Engineers & Consultants

Memorandum

Date: 10th November 2020
To: Matt Lillis (Hamilton City Council)
From: Stu Farrant
CC:
Reviewed by: Stu Farrant
Released by: Stu Joyce

Subject: Mangakootukutuku Water Quality Modelling Report

Introduction

Morphum Environmental (Morphum) has undertaken scenario testing in the Mangakootukutuku catchment in Hamilton to access the impact of different development scenarios and the effectiveness of various treatment train options. Six scenarios were developed by Morphum based on conversations with Hamilton City Council. Respective scenarios assumed different degrees of development within each subcatchment and applied specific treatment devices to the various land uses. Each scenario was modelled using MUISC software (Model for Urban Stormwater Improvement Conceptualisation) based on land use information derived from existing land cover and maximum probable development (MPD) layers in GIS. MPD and existing land cover layers were generated from previous work packages by Morphum for Hamilton City Council.

The Mangakootukutuku catchment was broken into four subcatchments including Existing Brownfields, Peacocke Growth Area, Remaining Greenfields and Rural. Subcatchments were delineated based on conversations with Hamilton City Council to combine areas of similar existing land cover and areas of proposed development information available. Details of the development of Peacocke Growth Area were provided to Morphum by BBO. Figure 1 shows each delineated sub catchment.

Each scenario looked at different development conditions in each subcatchment as well as different treatment options for specific land covers through retrofit of brownfields area and development of greenfield areas. The six different scenarios developed are detailed in Table 2. Treatment devices investigated included rain tanks, soakage devices, raingardens and wetlands. Details of the treated area applied in each scenario are detailed in Table 2.

Figure 1; Sub catchment Delineation of Mangakootukutuku

Inputs into MUSIC

MUSIC assesses contaminant loads and concentrations generated within catchments by grouping together certain land categories. Eight specific land covers were used to represent the catchment. These are detailed in Table 1 as well as their assumed impervious fractions and model assumptions. The total area for each of the eight categories was summed within each subcatchment as a single node using the relevant land cover layer to the scenario being modelled. Table 2 details the specific land cover layer(s) used for each specific scenario.

Four years of rainfall data in a 5-minute time step was input into the MUSIC model to provide a continuous simulation. Rainfall data was from 01/01/2006 and the 31/12/2010 was used. It is noted that the use of 5-minute data enables more accurate understanding of peak discharges (first flush) which is important to understand potential acute impacts on freshwater ecosystems. Due to the frequency of rainfall (when measured in 5-minute timesteps) these acute impacts are represented by the 95^{th} %ile and above.

<u>Existing Land Cover Layer:</u>

The existing landcover layer is based on work undertaken by Morphum in 2016 as part of the SWMP v1. The layer was developed by assessing land use classes including: roads, buildings/roofs, paved areas, urban grass and trees and farm pasture. The urban grass and trees category included residential pervious areas. To separate this, it was assumed that the residential pervious area was twice the residential paved area and subtracted from the urban grass and trees.

Maximum Probable Development Layer:

A maximum probable development (MPD) layer was created by Morphum in May 2019 based on available development planning information. This layer was updated with proposed zoning details from BBO provided in April 2019. The zoning layer was intersected with the MPD layer and used to provide future development details prioritised ahead of the previous MPD information.

Table 1 provides a summary of the respective land covers applied in modelling.

Table 1; MUSIC Land Covers and Assumptions

Model Node	Imperviousness	Model Assumptions
Residential Roofs	100	Comprised of residential roofs, proposed retirement village roofs and school roofs
Residential Paved	100	Comprised of residential paved area, proposed retirement village paved area and school paved area
Residential Pervious	0	Assumed twice the area of the residential paved area
Commercial / Industrial	95	All commercial and industrial roofs, paved and pervious areas grouped together
Roads	90	The entire road footprint including 10% pervious area
Parks, gullies and sport fields	15	Comprised of parks, gullies and sport fields minus the residential pervious area
Forested	0	Forested area
Rural	5	Comprised of rural roofs, paved and pervious surfaces

Modelling Nutrients and Metals in MUSIC

Separate models were built in MUSIC to represent the catchment scenarios to estimate the loads and concentrations of metals (total copper, TCu and total zinc, TZn) and nutrients (Total Phosphorus, TP and Total Nitrogen, TN) at the discharge point to the Waikato River, and directly downstream of the Peacocke Growth Area prior to the confluence with the western branch.

Each land cover in the catchment produces differing loads/concentrations of metals and nutrients during a rainfall event. To account for this, MUSIC uses the mean and standard deviation for contaminants attributed to base flow and rainfall (stormwater runoff) to generate specific contaminant discharges for each surface which are passed down through links (and modelled treatment devices) to represent the passage of water (and contaminants) through the hydrologic system. MUSIC reports outflows in terms of loads (kg/yr) and concentrations (mg/L) including cumulative frequency statistics which are used as a representation of percentile bands. For the purpose of modelling, landuses were lumped for the different areas of the catchment which is considered to provide a relatively accurate representation of the catchment characteristics suited for the comparative analysis of the different scenarios.

Assumptions on Hamilton-specific metal concentrations were derived from CLM value tracking and verified with work undertaken in development of the model (*Background Study for the revision of Melbourne Water's MUSIC Input Parameter Guidelines,* Fletcher 2007). Default inputs were used to model nutrient loads based on previous validation against the CLM reported annual yields for respective land uses.

