APPENDIX G

River Assessment of Environmental Effects

AFFCO (Feilding Meat Processing Plant) discharge to the Oroua River: Water Quality modelling and assessment of effects of proposed discharge regimes

Final September 2014

Report Prepared for AFFCO NZ Ltd

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AFFCO (Feilding Meat Processing Plant) discharge to the Oroua River: Water Quality modelling and assessment of effects of proposed discharge regimes

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EXECUTIVE SUMMARY

Context

AFFCO NZ Ltd (AFFCO) owns and operates a meat processing plant at Feilding. It operates a "dual" discharge system, where a portion of the treated effluent is applied to land and the remainder to the river. The proposed system includes elements of upgraded treatment, storage, land irrigation and river discharge.

The current discharge regime is authorised by resource consent N. 4219. Discharge to the river is permitted under the following conditions:

- During 2nd December to 30th March, up to 2,000 m^3/day only when the flow in the river is at or above three times the median flow (20,913 l/s) and the ponds are full;
- During the remainder of the year:
  - Up to 1,000 m^3/day when the flow in the river is between 3,000 and 4,000 l/s; and
  - Up to 2,000 m^3/day when the flow in the river exceeds 4,000 l/s.

For convenience, the two periods of the year identified in the existing resource consents will be thereafter referred to the "summer" (1 December to 30 March) and "winter" (rest of the year) discharges. The proposed discharge regime is described in LEI (2014a) and includes:

- During "summer" no changes from the current consent (i.e. up to 2,000 m^3/day only when the flow in the river is at or above 20,913 l/s and the ponds are full);
- During "winter" (1 April to 30 November):
  - No discharges when the river flow is at or below 7,590 l/s;
  - Possible discharge when the flow in the river is between 7,590 l/s and 16,193 l/s, at a rate calculated so the discharge does not cause the fully mixed concentration in the Oroua River to increase by more than 0.005 mg/L;
  - Up to 3,000 m^3/day when the flow in the river is greater than 16,193 l/s.

Assessment undertaken

The aim of this report is to provide an assessment of the likely nature and scale of effects of the proposed discharge of treated effluent from the AFFCO Feilding plant on the water quality of the Oroua River, primarily using modelling tools, and the potential effects of changes in water quality on aquatic life.

Section 2 of this report presents an assessment of the current effects of the discharge based on monitoring data.

A daily time step model was developed and calibrated to predict the effects of the proposed AFFCO discharge on water quality in the Oroua River downstream of the discharge, under the 'current' and 'proposed' discharge regime. The modelling methodology and calibration are desc4ribed in Section 3, and the modelling outcomes are presented in Section 4 of this report.

Lowe Environmental Impact (LEI) developed the assumptions, rules and triggers and undertook modelling of the discharge regime under different scenarios. The outputs of this modelling, in particular daily time series of volumes and quality of treated effluent discharged to the river for a period of approximately 20 years (1993 to 2013), constituted the base input for the assessment described in this report.

Modelling scenarios and model calibration

The outcomes of two scenarios are reported in this report:

- Current: This scenario is representative of the discharge regime as operated under the current resource consent conditions. It thus represents the historical discharge within recent history;
- Proposed: This scenario is representative of the proposed discharge regime.

Both scenarios assume similar effluent quality, based on historical effluent quality. The key difference between the two scenarios lies in the timing and volume of discharge. In particular, the proposed discharge regime does not include any discharge when the Oroua River is below 7.950 l/s in winter, while the current discharge regime allows discharges at river flows as low as 3,000 l/s in winter.

Six water quality determinands were modelled: DRP, SIN, total ammonia-N, *E. coli*, water clarity, and Soluble carbonaceous five-day Biochemical Oxygen Demand ($ScBOD_5$).

Model predictions for both the upstream water quality and the 'current' downstream water quality model show satisfactory goodness of fit with observed (i.e. measured) data.

Summer discharge ('current' and 'proposed')

In summer, the discharge is not allowed to operate at flows below three times the median flow. This flow cut-off is higher (more stringent) than any of the flow cut-offs (median or Q_{20}) set in the OP water quality targets. As a result, the discharge (both current and proposed) during the summer months will comply with all the OP water quality targets containing flow cut-offs (DRP, SIN, POM, $ScBOD_5$, water clarity, *E. coli*).

A number of the OP targets do, however, apply at all river flows: total ammonia-nitrogen (chronic and acute), water clarity change and biological indicators (periphyton biomass and cover, MCI and changes in QMCI).

The assessment presented in this report shows that both the 'current' and 'proposed' discharge are predicted to comply with the total ammonia-N and water clarity change targets at all times, and thus are not expected to result in any more than minor effects in relation to these water quality determinands.

Winter discharge (Current)

The modelling assessment presented in this report indicates that the 'current' discharge is not likely to cause any breaches of the One Plan targets relating to $ScBOD_5$, POM, water clarity or total ammonia-nitrogen.

The One Plan targets were designed to be set at levels that, if complied with, avoid significant adverse effects on river values. The 'current' discharge is therefore not expected to result in any significant adverse effects associated with these water quality determinands.

The 'current' discharge is however predicted to result in material increases in in-river nutrient concentrations at flows below Q_{20}. The OP DRP concentration target is just met upstream of the discharge but is predicted to be largely exceeded downstream of the discharge. The OP SIN concentration target is however expected to be met both upstream and downstream of the discharge in spite of predicted increase between the two sites.

Consequential effects on periphyton growth are difficult to predict with certainty, however, the three approaches undertaken (a qualitative risk assessment and two modelling approaches) indicate that the 'current' discharge does occur at times when river flow conditions are suitable for periphyton growth and accumulation and may result in periphyton increases in the order of 5 to 35%. Periphyton growth increases of this order may be measurable, which is supported by the measurable increase in periphyton cover reported by Stark (2011). However, whether these increases would lead to actual breaches of the OP periphyton biomass and/or cover targets is not able to be assessed robustly due to insufficient data.

Winter Discharge (Proposed)

The ‘proposed’ discharge regime is predicted to result in about an 8 % increase of the total volume of effluent and the total load of contaminants discharged to the river compared with the ‘current’ scenario. However, the timing of the discharges to the river is different in the two scenarios.

The ‘proposed’ scenario sees a complete elimination of the discharge to the River at flows below 7.950 l/s (approximately 1.1 times the median flow). Periods of low river flow are usually considered the most critical times for discharges of contaminants to streams and rivers, due to (1) less dilution available and (2) a higher risk of biological effects of contaminants, for example, excessive periphyton growth. By eliminating the discharge to the river at flows below median flow, the proposed discharge regime eliminates any risk of directly causing effects during the most sensitive times.

The modelling assessment presented in this report indicates that the ‘proposed’ discharge is predicted to cause lesser effects on water clarity and on concentrations of $ScBOD_5$, POM, total ammonia-nitrogen than the ‘current’ scenario’, and thus is unlikely to cause any breaches of the One Plan targets relating to these water quality determinands. As a result, the ‘proposed’ discharge is not expected to result in any significant adverse effects associated with these water quality determinands.

The proposed discharge regime also results in significant reduction in the proportion of effluent and contaminant loads discharged to the river at flows below Q_{20}. As a result, the effects of the ‘proposed’ discharge on in-stream dissolved nutrient concentrations (DRP and SIN) are predicted to be 87% less than under the ‘current’ scenario.

Potential effects on periphyton growth were assessed by three methods: one qualitative and two modelling methods. All three methods are in general agreement that the effects of the ‘proposed’ discharge are likely to be significantly less than those of the ‘current’ discharge. Predicted periphyton biomass increases under the proposed scenario are in the order of 1 to 10%. If these predictions are correct, increases of this magnitude would be very unlikely to be able to be detected using standard monitoring methods, given the large error generally associated with periphyton biomass measurements.

Although the effects of the discharge under the proposed scenario are predicted to be less than what they currently are, qualitatively, some increase in periphyton growth is still expected, and it is not possible to assess with certainty whether this increase will or not result in exceedances of the OP periphyton biomass or cover targets, and further monitoring and modelling of periphyton growth in this reach of the Oroua River would be advisable should the proposed discharge regime be implemented.

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1. Introduction

1.1. Background

AFFCO NZ Ltd (AFFCO) owns and operates a meat processing plant at Feilding. It operates a "dual" discharge system, where a portion of the treated effluent is applied to land and the remainder to the river. The proposed system includes elements of upgraded treatment, storage, land irrigation and river discharge.

The current discharge regime is authorised by resource consent N. 4219. Discharge to the river is permitted under the following conditions:

- During 2nd December to 30th March, up to 2,000 m^3/day only when the flow in the river is at or above three times the median flow (20,913 l/s) and the ponds are full;
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  - Up to 1,000 m^3/day when the flow in the river is between 3,000 and 4,000 l/s; and
  - Up to 2,000 m^3/day when the flow in the river exceeds 4,000 l/s.

For convenience, the two periods of the year identified in the existing resource consents will be thereafter referred to the "summer" (2 December to 30 March) and "winter" (rest of the year) discharges. The proposed discharge regime is described in LEI (2014a) and includes:

- During "summer" no changes from the current consent (i.e. up to 2,000 m^3/day only when the flow in the river is at or above 20,913 l/s and the ponds are full)
- During "winter" :
  - No discharges when the river flow is at or below 7,590 l/s;
  - Possible discharge when the flow in the river is between 7,590 l/s and 16,193 l/s, at a rate calculated so the discharge does not cause the fully mixed concentration in the Oroua River to increase by more than 0.005 mg/L;
  - Up to 3,000 m^3/day when the flow in the river is greater than 16,193 l/s

The proposed discharge regime is governed by a set of rules and triggers which assigns the amounts of effluent being discharged to land vs. the river on a daily basis. Lowe Environmental Impact (LEI) developed the assumptions, rules and triggers and undertook modelling of the discharge regime under different scenarios. The outputs of this modelling, in particular daily time series of volumes of treated effluent discharged to the river for a period of approximately 20 years (1993 to 2013), constituted the base input for the assessment described in this report.

1.2. Aim and scope

The aim of this report is to provide an assessment of the likely nature and scale of effects of the proposed discharge of treated wastewater from the AFFCO processing plant on the water quality of the Oroua River, primarily using modelling tools, and the potential effects of changes in water quality on aquatic life. It does not however address cumulative effects of this discharge in combination with other direct discharges occurring in the vicinity (such as the Feilding municipal WWTP discharge, or the stormwater discharge from Feilding Township). It specifically does not comprise assessments of effects of the proposed activities on other receiving environments, such as land/soil, groundwater or air. It also does not address cultural or planning issues.

A daily time step model was created to predict the effects of the proposed AFFCO discharge on water quality in the Oroua River downstream of the discharge. The assumptions and limitations of the modelling are detailed in Section 2 of this report. The results are presented in Section 3.

A number of key inputs to the model, in particular future daily discharge volumes and future effluent quality were provided to Aquanet by external parties, and were used as provided.

1.3. Planning context

Although this is primarily a technical report, the planning regime applicable to the discharge under consideration is an essential consideration in assessing the potential effects of the discharge against regional plan policies, in particular water quality targets. For the purpose of this report, the One Plan (OP) water quality framework, including targets, is considered as the primary "planning" consideration. All references to the One Plan in this report refer to the on line version of the One Plan available on the Horizons website (accessed on 1 May 2014). Water quality targets relevant to the middle Oroua Water management sub-zone (Mana_12b) are summarised in Table 1.

Table 1: Water Quality targets for all rivers and streams in the Middle Oroua management Zone (Mana12-b).

