and 1B. However, during stages 2A and 2B the network would have been upgraded to reduce I/I. Therefore, the volume of influent water from non-sewage inputs will have been reduced resulting in changes to the discharge water quality.

In the case of phosphorus the most likely effect will be a reduction in the volume of non-sewage water available to dilute the phosphorus concentrations. Therefore, the median input concentrations for phosphorus parameters in the discharge were scaled according to the predicted reduction in dilution that is a 20% reduction in volume in summer and a 35% reduction in volume in winter.

In the case of ammonia the reduced volume results in reduced dilution and increased residence time in the WWTP. The increased residence time results in the potential for increased ammonia stripping and nitrogen uptake from biomass. In order to estimate change in nitrogen species concentration as a result of the I/I reduction the following removal equation (from Sperling 2007) was used:

$$C_e = C_o \exp^{(-K[t+60.6 \text{ x } (pH -6.6)]}$$

Where:

- $C_e$ = effluent concentration
- $C_o$ = influent concentration
- K = 0.0064 x $1.039^{(T-20)}$
- T = temperature in °C
- pH = pH in the pond
- t = hydraulic retention time in the pond

The 95th percentile inputs for Stages 2A and 2B were predicted by assuming the ratio of the median to 95th percentile concentrations prior to I/I reduction will be the same as after I/I reduction.

**Table 13: Donald Creek upstream water quality model inputs**

| Input Parameter | TON | NH4-N | TN | DIN | TP | DRP |
|---|---|---|---|---|---|---|
| Median - Summer | 0.68 | 0.020 | 0.83 | 0.69 | 0.034 | 0.013 |
| 95th Percentile - summer | 0.96 | 0.058 | 1.3 | 1.0 | 0.12 | 0.036 |
| Median - Winter | 0.94 | 0.020 | 1.2 | 0.98 | 0.024 | 0.011 |

| Input Parameter | TON | NH4-N | TN | DIN | TP | DRP |
|---|---|---|---|---|---|---|
| 95th Percentile - Winter | 1.8 | 0.14 | 2.2 | 1.8 | 0.10 | 0.031 |

Source: SWDC Monitoring Data

**Table 14: Discharge water quality model inputs**

| Scenario/ Input Parameter | TON | $NH_4$-N | TN | DIN | TP | DRP |
|---|---|---|---|---|---|---|
| **Existing, Stage 1A and 1B** | | | | | | |
| Median - Summer | 0.32 | 4.3 | 9.1 | 4.5 | 2.5 | 1.8 |
| 95th Percentile -Summer | 1.3 | 11.1 | 13.6 | 11.2 | 5.3 | 4.5 |
| Ratio 95th Percentile/ Median - Summer | 3.9 | 2.6 | 1.5 | 2.5 | 2.2 | 2.6 |
| Scaling factor for post I/I - Summer | 1.1 | 1.1 | 1.1 | 1.1 | 1.3 | 1.3 |
| Median- Winter | 0.98 | 4.9 | 8.4 | 5.9 | 1.3 | 1.0 |
| 95th Percentile - Winter | 2.8 | 11.6 | 16.4 | 12.1 | 3.9 | 2.8 |
| Ratio 95th Percentile/ Median - Winter | 2.9 | 2.4 | 1.9 | 2.1 | 2.9 | 2.9 |
| Scaling factor for post I/I - Winter | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| **Stage 2A and 2B** | | | | | | |
| Median - Summer | 0.35 | 4.7 | 10.0 | 4.9 | 3.1 | 2.2 |
| 95th Percentile -Summer | 1.4 | 12.2 | 14.9 | 12.4 | 6.6 | 5.6 |
| Median- Winter | 1.5 | 7.3 | 12.6 | 8.8 | 2.0 | 1.5 |
| 95th Percentile - Winter | 4.3 | 17.4 | 24.5 | 18.2 | 5.9 | 4.4 |

### 5.2.4 Model assumptions and limitations

The following assumptions and limitations have been used in the modelling:

- The modelled concentrations and loads relate to full mixing, the concentrations and loads prior to full mixing are not considered;
- A conservative mass balance approach has been used and therefore changes in speciation of nitrogen species, settling of particulates in the stream and degradation of organic carbon are not considered;
- The model uses static water quality inputs at each daily time step and is a deterministic model. As such the model overestimates 95th percentile and maximum concentrations as it uses a fixed 95th percentile input for discharge and upstream monitoring data;
- The model assumes that the I/I works will result in a 20% and 35% reduction of inflow in summer and winter flow respectively,
- The measured water quality data is representative of the long term discharge and upstream water quality,
- The changes in concentration and flow following I/I reduction is assumed to occur at commencement of Stage 2A, however, the work will be staged and changes will occur gradually over time;
- The potential for leaching of nutrients into Donald Creek from the irrigation fields has been considered for the calculated annual mass load of TN and DIN only. Phosphorus leaching is not considered significant and is not accounted for; and
- The concentrations and volumes of leached nutrients from the irrigation field to Donald Creek has not been accounted for in the model predicting downstream concentrations. However, the concentration of leached nutrients is predicted to be low and similar to background concentrations and therefore the approach taken is conservative.

## 5.3 Flow Model Results

### 5.3.1 Discharge flow analysis

The discharge flows predicted by LEI (2017) have been analysed. Table 15 presents the percentage of the current volume discharged to Donald Creek for the various scenarios by month. The overall discharge volume decreases as the staged development occurs. At Stage 1B the discharge to Donald Creek is approximately 56% of the current discharge, dropping to 32% in Stage 2A and only 6% in Stage 2B.

Under all scenarios more discharge occurs in winter than summer. As the development proceeds the percentage of flow discharging in winter increases. By Stage 1B the majority of the discharge occurs in June, July and August. Once the development reaches Stage 2B discharge only occurs during July and August.

**Table 15: Percentage of current volume discharged to Donald Creek**

| Flow statistic | Current Discharge | Stage 1A Discharge | Stage 1B | Stage 2A | Stage 2B |
|---|---|---|---|---|---|
| January | 5% | 3.7% | 0.056% | 0.0075% | 0% |
| February | 4% | 2.6% | 0.069% | 0.013% | 0% |
| March | 4% | 4.1% | 0.23% | 0.23% | 0% |
| April | 6% | 6.2% | 1.9% | 0.77% | 0% |
| May | 9% | 9.4% | 4.0% | 1.4% | 0% |
| June | 10% | 10.6% | 11% | 7.1% | 0% |
| July | 14% | 14.4% | 14% | 10% | 1.6% |
| August | 13% | 13.8% | 14% | 9.1% | 4.9% |
| September | 11% | 10.7% | 5.3% | 2.2% | 0% |
| October | 11% | 10.5% | 5.1% | 2.1% | 0% |
| November | 8% | 6.7% | 0.40% | 0.025% | 0% |
| December | 6% | 4.7% | 0.25% | 0.025% | 0% |
| **Total** | **100%** | **97%** | **56%** | **32%** | **6%** |

Table 16 shows the volume of discharge to Donald Creek and number of days of discharge to Donald Creek occurring under Stage 2B for the years modelled. The model predicts that only four years out of the 11 years modelled would have a discharge in July and 3 years would not discharge at all.

**Table 16: Discharge to Donald Creek Stage 2B**

| Year | July ($m^3$) | August ($m^3$) | July (Days) | August (days) |
|---|---|---|---|---|
| 2006 | 70,818 | 104,701 | 16 | 26 |
| 2007 | - | - | - | - |
| 2008 | 43,594 | 150,805 | 8 | 31 |
| 2009 | - | 4,970 | - | 1 |
| 2010 | 18,244 | 49,998 | 4 | 15 |
| 2011 | 11,704 | 63,298 | 4 | 22 |
| 2012 | - | 63,537 | - | 17 |
| 2013 | - | 6,004 | - | 4 |
| 2014 | - | 14,106 | - | 5 |
| 2015 | - | - | - | - |

Source: Data provided by LEI in 2017

Tables 17 to 22 provide the volumes and number of days discharging for Stages 1A to 2A. The volume and number of days of discharge decrease considerably as the development progresses. By Stage 1B the majority of the discharge occurs between April and October.