Pervious and forest areas were excluded from the model of metals due to a lack of data around metal from these landuses and expectation of these being very low. It is noted that this potentially results in conservative reporting on metals (i.e. elevated concentrations) due to likely impacts of dilution from runoff from these undeveloped catchment areas.

Scenario Details

Each scenario modelled in MUSIC assumed different values and parameters to represent historic or possible future conditions. These assumptions are detailed in Table 2. Information on the scenario basis was provided to Morphum by HCC while the model assumptions were developed by Morphum to best represent each scenario.

Scenario 1 provided a base case (existing conditions) which was used to understand current conditions and to compare estimated contaminant concentrations in subsequent development scenarios against. Scenario 4 represents the understood conditions prior to European development which is taken to be defined by estimated landcover in 1863 when the *New Zealand Settlements Act 1863* was the catalyst for land confiscations and extensive clearance. The remaining four scenarios (2, 3, 5 and 6) represented possible development options in between these two cases whereby different extents of existing greenfield land is developed and different levels of investment in stormwater treatment are achieved.

The potential impact of developing different extents of the existing greenfield area can be understood by comparing scenarios 2 and 3 while scenario 5 provides an estimate of the effectiveness of 'an aspirational scenario with extensive implementation of stormwater treatment and retirement (to forest) of areas currently considered for future urbanisation. Scenario 6 provides a "no treatment" baseline for development of the Peacocke Growth Area. Table 2 summarises the assumptions underpinning these scenarios including how the different landcover types are represented in the model in terms of integrated treatment devices.

Table 2; Scenario Details and Assumptions

Scenario	Scenario Basis	Subcatchment	GIS Layers	Model Assumptions
Scenario 1- Existing	Existing development as of current conditions	All	Existing landcover	No treatment devices applied (considered conservative given small number of existing devices in parts of recent development)
Scenario 2- MPD	Retrofit raingardens and wetlands in Existing Brownfields to treat 15 % of subcatchment (excluding parks and gullies) plus the development of Peacocke Growth Area based on current BBO details with treatment. Remaining greenfield and rural sub catchments undeveloped.	Existing Brownfields	Existing landcover	Retro fit of raingardens to treat 20% of roads and wetlands to treat; 20% of roofs, 25% of paved surfaces and 20% of commercial / industrial
		Peacocke Growth Area	MPD	Implementation of rain tanks connected to 15% of roofs, soakage for 85% of roofs and paved surfaces, raingardens to treat high use roads (37%) and wetlands to treat all upstream areas (2 stage treatment).
		Remaining Greenfields and Rural	Existing landcover	No treatment, rural.

Scenario 3- Sensitivity test	The same treatment and development as Scenario 2 in existing brownfields, Peacocke Growth Area plus the maximum probable development in the remaining greenfields area with rain tanks, soakage, raingardens and wetlands	Existing Brownfields and Peacocke Growth Area	Existing landcover MPD	As scenario 2
		Remaining Greenfields	MPD	Implementation of rain tanks connected to 15% of roofs, soakage for 85% of roofs and paved surfaces, raingardens to treat high use roads (48%) and wetlands to treat all upstream areas (2 stage treatment).
		Rural	Existing landcover	No treatment.
Scenario 4-Pre 1863	Pre-European development condition	All	N. A	All subcatchments covered with forest
Scenario 5- Aspirational	Best practice conditions applied with retrofit of treatment of existing brownfields plus full treatment of Peacocke. Remaining greenfield returned to forested and rural undeveloped	Existing Brownfields	Existing landcover	Implementation of rain tanks connected to 15% of roofs, soakage for 85% of roofs and paved surfaces, raingardens to treat high use roads (13%) and wetlands to treat all residential roofs and paved area.
Scenario 5- Aspirational Scenario 6- MPD No treatment	Best practice conditions applied with retrofit of treatment of existing brownfields plus full treatment of Peacocke. Remaining greenfield returned to forested and rural undeveloped Equivalent to scenarios 2 and 3 for Peacocke only, but with no treatment	Peacocke Growth Area	MPD	Implementation of rain tanks connected to 15% residential roofs, soakage for 85% of roofs and paved surfaces, raingardens to treat high traffic roads and wetlands to treat all upstream areas (2 stage treatment).
		Remaining Greenfields	N. A	Remaining greenfield modelled as forested.
		Rural	Existing landcover	No treatment.
		Peacocke Growth Area only	MPD	No treatment

Note that under all scenarios, the Rural subcatchment remained undeveloped. See Appendix 1 for a complete list of the treatment percentages applied in the MUSIC model for each device.

Herein the scenarios are referred to as;

- Scenario 1 - Base Case
- Scenario 2 - Maximum probable development
- Scenario 3 - Sensitivity
- Scenario 4 - Pre 1863
- Scenario 5 - Aspirational
- Scenario 6 – Peacocke no treatment

Model Assumptions and Device Sizing

The MUSIC models were used to test the effectiveness of using raintanks, soakage devices (infiltration), raingardens and wetlands to treat contaminant loads/concentrations assocaited with urban development. Various assumptions were input into the models to give an approximate representation of contaminant removal, attenuation and infiltration that could be expected from the various devices tested. Table 3 details the key parameters and values that were used to represent the different devices based on the RITS and professional judgement.