Targets	Full Wording of the Target
pH	The **pH** of the *water*^ must be within the range **7 to 8.5** unless natural levels are already outside this range.
	The **pH** of the *water*^ must not be **changed** by more than **0.5**.
Temp (ºC)	The **temperature** of the *water*^ must not exceed **22** degrees Celsius.
	The **temperature** of the *water*^ must not be **changed** by more than **3** degrees Celsius.
DO (% SAT)	The concentration of dissolved oxygen (**DO**) must exceed **70 %** of saturation.
$sCBOD_5$ (g/m^3)	The monthly average five-days filtered / soluble carbonaceous biochemical oxygen demand (**$sCBOD_5$**) when the *river*^ flow is at or below the 20th *flow exceedance percentile** must not exceed **2** grams per cubic metre.
POM (g/m^3)	The average concentration of particulate organic matter (POM) when the *river*^ flow is at or below the 50th *flow exceedance percentile** must not exceed **5** grams per cubic metre.
Periphyton (*rivers*^)	The algal biomass on the *river*^ *bed*^ must not exceed **120** milligrams of chlorophyll *a* per square metre.
	The maximum cover of visible *river*^ *bed*^ by periphyton as filamentous algae more than 2 centimetres long must not exceed **30 %**.
	The maximum cover of visible river bed by periphyton as diatoms or cyanobacteria more than 0.3 centimetres thick must not exceed **60 %**.
DRP (g/m^3)	The annual average concentration of dissolved reactive phosphorus (DRP) when the *river*^ flow is at or below the 20th *flow exceedance percentile** must not exceed **0.010** grams per cubic metre, unless natural levels already exceed this target.
SIN (g/m^3)	The annual average concentration of soluble inorganic nitrogen (SIN) when the *river*^ flow is at or below the 20th *flow exceedance percentile** must not exceed **0.444** grams per cubic metre, unless natural levels already exceed this target.
QMCI	There must be no more than a **20 % reduction** in Quantitative Macroinvertebrate Community Index (**QMCI**) score between appropriately matched habitats upstream and downstream of discharges to *water*^.
Total Ammoniacal Nitrogen	The average concentration of **ammoniacal nitrogen** must not exceed **0.4** grams per cubic metre.
	The maximum concentration of **ammoniacal nitrogen** must not exceed **2.1** grams per cubic metre
Toxicants	For toxicants not otherwise defined in these targets, the concentration of toxicants in the *water*^ must not exceed the trigger values for freshwater defined in the 2000 ANZECC guidelines Table 3.4.1 for the level of protection of 95 % of species. For metals the trigger value must be adjusted for hardness and apply to the dissolved fraction as directed in the table.
Visual Clarity	The visual **clarity** of the *water*^ measured as the horizontal sighting range of a black disc must not be **reduced** by more than **30** %.
	The visual **clarity** of the *water*^ measured as the horizontal sighting range of a black disc must equal or exceed **2.5** metres when the *river*^ is at or below the 50th *flow exceedance percentile**
E. coli / 100 ml (rivers^)	The concentration of ***Escherichia coli*** must not exceed **260** per 100 millilitres 1 November - 30 April (inclusive) when the *river*^ flow is at or below the 50th *flow exceedance percentile**.
	The concentration of ***Escherichia coli*** must not exceed **550** per 100 millilitres year round when the *river*^ flow is at or below the 20th *flow exceedance percentile**.

2. Current effects

2.1. Effects on water quality

Table 2 presents a summary of water quality data collected upstream and downstream of the AFFCO discharge.

Comparisons of upstream/downstream results were carried out using a Wilcoxon Signed Rank Test in Statistix 9. Comparisons were run on three datasets: the whole dataset, data filtered to exclude times (based on river flow and date) when the discharge was not allowed to occur, and data filtered to only include times when the discharge was not allowed to occur.

When considering the overall dataset, statistically significant increases in total ammonia-nitrogen, DRP and SIN concentrations were identified between upstream and downstream of the AFFCO discharge. There was no significant changes in black disk or *E. coli* levels. Similar results were obtained when considering only the data collected at times when discharge was allowed to occur.

Comparisons of data when no discharge was allowed to occur showed no significant differences between upstream and downstream of the AFFCO discharge in any of these parameters, except *E. coli* which appeared to decrease.

2.2. Effects on aquatic ecology

To our knowledge, only one assessment of the effects of the discharge on periphyton and macroinvertebrate communities was undertaken, in November 2011, by Stark Environmental, as reported in Stark (2011).

The report concluded that the discharge resulted in:

- higher periphyton cover downstream of the discharge than upstream, although both sites complied with the OP periphyton cover targets; and
- reductions in both MCI and QMCI. Although there was some ambiguity in the testing results, the report concludes that, on balance, the downstream QMCI score was lower than the upstream's which indicates an exceedance of the OP QMCI change target (of no more than 20%).

Table 2: Summary of measured water quality upstream and downstream of the AFFCO discharge. N.D: No data.

	Year round						Winter						Summer			
	All flow		<20th FEP		<Med		All flow		<20th FEP		<Med		All flow		<3xMed	
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
DRP (average, g/m^3)	0.011	0.027	0.010	0.023	0.008	0.022	0.012	0.030	0.011	0.032	0.008	0.031	0.010	0.011	0.010	0.011
SIN (average, g/m^3)	0.311	0.407	0.253	0.347	0.139	0.237	0.407	0.547	0.349	0.506	0.165	0.313	0.125	0.135	0.125	0.135
TNH_3-N (average, g/m^3)	0.027	0.027	0.026	0.102	0.027	0.105	0.024	0.136	0.023	0.157	0.020	0.141	0.031	0.029	0.031	0.029
TNH_3-N (95^{th} $\%^{ile}$, g/m^3))	0.085	0.328	0.080	0.349	0.081	0.475	0.056	0.386	0.054	0.508	0.044	0.424	0.092	0.058	0.092	0.058
E. coli (average, /100mL)	1680	1457	362	370	198	286	2267	1985	237	332	166	256	529	422	529	422
BD change (95^{th} $\%^{ile}$, % reduction)	25%		34%		49%		44%		49%		48%		11%		11%	
$ScBOD_5$ (average, g/m^3)	N.D.	0.617	N.D.	N.D.	N.D.	0.619	N.D.	0.613	N.D.	0.595	N.D.	0.611	N.D.	0.625	N.D.	0.625
POM (average, g/m^3)	N.D.	N.D.	N.D.	N.D.	N.D.	2.37	N.D.	8.01	N.D.	2.56	N.D.	2.34	N.D.	2.40	N.D.	2.40

3. Water quality modelling

3.1. Introduction

The first step in the assessment of the effects of a discharge on an aquatic receiving environment is generally to estimate or calculate the changes in water quality (e.g. concentration of nutrients, water clarity) caused by the discharge, and the resulting water quality after reasonable mixing. Once effects on water quality are known, likely effects on aquatic life can be inferred.

In the case of discharges of effluent to rivers, the water quality assessment has often been conducted on the basis of a limited number of assumed river and discharge conditions: i.e. if we assume the river is flowing at x m^3/s and the discharge is y m^3/day with a DRP concentration of z g/m^3, then the concentration increase caused by the discharge can be calculated. Scenarios with different likeliness of occurrence, including "worst-case" scenarios are generally developed to provide a range of likely downstream conditions.

Whilst very acceptable in the case of continuous discharges to water, this type of static approach is ill-suited to assessing the effects of dual land/water discharge systems, as it is inherently unable to reflect the "stop-and-go" nature of the river discharge component. Further, a number of the One Plan's water quality targets are expressed as average values over variable combinations of river flow and/or time periods of time – for example, SIN and DRP water quality targets are expressed as annual average concentrations measured at flows below the 20^{th} flow exceedance percentile. "Static" scenario assessments are again ill-suited to assessing the degree of likely compliance with these water quality targets. A daily time-step approach, which accounts for the key elements, including discharge volumes, river flow, discharge quality and river water quality on a daily basis over a significant period of time (over 20 years in this case), was considered best suited to evaluating the likely outcomes of different discharge scenarios.

The model covers the period 1 January 1993 to 4 September 2013, referred to thereafter as the "modelling period".

3.2. Available data and data preparation

The river and discharge flow and water quality data used in this assessment are summarised in Table 3 below. Where data were available from various sources, aggregated datasets were prepared and used – for example, river water quality data for upstream and downstream of the discharge were available from Horizons and AFFCO.

The river and effluent water quality datasets contained a small proportion of "less than detection limit" results. To conduct statistical analysis, such censored data were replaced by numerical values. The "less than" values represented fewer than 10% of the total dataset for each parameter and were replaced by half of the detection limit, which is consistent with the recommendations of Scarsbrook and McBride (2007). Where values were greater than the detection limit the actual value was used.

Daily discharge volume (m^3/day) discharged to the river for 2 scenarios, "Current" and "Proposed", covering the 20-year modelling period were provided by Lowe Environmental Impact (LEI). The discharge regime, including its underlying assumptions, rules, triggers, and outcomes are described in separate reports.

The basic flow statistics at the Oroua at Kawa Wool synthetic flow site used in this assessment were as per Henderson and Diettrich (2007) (Table 4). Note that for simplicity, the 20^{th} flow exceedance percentile flow is abbreviated as Q_{20} in the rest of this report.

Table 3: Summary of data used in the modelling.

Site	Type	Parameters	Frequency	Period	Source
Oroua at Kawa Wool	River flow (synthetic)	Daily mean flow	Daily	1/01/1993 to 4/9/2013	Horizons
Oroua River upstream AFFCO discharge	River water quality	DRP, SIN, TNH_3-N, *E. coli*, TSS, POM, BOD, Clarity, Turbidity	Variable	17/07/2007 to 15/08/2013	Horizons
Oroua River downstream AFFCO discharge					
AFFCO effluent	Effluent quality	DRP, SIN, TNH_3-N, $ScBOD_5$, TSS, $TBOD_5$, *E. coli*	Daily	1/01/1993 to 4/9/2013	LEI
AFFCO effluent	Effluent	Daily discharge volume	Daily	1/01/1993 to 4/9/2013	LEI

Table 4: Flow statistics for the Oroua River at Kawa Wool, from Henderson and Diettrich (2007).

Flow statistic	Value (l/s)
MALF	1,240
Half median flow	3,486
Median flow	6,971
20^{th} percentile exceedance flow (Q_{20})	16,078
3 × median flow	20,913

3.3. Water quality model structure

The water quality component of the model calculates the concentrations or values (in the case of water clarity) of different water quality determinands downstream of the discharge. It is based on very simple mass conservation principles: a certain quantity of a given constituent is released into a certain quantity of receiving water, resulting in a certain concentration of the said constituent.

The concentration increase of a constituent C caused by the discharge after full mixing in the river is given by:

$$\Delta[C]ds = \frac{[C]_e \times Q_e}{(86.4\,Qr) + Q_e}$$

Where:

$[C]_e$: is the concentration of constituent C in the effluent g/m^3

Q_e : is the daily discharge volume to the river in m^3/d

Qr: is the flow in the river in L/s

The said constituent may be present in the river upstream of the discharge. In this case, the final concentration downstream of the discharge is given by:

$$[C]_{ds} = \frac{([C]e \ \times Q_e) + ([C]_{us} \times 86.4\, Qr)}{(86.4\, Q_r) + Q_e}$$

Where:

$[C]_{us}$: is the concentration of constituent C in the river upstream of the discharge in g/m^3;

Q_e : is the daily discharge volume to the river in m^3/d

Q_r: is the flow in the river in L/s

Calculations relating to effects on water clarity are based on beam attenuation principles. The downstream water clarity is given by:

$$y_{ds} = \frac{Q_r + \frac{Q_e}{86.4}}{\frac{Q_r}{y_{us}} + \frac{Q_e}{86.4 y_e}}$$

Where:

y_{ds}: is clarity of the river downstream of the discharge in metres (m);

y_{us} is the clarity of the river upstream of the discharge, in metres (m);

y_e is the clarity of the river upstream of the discharge, in metres (m).

3.3.1. Mixing

Most of the model predictions presented in this report assume full mixing of the discharge with the river. Depending on the size of the zone of reasonable mixing (ZRM) allowed by the future consent conditions, this assumption may not always be correct at the end of the ZRM. Simplistically, incomplete means that higher than predicted concentrations of the given constituent may prevail on one "side" of the river, with lower than predicted concentrations on the other side of the river.

3.3.2. Groundwater inflow component

PLACE HOLDER – we may need a groundwater component added to the modelling – in this case, the SIN concentration change due to the proposed activity will estimated by:

$$[SIN]_{ds} = \frac{([SIN]e \ \times Q_e) + ([SIN]_{us} \times 86.4\, Qr) + (\Delta L_{NGW})}{(86.4\, Q_r) + Q_e + \Delta Q_{GW}}$$

Where:

$[SIN]_{ds}$ is the SIN concentration in the river downstream of the reach of river influenced by groundwater from the land irrigation site.

ΔL_{NGW}: is the change in daily N load to the river from the land irrigation area compared with current, in g/d;

ΔQ_{GW}: is the change in daily drainage volume from the land irrigation area compared with current in m^3/d

Q_{GW} is the change in monthly drainage compared with current (m^3/d)

3.4. Modelling scenarios

The outcomes of two scenarios are reported in this report:

- Current: This scenario is representative of the discharge regime as operated under the current resource consent conditions. It thus represents the historical discharge within recent history and the outputs of this scenario was used in the model validation as presented in Section 3.7 of this report;
- Proposed: This scenario is representative of the proposed discharge regime as summarised in Section 1.1.

Both scenarios assume similar effluent quality, based on historical effluent quality. Daily effluent quality data series were provided by LEI and used as inputs to our modelling. The key difference between the two scenarios lies in the timing and volume of discharge. In particular, the proposed discharge regime does not include any discharge when the Oroua River is below median flow in winter (6,971 l/s), while the current discharge regime allows discharges at river flows as low as 3,000 l/s in winter.