**Table 17: Discharge to Donald Creek Stage 2A ($m^3$/month)**

| Year | January ($m^3$) | February ($m^3$) | March ($m^3$) | April ($m^3$) | May ($m^3$) | June ($m^3$) | July ($m^3$) | August ($m^3$) | September ($m^3$) | October ($m^3$) | November ($m^3$) | December ($m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | - | - | - | 2,319 | 16,521 | 71,798 | 151,515 | 99,719 | 2,534 | 23,573 | 266 | 703 |
| 2007 | - | - | - | 70 | - | 24,620 | 48,738 | 48,918 | 307 | 36,521 | - | - |
| 2008 | - | - | - | 1,841 | 16,761 | 59,901 | 126,974 | 174,500 | 43,809 | 31,781 | - | - |
| 2009 | - | 234 | - | 266 | 16,547 | 55,455 | 68,027 | 57,463 | 13,731 | 33,553 | - | 321 |
| 2010 | - | - | - | - | 5,925 | 85,803 | 66,334 | 53,594 | 53,772 | 10,688 | - | - |
| 2011 | 486 | - | - | 2,233 | 13,155 | 61,575 | 108,643 | 78,049 | 27,691 | 767 | - | 245 |
| 2012 | 209 | 190 | - | 769 | 4,357 | 71,843 | 74,498 | 77,283 | 13,257 | 2,944 | - | - |
| 2013 | - | 782 | 582 | 815 | 3,451 | 49,661 | 76,361 | 53,908 | 11,691 | 39,208 | 2,037 | 1,058 |
| 2014 | - | - | 2,181 | 42,377 | 25,470 | 56,645 | 49,277 | 94,519 | 20,530 | 6,374 | - | - |
| 2015 | - | - | - | - | 2,586 | 51,030 | 59,498 | 70,102 | 13,043 | 5,187 | - | - |

Source: Data provided by LEI in 2017

**Table 18: Discharge to Donald Creek Stage 2A (days/month)**

| Year | January (Days) | February (Days) | March (Days) | April (Days) | May (Days) | June (Days) | July (Days) | August (Days) | September (Days) | October (Days) | November (Days) | December (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | - | - | - | 6 | 30 | 30 | 31 | 31 | 8 | 19 | 3 | 3 |
| 2007 | - | - | - | 1 | - | 30 | 31 | 31 | 3 | 24 | - | - |
| 2008 | - | - | - | 2 | 12 | 30 | 31 | 31 | 30 | 30 | - | - |
| 2009 | - | - | - | 1 | 22 | 30 | 31 | 31 | 22 | 31 | - | 2 |
| 2010 | - | - | - | 0 | 8 | 30 | 31 | 31 | 30 | 18 | - | - |
| 2011 | 1 | - | - | 7 | 26 | 30 | 31 | 31 | 9 | 2 | - | 1 |
| 2012 | 1 | 1 | - | 2 | 14 | 30 | 31 | 31 | 20 | 6 | - | - |
| 2013 | - | 1 | 1 | 2 | 11 | 30 | 31 | 31 | 20 | 26 | 4 | 2 |
| 2014 | - | - | 3 | 18 | 26 | 30 | 31 | 31 | 20 | 10 | - | - |
| 2015 | - | - | - | - | 6 | 30 | 31 | 31 | 19 | 10 | - | - |

Source: Data provided by LEI in 2017

### Table 19: Discharge to Donald Creek Stage 1B (m$^3$/month)

| Year | January (m$^3$) | February (m$^3$) | March (m$^3$) | April (m$^3$) | May (m$^3$) | June (m$^3$) | July (m$^3$) | August (m$^3$) | September (m$^3$) | October (m$^3$) | November (m$^3$) | December (m$^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | - | - | - | 11,429 | 48,338 | 107,375 | 224,843 | 150,392 | 20,205 | 54,766 | 16,469 | 10,474 |
| 2007 | - | - | - | 648 | 352 | 36,220 | 72,726 | 74,517 | 9,462 | 76,875 | 196 | - |
| 2008 | - | - | - | 4,317 | 40,720 | 89,259 | 189,185 | 264,639 | 93,840 | 74,377 | 2,239 | - |
| 2009 | - | 2,066 | - | 2,146 | 42,763 | 83,573 | 103,638 | 86,888 | 43,838 | 75,254 | 1,633 | 4,838 |
| 2010 | 526 | - | - | - | 13,286 | 128,009 | 100,331 | 79,927 | 105,596 | 36,293 | 3,574 | - |
| 2011 | 1,376 | - | - | 10,381 | 40,709 | 93,517 | 164,684 | 118,462 | 52,466 | 2,998 | 115 | 723 |
| 2012 | 3,283 | 3,231 | 710 | 5,988 | 22,310 | 107,656 | 111,811 | 117,592 | 41,765 | 16,087 | - | - |
| 2013 | - | 1,144 | 722 | 3,326 | 19,820 | 71,730 | 115,945 | 82,373 | 34,574 | 80,487 | 10,787 | 6,997 |
| 2014 | - | - | 8,751 | 76,184 | 64,220 | 86,989 | 74,771 | 143,976 | 51,705 | 25,673 | - | - |
| 2015 | - | - | - | 1,775 | 11,264 | 77,338 | 91,053 | 107,389 | 39,010 | 20,644 | 2,482 | - |

Source: Data provided by LEI in 2017

### Table 20: Discharge to Donald Creek Stage 1B (days/month)

| Year | January (Days) | February (Days) | March (Days) | April (Days) | May (Days) | June (Days) | July (Days) | August (Days) | September (Days) | October (Days) | November (Days) | December (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 0 | 0 | 0 | 21 | 31 | 30 | 31 | 31 | 27 | 31 | 25 | 11 |
| 2007 | 0 | 0 | 0 | 3 | 2 | 30 | 31 | 31 | 23 | 30 | 1 | 0 |
| 2008 | 0 | 0 | 0 | 11 | 28 | 30 | 31 | 31 | 30 | 31 | 5 | 0 |
| 2009 | 0 | 3 | 0 | 7 | 30 | 30 | 31 | 31 | 30 | 31 | 3 | 5 |
| 2010 | 1 | 0 | 0 | 0 | 8 | 30 | 31 | 31 | 30 | 26 | 4 | 0 |
| 2011 | 2 | 0 | 0 | 21 | 27 | 30 | 31 | 31 | 17 | 7 | 2 | 1 |
| 2012 | 4 | 3 | 3 | 15 | 28 | 30 | 31 | 31 | 30 | 26 | 0 | 0 |
| 2013 | 0 | 1 | 1 | 4 | 28 | 30 | 31 | 31 | 25 | 28 | 7 | 4 |
| 2014 | 0 | 0 | 3 | 21 | 29 | 30 | 31 | 31 | 30 | 28 | 0 | 0 |
| 2015 | 0 | 0 | 0 | 10 | 15 | 30 | 31 | 31 | 28 | 22 | 3 | 0 |

Source: Data provided by LEI in 2017

### Table 21: Discharge to Donald Creek Stage 1A (m$^3$/month)

| Year | January (m$^3$) | February (m$^3$) | March (m$^3$) | April (m$^3$) | May (m$^3$) | June (m$^3$) | July (m$^3$) | August (m$^3$) | September (m$^3$) | October (m$^3$) | November (m$^3$) | December (m$^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 19,957 | 15,173 | 28,367 | 57,150 | 95,187 | 107,192 | 224,352 | 150,213 | 65,805 | 104,912 | 106,593 | 93,791 |
| 2007 | 39,681 | 19,147 | 20,933 | 30,425 | 33,352 | 36,122 | 72,592 | 74,473 | 54,930 | 123,751 | 43,259 | 21,691 |
| 2008 | 21,692 | 16,310 | 28,484 | 33,983 | 86,236 | 89,087 | 188,820 | 264,412 | 140,934 | 123,066 | 67,823 | 25,414 |
| 2009 | 27,339 | 43,966 | 35,922 | 35,439 | 89,381 | 83,470 | 103,577 | 86,798 | 91,554 | 123,994 | 73,718 | 76,103 |
| 2010 | 40,211 | 47,258 | 36,068 | 18,874 | 43,383 | 127,771 | 100,229 | 79,778 | 151,316 | 82,641 | 55,483 | 22,622 |
| 2011 | 32,377 | 18,418 | 32,866 | 54,682 | 85,126 | 93,444 | 164,538 | 118,366 | 95,469 | 39,992 | 55,046 | 51,688 |
| 2012 | 66,108 | 36,213 | 56,793 | 47,687 | 67,695 | 107,486 | 111,644 | 117,515 | 89,199 | 59,290 | 27,946 | 20,567 |
| 2013 | 19,608 | 14,252 | 15,719 | 32,704 | 66,126 | 71,453 | 115,854 | 82,340 | 80,397 | 125,766 | 78,805 | 56,224 |
| 2014 | 45,059 | 22,690 | 41,635 | 117,835 | 108,011 | 86,980 | 74,709 | 143,890 | 98,794 | 73,903 | 37,499 | 19,851 |
| 2015 | 4,126 | 3,370 | 40,901 | 33,057 | 52,297 | 77,268 | 91,025 | 107,361 | 85,609 | 65,145 | 53,997 | 24,960 |