Table 3; Treatment Device Model Inputs

Treatment Device	MUSIC Treatment Device Parameter Values
Rain tank	Sized to capture 10 mm of rainfall across connected roof area Tank modelled as empty at start of time series Constant Daily Reuse: 0.191 KL/dwelling/day (toilets and cold laundry) Variable Annual Reuse: 26.2 KL/dwelling/year (irrigation and other external demands)
Soakage	Sized to capture 10 mm of rainfall across treated area Exfiltration rate: 10 mm/hr (expected conservative average of variable rates across catchment)
Raingarden	Sized as 2% of connected impermeable area Extended detention depth: 200 mm Saturated hydraulic conductivity: 180 mm/hr Exfiltration rate: 20 mm/hr Filter Depth: 0.6 m Unlined base
Wetland	Sized as 4% of connected impermeable area Permanent pool volume: surface area multiplied by an average depth of 350 mm Notional detention time: 24 hours

<u>Modelling of Rain Tanks and Reuse</u>

Capture and reuse of rainwater from roofs was modelled in MUSIC. Reuse is separated into daily reuse and annual reuse where daily reuse represents constant water demand (such as toilets and laundry) and annual reuse represents temporal changes in water demand throughout different seasons (such as irrigation demands). It was assumed that there are 2.9 persons per dwelling, with an average dwelling roof area of 200 m^2 and an average water demand per person 165 L/person/day. The daily and annual reuse was dependent on the area of roof that was draining into the rain tanks for a specific subcatchment and scenario condition.

<u>Modelling of Raingardens</u>

Under scenario 2 and 3, and 5, relevant subcatchments were modelled with raingardens to receive runoff from high use roads. This was estimated by identifying all roads classified as motor/expressway and/or arterial roads which were assumed to have > 10,000 VPD/day.

By default, MUSIC is configured to model nutrient (TN/TP), sediments (TSS) and flow as proxy metrics to represent the range of other contaminants associated with urban stormwater. For the purposes of modelling metals, changes were made to the model source nodes for mean and standard deviation concentrations of zinc and copper but load reductions (in treatment devices) are specifically calibrated for performance in removing nutrients based on extensive applied research. Metal reductions were therefore represented by applying a simple transfer function (via a generic node) whereby metals were reduced by 75% (copper) and 70% (zinc) for raingardens in accordance with the reductions estimated in the WRC Stormwater Guidelines.

<u>Modelling of Wetlands</u>

Under Scenario 2 and 3, and 5, relevant subcatchments were modelled with wetlands to receive stormwater prior to discharge to the waterway. These were effectively modelled as subcatcment scale devices located downstream of other treatment devices (lot scale and streetscape raingardens) to represent a treatment train approach to water quality improvements.

By default MUSIC is configured to model nutrient (TN/TP), sediments (TSS) and flow as proxy metrics to represent the range of other contamuinants associated with urban stormwater. For the purposes of modelling metals, changes were made to the model source nodes for mean and standard deviation concentrations of zinc and copper but load reductions (in treatment devices) are specifically calibrated for performance in removing nutrients based on extensive applied research. Metal reductions were therefore represented by applying a simple transfer function (via a generic node) whereby metals were reduced by 70% (copper) and 60% (zinc) for wetlands in accordance with the reductions estimated in the WRC Stormwater Guidelines.

<u>Modelling architecture</u>

Figure 2 provides an example of how the MUSIC model represents catchment characteristics and treatment. As an example, this shows the configuration of the existing brownfields under Scenario 5 - Aspirational. It is noted that treatment devices were substituted with generic nodes in the modelling of metals to represent the removal efficiency of devices in accordance with WRC Guidelines.