Six water quality determinands were modelled: DRP, SIN, total ammonia-N, *E. coli*, water clarity, and Soluble carbonaceous five-day Biochemical Oxygen Demand ($ScBOD_5$).

3.5. Synthetic upstream water quality input data series

In order to provide "background" river water quality, a synthetic daily river water quality data series was created. The aim of this synthetic data series was to simulate upstream water quality based on measured historical water quality.

River water quality for the Oroua River upstream of the AFFCO discharge were available from Horizons' compliance monitoring programme. Daily mean flow for each day of sampling was extracted from the Oroua at Kawa Wool synthetic flow series provided by Horizons.

The existing river water quality data were partitioned in 5 "bins" based on river flow exceedance percentiles (Table 5).

The median and standard deviation of concentration were calculated in each bin. For SIN and DRP, the data were LOG-transformed, and LOG-transformed data were assumed to be normally distributed. DRP and SIN concentrations for each day of the 20 year modelling period were simulated by random sampling within the assumed normal log-transformed data frequency distribution. The final data series were created allocating to each day of the modelling period either the measured value for that day (when available) or the modelled value.

Figure 1 and Figure 2 present the measured (observed) in the river and modelled (predicted) probability distributions of the nutrient concentrations upstream of the discharge point. The black dotted lines represent the observed concentrations plus or minus the standard deviation of the observed data, as a measure of tolerance in variability.

These figures show that the predicted SIN and DRP concentrations fall within the tolerance range given by the observed concentrations ± one standard deviation, showing acceptable fit between observed and predicted concentrations. Good agreement between observed and predicted concentrations was achieved across the whole range of both DRP and SIN concentrations (Figure 2).

For each other determinand, an upstream daily water quality series was created by allocating to each day of the modelling period either the measured value for that day (when available) or the median concentration of actual observations within the corresponding flow/season bin.

No data were available relative to effluent visual clarity, and an effluent clarity of 0.1m it was assumed.

Table 5: Flow and seasonal data bins used in the modelling of synthetic water quality datasets. (Flow exceedance percentiles from Henderson and Diettrich, 2007). Summer defined as 1 December to 31st March.

Bin	River flow		Season
	Exceedance percentile	Flow (L/s)	
1	100-80	min - 3,094	All
2	80-50	3,094 - 6,971	All
3	50-40	6,971 – 9,027	All
4	40-20	9,027 – 16,078	All
5	20-0	16,078 – Max	All

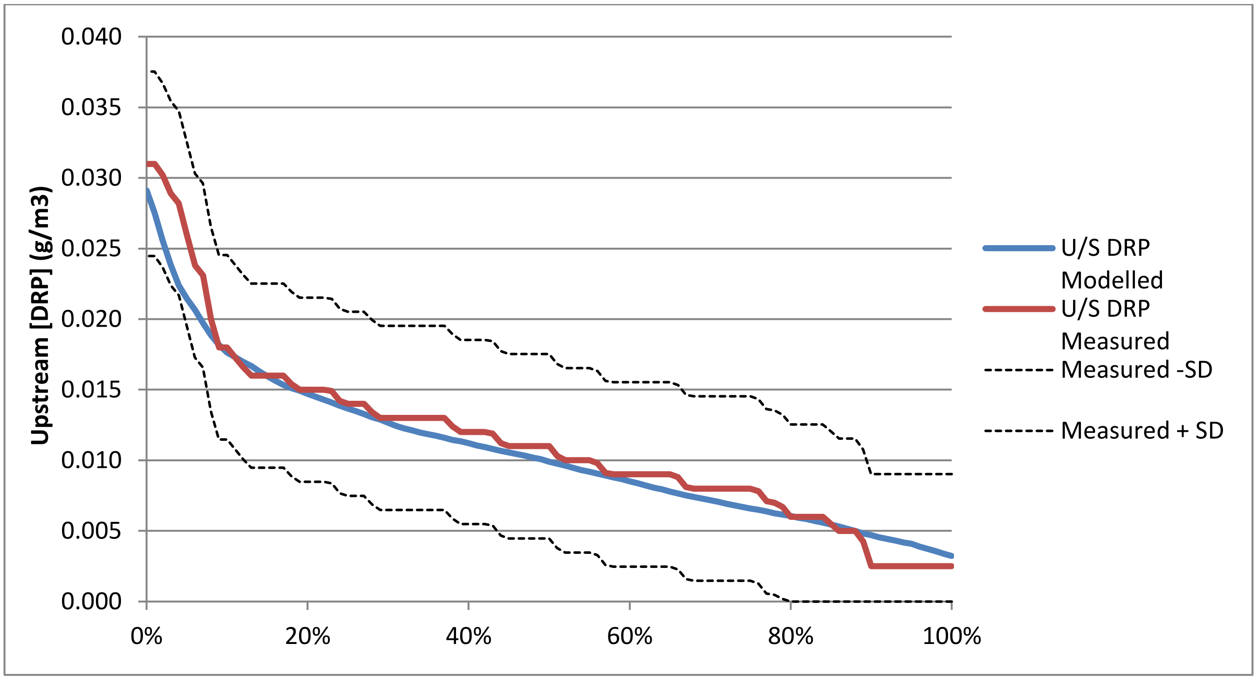

Figure 1: Probability distribution of DRP concentrations upstream of the AFFCO Feilding discharge point, as measured in the river (red line) and predicted by the model (blue line). The dotted black lines represent the measured concentrations plus or minus the standard deviation of the observed data, as a measure of tolerance in variability.

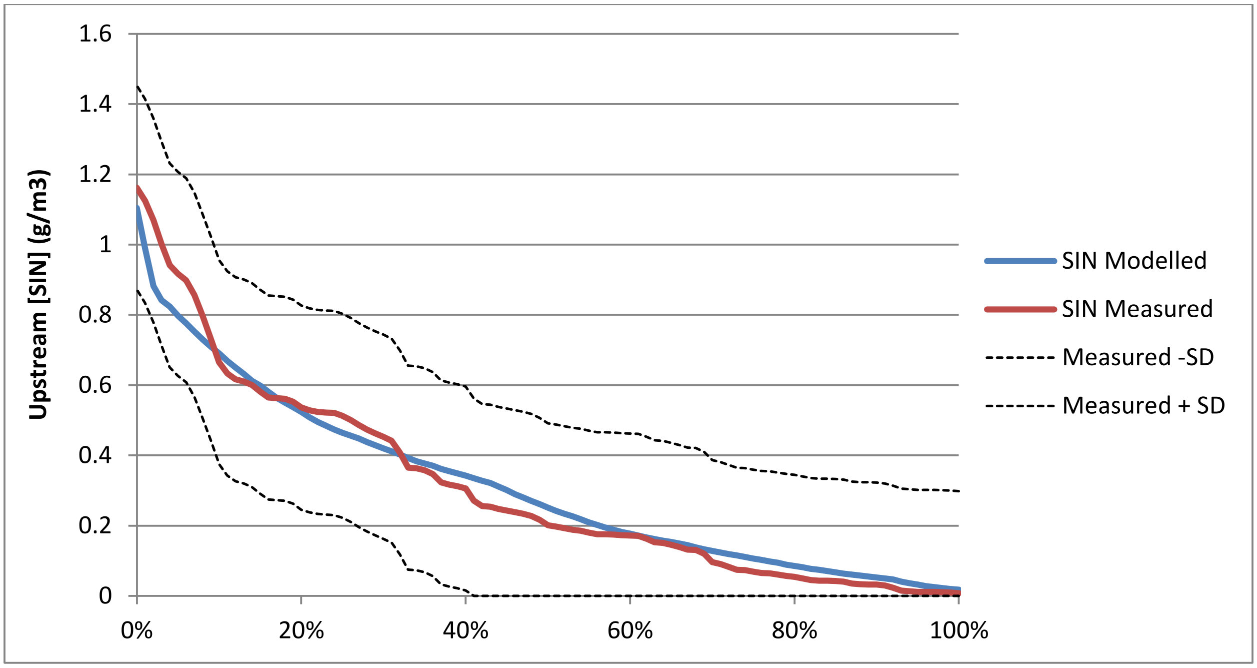

Figure 2: Probability distribution of SIN concentrations upstream of the AFFCO Feilding discharge point, as measured in the river (red line) and predicted by the model (blue line). The dotted black lines represent the measured concentrations plus or minus the standard deviation of the observed data, as a measure of tolerance in variability.

3.5.1. Discharge quality data series

Daily discharge quality data series for SIN, DRP, Total Ammonia-nitrogen (TNH_3-N), *E. coli* and $cBOD_5$ used in the modelling period were provided by LEI (LEI, 2014a). The same discharge quality was assumed for the two scenarios.

3.6. Output data and indicators

For each scenario daily water quality data series covering the 20-year modelling period were produced relative to:

- Daily concentration increase caused by the discharge and resulting daily downstream concentration of DRP, SIN, total ammonia-N, TSS, *E. coli* and $cBOD_5$;
- Daily downstream water clarity and daily change in water clarity between upstream and downstream;
- Daily load increase caused by the discharge and resulting daily downstream load of DRP, SIN, total ammonia-N, TSS, *E. coli*; POM and $ScBOD_5$.

These were calculated on the basis of fully mixed concentrations. Mixing is discussed further in relation to each water quality determinand in Section 4.

From 20-year long daily data series, all sorts of statistics and data summaries and graphic displays can be produced, and the challenge is to summarise the data into summary indicators that are at the same time simple, easy to understand, able to be compared between scenarios and relevant in terms of potential effects and Regional Plan water quality targets. The key indicators used in this report are:

- Nutrients (SIN and DRP): The relevance of SIN and DRP concentrations is that they may promote periphyton growth. This means that to have an effect, the nutrient concentrations need to be present for a relatively extended period of time. Instantaneous or short-term spikes in nutrient concentrations are unlikely to result in significant increase in periphyton growth, and average concentrations over a given period of time are generally considered a useful indicator of risk posed by nutrients with regards to periphyton growth. The One Plan water quality targets for DRP and SIN are expressed as annual average concentrations at flows below the Q_{20}[1]. This statistic was calculated and reported for each scenario. Annual and monthly average concentrations under different river flow conditions were also calculated;
- Ammonia (chronic): The One Plan chronic ammonia toxicity target is expressed as an average concentration, but does not prescribe the length of the time period the average should be calculated over. Ecotoxicity studies of four days or less are generally considered acute toxicity. Chronic toxicity studies are generally based on longer exposures, typically from 6-7 days to weeks or months. The USEPA updated (2009) chronic ammonia exposure criterion is based on a 30 day average concentration. For the purpose of this report, a 7-day rolling average total ammonia concentration was calculated for each day of the modelling period and used as the main chronic ammonia toxicity indicator, i.e. the percentage of compliance of this indicator with the OP target was calculated and reported. Using a relatively short averaging period of seven days is considered a conservative approach in the context of chronic toxicity;
- Ammonia (acute): The One Plan sets a maximum total ammonia-N concentration target of 2.1 mg/L. The total ammonia concentrations calculated for each day of the modelling period can be assimilated to instantaneous concentrations and thus are considered suitable to be directly compared with the OP acute ammonia target. The percentage of compliance of this indicator with the OP target was calculated and reported;
- Water clarity change: The OP water clarity change target is a reduction in water clarity of no more than 30%. The percentage of reduction in water clarity was calculated for each day of the modelling period and compared with the OP target. The percentage of compliance of this indicator with the OP target was calculated over the modelling period and reported.
- *E. coli*: The One plan sets two water quality targets, applying at different river flows/time of the year. The key indicator reported here is the % compliance of daily concentration with each target.

Table 6: Summary table of water quality determinands, One Plan targets and indicators calculated from the modelled daily water quality output series for each modelled scenario.

Determinand	OP target		Indicator in this report
Dissolved reactive phosphorus (DRP)	Annual average at flows <Q_{20}	0.010 g/m^3	Annual and monthly average concentration at : • Flows <1/2 median flow • Flows < median flow • Flows <Q_{20} • All flows
Soluble Inorganic Nitrogen (SIN)	Annual average at flows <Q_{20}	0.444 g/m^3	
Total Ammonia-nitrogen (TNH_3-N)	Average concentration	0.400 g/m^3	% compliance of 7-day rolling average concentration
	Maximum concentration	2.1 g/m^3	% compliance of daily concentration
E. coli	Concentration at flows < median in summer	260/100mL	% compliance of daily concentration at summer flows< median
	Concentration at flows <Q_{20}	550/100mL	% compliance of daily concentration at flows <Q_{20}
Water clarity	% change at all flows	30%	% compliance of daily clarity change

[1] Q_{20} is 20th flow exceedance percentile, which is the flow under which the SIN and DRP One Plan water quality targets apply.