Source: Data provided by LEI in 2017

### Table 22: Discharge to Donald Creek Stage 1A (days/month)

| Year | January (Days) | February (Days) | March (Days) | April (Days) | May (Days) | June (Days) | July (Days) | August (Days) | September (Days) | October (Days) | November (Days) | December (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 21 | 16 | 28 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 |
| 2007 | 27 | 20 | 22 | 29 | 31 | 30 | 31 | 31 | 30 | 31 | 24 | 22 |
| 2008 | 20 | 20 | 26 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 29 | 25 |
| 2009 | 23 | 26 | 29 | 28 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 |
| 2010 | 30 | 28 | 29 | 26 | 31 | 30 | 31 | 31 | 30 | 31 | 28 | 23 |
| 2011 | 23 | 19 | 28 | 30 | 31 | 30 | 31 | 31 | 29 | 31 | 30 | 29 |
| 2012 | 29 | 25 | 29 | 28 | 31 | 30 | 31 | 31 | 30 | 30 | 24 | 21 |
| 2013 | 21 | 15 | 17 | 29 | 31 | 30 | 31 | 31 | 30 | 30 | 29 | 28 |
| 2014 | 29 | 19 | 27 | 29 | 31 | 30 | 31 | 31 | 30 | 31 | 27 | 20 |
| 2015 | 6 | 9 | 30 | 30 | 31 | 30 | 31 | 31 | 30 | 30 | 28 | 22 |

Source: Data provided by LEI in 2017

### 5.3.2 River flow regime compared to discharge frequency

The development of nuisance growths such as periphyton and sewage fungus in river systems is dependent on a number of factors including nutrient concentrations, habitat type, water temperature and flow conditions. As the flow rate of a river increases nuisance growths can be displaced from the river bed (referred to as sloughing). Under flood events total displacement of the periphyton and sewage fungus communities will occur. It is generally accepted that flood events above 3 times the median flow of river will result in total displacement of nuisance growths (NIWA,2000). However, it is likely that lower flow events will result in some removal of nuisance growths from a river bed.

The modelled discharge and Donald Creek data were assessed to determine the Creek flow regimes occurring when the WWTP is discharging to the Creek (Table 23 and Table 24). As the project progresses the frequency of the discharge to the Creek decreases and the proportion of time the discharge occurs during elevated Creek flows (2 x and 3 x median flow) increases.

Under the current scenario and Stage 1A the WWTP discharges 99% of the time with the discharge occurring 13% of the time above 3 x median flow and 23% above 2 x the median flow. At Stage 1B the frequency of discharge to the Creek reduces to 51% with discharge occurring 25% of the above 3 x median flow and 46% of the time above 2 x median flow.

Once Stage 2B is operational the WWTP discharges to the Creek less than 5% of the time, 75% of discharges occur while the Creek is above 3 x the median flow and over 90% of the discharges occur at 2 x median flow.

**Table 23: Frequency of discharge to Donald Creek**

| Flow statistic | Current Discharge | Stage 1A | Stage 1B | Stage 2A | Stage 2B |
|---|---|---|---|---|---|
| <0.5x Median | 27% | 20% | 1.8% | 1.0% | 0.0% |
| 0.5x Median - 1x Median | 22% | 20% | 6.1% | 3.6% | 0.0% |
| 1x Median – 2x Median | 26% | 25% | 19% | 14% | 0.32% |
| 2x Median – 3x Median | 11% | 11% | 11% | 9.4% | 0.68% |
| >3x Median | 13% | 13% | 13% | 13% | 2.7% |
| Total | **99%** | **90%** | **51%** | **40%** | **3.7%** |

Source: Data provided by LEI in 2017

**Table 24: Frequency of discharge to Donald Creek as a percentage of days when discharge is occurring**

| Flow statistic | Current Discharge | Stage 1A | Stage 1B | Stage 2A | Stage 2B |
|---|---|---|---|---|---|
| <0.5x Median | 27% | 23% | 3.6% | 2.4% | 0.0% |
| 0.5x Median - 1x Median | 22% | 22% | 12% | 9.0% | 0.0% |
| 1x Median – 2x Median | 26% | 28% | 38% | 34% | 8.5% |
| 2x Median – 3x Median | 11% | 12% | 21% | 23% | 18% |
| >3x Median | 13% | 14% | 25% | 31% | 73% |
| Total | 100% | 100% | 100% | 100% | 100% |

Source: Data provided by LEI in 2017

## 5.4 Water Quality Model Results

### 5.4.1 Nitrate

The NIWA (2013) nitrate guidelines have been used for the assessment, these guidelines require comparison of the annual downstream median and 95th percentile concentrations with grading and surveillance guidelines respectively. As Donald Creek would be considered at best a slightly to moderately disturbed ecosystem the relevant grading (for comparison to the annual median) and surveillance (for comparison to the annual 95th percentile) guideline concentrations at the 95% level of protection are 2.4 g/m$^3$ and 3.5 g/m$^3$ respectively.

The model was used to predict the nitrate concentration downstream of the site under the different scenarios for the different years modelled. The median concentration is the annual median from the median model, while the 95th percentile is the 95th percentile of the Conservative Model (Table 25). The model predicts that under all scenarios the median concentration downstream of the discharge would be less than 1 g/m$^3$ and the 95th percentile concentration would less than 2 g/m$^3$. Therefore, the concentration of nitrate downstream of the site is predicted to comply with the NIWA (2013) guidelines at all times and the discharge is unlikely to result in impacts due to nitrate toxicity.

It should be noted, as a conservative measure, the guideline concentrations have been compared to modelled Total Oxidised Nitrogen rather than nitrate so that the nitrite concentrations are considered in the assessment.

### 5.4.2 Total ammoniacal nitrogen

**Introduction**

The NIWA (2014) indicative ammonia guidelines and the NPS-FM (2014) National Bottom Line have been used in this assessment. The NIWA (2014) guidelines require comparison of the annual downstream median and 95th percentile concentrations with grading and surveillance guidelines respectively. These guideline values vary with pH as the toxicity of $NH_4$-N increases with increasing pH due to the increasing concentration of the unionised form ($NH_3$). According to the guidelines, the 95th percentile of the water bodies pH values should be used to determine the guideline value, thus a pH in Donald Creek of 7.9 was applied. Both the 95% level of protection and 90% level of protection have been considered. Therefore the guidelines were:

- NIWA (2014) guideline protective of Freshwater Mussels: 0.27 g/m$^3$ and 0.46 g/m$^3$ for comparison to annual median and annual 95th percentile respectively;
- NIWA (2014) guideline protective of the Fingernail Clam: 0.6 g/m$^3$ and 1.05 g/m$^3$ for comparison to annual median and annual 95th percentile respectively; and
- NPS (2014) national bottom line: 1.3 g/m$^3$ and 2.2 g/m$^3$ for comparison to the annual median and maximum respectively.

The model was used to predict the $NH_4$-N concentration downstream of the site under the different scenarios for the different years modelled. The median concentration is the annual median from the median model, while the 95th percentile is the 95th percentile of the Conservative Model (Table 26). As the Conservative model is highly conservative it is appropriate to consider the 95th percentile as the annual maximum as the predicted highly elevated maximum values in the model are not likely to occur.

The measured data has been included in Table 26 for comparison to the modelled existing scenario. It is apparent from the comparison that the annual median concentrations are in reasonable agreement while the modelled 95th percentile concentrations typically overestimate for all years other than 2007, confirming that the model is highly conservative for the 95th percentile assessment. This is a major limitation with the modelling approach, and although the predicted outcomes are discussed below further modelling was undertaken, using Monte Carol simulation. The Monte Carlo modelling is discussed in Section 6.

**NIWA (2014) guideline protective of Freshwater Mussels**

Based on the model the $NH_4$-N concentration would exceed both the median and 95th percentile values at the 95% level of protection for all years under the Existing Scenario and Stage 1A. This is likely as there is only a minimal reduction in discharge volumes for Stages 1A.