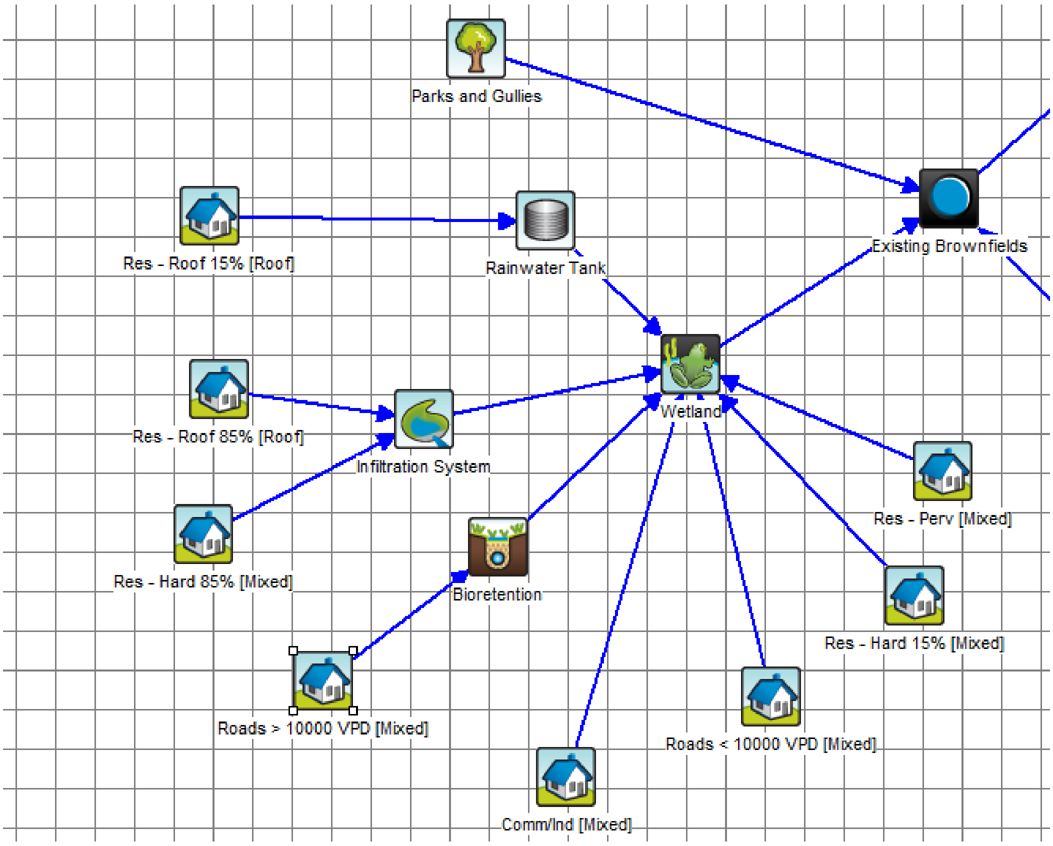

Figure 2; Configuration of Existing Brownfields Sub catchment in Scenario 5 MUSIC Model

Validation

Model inputs and outputs were validated based on available data. Input loads were calculated from the model for different surface types and compared against equivalent load standards used by WRC and others where available.

The cumulative frequency plots of instream contaminant concentration for the maximum probable development (untreated) scenario were compared against event mean concentration data gathered under the SREMPE for untreated urban catchments, and against monthly sampling in Peacocke.

Validation showed a reasonable equivalency in results and measured data/standards that supports the use of the model results in decision making, with appropriate consideration for the uncertainty in modelling recognised.

Results – Full Catchment

Scenarios were tested in MUSIC with total phosphorus, total nitrogen, total copper and total zinc loads and concentrations reported at the discharge into the Waikato River. Estimates of mean annual flow and TSS is also reported to provide an understanding of the likely comparative performance between scenarios rather than a definitive load estimate. Full results are provided in Appendix 2. Table 10 (refer Appendix 2) shows the modelled results for nutrients, sediment and flow based on the entire catchment area (including undeveloped landuse). These are presented as a mean annual load with the percentage load reduction based on the total contaminant load in versus the load discharged into the Waikato River. Table 11 (refer Appendix 2) provides the same metrics but is reported only for the urbanising portion of the catchment (Peacocke). This therefore excludes the large rural and undeveloped portions of the catchment

Table 12 (refer Appendix 2) presents the modelled metal performance measured in terms of instream concentrations. Metrics are reported for the downstream portion of the catchment (prior to Waikato River) with concentrations from respective scenarios compared relative to the existing case (Scenario 1) to identify where water quality could be expected to improve/degrade. A positive % infers that the concentration has reduced (improved) whereas a negative infers an increase (degraded). It is noted that the use of statistics up to the 95th %ile do not necessarily capture the acute impacts of peak discharges during rainfall. Based on a 5-minute timestep, events occuring less frequently than the 95th %ile represent over 430 hours of cumulative rainfall over a year which is typically characterised as the first flush with elevated concentrations which can have adverse impacts on sensitive biota. Therefore the use of these statistical bands (which are the basis of nationally recognised guidance such as ANZEC and the NPS-FM) need to be understood within the context of the highly variable nature of stormwater when compared to more steady state conditions typical of larger rivers and rural runoff situations. All modelled concentrations reported up to the 90th or 95th percentile for the scenarios that include treatment (2, 3 and 5) sit well below ANZEC trigger levels. Scenario 6 was carried out specifically as a baseline for the Peacocke assessment and is not addressed in the full catchment assessment.

A brief summary of each scenario is provided in following sections.

Scenario 1: Base case

Scenario 1 represents the current conditions in terms of development and stormwater management. This is used as the base to measure changes attributed to potential scenarios against.

In terms of metals, the mean concentration of Total Copper (TCu) is 0.004 mg/L and the 95th %ile is 0.002 mg/L. The mean concentration of Total Zinc (TZn) is 0.0027 mg/L and the 95th %ile is 0.028 mg/L. As noted earlier these illustrate the diluted nature of runoff for the vast majority of events which do not account for the less frequent acute events.

Scenario 2: Maximum Probable Development

Scenario 2 includes the development of the Peacocke Growth area (with water sensitive design) and moderate retrofit of existing brownfield areas. This represents an increased urban extent with associated water quality implications.

In terms of metals, the mean concentration of Total Copper (TCu) is 0.0006 mg/L (53 % increase from present) and the 95th %ile is 0.004 mg/L (100% increase from present). The mean concentration of Total Zinc (TZn) is 0.0031 mg/L (16 % increase from present) and the 95th %ile is 0.033mg/L (18% increase from present).

Scenario 3: Sensitivity Test

Scenario 3 includes the development of the Peacocke Growth area (with water sensitive design), development of the remaining greenfield areas (with WSD) and moderate retrofit of existing brownfield areas. This represents a significantly increased urban extent (albeit with WSD) with associated water quality implications.

In terms of metals, the mean concentration of Total Copper (TCu) is 0.0005 mg/L (31 % increase from present) and the 95th %ile is 0.003 mg/L (50% increase from present). The mean concentration of Total Zinc (TZn) is 0.0027 mg/L (2 % increase from present) and the 95th %ile is 0.03mg/L (7 % increase from present).