3.7. Water quality model accuracy and uncertainty

The main water quality component of the model is based on simple mass-conservation equations, and does not involve any calibration parameters, and has therefore no uncertainty associated with the water quality calculations themselves. Sources of error and uncertainty are primarily associated with the input data, including effluent quality. Extreme values outside the modelled effluent quality ranges are not predicted by the model. The water clarity assessment is based on assumed, not measured, effluent clarity.

As explained in Section 3.4, the "current" scenario is considered representative of the discharge operating under its current consent. Model predictions for the "current" scenario were compared with SIN and DRP concentrations measured downstream of the AFFCO discharge, in order to provide an assessment of the model's goodness of fit.

Figure 3 and Figure 4 present the measured (observed) in the river and modelled (predicted) probability distributions of the nutrient concentrations downstream of the discharge point. The black dotted lines represent the observed concentrations plus or minus the standard deviation of the observed data, as a measure of tolerance in variability.

These figures show that the predicted SIN and DRP concentrations fall within the tolerance range given by the observed concentrations ± one standard deviation, showing acceptable fit between observed and predicted concentrations downstream of the discharge.

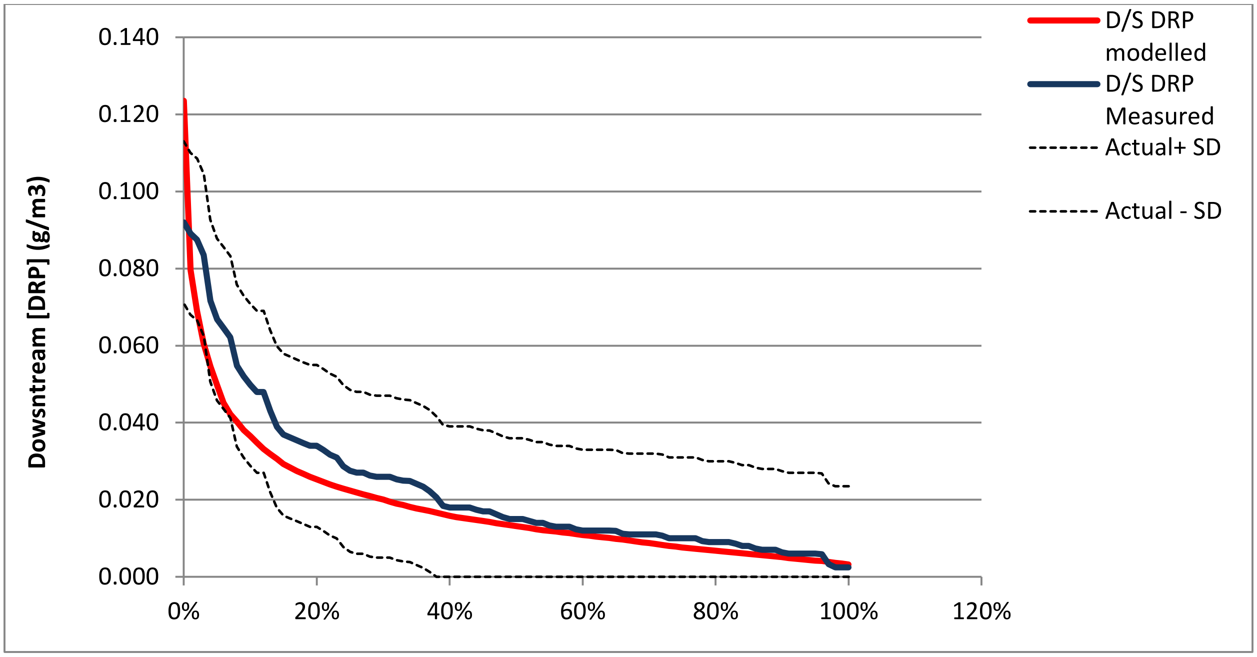

Figure 3: Probability distribution of DRP concentrations <u>downstream</u> of the AFFCO Feilding discharge point, as measured in the river (red line) and predicted by the model (blue line). The dotted black lines represent the measured concentrations plus or minus the standard deviation of the observed data, as a measure of tolerance in variability.

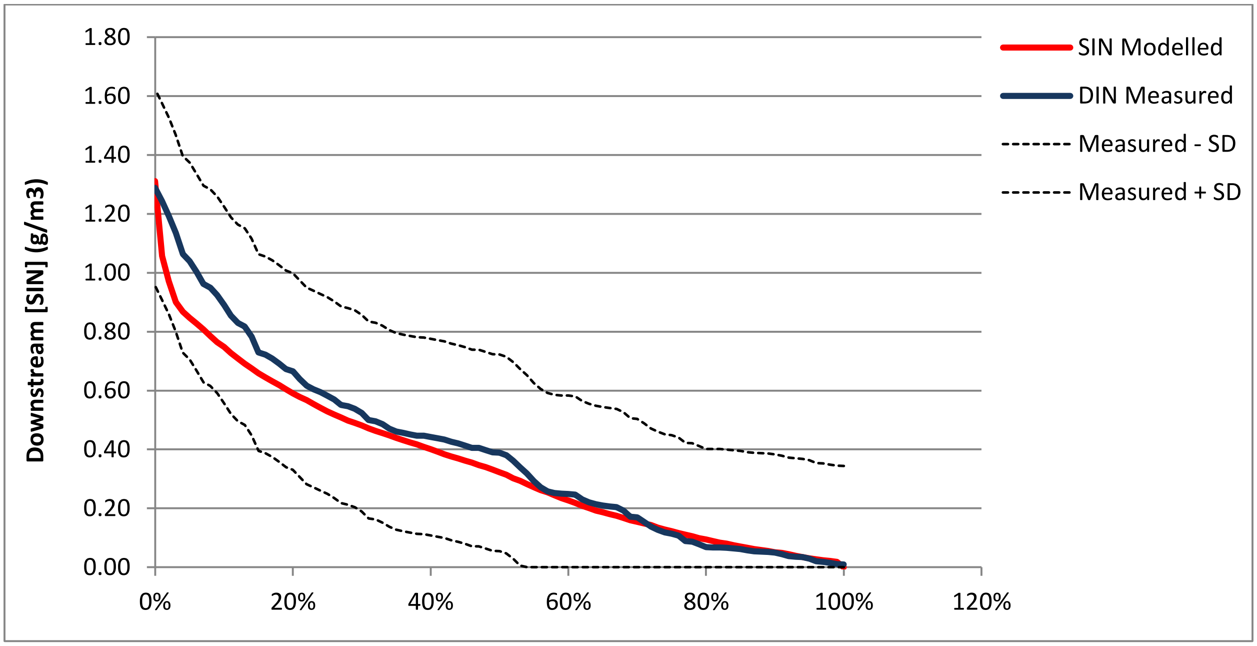

Figure 4: Probability distribution of SIN concentrations <u>downstream</u> of the AFFCO Feilding discharge point, as measured in the river (red line) and predicted by the model (blue line). The dotted black lines represent the measured concentrations plus or minus the standard deviation of the observed data, as a measure of tolerance in variability.

4. Results

4.1. Dissolved reactive Phosphorus (DRP)

4.1.1. DRP Loads

The proposed discharge regime results in a 7.3 % increase in the average total DRP loads discharged to the river compared with the 'current' scenario, from 2.21 to 2.37 Tonnes per year (T/yr) (Figure 5). This compares with an estimated in-river load upstream of the discharge of 4.5 T/yr.

The distribution of DRP loads discharged to the river is very different between the two scenarios. In particular, whilst the 'current' scenario results in the discharge of 0.48 T/yr at flows below median flow, the 'proposed' scenario does not result in any DRP load discharged to the river below median flow. The upstream load at river flows below the median flow is 0.40 T/yr.

When considering all flows below Q_{20}, the 'proposed' scenario results in 0.25 T/yr discharge to the river, versus 1.3 T/yr under the 'current' scenario (an 81% reduction). This compares with an upstream average load of 1.6 T/yr at flows below Q_{20}.

The reason for the reduction in loads discharged below Q_{20} is that a greater proportion of effluent is discharged at flows above Q_{20} in the 'Proposed' scenario (i.e. when the OP water quality targets do not apply): 82% under the 'proposed' scenario versus 41% under the 'current' scenario (Figure 6).

4.1.1. DRP concentrations

Figure 7 shows the predicted annual average DRP concentration increase in the Oroua River caused by the discharge downstream of the AFFCO discharge after full mixing, under 'current' and 'proposed' scenarios.

The 'current' scenario results in concentration increases under all flow categories assessed, including under half median flow. The increase under half median flow (0.0014 g/m^3, or 14% of the POP target) is due to the small number of days when the discharge is operating in winter when the flow in the river is above the consented threshold of 3,000 l/s but below half median flow (3,486 L/s).

The current scenario also results in more significant increase in annual average concentration at flows under median flow (0.0067 g/m^3, or 67% of the OP target) and flows below Q_{20} (0.0079 g/m^3, or 79% of the POP target). The upstream annual average concentration at flows below Q_{20} is 0.0096 g/m^3, i.e. just below the OP target of 0.010 g/m^3 (Figure 7). The resulting annual average concentration downstream of the discharge is 0.0175 g/m^3, i.e. well in excess of the OP target (Figure 8).

Analysis of predicted monthly average concentration increases indicates that the 'current' scenario results in DRP concentration increases at river flows below Q_{20} equivalent to or larger than the OP target during the months of April to July, and equivalent to about 20 to 70% of the OP target during the months of August to November (Figure 9).

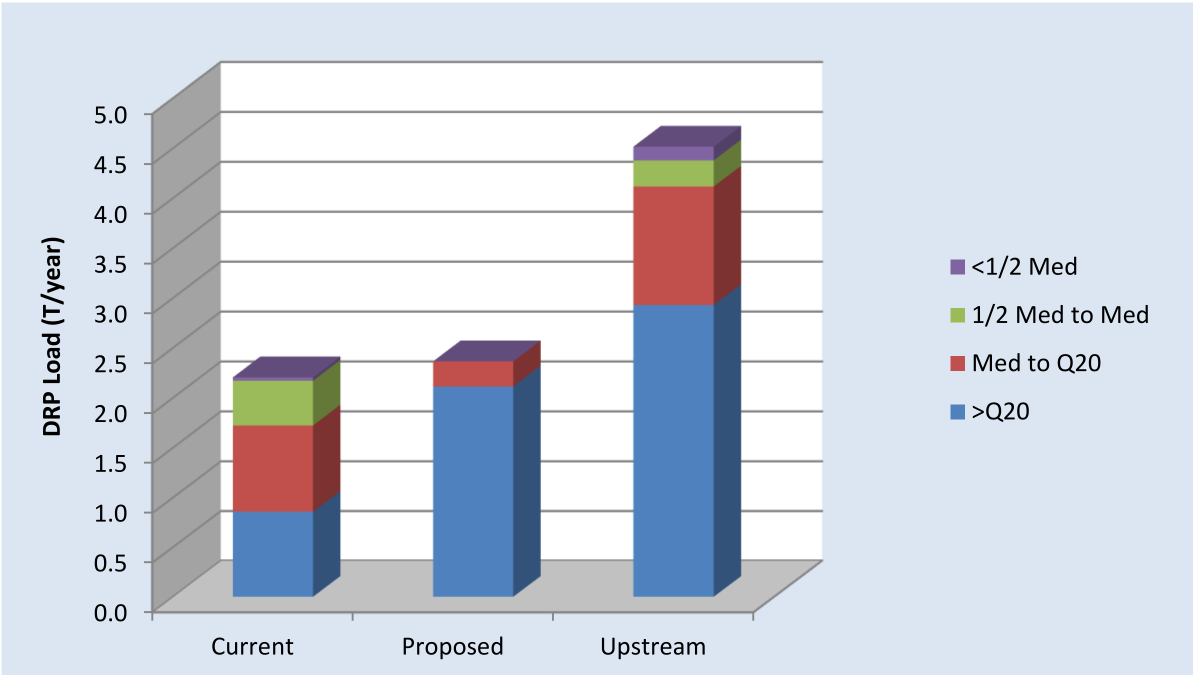

Figure 5: Annual average DRP loads in the Oroua River upstream of the AFFCO discharge (‘upstream) and added by the AFFCO discharge to the river under ‘current’ and ‘proposed’ scenarios.