Under Stage 1B and Stage 2A the model predicts that the median guideline would not be exceeded, while the 95th percentile guideline would be exceeded in all years modelled.

Once the development reaches Stage 2B only 6% of the current discharge volume is discharged to Donald Creek and all of this discharge occurs in July and August (Table 16). As a result no exceedances in the median guideline are predicted to occur, and the predicted compliance with the 95th percentile guideline improves. However, the model predicts that the 95th percentile guideline would be exceeded in four of the years modelled. These exceedances occur in 2006, 2008, 2010 and 2011. These are the years in which the model predicts discharge occurring during both July and August with between 19 and 42 total days of discharge (Table 16).

It is reiterated here that the model used to predict the 95th percentile concentrations is highly conservative as it uses a highly elevated ammonia concentration of 17 $g/m^3$ in winter.

**NIWA (2014) guideline protective of the Fingernail Clam**

Comparison of the model outputs to the NIWA (2014) guideline protective of the Fingernail Clam indicates there would be no exceedances of median guideline under all stages modelled. However, there would be exceedances of the annual 95th percentile guideline until Stage 2B is in operation when no exceedances are predicted.

**NPS (2014) National Bottom Line**

The model predicts that the National Bottom Line median guideline would not be exceeded under all modelled stages. The model predicts that the National Bottom Line maximum has potential to be exceeded during Stage 1A which is to be expected as Stage 1A is similar to the existing scenario, where concentrations would have exceeded the national bottom line if pH values were lower.

**Table 25: Modelled nitrate concentration downstream of the discharge**

| Year | Existing | | Stage 1A | | Stage 1B | | Stage 2A | | Stage 2B | |
|---|---|---|---|---|---|---|---|---|---|---|
| Statistic | Median | 95th Percentile | Median | 95th Percentile | Median | 95th Percentile | Median | 95th Percentile | Median | 95th Percentile |
| 2005 | 0.94 | 1.87 | 0.94 | 1.87 | 0.94 | 1.85 | 0.94 | 1.90 | 0.94 | 1.77 |
| 2006 | 0.94 | 1.93 | 0.94 | 1.94 | 0.94 | 1.88 | 0.94 | 1.94 | 0.94 | 1.89 |
| 2007 | 0.94 | 1.94 | 0.94 | 1.96 | 0.94 | 1.94 | 0.94 | 2.03 | 0.94 | 1.77 |
| 2008 | 0.94 | 1.89 | 0.94 | 1.89 | 0.94 | 1.88 | 0.94 | 1.94 | 0.94 | 1.89 |
| 2009 | 0.94 | 1.89 | 0.94 | 1.90 | 0.94 | 1.87 | 0.94 | 1.92 | 0.94 | 1.77 |
| 2010 | 0.94 | 1.87 | 0.94 | 1.87 | 0.94 | 1.85 | 0.94 | 1.88 | 0.94 | 1.83 |
| 2011 | 0.94 | 1.91 | 0.94 | 1.92 | 0.94 | 1.91 | 0.94 | 1.98 | 0.94 | 1.89 |
| 2012 | 0.94 | 1.86 | 0.94 | 1.87 | 0.94 | 1.85 | 0.94 | 1.89 | 0.94 | 1.77 |
| 2013 | 0.94 | 1.93 | 0.94 | 1.94 | 0.94 | 1.88 | 0.94 | 1.92 | 0.94 | 1.77 |
| 2014 | 0.94 | 1.88 | 0.94 | 1.88 | 0.94 | 1.86 | 0.94 | 1.89 | 0.94 | 1.77 |
| 2015 | 0.94 | 1.93 | 0.68 | 1.93 | 0.94 | 1.91 | 0.94 | 1.98 | 0.94 | 1.77 |

Source: Mass balance model outputs, median is from the median model, 95th percentile is from the conservative model. Guideline values 95% level of protection from NIWA (2013): Median = 2.4 g/m$^3$, 95th percentile = 3.5 g/m$^3$. Note for the purpose of the model all TON is assumed to be nitrate.

### Table 26: Modelled total ammoniacal nitrogen concentration downstream of the discharge

| Year | Measured | | Existing | | Stage 1A | | Stage 1B | | Stage 2A | | Stage 2B | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Statistic | Median | 95th Percentile | Median | 95th Percentile | Median | 95th Percentile | Median | 95th Percentile | Median | 95th Percentile | Median | 95th Percentile |
| 2005 | **-** | **-** | **0.37** | **1.6** | **0.35** | **1.5** | 0.14 | **1.0** | 0.04 | **1.0** | 0.02 | 0.14 |
| 2006 | **0.28** | **0.77** | **0.49** | **2.3** | **0.45** | **2.4** | 0.11 | **1.4** | 0.02 | **1.3** | 0.02 | **0.96** |
| 2007 | **0.99** | **2.5** | **0.57** | **2.0** | **0.55** | **2.2** | 0.02 | **2.0** | 0.02 | **2.0** | 0.02 | 0.14 |
| 2008 | **0.80** | **1.9** | **0.46** | **2.4** | **0.43** | **2.1** | 0.06 | **1.3** | 0.02 | **1.3** | 0.02 | **0.96** |
| 2009 | **0.45** | **0.72** | **0.49** | **2.6** | **0.47** | **2.4** | 0.13 | **1.2** | 0.02 | **1.2** | 0.02 | 0.14 |
| 2010 | **0.32** | **1.1** | **0.36** | **1.5** | **0.34** | **1.60** | 0.02 | **0.93** | 0.02 | **0.90** | 0.02 | **0.58** |
| 2011 | **0.37** | **0.90** | **0.51** | **2.6** | **0.48** | **2.5** | 0.02 | **1.6** | 0.02 | **1.6** | 0.02 | **0.96** |
| 2012 | **0.39** | **0.80** | **0.35** | **1.8** | **0.33** | **1.8** | 0.06 | **1.0** | 0.02 | **0.99** | 0.02 | 0.14 |
| 2013 | **0.40** | **0.65** | **0.48** | **2.2** | **0.42** | **2.2** | 0.08 | **1.3** | 0.02 | **1.3** | 0.02 | 0.14 |
| 2014 | **0.35** | **0.74** | **0.39** | **2.0** | **0.35** | **1.8** | 0.09 | **1.2** | 0.02 | **1.1** | 0.02 | 0.14 |
| 2015 | **0.33** | **0.83** | **0.53** | **3.7** | **0.46** | **3.3** | 0.02 | **1.6** | 0.02 | **1.6** | 0.02 | 0.14 |
| 2016 | NA | **3.1** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

Source: Mass balance model outputs, median is from the median model, 95th percentile is from the conservative model. **Bolded** values exceed guideline values for protection of Freshwater Mussels from NIWA (2014) assuming a pH of 7.9: Median = 0.27 g/m$^3$, 95th percentile = 0.46 g/m$^3$, blue highlighted values exceed guidelines for the protection of the Fingernail Clam from NIWA (2014) assuming a pH of 7.9: Median = 0.62 g/m$^3$, 95th percentile = 1.05 g/m$^3$. Red values equal or exceed the national bottom line at pH 7.9 - 2.5 g/m$^3$ for the annual maximum.

### 5.4.3 Nutrients

The predicted concentration and annual loads of nutrients from the mass balance model are presented in Tables 27 to 30 below. The measured upstream and downstream data is also presented for comparison. There is good agreement between the measured downstream data and modelled existing scenario, indicating the model is predicting the concentrations with a reasonable level of confidence. The changes to nutrient concentrations and loads are discussed in the sections below.

#### 5.4.3.1 Total Nitrogen

Stage 1A is not predicted to result in any significant reduction of load or concentration of TN (Table 27). When Stage 1B is operational there will be very little discharge to the Creek during summer and the median downstream TN concentration will be similar to background concentrations. During winter, median TN concentrations are estimated to decrease from the current concentrations to 1.6 g/m$^3$. Stage 1B is predicted to result in a significant (42%) reduction in TN loads discharged to the river compared to the existing scenario.

Stage 2A will result in a minor decrease in winter median TN concentration compared to Stage 1B and a 47% reduction of TN load compared to the existing scenario. Further improvement occurs in Stage 2B at which time it is predicted that the median winter TN concentration will be similar to background concentrations and there will be approximately 79% reduction in annual TN load to the Creek.

