STORMWATER TREATMENT DESIGN AND SIMULATION FOR TRANSMISSION GULLY PROJECT

Jahangir Islam and Mike Summerhays

AECOM New Zealand Ltd

ABSTRACT

Stormwater runoff from roads creates detrimental impacts downstream. This is a result of an increased level of stormwater runoff conveying contaminants to downstream receiving environments. The philosophy and focus of the stormwater treatment design for the Transmission Gully project was to reinstate or improve the natural vegetation and pre-development processes and conditions using Low Impact Development (LID) principles wherever possible. This LID process used primary and secondary treatment measures ("treatment train" approach) to achieve the desired level of treatment.

The performance of the proposed treatment measures has been evaluated using two alternative approaches. The first was an instantaneous peak design flow spreadsheet based on the New Zealand Transport Agency (NZTA) stormwater treatment standards and guidelines. The second is MUSIC modelling, which is a software tool adopted extensively in Australia to assess pollutant removal efficiencies based on long term rainfall-runoff analysis.

MUSIC modelling was applied to three segments of the proposed Transmission Gully road alignment. This enabled the comparison of the estimated long term treatment performance against the instantaneous peak spreadsheet results. Ten years of continuous rainfall time series data from two rainfall gauges near the Transmission Gully project were used in the MUSIC modelling. A range of sensitivity analyses were undertaken to quantify the potential variation in treatment performance results and thereby gain a level of confidence in the overall outcomes.

KEYWORDS

Stormwater Management, Continuous Simulation, LID, MUSIC, Treatment Train.

PRESENTER PROFILE

Dr Jahangir Islam (BSc Eng, MSc Eng, PhD, MIPENZ, CPEng, IntPE)

Jahangir Islam is an Associate Director at AECOM in New Zealand. Jahangir has over 25 years of experience working for local authorities and as a consulting engineer. He has been involved with a wide variety of environmental management projects including stormwater catchment planning, hydrological and hydraulic modelling, stormwater quality improvement and remedial options investigations.

1 INTRODUCTION

Transmission Gully (TG), a 27km long four-lane motorway to be built north of Wellington, is one of the largest Private-Public-Partnership transport projects in New Zealand. The project is in the construction phase at the time of this presentation.

Stormwater runoff from roads will convey contaminants to downstream receiving environments if treatment is not considered.

The TG stormwater treatment design had a clear purpose to reinstate or improve the natural vegetation and pre-development processes and conditions using Low Impact Development (LID) principles. This was achieved through primary and secondary treatment measures ("treatment train" approach).

TG crosses eight stormwater catchment areas on its journey from Mackays Crossing in the north to Linden in the south, a distance of around 27km with approximately 0.8 km^2 (80ha) of carriageway. These catchments are indicated in Figure 1. Six of the catchments (Horokiri and those to the south of it) all discharge to Porirua Harbour. The TePuka-Wainui and Whareroa catchments discharge to the ocean in the north.

The philosophy that guided the design development was based on a simple, self-sufficient and sustainable drainage management solution. The design approach utilised natural drainage processes and vegetated batters and swales, alongside reduced reliance on traditional hard infrastructure such as underground pipe systems. Consideration of safety, extreme weather events, and minimising the impact on drainage infrastructure from seismic activity were also fundamental.

A schematic of the stormwater treatment approach for a minor local catchment scale is shown in Figure 2. The transverse culverts at the end of the rock cut chutes incorporate measures to provide for drainage and debris flood conveyance with a reduced risk of culvert blockage. Any rock falls in cut batters are designed to be captured within a vegetated swale or rubble drain at the base of the cut batter face. These swales and rubble drains are also intended to provide a degree of treatment for low flow (first flush) runoff events and conveyance during larger rainfall events.

The LID techniques generally employed included:

- Infiltration and evapotranspiration (increased re-vegetation of upper catchment areas, stream rehabilitation, fill batters and the works corridor in general),

- Increased times of concentration for reduced discharge rates (through longer and flatter drainage flow paths, vegetated batters flatter than natural slopes in most areas, vegetated swales, rougher conveyance channels (rubble lined) etc.),

- Collecting and treating stormwater in a distributed fashion at the source as it is generated (through sheet flow down vegetated batters or swales and rubble filter drains rather than concentrated discharge points),

- Runoff conveyance through vegetated swales and filter (buffer) strips (both man-made and natural),

- Removal of hard infrastructure (concrete kerbs, pits and pipes) wherever practical.

- Flow detention storage at various locations as required (including dedicated on-site storage).