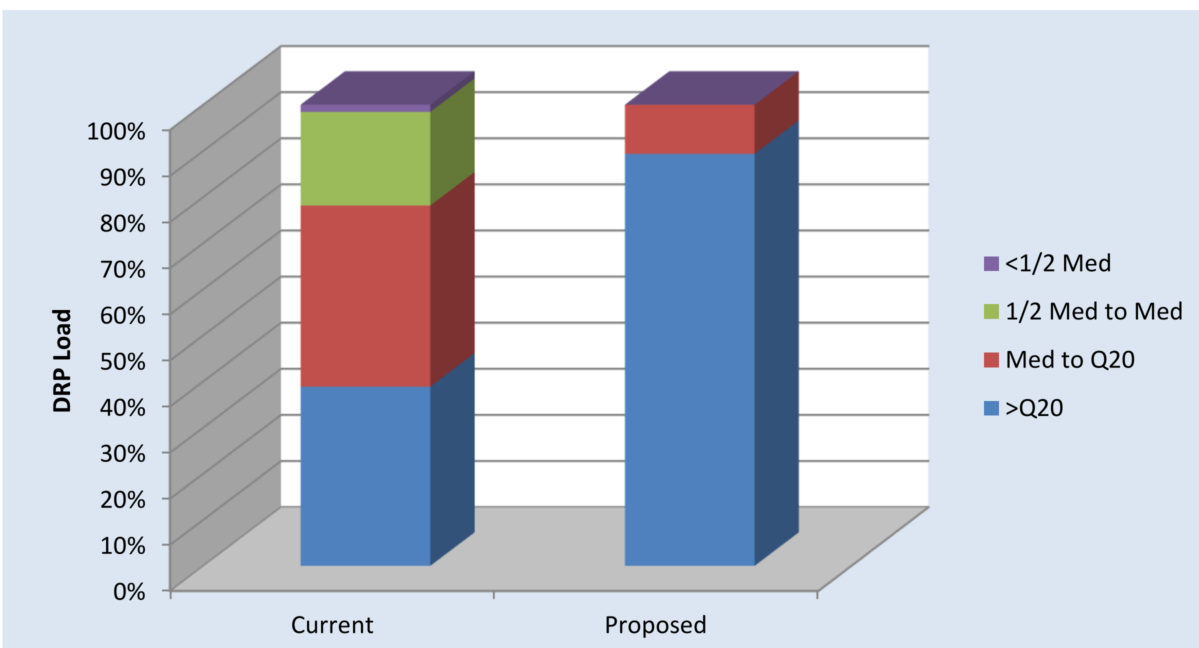

Figure 6: Distribution of annual DRP loads in the AFFCO discharge within river flow categories, under ‘current’ and ‘proposed’ scenarios.

In comparison, the proposed discharge regime:

- Does not include any discharges at river flows below median flows, so does not result in any increases in DRP concentrations at flows below half median or below median flow;
- Results in a smaller increase in annual average DRP concentration increases at flows below Q_{20}: 0.0010 g/m^3, or 10% of the POP target. This represents an 88% reduction of the effects of the AFFCO discharge on in-stream DRP concentration increases compared with the 'current' scenario;
- Compared with upstream, it results in an approximately 10% increase in in-river concentration at flows below Q_{20}, from 0.096 g/m^3 upstream of the discharge (i.e. 4% under the OP target) to 0.0106 g/m^3 (i.e. 6% over the OP target);
- Monthly average concentration increases at flows below Q_{20} range from 0.0004 g/m^3 (4% of the OP target) in November to 0.0039 g/m^3 (39% of the OP target) in July (with no increase in December to March inclusive). This represents a 60 to 94% reduction of the effects of the AFFCO discharge on in-stream DRP concentrations.

The potential effects of the discharge on periphyton growth are discussed in Section 4.3.

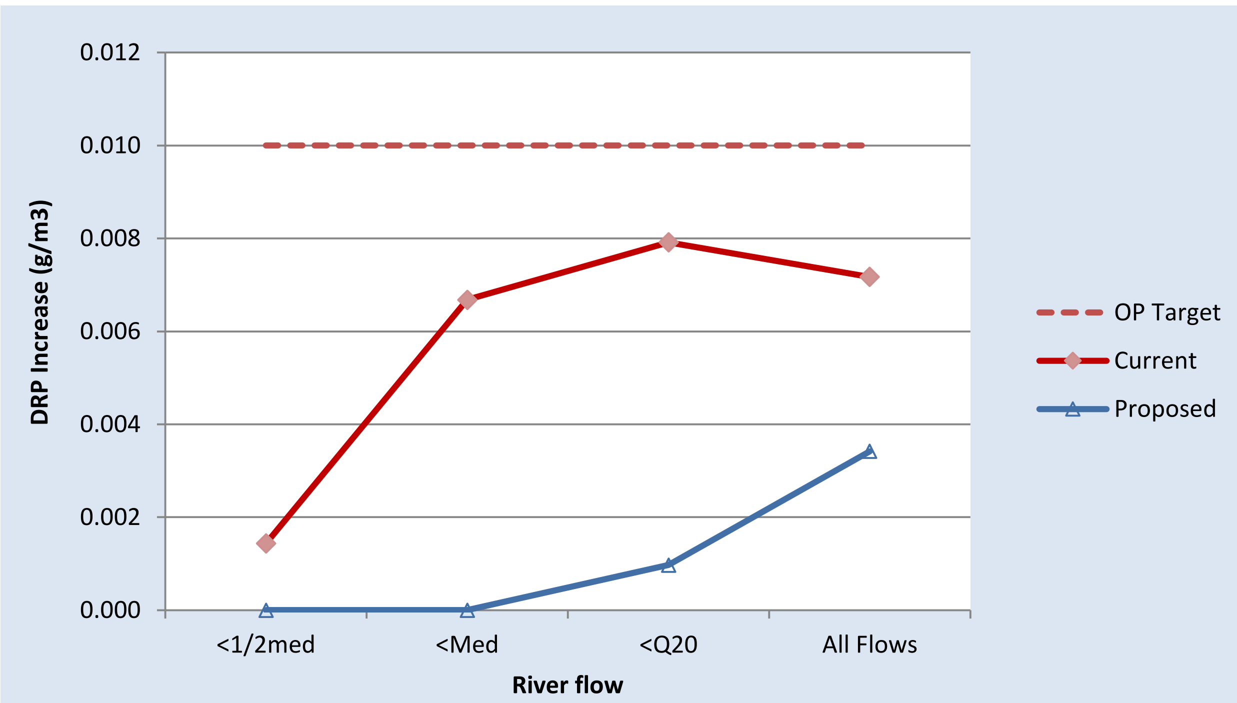

Figure 7: Predicted annual average DRP concentration <u>increase</u> in the Oroua River due to the AFFCO at different river flows under current and proposed discharge scenarios.

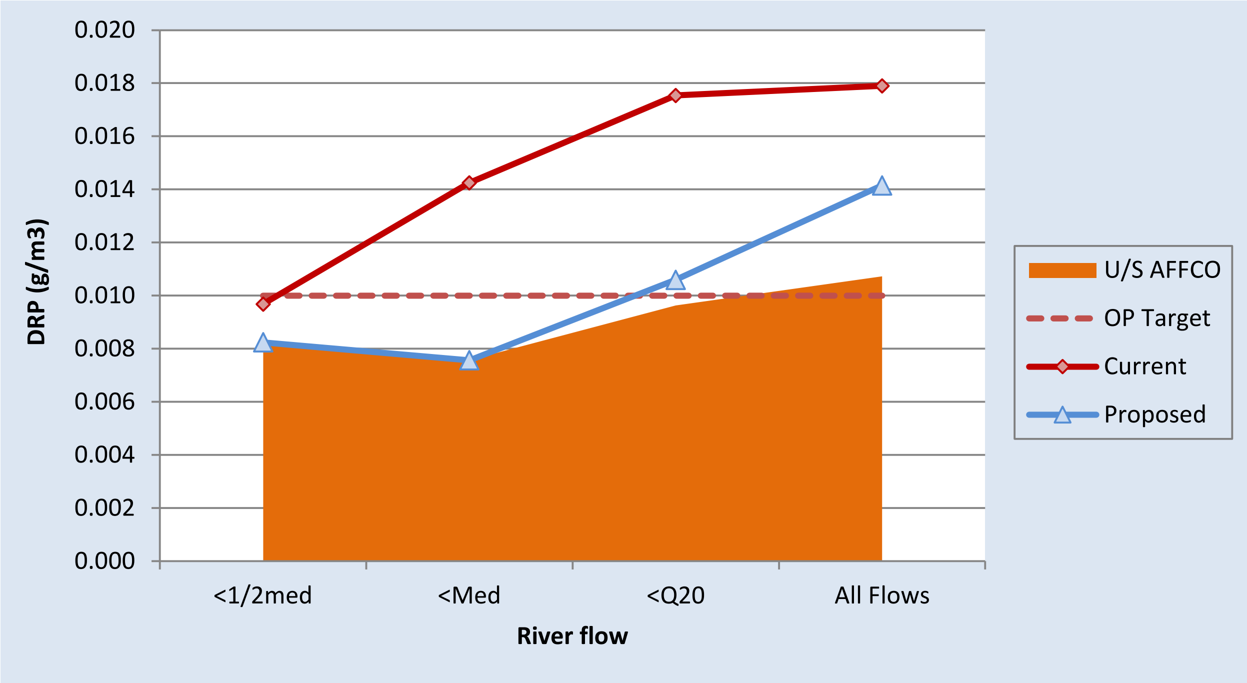

Figure 8: Predicted annual average DRP concentration upstream and downstream of the AFFCO discharge at different river flows under current and proposed discharge scenarios.

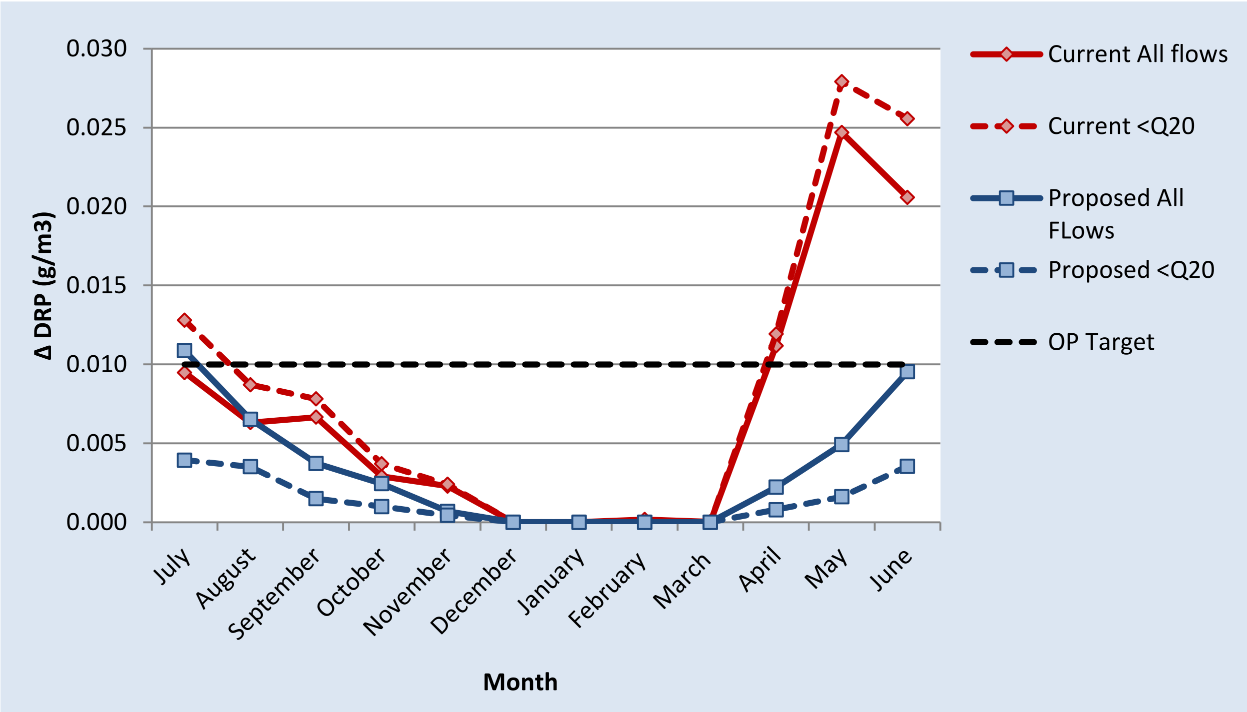

Figure 9: Predicted <u>monthly</u> average DRP concentration <u>increases</u> caused by the AFFCO discharge at different river flows under current and proposed discharge scenarios.

4.2. Soluble Inorganic Nitrogen (SIN)

4.2.1. SIN Loads

The ‘proposed’ discharge regime results in an 11% increase in the total SIN loads discharged to the river compared with the ‘current’ scenario, from 14.1 to 15.7 T/yr (Figure 10). The total annual load contributed by the discharge under both scenarios represents approximately 10% of the upstream annual load (154 T/yr) (Figure 10).

Similarly to what was observed with DRP, the distribution of SIN loads discharged to the river is very different between the two scenarios. In particular, the ‘current’ scenario results in the discharge of 2.9 T/Y at flows below median flow, whilst the ‘proposed’ scenario does not result in any load discharged to the river below median flow.