Scenario 4: Pre 1863

Modelling of the scenario which represents pre-European conditions was based on the entire catchment being in mature forest. This includes all existing areas of urban development and existing rural areas.

Metals were not modelled as it is inferred that metals loads are not represented in the forested condition.

Scenario 5: Aspirational

Scenario 5 is intended to represent a highly aspirational (beyond what may be considered feasible with current technology) scenario. This includes the development of the Peacocke Growth area (with comprehensive water sensitive design), conversion of the remaining greenfield areas to mature forest and extensive retrofit of existing brownfield areas. The existing rural area is retained in existing landuse. This represents the same increase in urban extent as scenario 2 but includes further implementation of WSD and reduction in rural landuse with associated water quality implications.

In terms of metals, the mean concentration of Total Copper (TCu) is 0.0003 mg/L (11 % reduction from present) and the 95th %ile is 0.002 mg/L (equal to present). The mean concentration of Total Zinc (TZn) is 0.0020 mg/L (27 % reduction from present) and the 95th %ile is 0.017mg/L (39 % reduction from present).

It is noted that these contaminant characteristics are still considerably worse (in terms of expected ecological outcomes) when compared with the projected outcomes from Scenario 4 (pre 1863) which represents the entire catchment in mature vegetation.

Comparison against 'Healthy Rivers Plan Change' targets

Waikato Regional Council has released the Healthy Rivers/Wai Ora; Proposed Waikato Regional Plan Change 1 (The Plan) which aims to provide water quality targets across the entire catchment which support improvements in the environment in terms of ecology, cultural wellbeing and community health. Specifically, the proposed plan seeks to reduce the amount of contaminants entering the Waikato and Waipā catchments to achieve the vision of making the river swimmable and viable for food collection along the entire length. The plan has been developed based on numerous management units (sub catchments) and reporting points covering the main stem and tributaries. This includes a reporting point (with nominated water quality targets) at the bottom of the MangakootukutukuStream where it crosses Peacockes Road immediately upstream of the confluence with the Waikato River.

Water quality targets are proposed in The Plan for a range of attributes. These include numerical targets, but it is stated that these are not intended to be used directly as receiving water compliance limits/standards with achievement of long and short term targets to be verified through analysis of 5 year monitoring data. It is unclear at what frequency monitoring will be undertaken to support this analysis but it is anticipated that continuous (event) monitoring for all attributes will not be practical. Table 4 shows the targets for the Mangakootukutukupresented in The Plan. Table 5 presents the modelled results for nutrient concentrations (TN and TP). This represents the nutrient concentrations attributed to the entire catchment with those attributed solely to the Peacocke Growth Area presented separately in Table 7.

Table 4; Stipulated water quality targets for Mangakootukutuku Stream (from WRC Healthy Rivers Plan)

Annual Median Nitrate (mg NO 3 -N/L)		Annual 95th percentile Nitrate (mg NO3-N/L)		Annual Median Ammonia (mg NH4-N/L)		Annual Maximum Ammonia (mg NH4-N/L)		95th percentile E. coli (E. coli/100mL)		Clarity (m)	
Short term	80 year	Short term	80 year	Short term	80 year	Short term	80 year	Short term	80 year	Short term	80 year
0.80	0.80	1.788	1.5	0.077	0.03	0.132	0.05	11394	540	0.5	0.5

Table 5; Estimated nutrient concentrations for entire catchment based on MUSIC modelling

	Median TN (mg/L)	Median TP (mg/L)	10th %-ile TN (mg/L)	10th %-ile TP (mg/L)	95th %-ile TN (mg/L)	95th %-ile TP (mg/L)
Scenario 1 – Base Case	1.220	0.125	0.935	0.0943	1.952	0.225
Scenario 2 - MPD	1.210	0.116	0.960	0.0745	1.862	0.202
Scenario 3 – Sensitivity Test	1.190	0.107	0.915	0.0674	1.850	0.199
Scenario 4 – Pre 1863	0.743	0.0324	0.596	0.026	0.988	0.043
Scenario 5 - Aspirational	1.080	0.0923	0.804	0.0649	1.700	0.159

The results presented in Table 5 show the relative nutrient concentrations expected based on changes in land use and implementation of water quality actions. It is noted that modelling does not distinguish ammonia and nitrate and rather reports at a total nutrient basis. This estimates a slight improved nutrient concentration based on Scenario 2 (short term growth) and Scenario 3 (Maximum probable development). These reflect the reduction in agricultural land and inclusion of water sensitive design in new development areas. Scenario 5 (aspirational) shows further improvement as current agricultural land is reforested and comprehensive retrofit of water sensitive design in existing brownfield areas is implemented. It is noted that nutrient concentrations in all scenarios are still significantly elevated in comparison to Scenario 5 (pre 1863 condition). Based on these results it is inferred that Scenarios 4 and 5 would be likely to achieve The Plan targets for ammonia and nitrate, with scenarios 2 and 3 considered less likely to achieve the targets.

Modelling of E-Coli. was not undertaken given the uncertainty around existing infrastructure factors (contributing to inflow/infiltration and/or network capacity resulting in overflows) and lack of reliable monitoring to calibrate against. It is expected that current concentrations will exceed targets during large rainfall events (where overflows occur) with monitoring needed to assess concentrations in baseflow or smaller rainfall. The discharge of E-Coli (human derived wastewater) needs to be addressed through upgrades to existing infrastructure and the delivery of fit for purpose new infrastructure in growth areas. These programs need to be undertaken strategically to identify actions which will support the most efficient improvements in water quality related to wastewater.