Figure 1 – Stormwater Catchments traversed by Transmission Gully

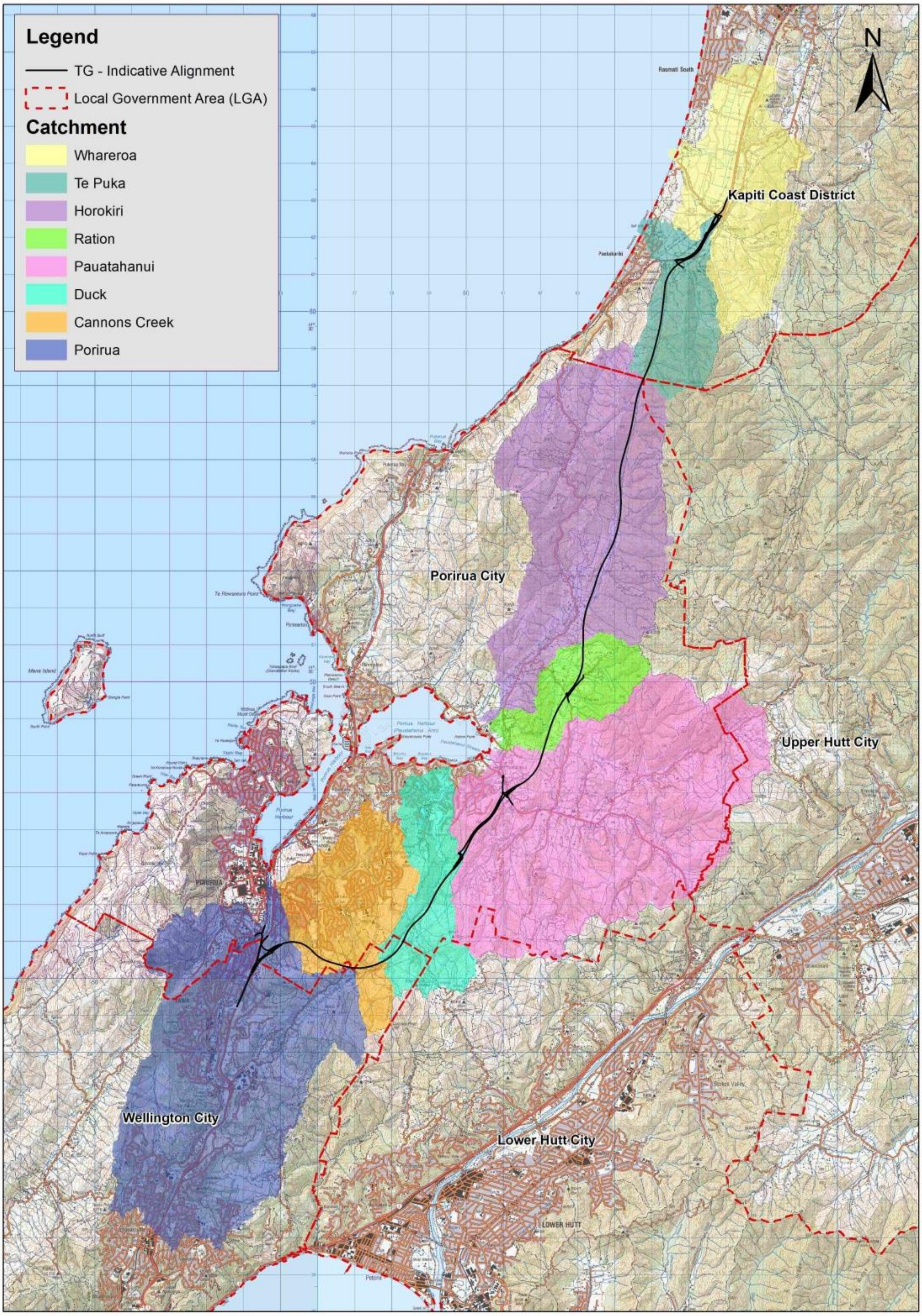
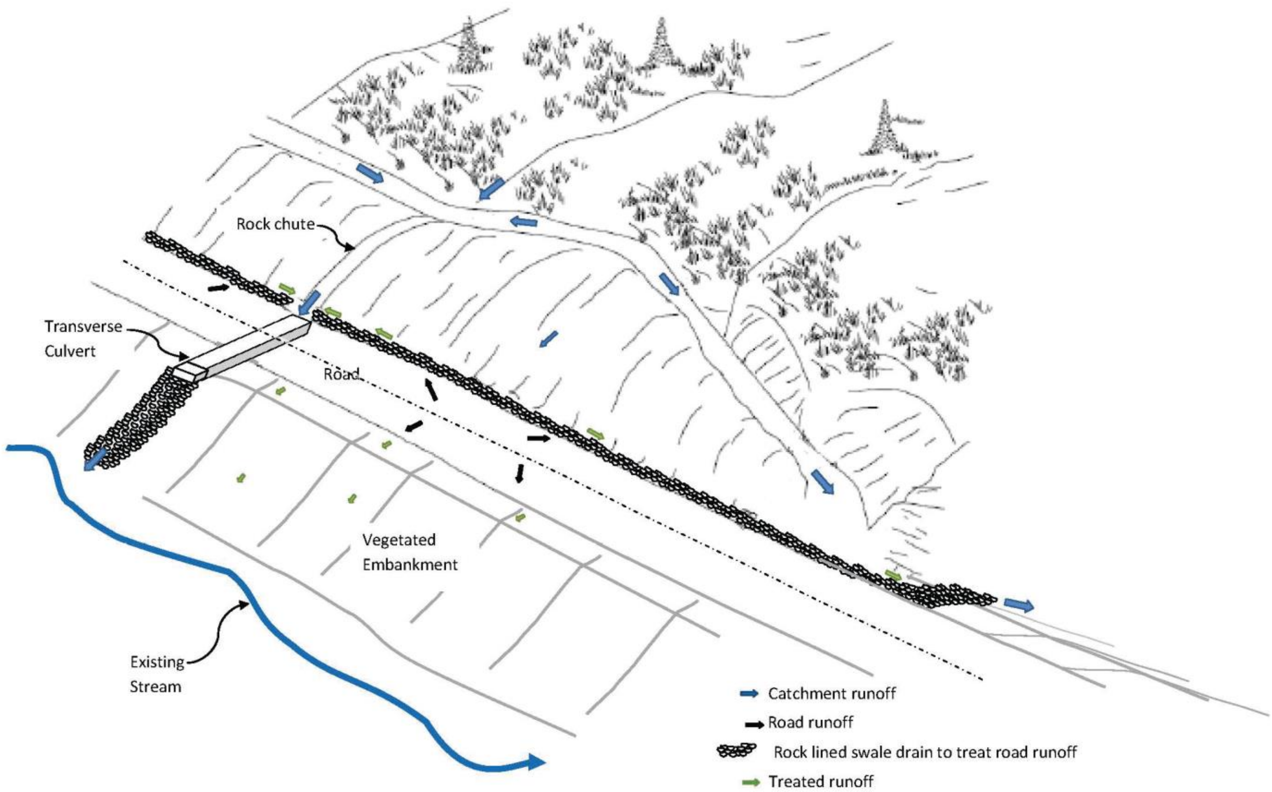