When considering all flows below Q_{20}, the proposed scenario results in 1.6T/Y discharge to the river, versus 8.5 T/Y under the ‘current’ scenario (an 81% reduction).

Consequently, the ‘proposed’ scenario also results in proportionally more SIN load being discharged at flows above Q_{20} (i.e. when the OP water quality targets do not apply): 96% versus 78% under the ‘current scenario (Figure 11).

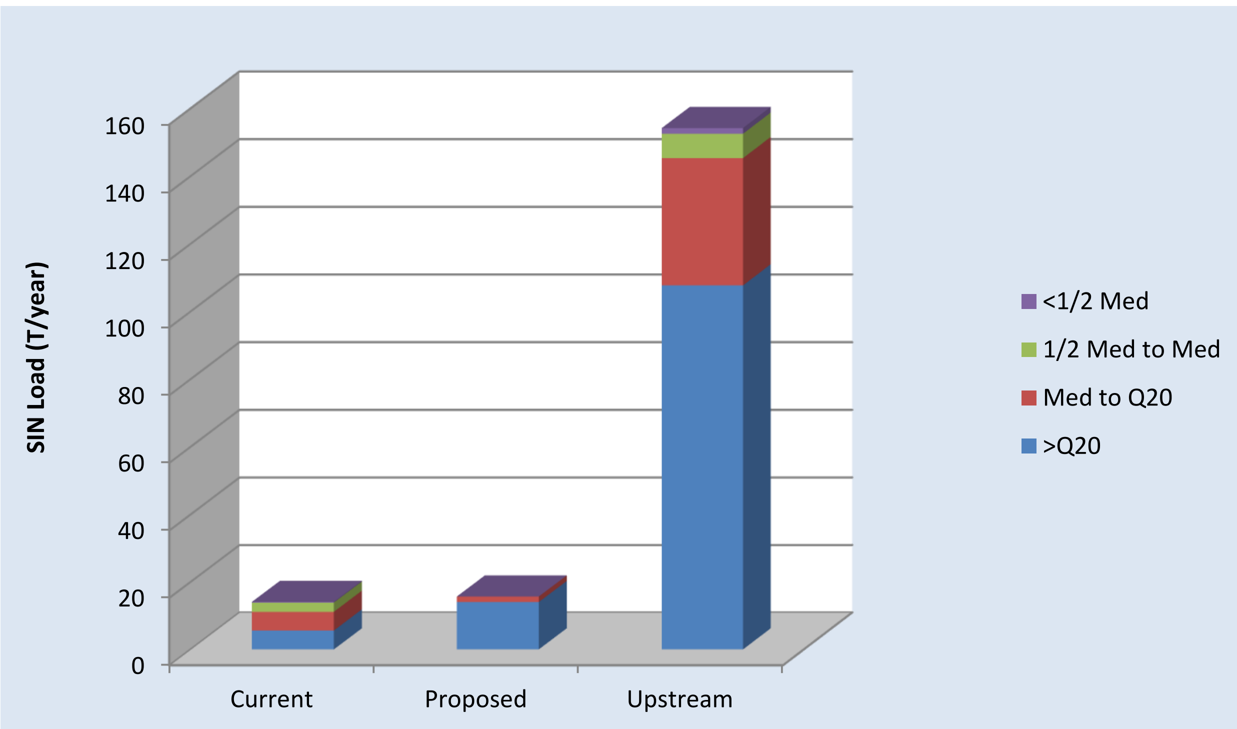

Figure 10: Annual average SIN loads in the Oroua River upstream of the AFFCO discharge (‘upstream’) and added by the AFFCO discharge to the river under ‘current’ and ‘proposed’ scenarios.

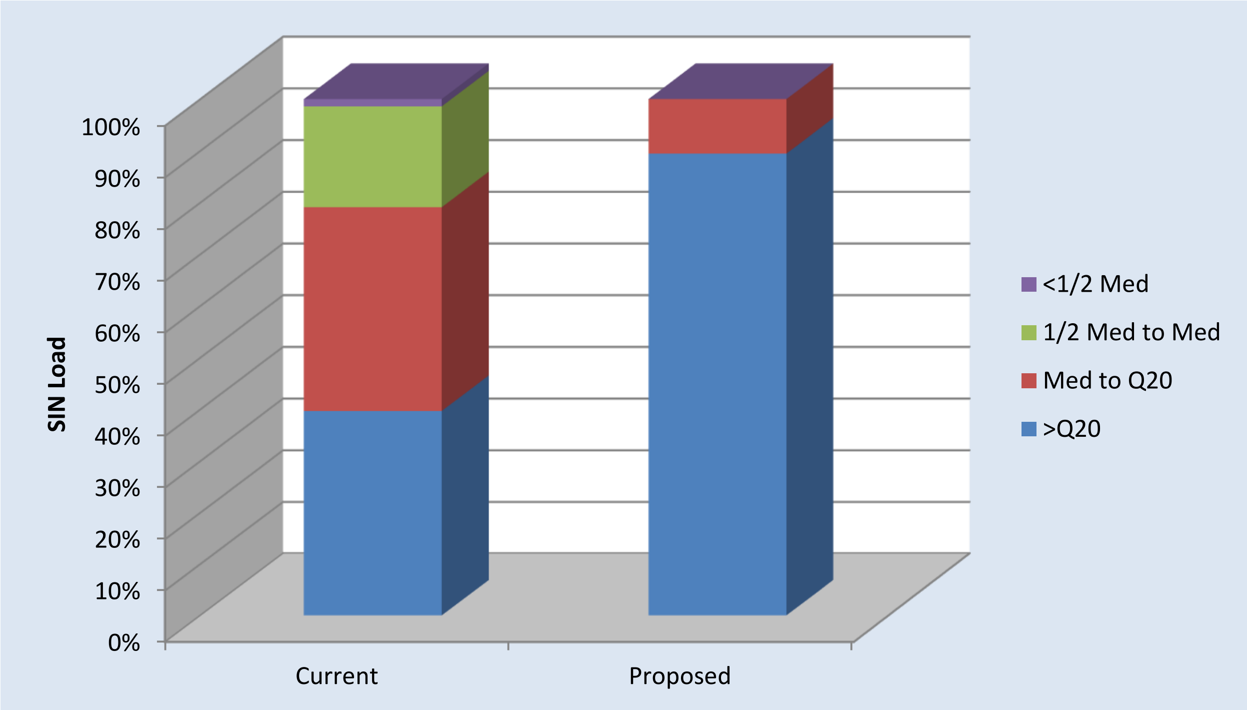

Figure 11: Distribution of annual average SIN loads in the AFFCO discharge to the Oroua River within river flow categories, under 'current' and 'proposed' scenarios.

4.2.2. SIN concentrations

Figure 7 shows the predicted annual average SIN concentration <u>increase</u> caused by the discharge downstream of the AFFCO discharge after full mixing, under 'current' and 'proposed' scenarios.

The current scenario results in concentration increases under all flow categories assessed, including a small increase (0.008 g/m^3 or 1.9% of the OP target) at river flows under half median flow.

The 'current' scenario also results in increases in annual average concentration at flows under median flow (0.041 g/m^3, or 9.2% of the OP target) and flows below Q_{20} (0.049 g/m^3, or 11% of the OP target).

The upstream annual average concentration at flows below Q_{20} is 0.247 g/m^3, i.e. well below the OP target of 0.444 g/m^3 (Figure 13). The resulting annual average concentration downstream of the discharge after full mixing is 0.296 g/m^3, well within the OP SIN target of 0.444 g/m^3.

Analysis of predicted monthly average concentration increases indicates that the 'current' scenario results in SIN concentration increases at river flows below Q_{20} of 0.044 to 0.150 g/m^3 (i.e. approximately 1/10th to 1/3rd of the OP 0.444 g/m^3 target) during the months of April to September, with smaller increases (less than 0.020 g/m^3, i.e. less than 5% of the OP target) during the months of October and November (Figure 14).

In comparison to the 'current' scenario, the 'proposed' discharge regime:

- Does not include any discharges at flows below median flows, so does not result in any increases in SIN concentrations at flows below half median or below median flow;
- Results in a much smaller increase in annual average SIN concentration increases at flows below Q_{20}: 0.006 g/m^3 (vs. 0.049 g/m^3 in the 'current' scenario), or 1.4% of the OP target. This represents an 87% reduction of the effects of the AFFCO discharge on in-stream SIN concentration increases;

- Results in an approximately 2.6% increase in annual average in-river concentration at flows below Q_{20}, from 0.249 g/m^3 upstream of the discharge (i.e. 56% of the OP target) to 0.255 g/m^3 (i.e. 57.5% of the OP target);
- Monthly average concentration increases range from 0.002 g/m^3 (0.5% of the OP target) in November to 0.028 g/m^3 (6.2% of the OP target) in July (with no increase in December to March inclusive). This represents a 60 to 94% reduction of the effects of the AFFCO discharge on in-stream SIN concentrations.

The potential effects of the discharge on periphyton growth are discussed in Section 4.3.

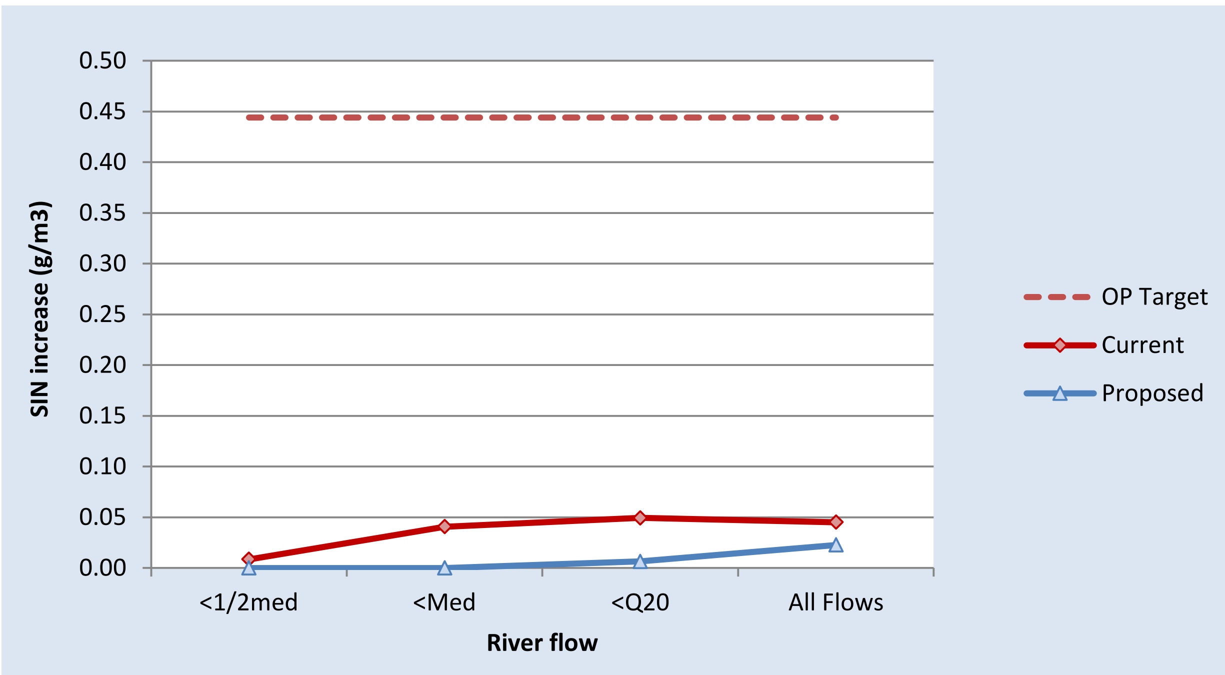

Figure 12: Predicted annual average DRP concentration <u>increase</u> in the Oroua River due to the AFFCO at different river flows under current and proposed discharge scenarios.