Clarity targets in The Plan are not linked to any statistical frequency. It is therefore difficult to know how the targets are intended to be applied. It is expected that following development, the clarity in urban derived stormwater will be greater (better) than 0.5m due to flows passing through treatment devices and being generated off impervious surfaces. Typically, elevated sediments which reduce clarity will be the result of instream scour/erosion, rural runoff or earthworks activity. It is therefore inferred that reductions in TSS loads at the point of discharge will translate to improved clarity within the stream and that the contribution from urban land use changes will not be a contributor to exceedances.

Results - Peacocke Growth Area

Further modelling was undertaken to look at the Peacocke Growth Area (PGA), (as shown in Figure 1) in isolation. This was done based on the same scenarios as previously discussed but with only the contribution of the PGA represented in the MUSIC model. An MPD scenario equivalent to Scenario 6 but without treatment was also run as a baseline. This was referred to as Scenario 6. Results were measured at the downstream end of the PGA effectively where any development derived flows would enter the Mangakootukutuku Stream and Waikato River.

Results from this are presented in Table 6 and Table 7 for nutrients and metals respectively.

Table 6; Estimated metal concentrations for PGA only based on MUSIC modelling

	Median TZn(ug/L)	Median TCu (ug/L)	10^{th} %-ile TZn (ug/L)	10^{th} %-ile TCu (ug/L)	90^{th} %-ile TZn (ug/L)	90^{th} %-ile TCu (ug/L)
Scenario 1 – Base Case	0.0607	0.0263	<0.001	<0.001	0.130	0.0935
Scenario 2 - MPD	0.198	0.0655	<0.001	<0.001	0.395	0.209
Scenario 3 – Sensitivity Test	0.226	0.0745	<0.001	<0.001	0.468	0.253
Scenario 4 – Pre 1863	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Scenario 5 - Aspirational	0.0791	<0.001	<0.001	<0.001	0.171	0.0782
Scenario 6 – MPD Untreated	0.682	0.320	<0.001	<0.001	1.21	0.835

Table 7 Estimated nutrient concentrations for PGA only based on MUSIC modelling

	Median TN (mg/L)	Median TP (mg/L)	10^{th} %-ile TN (mg/L)	10^{th} %-ile TP (mg/L)	95^{th} %-ile TN (mg/L)	95^{th} %-ile TP (mg/L)
Scenario 1 – Base Case	1.22	0.134	0.810	0.009	2.17	0.256
Scenario 2 - MPD	1.01	0.060	<0.001	<0.001	1.38	0.063
Scenario 3 – Sensitivity Test	1.01	0.060	<0.001	<0.001	1.38	0.063
Scenario 4 – Pre 1863	0.719	0.031	0.473	0.021	1.19	0.052
Scenario 5 - Aspirational	1.00	0.060	<0.001	<0.001	1.29	0.060
Scenario 6 – MPD Untreated	2.02	0.151	1.32	0.0779	3.176	0.322

To provide further analysis against relative triggers, cumulative frequency plots of instream contaminant concentration were produced. To interpret these, the frequency of time that trigger values are exceeded is plotted in Table 8. The scenarios have been reordered to show existing development (Scenario 1) first, then maximum probable development without treatment (Scenario 6, maximum probable development with treatment (Scenario 2), maximum probable development with aspirational treatment (Scenario 5), and native bush (Scenario 4).

Table 8: Frequency of exceedance of trigger concentrations in different scenarios.

	Scenario 1 ED		Scenario 6 (MPD no Treatment)		Scenario 2 MPD Treated		Scenario 5 Aspirational		Scenario 4 Native Bush	
	Percentage of Time Exceeded	Concentration	Percentage of Time Exceeded	Concentration	Percentage of Time Exceeded	Concentration	Percentage of Time Exceeded	Concentration	Percentage of Time Exceeded	Concentration
TP mg/L (98% percentile event)*	2%	0.55	2%	0.38	2%	0.075	2%	0.068	2%	0.06
TN mg/L (ammonia ANZECC Limit)	5%	2.18	38%	2.18	0%	2.18	0%	2.18	0%	2.18
TC ug/L (SREMPE acute limit)	1%	4.3	5%	4.3	2%	4.3	1%	4.3	0%	4.3
TZ ug/L (SREMPE acute limit)	0%	42	4%	42	3%	42	3%	42	0%	42

*Phosphorus targets proposed under PC1 are limited to no further degradation for this catchment. Instead of plotting against a trigger value, the 98th percentile phosphorus value has been plotted for each scenario to allow for comparison.

Table 7 shows that for Scenario 1 (existing case) the expected nutrient concentrations are broadly equivalent to those expected from the entire existing catchment. This reflects the largely undeveloped condition at present within the PGA which is comparable proportionally to the entire catchment. For Scenario's 2 and 3 (which are the same for the PGA area) the expected concentrations are reduced significantly for all measures. This reflects the conversion of existing rural land to urban with the inclusion of significant stormwater management measures which will treat frequent flows (first flush) in particular. 10^{th} %-ile concentrations were modelled as being almost undetectable with medians modelled to be reduced by 20% (TN) and 55% (TP) from the existing. For the 95^{th} %-ile reductions of 36% (TN) and 75% (TP) were modelled. Scenario 4 aligns with expected nutrients for the whole catchment with some small variability resulting from comparative time of concentrations through the model architecture. Scenario 5 is expected to result in comparable medians for the PGA compared to entire catchment with improvements and for 95^{th} %-ile concentrations it is estimated to have reductions of 24% (TN) and 62% (TP). This reflects the lack of rural land in the developed PGA and the inclusion of aspirational water sensitive design measures to mitigate impacts.