**Table 27: Summary of TN measured and modelled values – summer and winter**

| | Summer | | Winter | | Full Dataset | |
|---|---|---|---|---|---|---|
| Scenario | Median (g/m$^3$) | 95th percentile (g/m$^3$) | Median (g/m$^3$) | 95th percentile (g/m$^3$) | Annual Load (t/year) | Reduction in Annual Load (%) |
| Measured upstream | 0.83 | 1.3 | 1.2 | 2.2 | | |
| Measured downstream | 1.9 | 3.8 | 1.9 | 2.9 | | |
| Existing – modelled | 1.8 | 4.0 | 1.7 | 4.3 | 7.1 | |
| Stage 1A – Modelled | 1.6 | 4.0 | 1.7 | 4.5 | 6.9 | 3.0 |
| Stage 1B – Modelled | 0.83 | 1.7 | 1.6 | 4.1 | 4.1 | 42 |
| Stage 2A – Modelled | 0.83 | 1.3 | 1.5 | 4.2 | 3.8 | 47 |
| Stage 2B – Modelled | 0.83 | 1.3 | 1.2 | 3.3 | 1.5 | 79 |

#### 5.4.3.2 Dissolved Inorganic Nitrogen

The change in DIN concentration and load is predicted to be similar to that of TN, with no significant improvement in Stage 1A (Table 28). Stage 1B is predicted to have summer median concentrations similar to the medium background concentration, and winter concentrations will reduce compared to the existing scenario. A 35% reduction in DIN load, compared to the existing scenario is predicted for Stage 1B. Stage 2A will result in a further decrease in DIN concentrations compared to stage 1B.

At Stage 2B both the summer and winter median DIN concentration is predicted to be similar to background concentrations. The annual DIN load to the river is estimated to be reduced to 70% of the existing scenario.

As the median upstream input values in the model are above the guideline of 0.63 g/m$^3$ improvement in compliance cannot be assessed, but it is likely that median DIN concentration downstream of the WWTP will exceed the indicative guideline most of the time.

**Table 28: Summary of DIN measured and modelled values – summer and winter**

| | Summer | | Winter | | Full Dataset | | |
|---|---|---|---|---|---|---|---|
| Scenario | Median (g/m$^3$) | 95th percentile (g/m$^3$) | Median (g/m$^3$) | 95th percentile (g/m$^3$) | Exceedance of guideline (%) | Annual Load (t/year) | Reduction in Annual Load (%) |
| Measured upstream | 0.69 | 1.0 | 0.98 | 1.8 | 72 | | |
| Measured downstream | 1.2 | 2.7 | 1.6 | 2.4 | 95 | | |
| Existing – modelled | 1.1 | 3.3 | 1.3 | 3.3 | 100 | 4.5 | |
| Stage 1A – Modelled | 1.1 | 3.2 | 1.3 | 3.4 | 100 | 4.4 | 1.6 |
| Stage 1B – Modelled | 0.69 | 1.4 | 1.2 | 3.3 | 100 | 2.7 | 35 |
| Stage 2A – Modelled | 0.69 | 1.0 | 1.2 | 3.3 | 100 | 2.3 | 38 |
| Stage 2B – Modelled | 0.69 | 1.0 | 0.98 | 3.3 | 100 | 0.47 | 70 |

Source: [1]Median concentrations compared to NIWA (2016) DIN guideline for good water quality for angling of 0.63 g/m$^3$

#### 5.4.3.3 Dissolved Reactive Phosphorus

Implementation of Stage 1A results in no significant change in DRP concentration or load compared to the existing scenario (Table 29). Once Stage 1B is operational the median summer concentration is predicted to be similar to the background median concentration (0.013 g/m$^3$) and a 53% reduction in DRP load is predicted. During Stage 1B the median winter DRP concentration is predicted to decrease from the existing scenario (0.094 g/m$^3$) to 0.061 g/m$^3$. The model predicts that the DRP concentration will exceed the DRP guideline (NIWA, 2016) (0.011 g/m$^3$) 95% of the time.

Once Stage 2A is operational the median winter DRP concentration will decrease slightly from that of Stage 1B (0.061 g/m$^3$ to 0.053 g/m$^3$). At Stage 2A a load reduction of 60% compared to the existing load is predicted. The model predicts that during Stage 2A the indicative DRP guideline will be exceeded 88% of the time.

Further improvement occurs under Stage 2B at which time both summer and winter median DRP concentrations are predicted to be similar to background concentrations and the load reduced by 92%. The compliance with the indicative guideline improves in Stage 2B with an estimated frequency of exceedance of 53%, this is in a similar range to the current upstream exceedance frequency of 49%.

**Table 29: Summary of DRP measured and modelled values – summer and winter**

| Scenario | Summer Median (g/m³) | Summer 95th percentile (g/m³) | Winter Median (g/m³) | Winter 95th percentile (g/m³) | Frequency of guideline exceedance[1] (%) | Annual Load (t/year) | Reduction in Annual Load (%) |
|---|---|---|---|---|---|---|---|
| Measured upstream | 0.013 | 0.036 | 0.011 | 0.031 | 49 | | |
| Measured downstream | 0.22 | 0.95 | 0.094 | 0.45 | 100 | | |
| Existing – modelled | 0.21 | 1.0 | 0.082 | 0.45 | 100 | 1.0 | |
| Stage 1A – Modelled | 0.19 | 1.0 | 0.083 | 0.48 | 99 | 0.97 | 4.9 |
| Stage 1B – Modelled | 0.013 | 0.18 | 0.061 | 0.40 | 95 | 0.48 | 53 |
| Stage 2A – Modelled | 0.013 | 0.036 | 0.053 | 0.41 | 88 | 0.41 | 60 |
| Stage 2B – Modelled | 0.013 | 0.036 | 0.011 | 0.24 | 53 | 0.08 | 92 |

Source: [1]Median concentrations compared to NIWA (2016) DRP guideline for good water quality for angling of 0.011 g/m³

### 5.4.3.4 Total Phosphorus

The change in TP concentration and load over the development stages is similar to that of DRP. There is no predicted improvement in TP concentration or load due to implementation of Stage 1A (Table 30).

The model predicts under Stage 1B that the summer median concentration downstream of the WWTP will be similar to upstream, the winter median TP concentration will decrease from the current downstream concentration (0.13 g/m³) to 0.091 g/m³ and there will be a 54% reduction in load discharged to the Creek. The model predicts that the TP concentration downstream of the WWTP will exceed the guideline (0.045 g/m³) 46% of the time compared to 96% of the time observed in the monitoring data.

Some minor improvement, compared to Stage 1B, in load (60% reduction) and median winter concentration (0.080 g/m³) is predicted under stage 2A.

It is predicted that when Stage 2B is operational both the winter and summer median concentrations will be similar to background concentrations. The annual load at Stage 2B is predicted to be 92% of the existing load. At this time the downstream site is also predicted to almost always comply with the indicative TP guideline.

**Table 30: Summary of TP measured and modelled values – summer and winter**

| Scenario | Summer | | Winter | | | | |
|---|---|---|---|---|---|---|---|
| | Median (g/m$^3$) | 95th percentile (g/m$^3$) | Median (g/m$^3$) | 95th percentile (g/m$^3$) | Exceedance of guideline (%) | Annual Load (t/year) | Reduction in Annual Load (%) |
| Measured upstream | 0.034 | 0.12 | 0.024 | 0.10 | 20 | | |
| Measured downstream | 0.34 | 1.05 | 0.13 | 0.62 | 96 | | |
| Existing – modelled | 0.31 | 1.3 | 0.12 | 0.67 | 98 | 1.4 | |
| Stage 1A – Modelled | 0.27 | 1.3 | 0.12 | 0.70 | 98 | 1.3 | 5.1 |
| Stage 1B – Modelled | 0.034 | 0.29 | 0.091 | 0.60 | 46 | 0.64 | 54 |
| Stage 2A – Modelled | 0.034 | 0.12 | 0.080 | 0.61 | 35 | 0.56 | 60 |
| Stage 2B – Modelled | 0.034 | 0.12 | 0.024 | 0.38 | 3.7 | 0.11 | 92 |

Source: [1]Median concentrations compared to NIWA (2016) TP guideline for good water quality for angling of 0.045 g/m$^3$

### 5.4.3.5 Biochemical Oxygen Demand

The change in $TBOD_5$ concentration and load over the development stages is similar to that of the nutrients. There is no predicted improvement in $TBOD_5$ concentration or load due to implementation of Stage 1A (Table 31).