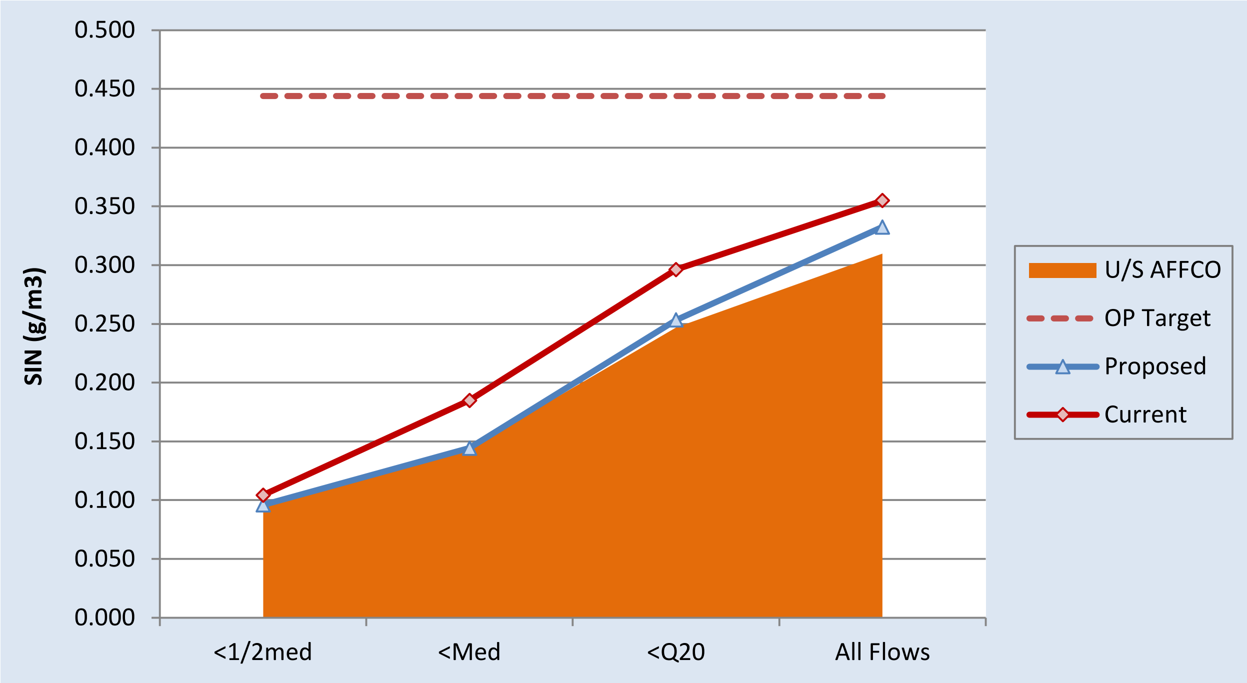

Figure 13: Predicted annual average SIN concentration upstream and downstream of the AFFCO discharge at different river flows under current and proposed discharge scenarios.

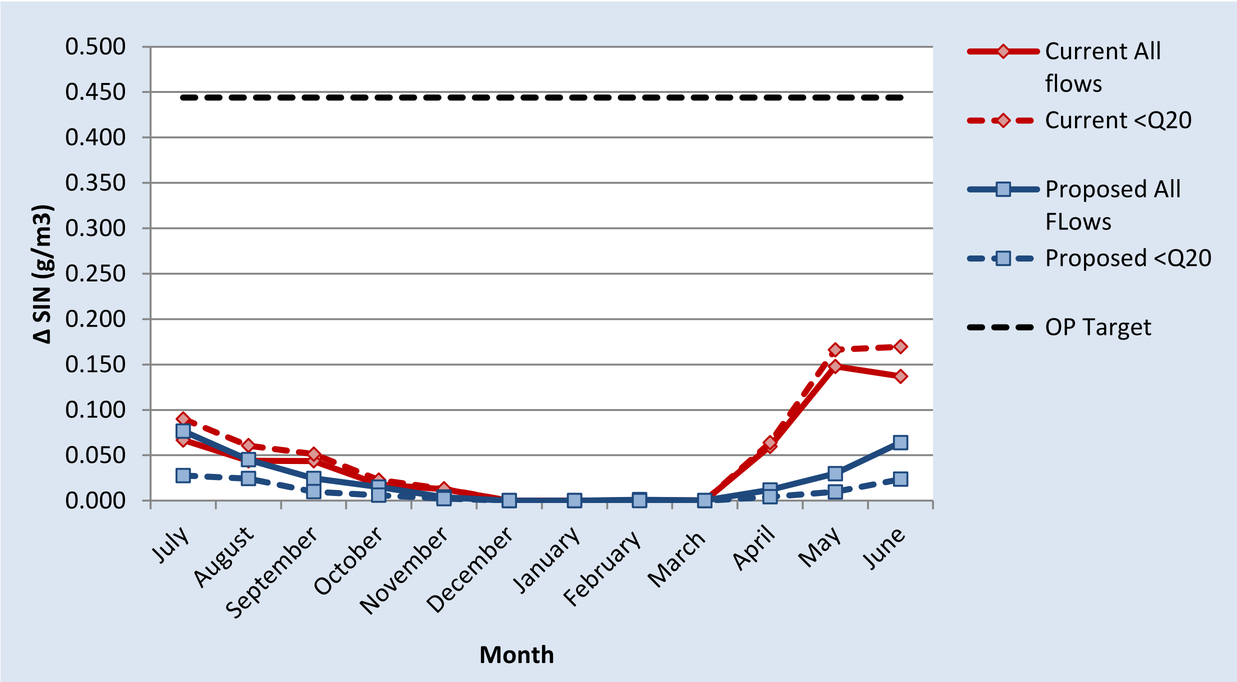

Figure 14: Predicted monthly average SIN concentration increases caused by the AFFCO discharge at different river flows under current and proposed discharge scenarios.

4.3. Periphyton

Periphyton is the green or brown slime or filaments coating stones, wood or any other stable surfaces in streams and rivers. Although periphyton is a normal and essential part of the aquatic ecosystem, it can affect a number of ecological, recreational and aesthetic values.

The One Plan defines two types of targets relative to periphyton a maximum periphyton biomass of 120 mg/m^2 and maximum periphyton cover values of 30% for long (>2cm) filamentous algae and 60% cover for thick (>3mm) mats.

4.3.1. Current effects

Currently there is very little information on periphyton growth upstream or downstream of the AFFCO discharge. The only source of information is the Stark (2013) report, which concludes that, at the time of the assessment, there was an increase in periphyton biomass and cover between upstream and downstream of the discharge, but that both sites were well below the One Plan targets, i.e. well below nuisance levels that would be likely to significantly affect river values. This information however only represents only one point in time, and, although useful, is insufficient in itself to support any firm conclusions.

4.3.2. Future effects during summer

The current consent does not allow any direct discharges of treated effluent to the river between December and March inclusive, apart when the river flow is above three times the median flow (i.e. 6,971 L/s). It is our understanding that the proposed discharge regime maintains these provisions.

The One Plan in-stream nutrient concentration targets for both DIN and DRP do not apply at river flows above Q_{20}. The reason for excluding high river flows was that high river flows can reset periphyton biomass to very low levels, and that periphyton growth is unlikely to be significant during high flow events. Q_{20} is a smaller flow than three times median flow in the Oroua River, meaning that the AFFCO discharge is not allowed to operate in summer at times when the One Plan DIN and DRP targets apply. The effects of the discharge on periphyton growth during the December to March inclusive period are therefore likely to be no more than minor.

It is noted that this restriction on the timing of the discharge effectively removes any risk of significant adverse effect during the 'summer' months, which are typically the months during which the most stable and lowest flows of the year occur. This is supported by the analysis of seasonal distribution of monthly flows for the Oroua River at Kawa Wool undertaken by Henderson and Diettrich (2007), which shows that the lowest monthly flows of the year tend to occur in February, then March and January.

4.3.3. Future effects during winter

Qualitatively, it is expected that periphyton growth downstream of the discharge (or rather the effects of the AFFCO discharge on periphyton growth) will reduce during the remainder of the year as a result of the changes from the 'current' to the 'future' discharge scenarios, due to:

- The significant reduction in nutrient loads discharged at river flows below Q_{20} (i.e. the time when periphyton biomass may be present and growth may occur);
- The significant (87%) reduction in the effect of the discharge on in-stream nutrient concentrations at flows below Q_{20};
- The avoidance of any direct discharge at flows below median flows, i.e. removing the discharge to the river during the most 'at risk' periods of low and/or stable flow.

The above assessment is purely qualitative, and does not provide any indication of the degree of improvement brought by the change from 'current' to 'proposed' discharge scenarios, or of whether each of these scenarios is likely to result in exceedances of the OP periphyton targets. Two methods have been used to provide a semi-quantitative indication of the degree of change in periphyton growth.

4.3.4. New Zealand Periphyton Guidelines Model

The periphyton growth model published in the New Zealand Periphyton Guidelines (NZPG) (Biggs, 2000) was applied to annual and monthly average concentrations at flows below Q20 upstream and downstream of the discharge in both 'current' and 'proposed' scenarios. The NZPG model predicts the peak biomass concentration from dissolved nutrient concentrations and a measure of flow variability (the Mean Days of Accrual – MDA). The MDA value (30.4 days) for the Oroua River at Feilding was sourced from Henderson and Diettrich (2007). Results of this modelling are presented in Table 8, and indicate that the 'current' discharge regime may result in increases in peak periphyton biomass of:

- 12 to 96% over upstream levels during individual winter months, and 35% annually (based on DRP concentrations)
- 2 to 28% over upstream levels during individual winter months, and 10% annually (based on SIN concentrations).

The 'proposed' discharge scenario also resulted in predicted increases, but lesser than those predicted under the 'current' scenario, e.g. 5% (vs. 35% under the 'current' scenario) based on DRP concentrations and 1% (vs 10%) based on SIN concentrations.

The NZPG model predictions can be considered conservative because:

- The NZPG model is inherently conservative, i.e. tends to predict higher biomass levels than generally observed [2];
- The annual MDA was used and applied to winter month – it is likely that the MDA for each individual winter month is much smaller
- The NZPG model predicts the maximum biomass based on concentration of one nutrient assuming that the other nutrient is in abundant supply – i.e. does not account for any co-limitation or changes in limitation of periphyton growth.

It is arguable whether the small increases predicted would be detectable, given the very high sampling variability in periphyton biomass measurements.

4.3.1. Feilding WWTP periphyton growth model

The model developed by Ausseil (2013) to assess the potential effects of the Feilding municipal WWTP discharge to the Oroua River was also applied to the upstream, and downstream 'current' and proposed' scenarios. This model was partially calibrated using monthly observations of periphyton biomass upstream of the Feilding WWTP discharge. However, insufficient data were available to fully calibrate the model, and Ausseil (2013) concluded that the model predictions were useful to provide an assessment of the likely direction of change and an indication of the degree of change in periphyton growth between different scenarios, and also when these differences might occur in response to specific timing of the discharge, but that absolute periphyton biomass values predicted by the model should be used with caution. It was not recommended that the model output be used to assess the likely future degree of compliance with specific periphyton biomass target, until or unless the model was more fully calibrated using site-specific data.

Using the model as a conceptual tool to comparatively assess the risk of increased periphyton growth caused by different discharge scenarios is however considered useful, as the model incorporates known key drivers of periphyton growth, including river flow and dissolved nutrient concentrations.

Results, summarised in Table 8 indicate that the "current scenario results in an increase of 20% of the average periphyton biomass downstream of the discharge (when compared with upstream), and increases

[2] Biggs, pers. comm in Ausseil and Clark (2007).

of 36-53% of the peak biomass (99th percentile and maximum). The 'proposed scenario is predicted to result in a 3% increase in average periphyton biomass, and <1% increases in peak biomass.

These results tend to indicate that, the 'current' scenario results in a risk of detectable periphyton growth increase. This is consistent with the results of the 2011 biomonitoring report (Stark, 2011).

The 'proposed' scenario however, is predicted to result in much lesser periphyton growth increases, which is consistent with the qualitative assessment proposed above. Periphyton growth increases in the order of those predicted (less than 5%) would be very unlikely to be able to be detected by standard periphyton biomass monitoring methods.

Table 7: Summary of predicted periphyton biomass increase downstream of the AFFCO discharge compared with predicted daily biomass upstream of the discharge, using the New Zealand Periphyton Guidelines model (Biggs, 2000) .

	NZPG outputs based on DRP concentrations		NZPG outputs based on SIN concentrations	
	D/S Current	D/S Proposed	D/S Current	D/S Proposed
January	0%	0%	0%	0%
February	0%	0%	0%	0%
March	0%	0%	0%	0%
April	52%	4%	15%	1%
May	96%	8%	28%	2%
June	73%	13%	22%	3%
July	42%	15%	12%	4%
August	29%	13%	8%	3%
September	30%	7%	8%	2%
October	15%	4%	3%	1%
November	12%	2%	2%	0%
December	0%	0%	0%	0%
Annual	35%	5%	10%	1%

Table 8: Summary of predicted daily periphyton biomass increase downstream of the AFFCO Feilding discharge compared with predicted daily biomass upstream of the discharge, based on the Feilding WWTP periphyton growth model.