Figure 2 - Schematic of stormwater drainage elements within the road corridor



The performance of the proposed treatment measures was evaluated using two alternative approaches. The first was the instantaneous peak design flow spreadsheet based on NZTA stormwater treatment standard and guidelines. The second was Model for Urban Stormwater Improvement Conceptualisation (MUSIC) modelling, a software tool adopted extensively in Australia to assess pollutant removal efficiencies using long term rainfall-runoff analysis.

This paper summarises the project wide assessment of stormwater treatment measures and their performance using two alternative approaches.

2 STORMWATER TREATMENT MEASURES

The various measures considered to provide stormwater quality treatment for the TG project are described below.

2.1 VEGETATED BATTERS (FILTER/BUFFER STRIPS)

Road surface runoff will flow to the edge of the road formation, over a sealed verge and then hinge down the batter as sheet flow. Filter strips, in the form of established grass, will run continuously along the edge of the seal. The remainder of the batter will also be established with a good coverage of permanent vegetation to provide a buffer that varies from dense grass to grass with shrubs and native landscape plantings along the alignment. A typical cross-section is shown in Figure 3 with an actual application shown in Figure 4.

These vegetated batters provide a very high standard of pollutant removal as water feeds through the dense vegetation as shallow distributed flow under quiescent conditions. Pollutant removal mechanisms include settling and screening/entrapment for particulate pollutants and dissolved pollutants are removed through cohesion and adsorption to charged particles in soil and organic matter.

The proposed extended sealing of the edge of the verge over and beyond the hinge point (refer to Figure 3) aims to ensure a continuous well distributed sheet flow is established without the opportunity to form concentrations and/or erosion rills.

Dense grasses between 100 and 150mm deep provide the best treatment potential, although grasses of greater height will grow subject to maintenance regimes, however this will not detract from the treatment efficiency.