The model predicts under Stage 1B that the summer median concentration downstream of the WWTP will be similar to upstream, the winter median $TBOD_5$ concentration will decrease from the current downstream concentration of 2.0 g/m$^3$ to 1.3 g/m$^3$, and there will be a 47% reduction in load discharged to the Creek.

Some improvement, compared to Stage 1B, in load (69% reduction) and median winter concentration (1.0 g/m$^3$) is predicted under Stage 2A.

It is predicted that when Stage 2B is operational both the winter and summer median concentrations will be similar to background concentrations. The annual load at Stage 2B is predicted to be 94% of the existing load.

**Table 31: Summary of BOD measured and modelled values – summer and winter**

| Scenario | Summer | | Winter | | Full dataset | |
|---|---|---|---|---|---|---|
| | Median (g/m$^3$) | 95th percentile (g/m$^3$) | Median (g/m$^3$) | 95th percentile (g/m$^3$) | Annual Load (t/year) | Reduction in Annual Load (%) |
| Measured upstream | 0.60 | 1.7 | 0.58 | 2.8 | | |
| Measured downstream | 4.0 | 8.4 | 2.0 | 6.1 | | |
| Existing – modelled | 2.5 | 8.8 | 1.6 | 3.0 | 12.6 | |
| Stage 1A – Modelled | 2.2 | 8.7 | 1.6 | 3.0 | 12.1 | 3.5 |
| Stage 1B – Modelled | 0.60 | 2.7 | 1.3 | 2.9 | 6.7 | 47 |
| Stage 2A – Modelled | 0.60 | 1.68 | 1.0 | 3.1 | 3.8 | 69 |
| Stage 2B – Modelled | 0.60 | 1.68 | 0.58 | 2.9 | 0.76 | 94 |

# 6 Monte Carlo Mass Balance Modelling for Ammonia

## 6.1 Introduction

Elevated concentrations of total ammoniacal nitrogen is one of the key concerns of the current and future discharges to Donald Creek. The conservative mass balance modelling described in Section 5 is highly conservative and therefore further work was undertaken using Mote Carlo simulation to get a better idea of the likely compliance with the relevant guidelines. Monte Carlo mass balance modelling was undertaken using the River Quality Planning (RQP) model (MB v2.5) from the United Kingdom Environment Agency. Monte Carlo simulation allows for distributions (assuming a log-normal distribution) to be used as inputs and randomly combines the distributions in a statistically valid way to generate a statistical output.

The model was used to predict the in river concentrations of $TNH_4$-N downstream of the discharge under the different stages of development. The model runs a minimum of 1000 scenario combinations for each simulation and provides mean, 95th percentile and 99th percentile outputs.

In the case of the RQP model the requires following distributions:

- River flow data - input as mean and 5th percentile of flow;
- Discharge data – input as mean and standard deviation;
- Upstream $TNH_4$-N– input as mean and standard deviation;
- Discharge $TNH_4$-N concentrations– input as mean and standard deviation.

The model was run in continuous mode for the existing scenario, Stage 1B and Stage 2A as discharge occurs throughout the year, although considerably reduced from the existing situation in Stage 1B and 2A (Table 20 and Table 18). Stage 2B was run as an intermittent discharge as discharge only occurs occasionally during winter (see Table 16).

The model was run for individual years (2005 to 2015) as well as for the full dataset. At time summer and winter flows were modelled as the discharge has a strong seasonal effect from Stage 1B onwards. It should be noted that the RQP model does not include functionality to run seasonal scenario’s.

## 6.2 Model Input Data

### 6.2.1 River flow input data

The river flow input data was based on the synthetic flow data provided by PGWES (2016). The mean flow and 5th percentile flow (flow at which the river exceeds 95% of the time) were calculated for individual years, the full dataset and summer and winter for the full dataset (Table 32). In the case of the 2008 year further resolution in the modelling was required and summer and winter flows statistics were also calculated for that year (Table 32).

**Table 32: Donald Creek flow data used in the modelling**

| Year | Mean Flow ($m^3$/day) | 5th Percentile of Flow ($m^3$/day) | Ratio of 5th Percentile of Flow to Mean Flow (%) |
|---|---|---|---|
| 2005 | 34,012 | 6,841 | 20 |
| 2006 | 46,091 | 3,856 | 8.4 |
| 2007 | 12,448 | 5,870 | 47 |
| 2008 | 38,133 | 4,028 | 11 |
| 2008 - Summer | 10,629 | 3,671 | 35 |
| 2008 - Winter | 65,338 | 23,106 | 35 |
| 2009 | 26,768 | 5,274 | 20 |
| 2010 | 38,467 | 7,760 | 20 |
| 2011 | 27,150 | 3,935 | 14 |
| 2012 | 34,631 | 7,540 | 22 |
| 2013 | 27,812 | 4,106 | 15 |
| 2014 | 35,731 | 6,604 | 18 |
| 2015 | 17,976 | 3,529 | 20 |
| 2016 | 34,012 | 6,841 | 20 |
| Full dataset winter 2005 -2016 | 46,997 | 9,140 | 19 |
| Full dataset summer 2005 -2016 | 12,600 | 3,701 | 29 |
| Full dataset 2005-2016 | 29,870 | 4,221 | 14 |

### 6.2.2 Discharge flow input data

The discharge flow input data was based on the synthetic flow data provided by LEI (2017). The mean flow and standard deviation of the flows calculated for individual years, the full dataset, and summer and winter for the full dataset are presented in Table 33. In the case of the 2008 year further resolution in the modelling was required and summer and winter flow statistics were also calculated for that year (Table 33). In the case of Stage 2B the frequency of discharge was calculated as this is required to run an intermittent discharge in the RQP model (Table 33).

## Table 33: Discharge flow input data

| Year | Existing Mean Flow (m$^3$/day) | Existing Standard Deviation of Flow (m$^3$/day) | Stage 1B Mean Flow (m$^3$/day) | Stage 1B Standard Deviation of Flow (m$^3$/day) | Stage 2A Mean Flow (m$^3$/day) | Stage 2A Standard Deviation of Flow (m$^3$/day) | Stage 2B Mean Flow (m$^3$/day) | Stage 2B Standard Deviation of Flow (m$^3$/day) | Stage 2B Frequency of discharge (%) |
|---|---|---|---|---|---|---|---|---|---|
| 2005 | 2,224 | 3,668 | 1,311 | 1,435 | 734 | 963 | | No discharge | |
| 2006 | 2,910 | 5,164 | 1,765 | 2,416 | 1,011 | 1,678 | 4,179 | 1,360 | 11.5 |
| 2007 | 1,668 | 2,556 | 742 | 1,181 | 436 | 765 | | No discharge | |
| 2008 | 3,027 | 6,921 | 2,073 | 2,849 | 1,245 | 1,909 | 4,985 | 1,033 | 10.7 |
| 2009 | 2,421 | 3,701 | 1,224 | 1,374 | 673 | 893 | 4,970 | 0 | 0.3 |
| 2010 | 2,226 | 4,337 | 1,281 | 1,663 | 756 | 1,068 | 3,592 | 1,419 | 5.2 |
| 2011 | 2,354 | 4,037 | 1,330 | 2,033 | 802 | 1,390 | 2,885 | 1,689 | 7.1 |
| 2012 | 2,254 | 3,754 | 1,176 | 1,621 | 670 | 1,100 | 3,737 | 1,004 | 4.6 |
| 2013 | 2,131 | 4,297 | 1,172 | 1,612 | 656 | 1,057 | 1,501 | 161 | 1.1 |
| 2014 | 2,481 | 5,044 | 1,458 | 1,880 | 815 | 1,242 | 2,821 | 521 | 1.4 |
| 2015 | 1,888 | 3,640 | 962 | 1,424 | 552 | 939 | | No discharge | |
| Full dataset winter | NA | NA | 2,405 | 1,979 | 1,418 | 1,407 | 3933 | 1516 | 7.5 |
| Full dataset summer | NA | NA | 132 | 596 | 44 | 345 | | No discharge | |
| Full dataset | 2,267 | 1,612 | 1,273 | 1,853 | 733 | 1,235 | 3933 | 1516 | 3.7 |

Source: Note – Existing, Stage 1B and Stage 2A were modelled as continuous discharges, and therefore means and standard deviations were calculated on the full dataset including zero discharge days. Stage 2B was modelled as an intermittent discharge and therefore the mean and standard deviation were calculated for days when the discharge is occurring, the frequency of discharge was calculated as a model input.