Table 8 shows that all treated scenarios bring nutrient levels below existing levels, and that there is marginal benefit for the second level of treatment in the aspirational scenario compared to the MPD treated scenario.

Overall, the modelling of the urbanised Peacocke Growth Area demonstrates a likely improvement in terms of nutrients from the existing case and demonstrates that residual nutrient discharges will be proportionally greater from the remainder of the Mangakootukutuku Stream catchment than from the PGA itself. This reflects the combined influence of a reduction in urban landuse and capture and treatment of development derived stormwater. This includes the combined benefits of rainwater harvesting (which effectively diverts to wastewater network following reuse), infiltration and treatment via wetlands and raingardens.

Updated modelling was also undertaken for metals with consideration given to the optimal treatment approach to manage road runoff. Table 6 and Table 8 show that whilst overall instream concentrations of metals are expected to be low for the majority of time they will spike during rainfall events as stormwater derived contaminants are washed off surfaces. This is accentuated by the short 5-minute timestep for modelling which captures the acute concentrations (greater than 90^{th} %ile) well. Across all scenarios the 10^{th} %ile values were too low to report. Modelling indicates that there could be expected to be a slight reduction in metals when going from Scenario 2 (wetlands and on-lot devices) to Scenario 5 (full two stage treatment) but the overall benefits are limited by the incidence of peak runoff events that will potentially bypass both devices and the fact that the upstream device would effectively treat contaminants to a low level which makes it more difficult for the downstream wetland to provide further substantive reductions. This would be demonstrated by the modelling of loads (rather than concentrations) which would demonstrate that the load reduction from two stage treatment is not improved relative to the increased efforts to construct devices in sequence. This highlights the value in designing devices at a size appropriate to the contributing catchment and, where devices are configured in series, reducing the scale of devices to optimise the overall performance. Construction of two (or more) full size devices in series will not provide double the treatment performance and in likelihood will present operational problems due to uneven loading (similar to stepped raingardens). It is also important to recognise the increased lifecycle costs of multiple devices with a risk that these will also be increased (more than double) due to the likelihood of opportunistic weeds from poor plant health in downstream devices. Where the downstream device is a wetland this could result in excessive draw down over summer due to not enough stormwater entering the wetland due to being 'intercepted' in the streetscape system.

Conclusions and Recommendations

Based on modelling estimates of current and potential future water quality outcomes for the Mangakootukutuku Stream catchment have been made. This demonstrates the potential change in contaminant loads (and instream concentrations) from anticipated change in landuse and implementation of water sensitive design practices.

This highlights the challenge with addressing the existing water quality impacts from the existing urbanised portion of the catchment and the importance of implementing robust stormwater management in future growth areas. It also highlights the difficulty in balancing future (and existing) urban development with the long-term aspirations to return the Waikato River (and tributaries) to the pre 1863 conditions. Whilst there are opportunities to regulate for industry practice to curtail (or limit) some of these contaminants from our built environments (such as regulating copper from vehicle brake pads) it is reasonable to expect other current and emerging contaminants (including temperature) to continue to be associated with urban development and require mitigation measures to reduce adverse impacts on receiving environments.

The following recommendations are made based on modelling results;

- All new greenfield areas need to integrate best practice stormwater management including on-lot measures (infiltration where feasible/required by the ICMP and rainwater harvesting otherwise), priority treatment of main roads and catchment scale wetlands. Small, on-road raingardens, as an additional phase of treatment, are not recommended as the preferred option to manage water quality due to limited benefits (in terms of water quality), increased risk of failure of downstream devices (from not enough inflows) and greatly increased lifecycle costs. It is accepted that residual contaminant loads will remain following treatment but the complete removal of this is not achieved simply through upsizing (or duplication) of devices due to background concentrations which cannot be reduced and the reality of some contaminant in bypass events. Whether on-road devices are required for stormwater retention is beyond the scope of this report. A water quality offsetting provision would allow for some of these resources to be used for more impactful environmental interventions and should be considered.
- Develop policy and long-term programs to retrofit water sensitive design into existing brownfield areas. This will require planning rules which capture future redevelopment opportunities (including small scale) through requirements to implement on-site devices and/or contribution into schemes to fund wider public infrastructure. Consideration of retrofit opportunities should consider flood prone land and strategic locations where procurement of private land can support implementation of required stormwater devices. This will likely occur over a prolonged timeframe due to the cost and political will around such expenditure. It will also be important to ensure that future roading upgrades include triggers to investigate and co-design stormwater management into the projects.
- Investigate/research means to effectively reduce all contaminants at source as a means of improving water quality. This should include recent and ongoing technological innovations, materials and behavior change. This would not negate the need for further stormwater treatment but will increase the overall outcomes by reducing the inflow concentrations of contaminants where feasible.
- Investigate/research technological innovations to reduce the volume of wastewater to reduce frequency/magnitude of overflows. This could include low water toilets, vacuum sewers or distributed buffer storage.
- Consideration on future growth boundaries needs to consider likely water quality impacts from further development. Spatial planning should factor the vision of the Healthy Rivers plan

and long-term water quality expectations in decision making.