	Current	**Proposed**
Average	+20%	+3.3%
90th %ile	+14%	+0.5%
95th %ile	+12%	+0.7%
99th %le	+36%	+0.02%
Max (peak biomass)	+53%	+0.00%

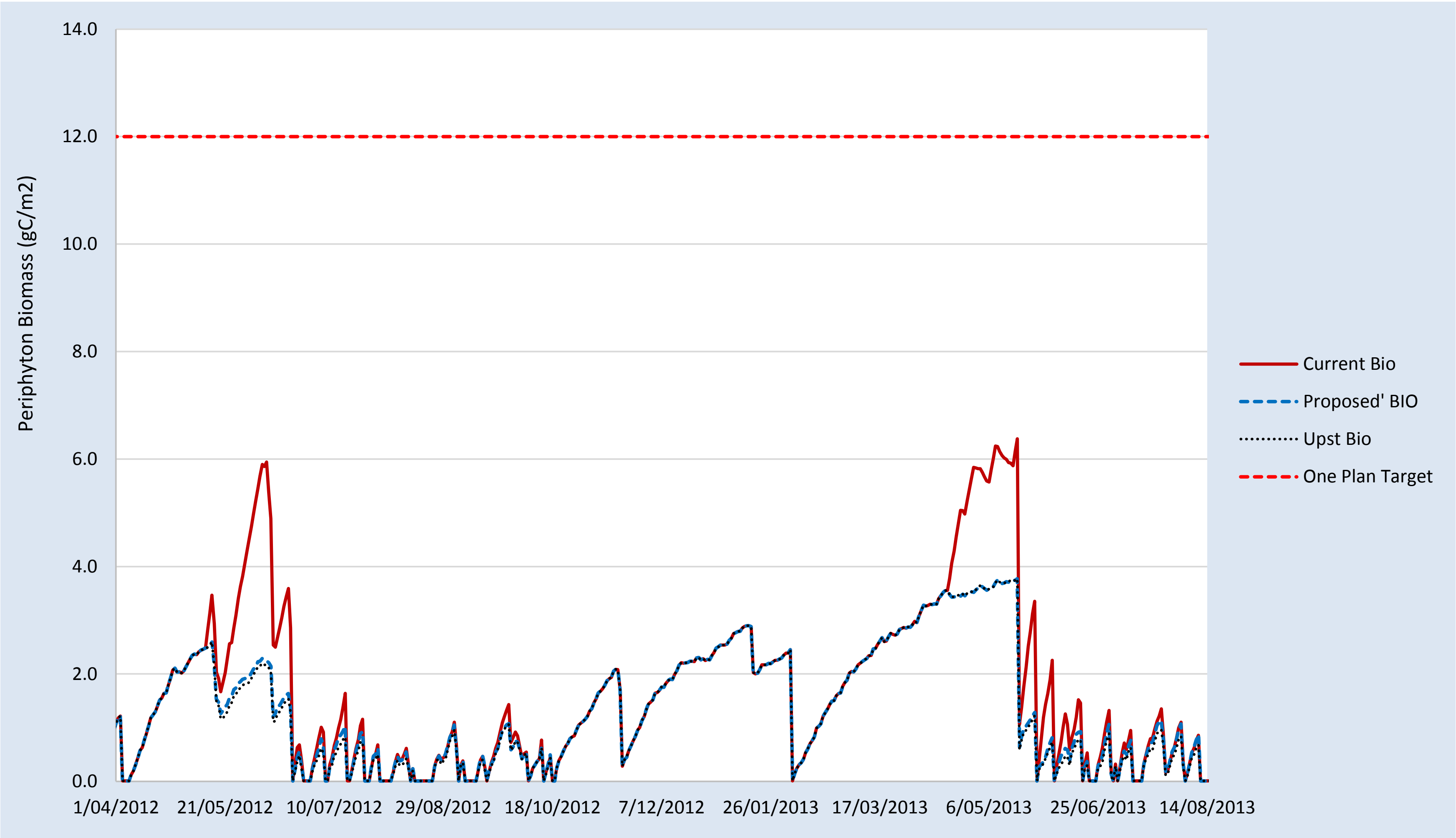

Figure 15: Predicted periphyton biomass (gC/m^2) under different scenarios. The horizontal dashed red line represents the One Plan periphyton biomass target (12 gC/m^2, corresponding to 120 mg Chlorophyll *a*/m^2 (selected time period 19/04/2012 to 14/08 /2013).

4.4. Ammonia

The One Plan sets two water quality targets in relation to total ammonia-N:

- A "chronic" toxicity target of 0.400 g/m^3, expressed as an average concentration over an undefined period.
- An "acute" toxicity target of 2.1 g/m^3, expressed as a maximum concentration

As explained in Section 3.5.1, the seven-day rolling average concentration was calculated for each day of the modelling period and used to provide an assessment against the "chronic" target. Daily predicted concentrations were directly compared with the "acute" target.

The highest predicted daily total ammonia-N concentration downstream of the discharge is 0.532 g/m3 and 0.277 g/m^3 under the 'proposed' scenario – the discharge is thus predicted to comply with the "acute" limit at all times under both scenarios.

The highest predicted 7-day average concentration downstream of the discharge is 0.384 g/m^3 under the 'current' scenario and 0.218 g/m^3 under the 'proposed' scenario. The discharge is thus also predicted to comply with the "chronic" OP total ammonia-N concentration target at all times under both scenarios.

4.5. Particulate organic matter (POM)

The OP defines an in-river POM concentration target of 5 g/m^3, expressed as an average concentration when the river flow is at or below median.

The 'proposed' discharge regime does not involve any direct discharges to the river at flows below the median flow, consequently the 'proposed' discharge regime will fully comply with this water quality target.

4.6. Soluble carbonaceous Biochemical oxygen demand ($ScBOD_5$)

The OP defines an in-river $ScBOD_5$ concentration target of 2 g/m^3, expressed as an average concentration when the river flow is at or below Q_{20}.

The assessment presented below is made on the basis of total (not soluble) $cBOD_5$ concentrations in the effluent (as soluble $cBOD_5$ data were not available). Soluble $cBOD_5$ is a sub-set of total $cBOD^5$, which means that the modelled concentrations increases overestimate in-river soluble $cBOD_5$ concentration increases caused by the discharge.

The highest predicted daily $cBOD_5$ concentration increases caused by the discharge are 0.2 g/m^3 under the 'current' scenario and less than 0.1 g/m^3 under the 'proposed' scenario. This indicates that the discharge is unlikely to cause any breaches of the OP $ScBOD_5$ target under either scenario.

4.7. Water clarity

Effluent clarity data were not available, preventing a full assessment of the likely changes in water clarity caused by the discharge. Modelled predictions were thus made on the basis of an assumed effluent clarity of 0.1 m (10cm).

The maximum water clarity reduction predicted to occur downstream of the AFFCO discharge were:

- 22% water clarity reduction (with a 95th percentile of 5.5 %) under the 'current' scenario; and
- 3.3 % water clarity reduction (with a 95th percentile of 0.4 %) under the 'proposed' scenario.

Thus, the discharge is predicted with the OP water clarity change target (a maximum reduction of 30%) under both scenarios. The 'proposed' scenario is predicted to result in a significant reduction in the effects of the discharge on water clarity.

The One Plan also defines a minimum water clarity of 2.5m at river flows below median flows. Although compliance with this target upstream of the discharge is outside the control of AFFCO, it is useful to assess the degree of change in compliance with this target caused by the discharge. The modelled overall upstream compliance with the 2.5m target is 85% upstream of the discharge, and only a very minor change (<0.001%) in the degree of compliance is predicted downstream of the discharge under both the 'current' and the 'proposed' scenarios.

4.8. *E. coli*

The One plan sets two water quality targets relative to *E. coli*:

- 260 *E. coli*/100 mL at flows below median flow during the November to April period;
- 550 *E. coli*/100mL the rest of the time.

Compliance with both targets is intended to be assessed against the 95th percentile of the data (Ausseil and Clark, 2007).

The 'proposed discharge regime does not involve any discharges below median flow, thus only the 550 *E. coli*/100 mL target is applicable to that scenario.

The predicted 95th percentile of the concentration increases associated with the 'proposed' discharge is 4.8 *E. coli*/100mL (with a maximum of 5.8 *E. coli*/100mL). These are quite minor increases compared with the 550 *E. coli*/100mL target, and the overall level of compliance with that target is not predicted to be affected in a more than very minor way by the 'proposed' discharge.

5. Synthesis and assessment of effects

5.1. Summer discharge (current and proposed)

In summer, the discharge is not allowed to operate at flows below three times the median flow. This flow cut-off is higher (more stringent) than any of the flow cut-offs (median or Q_{20}) set in the OP water quality targets. As a result, the discharge (both current and proposed) during the summer months will comply with all the OP water quality targets containing flow cut-offs (DRP, SIN, POM, $ScBOD_5$, water clarity, *E. coli*).

A number of the OP targets do, however, apply at all river flows: total ammonia-nitrogen (chronic and acute), water clarity change and biological indicators (periphyton biomass and cover, MCI and changes in QMCI).

The assessment presented above shows that both the 'current' and 'proposed' discharges are predicted to comply with the total ammonia-N and water clarity change targets at all times (not only in summer), and thus are not expected to result in any more than minor effects in relation to these water quality determinands.

5.2. Winter discharge (current)

The modelling assessment presented in this report indicates that the 'current' discharge is not likely to cause any breaches of the One Plan targets relating to $ScBOD_5$, POM, water clarity or total ammonia-nitrogen.

The One Plan targets were designed to be set at levels that, if complied with, avoid significant adverse effects on river values. The 'current' discharge is therefore not expected to result in any significant adverse effects associated with these water quality determinands.

The 'current' discharge is however predicted to result in material increases in in-river nutrient concentrations at flows below Q_{20}. The OP DRP concentration target is just met upstream of the discharge but is predicted to be largely exceeded downstream of the discharge. The OP SIN concentration target is however expected to be met both upstream and downstream of the discharge in spite of predicted increase between the two sites.

Consequential effects on periphyton growth are difficult to predict with certainty, however, the three approaches undertaken (a qualitative risk assessment and two modelling approaches) indicate that the 'current' discharge does occur at times when river flow conditions are suitable for periphyton growth and accumulation and may result in periphyton increases in the order of 5 to 35%. Periphyton growth increases of this order may be measurable, which is supported by the measurable increase in periphyton cover reported by Stark (2011). However, whether these increases lead to actual breaches of the OP periphyton biomass and/or cover targets is not able to be assessed robustly due to insufficient data.

5.3. Winter discharge (proposed)

The 'proposed' discharge regime is predicted to result in about a 8 to 10 % increase of the total volume of effluent and the total load of contaminants discharged to the river compared with the 'current' scenario. However, the timing of the discharges to the river are different in the two scenarios, resulting in a lessening of the effects of the discharge under the 'proposed' scenario compared with the 'current' scenario.

The 'proposed' scenario sees a complete elimination of the discharge to the River at flows below the median flow. Periods of low river flow are usually considered the most critical times for discharges of contaminants to streams and rivers, due to (1) less dilution available due to lesser volumes of water in the river leading to higher contaminant concentration increases downstream of the discharge and (2) a higher risk of biological effects of contaminants. For example, excessive periphyton growth and accumulation are more likely to occur during periods of stable/low river flows. By eliminating the discharge to the river at flows below median flow, the proposed discharge regime eliminates the risk of directly causing effects during the most critical times.

The modelling assessment presented in this report indicates that the 'proposed' discharge is predicted to cause lesser effects on water clarity or on concentrations of $ScBOD_5$, POM, total ammonia-nitrogen than the 'current' scenario', and thus is unlikely to cause any breaches of the One Plan targets relating to these water quality determinands. As a result, the 'proposed' discharge is not expected to result in any significant adverse effects associated with these water quality determinands. The 'proposed' discharge scenario is also not predicted to result in more than minor increases in *E. coli* concentrations.

The proposed discharge regime results in significant reductions in the proportion of effluent and contaminant loads discharge at flows below Q_{20}. As a result, the effects of the 'proposed' discharge on in-stream dissolved nutrient concentrations (DRP and SIN) are predicted to be 87% less than under the 'current' scenario.

Potential effects on periphyton growth were assessed by three methods: one qualitative and two modelling methods. All three methods are in general agreement that the effects of the 'proposed' discharge are likely to be significantly less than those of the 'current' discharge. Predicted periphyton biomass increases under the proposed scenario are in the order of 1 to 10%. If correct, increases of this magnitude would be very unlikely to be able to be detected using standard monitoring methods, given the large error generally associated with periphyton biomass measurements.

Although the predicted effects of the discharge under the proposed scenario are predicted to be less than what they currently are, some increase is still expected, and it is not possible to assess with certainty whether this increase will, or not, result in exceedances of the OP periphyton biomass or cover targets. This is in part due to the lack of knowledge of the current effects of the discharge. For these reason, further monitoring and modelling of periphyton growth in this reach of the Oroua River would be advisable should the proposed discharge regime be implemented.

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