### 6.2.3 Water quality inputs

The water quality inputs for upstream in Donald Creek and the discharge were based on monitoring data from 2005 to 2016. The mean and standard deviation were calculated and are presented in Table 34. The $TNH_4$-N concentration was scaled up to account for changes in influent and effluent quality due to reduction of groundwater and stormwater into the network (see Section 5.2.3).

**Table 34: TNH4-N concentration model inputs**

| Statistic | Upstream Donald Creek | Featherston WWTP Pre I/I works | Featherston WWTP Post I/I works |
|---|---|---|---|
| Mean (g/m$^3$) | 0.020 | 5.0 | 7.5 |
| Standard Deviation (g/m$^3$) | 0.041 | 3.2 | 4.7 |
| Number of samples | 92 | 79 | Calculated from pre I/I |
| Stages | All Stages | 1B | 2A and 2B |

Source: SWDC monitoring data

## 6.3 Modelling Results

The mean and 95th percentile outputs were compared to the NIWA guidelines that are protective of the Fingernail Clam and Freshwater Mussels. The 99th percentile was assumed to represent the maximum concentrations and was compared to the NPS National Bottom Line and the USEPA acute criteria.

As the annual median pH cannot be determined for modelled scenarios, the 95th percentile of the measured downstream pH was used to determine the pH adjusted NIWA guidelines. This is conservative as in reality the annual 95th percentile pH at the downstream site typically varied between 7.1 and 7.9 and therefore the guidelines have a considerable range (Table 7).

**Stage 1B**

As development of Stages 1A and 1B will occur in parallel and will be complete within two years of a consent being granted, only the Stage 1B scenario, which includes the effect of Stage 1A, was modelled.

The model predicts a significant decrease in median and 95th percentile concentrations of $TNH_4$-N downstream of the WWTP discharge, with no exceedances of the national bottom line.

Comparison of the modelled concentrations with the NIWA (2014) guideline that would be protective of the Fingernail Clam indicates the median guideline would be complied with in all modelled years. The model predicts that the annual 95th percentile guideline would be exceeded in only 2008 out of the 10 the years modelled. Comparison to the model run on the full dataset complies with both median and 95th percentile guideline.

It should be noted that the 2008 year had one of the highest discharge flows, which will occur predominately in winter and one of the lower summer low flows in Donald Creek. As such the Monte Carlo simulation, based on a full year of data, will at times combine high discharge flows with low summer flows, a situation that is unlikely to occur. Therefore, the model was run seasonally of summer and winter for the 2008 year, under these scenarios the predicted annual median (0.35 g/m$^3$) and annual 95th percentile (0.88 g/m$^3$) $NH_4$-N concentrations were predicted to be below the relevant guidelines for protection of the Fingernail Clam.

In addition, the assessment has been carried out with guideline values calculated for pH 7.9, the 95th percentile of the measured values. Should the 95th percentile pH be 7.7 or lower the 2008 year would be fully compliant with the NIWA guidelines protective of the Fingernail Clam.

Comparison of the model results to the more stringent guidelines, that would be protective of Freshwater Mussels, indicates that at stage 1B there would be some exceedances of the median $TNH_4$-N guideline (5/11 years modelled) and the downstream concentration would consistently exceed the annual 95th percentile guideline.

### Stage 2A

Implementation of Stage 2A will further reduce the frequency and volume of summer discharges and this will further reduce $TNH_4$-N concentrations downstream of the discharge.

The level of compliance with the NIWA (2014) guideline protective of the Fingernail Clam will remain the same as Stage 1B with an exceedance of the 95th percentile guideline in 2008. As with Stage 1B this is most likely an overestimate.

The level of compliance will improve in relation to the median NIWA (2014) guideline protective of the Freshwater Mussels with exceedances in 3 out of ten years predicted compared to 5 out of 10 in Stage 1B

### Stage 2B

Under Stage 2B no summer discharge occurs and discharge is only predicted to occur in July and August, thereby eliminating any potential summer effects from $TNH_4$-N toxicity.

The model predicts a significant decrease in 95th percentile and median $TNH_4$-N concentrations downstream of the WWTP, with no exceedances of the NIWA guideline protective of the Fingernail Clam, and only 1 exceedance of the NIWA 95th percentile guideline that would be protective of Freshwater Mussels. This exceedance is predicted to occur in 2008, when as discussed above (under Stage 1B) the model will be predicting some summer time discharges, when flow in Donald Creek is lower. As there will be no summer discharge under Stage 2B this is overestimating the concentrations in the Creek. Therefore, the model was re-run with winter Creek flows and the model predicts full compliance with the NIWA guidelines (mean = 0.06 $g/m^3$, 95th percentile = .34 $g/m^3$).

## 6.4 Modelling Assumptions and Limitations

The following assumptions and limitations have been used in the modelling:

- The modelled concentrations and loads relate to full mixing, the concentrations and loads prior to full mixing are not considered;
- The model assumes all distributions are log-normal, however, the model used does not provide information regarding goodness of fit of the distributions. Typically the log-normal distribution is the best fit for water quality and river flow data;
- A conservative mass balance approach has been used and therefore changes in speciation of nitrogen species, settling of particulates in the stream and degradation of organic carbon are not considered;
- The model assumes that the I/I works result in a 20% and 35% reduction of average daily inflow in summer and winter respectively;
- The measured water quality data is representative of the long-term discharge and upstream water quality; and
- The changes in concentration and flow following I/I reduction is assumed to occur at commencement of Stage 2A, however, the work will be staged and changes will occur gradually over time.

**Table 35: Modelled total ammoniacal nitrogen downstream of the discharge – Measured maximum and modelled 99th percentile**

| Year | Measured (g/m$^3$) | Existing Modelled (g/m$^3$) | Stage 1B Modelled (g/m$^3$) | Stage 2A Modelled (g/m$^3$) | Stage 2B Modelled (g/m$^3$) |
|---|---|---|---|---|---|
| Statistic | Maximum | 99th Percentile | 99th Percentile | 99th Percentile | 99th Percentile |
| 2005 | - | 3.1 | 1.2 | 1.1 | No discharge |
| 2006 | 0.83 | 1.9 | 1.9 | 1.7 | 1.3 |
| 2007 | **2.6** | **2.5** | 1.8 | 1.9 | No discharge |
| 2008 | 2.1 | **2.8** | 2.1 | 2.1 | 1.7 |
| 2009 | 0.74 | **2.5** | 1.4 | 1.3 | 0.22 |
| 2010 | 1.3 | 1.7 | 1.1 | 1.0 | 0.72 |
| 2011 | 1.1 | **2.8** | 1.7 | 1.7 | 0.98 |
| 2012 | 0.92 | 1.8 | 11 | 1.0 | 0.73 |
| 2013 | 0.77 | **2.6** | 1.5 | 1.2 | 0.23 |
| 2014 | 0.79 | 2.1 | 1.3 | 1.2 | 0.27 |
| 2015 | 0.90 | **2.7** | 1.6 | 1.6 | No discharge |
| 2016 | **3.18**[1] | **-** | - | - | - |
| Full dataset | | **2.6** | 1.6 | 1.5 | 0.79 |

Source: Monte Carlo Mass balance model outputs, Red values are equal to or exceed the national bottom line of, at an assumed pH of 7.9, =2.5 g/m$^3$ for the annual maximum. [1]Maximum value measured in 2016.