- Consideration to widescale tree planting should reflect the aspirations towards 1863 water quality and the opportunities for more regenerative landcover. This could be implemented progressively where initially riparian buffers (and wetland/waterway enhancements) are extended beyond minimal requirements and agricultural areas are optimized to land with the lowest potential connectivity with waterways.
- Emphasis on effective operations and maintenance, including consideration of whole of life operation as part of stormwater device design.

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APPENDIX 1: Specific Treatment Factors applied

Table 9; Summary of Treatment Percentages for Development Scenarios

Scenario	Subcatchment	Device	Residential Roofs	Residential Paved	Roads	Commercial / Industrial
Scenario 2	Existing Brownfields	Raingardens			20%	
		Wetlands	20%	25%		20%
	Peacocke Growth Area	Rain tanks	15%			
		Soakage	85%	85%		
		Raingardens			21%	
		Wetlands	100%	100%		
Scenario 3	Existing Brownfields	Raingardens			20%	
		Wetlands	20%	25%		20%
	Peacocke Growth Area	Rain tanks	15%			
		Soakage	85%	85%		
		Raingardens			21%	
		Wetlands	100%	100%		
	Remaining Greenfields	Rain tanks	15%			
		Soakage	85%	85%		
		Raingardens			46%	
		Wetlands	100%	100%		
Scenario 5	Existing Brownfields	Rain tanks	15%			
		Soakage	85%	85%		
		Raingardens			12%	
		Wetlands	100%	100%		100%
	Peacocke Growth Area	Rain tanks	100%			
		Soakage	100%	100%		
		Raingardens			100%	
		Wetlands	100%	100%		

APPENDIX 2: Scenario Results

Table 10; Modelled nutrients, flow and TSS for entire catchment including rural and parks/gully

		Generated	Discharge	% reduction
Scenario 1	**Flow (ML/yr)**	540	540	n/a
	TSS (kg/yr)	44,500	44,500	n/a
	TP (kg/yr)	125	125	n/a
	TN (kg/yr)	975	975	n/a
Scenario 2	**Flow (ML/yr)**	554	510	8%
	TSS (kg/yr)	48,400	33,500	31%
	TP (kg/yr)	133	103	23%
	TN (kg/yr)	1,050	870	17%
Scenario 3	**Flow (ML/yr)**	602	512	15%
	TSS (kg/yr)	61,000	29,400	52%
	TP (kg/yr)	155	92	41%
	TN (kg/yr)	1,210	834	31%
Scenario 4	**Flow (ML/yr)**	470	470	n/a
	TSS (kg/yr)	6,350	6,350	n/a
	TP (kg/yr)	17	17	n/a
	TN (kg/yr)	361	361	n/a
Scenario 5	**Flow (ML/yr)**	549	480	13%
	TSS (kg/yr)	39,800	18,200	54%
	TP (kg/yr)	112	65	42%
	TN (kg/yr)	983	685	30%

Table 11; Modelled nutrients, flow and TSS for urbanised areas of catchments only

		Generated	Discharge	% reduction
Scenario 1	**Flow (ML/yr)**	114	114	n/a
	TSS (kg/yr)	19,700	19,700	n/a
	TP (kg/yr)	41	41	n/a
	TN (kg/yr)	273	273	n/a
Scenario 2	**Flow (ML/yr)**	279	234	16%
	TSS (kg/yr)	32,900	18,100	45%
	TP (kg/yr)	80	51	37%
	TN (kg/yr)	619	435	30%
Scenario 3	**Flow (ML/yr)**	326	236	28%
	TSS (kg/yr)	45,600	13,900	70%
	TP (kg/yr)	102	40	61%
	TN (kg/yr)	775	398	49%
Scenario 4	**Flow (ML/yr)**			
	TSS (kg/yr)			
	TP (kg/yr)			
	TN (kg/yr)			
Scenario 5	**Flow (ML/yr)**	197	128	35%
	TSS (kg/yr)	23,100	1,490	94%
	TP (kg/yr)	57	10	83%
	TN (kg/yr)	483	185	62%

Table 12; Modelled metal performance for urban portion of catchment

	Scenario 1 (existing)	Scenario 2	% change from existing	Scenario 3	% change from existing	Scenario 5	% change from existing
Cu Mean (mg/L)	0.0003970	0.0006070	-53%	0.0005210	-31%	0.0003540	11%
Cu Median (mg/L)	0.0001890	0.0002410	-28%	0.0001760	7%	0.0000703	63%
Cu 90th (mg/L)	0.0004500	0.0005780	-28%	0.0004060	10%	0.0002200	51%
Cu 95th (mg/l)	0.0020000	0.0040000	-100%	0.0030000	-50%	0.0020000	0%
Zn Mean (mg/L)	0.0026700	0.0031000	-16%	0.0027200	-2%	0.0019600	27%
Zn Median (mg/L)	0.0005780	0.0006360	-10%	0.0004310	25%	0.0002350	59%
Zn 90th (mg/L)	0.0009150	0.0010100	-10%	0.0006870	25%	0.0004560	50%
Zn 95th (mg/L)	0.0280000	0.0330000	-18%	0.0300000	-7%	0.0170000	39%

*It is noted that negative (-%) represents an increase in the particular contaminant. This is typically related to the variance in landcover as the scenarios result in increased urban surfaces.