### Table 36: Modelled total ammoniacal nitrogen concentration downstream of the discharge – median and 95th percentile

| Year | Measured (g/m$^3$) | | Existing Modelled (g/m$^3$) | | Stage 1B Modelled (g/m$^3$) | | Stage 2A Modelled (g/m$^3$) | | Stage 2B – Modelled (g/m$^3$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Statistic** | **Median** | **95th Percentile** | **Median** | **95th Percentile** | **Mean** | **95th Percentile** | **Mean** | **95th Percentile** | **Mean** | **95th Percentile** |
| 2005 | - | - | **0.45** | **1.2** | 0.25 | **0.69** | 0.21 | **0.59** | No discharge | |
| 2006 | **0.28** | **0.77** | **0.63** | **1.9** | **0.33** | **1.03** | **0.28** | **0.91** | 0.08 | 0.40 |
| 2007 | **0.99** | **2.5** | **0.63** | **1.6** | 0.22 | **0.78** | 0.21 | **0.74** | No discharge | |
| 2008 | **0.80** | **1.9** | **0.44** | **1.4** | **0.39** | **1.23** | **0.36** | **1.16** | 0.09 | **0.51** |
| 2008 - Winter | - | - | - | - | **0.35** | **0.88** | - | - | 0.06 | 0.34 |
| 2008 - Summer | - | - | - | - | 0.03 | 0.11 | - | - | No discharge | |
| 2009 | **0.45** | **0.72** | **0.63** | **1.6** | **0.29** | **0.81** | 0.24 | **0.68** | 0.02 | 0.08 |
| 2010 | **0.32** | **1.1** | **0.40** | **1.1** | 0.21 | **0.59** | 0.19 | **0.55** | 0.04 | 0.18 |
| 2011 | **0.37** | **0.90** | **0.62** | **1.7** | **0.31** | **0.93** | **0.31** | **0.92** | 0.05 | 0.22 |
| 2012 | **0.39** | **0.80** | **0.44** | **1.1** | 0.20 | **0.58** | 0.17 | **0.51** | 0.04 | 0.17 |
| 2013 | **0.40** | **0.65** | **0.56** | **1.5** | **0.28** | **0.84** | 0.20 | **0.62** | 0.02 | 0.08 |
| 2014 | **0.35** | **0.74** | **0.48** | **1.3** | 0.26 | **0.74** | 0.21 | **0.64** | 0.02 | 0.09 |
| 2015 | **0.33** | **0.83** | **0.67** | **1.7** | **0.30** | **0.89** | 0.26 | **0.79** | No discharge | |
| Full dataset | **0.44** | **1.7** | **0.57** | **1.57** | **0.29** | **0.88** | 0.24 | **0.73** | 0.04 | 0.14 |
| Winter | | | | | **0.34** | **0.95** | **0.30** | **0.85** | 0.05 | 0.24 |
| Summer | | | | | 0.06 | 0.20 | 0.04 | 0.13 | NA | NA |

Note – Source Monte Cralo Mass Balance Model. Blue highlighted values exceed the NIWA (2014) guidelines that are protective of the Fingernail Clam at pH 7.9: Median 0.62 g/m$^3$, 95th percentile 1.05 g/m$^3$. **Bolded** values exceed the NIWA (2014) guidelines that are protective of Freshwater Mussels at pH 7.9: median = 0.27 g/m$^3$, 95th percentile = 0.46 g/m$^3$.

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# Appendices

<Body text>

# A. Receiving Environment Monitoring Summary

**Table 37: Summary of water quality monitoring**

**Upstream**

| | | DO (g/m3) | DO SAT% | pH | Temp (°C) | Black Disc (mm) | SS (g/m$^3$) | Turbidity (NTU) | BOD (g/m$^3$) | NO3-N (g/m$^3$) | NO2-N (g/m$^3$) | NOx-N (g/m3) | NH4-N (g/m$^3$) | DIN (g/m3) | Total P (g/m$^3$) | DRP (g/m$^3$) | Total N (g/m$^3$) | Ecoli (cfu/100ml) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Median | 109 | 10.03 | 94.31 | 7.25 | 13.10 | 2570 | 3.00 | 1.92 | <1.00 | 0.80 | <0.002 | 0.80 | 0.02 | 0.84 | 0.03 | 0.01 | 0.97 | 270 |
| Minimum | 55 | 6.27 | 62.15 | 5.70 | 7.31 | 1100 | <3.00 | 0.71 | <1.00 | <0.01 | <0.002 | 0.01 | <0.01 | 0.01 | 0.01 | <0.005 | 0.35 | 20 |
| Maximum | 150 | 12.56 | 112.93 | 8.33 | 18.00 | 3500 | 79.00 | 36.00 | 3.00 | 1.85 | 0.68 | 1.85 | 0.30 | 1.87 | 0.22 | 0.09 | 2.43 | 12960 |
| 95th %ile | 144 | 11.87 | 110.40 | 7.76 | 16.70 | 3230 | 16.20 | 10.74 | 2.41 | 1.55 | 0.14 | 1.55 | 0.08 | 1.57 | 0.11 | 0.03 | 1.86 | 3292 |
| Count | 92 | 88 | 86 | 92 | 61 | 19 | 95 | 89 | 87 | 89 | 89 | 89 | 88 | 89 | 91 | 89 | 96 | 95 |

**Downstream**

| | Conductivity (µS/m) | DO (g/m3) | DO SAT% | pH | Temp (°C) | Black Disc (mm) | SS (g/m$^3$) | Turbidity (NTU) | BOD (g/m$^3$) | NO3-N (g/m$^3$) | NO2-N (g/m$^3$) | NOx-N (g/m3) | NH4-N (g/m$^3$) | DIN (g/m3) | Total P (g/m$^3$) | DRP (g/m$^3$) | Total N (g/m$^3$) | Ecoli (cfu/100ml) (post UV-installed 08/2011) | Ecoli (cfu/100ml) (pre UV) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Median | 105.0 | 9.45 | 88.92 | 7.9 | 13.99 | 1060 | 7.00 | 3.80 | 2.85 | 0.85 | 0.03 | 0.90 | 0.43 | 1.43 | 0.22 | 0.16 | 1.92 | 23 | 22 |
| Minimum | 54.4 | 4.73 | 47.59 | 1.59 | 7.22 | 450 | <3.00 | 1.21 | <1.00 | <0.01 | 0.01 | 0.02 | <0.01 | 0.11 | 0.01 | 0.01 | <0.05 | <1 | <1 |
| Maximum | 157.1 | 13.20 | 115.30 | 8.34 | 19.52 | 1900 | 136.00 | 44.00 | 17.20 | 2.24 | 1.10 | 2.25 | 3.18 | 3.49 | 2.20 | 1.06 | 4.20 | 51 | 65 |
| 95th %ile | 137.8 | 11.88 | 110.11 | 7.93 | 17.60 | 1900 | 26.35 | 18.40 | 7.68 | 1.60 | 0.26 | 1.63 | 1.72 | 2.53 | 0.97 | 0.84 | 3.69 | 40 | 51 |
| Count | 99 | 91 | 89 | 99 | 99 | 20 | 114 | 93 | 92 | 94 | 94 | 94 | 94 | 94 | 110 | 94 | 114 | 44 | 70 |

**Discharge**

| | Conductivity (µS/m) | DO (g/m3) | DO SAT% | pH | Temp (°C) | Black Disc (mm) | SS (g/m$^3$) | Turbidity (NTU) | BOD (g/m$^3$) | NO3-N (g/m$^3$) | NO2-N (g/m$^3$) | NOx-N (g/m3) | NH4-N (g/m$^3$) | DIN (g/m3) | Total P (g/m$^3$) | DRP (g/m$^3$) | Total N (g/m$^3$) | Ecoli (cfu/100ml) (post UV-installed 08/2011) | Ecoli (cfu/100ml) (pre UV) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Median | 228.0 | 8.15 | 79.01 | 7.41 | 13.33 | 250 | 35.00 | 14.10 | 16.70 | 0.49 | 0.10 | 0.61 | 4.41 | 5.60 | 1.82 | 1.49 | 8.66 | 26 | 2134 |
| Minimum | 88.0 | 0.41 | 4.40 | 6.20 | 6.39 | 30 | <3.00 | 3.39 | 2.00 | <0.01 | <0.002 | 0.01 | 0.04 | 0.19 | 0.49 | 0.05 | 2.63 | 2 | 31 |
| Maximum | 452.0 | 12.17 | 121.32 | 8.86 | 23.60 | 1500 | 175.00 | 67.90 | 38.30 | 3.36 | 1.34 | 2009.00 | 15.57 | 15.89 | 39.00 | 5.31 | 19.33 | 2100 | 76700 |
| 95th %ile | 393.0 | 11.27 | 108.33 | 8.12 | 21.91 | 1280 | 125.40 | 45.41 | 31.96 | 2.05 | 0.44 | 2.45 | 11.34 | 11.86 | 4.84 | 3.91 | 15.30 | 820 | 17380 |
| Count | 71 | 69 | 69 | 72 | 40 | 12 | 77 | 70 | 77 | 76 | 76 | 77 | 82 | 82 | 74 | 76 | 74 | 21 | 58 |

Source: <Insert Notes or Source>