Figure 3 - Typical section showing vegetated embankment and additional swale

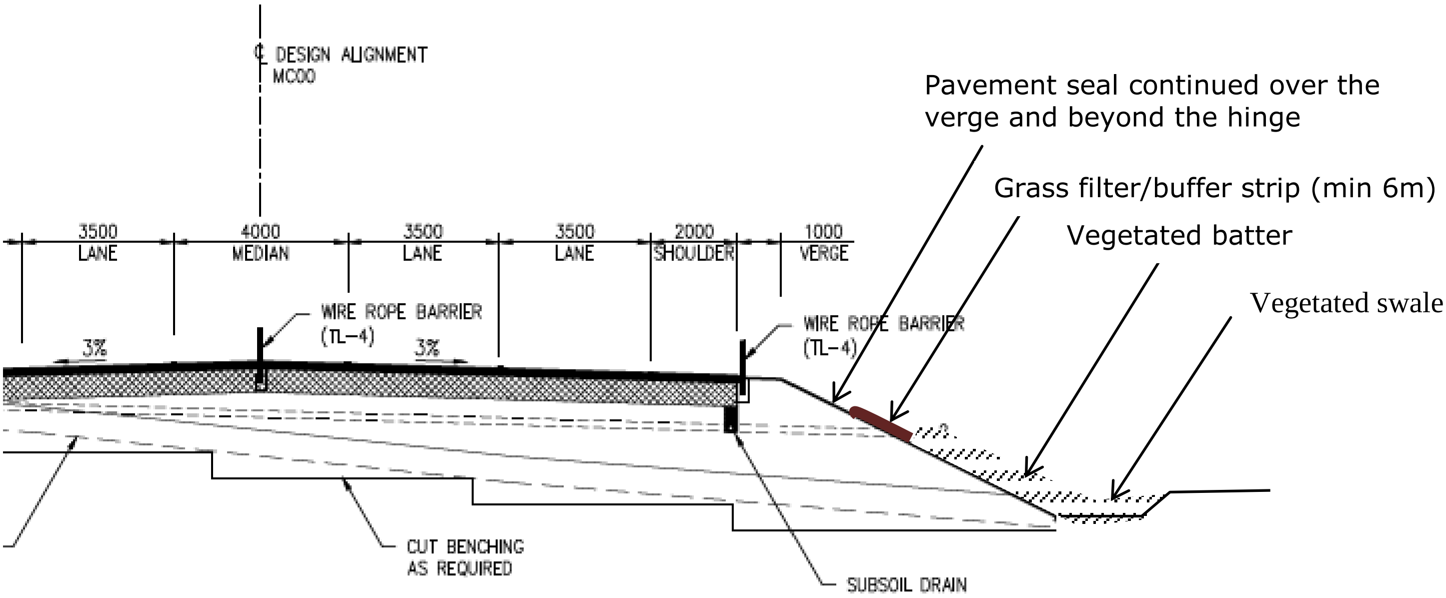


Figure 4 - Highway seal extended over verge and hinge with filter strip and vegetated batter

2.2 VEGETATED SWALES

Vegetated swales are proposed as a primary treatment measure located beside and parallel to the road surface, or as a secondary treatment measure placed at the base of a vegetated batter, end of a drain or pipe system. Treatment is provided as water passes through or infiltrates the vegetation of the swale. The removal efficiency is determined by the height and thickness/density of the vegetation - the minimum vegetation height being 50mm. Dense grasses between 100 and 150mm high provide the best treatment potential.

Examples of typical planted swales are shown in Figure 5.

Figure 5 – Examples of vegetated swales for the treatment of road runoff (State Highway 1, Auckland)

Rock check dams were specified, where swales are steeper than 5%, to slow velocities in general and encourage sedimentation treatment. The water will drain downstream through the check dam after the runoff event has passed, with any sediment settling out or attaching itself to the swale vegetation upstream. The peak velocity has been kept well below 1.5m/s (typically <0.5m/s) for the 10 year rainfall event to prevent the risk of sediment re-suspension.

2.3 LEVEL SPREADERS

Level spreaders are a feature often added at the end of a linear treatment device, for example at the end of a swale or drain. These “turn out” the concentration of flow and direct it along a contour, thereby encouraging sheet flow to ‘spill’ down a naturally vegetated slope or embankment. They are designed to receive only the water quality flow, with larger peak flows bypassing down a protected channel to a discharge point. The level spreader affords an additional degree of treatment over and above the primary treatment device, by utilising the naturally vegetated slope in a similar manner to a filter/buffer strip.

2.4 TREATMENT PONDS

Treatment ponds detain flows to allow sediments to settle, and also help to remove a significant proportion of contaminants by their adhesion to vegetation and aerobic decomposition. Vegetation is an integral component of the pond system and assists each of the treatment mechanisms. It reduces velocities and turbulence, provides significant surface area for silt adhesion and can help to reduce dissolved metals and nutrients through biological uptake. Treatment ponds can also provide peak flow attenuation and provision of extended detention if appropriate.

For the TG project, treatment ponds have been designed around the interchange areas which generally comprise the largest areas of imperviousness with associated pit and pipe drainage systems. These area also tend to generate greater pollutant loads from increased vehicle demands/movements (braking and turning). Two treatment ponds with Extended Detention Volume (EDV) provisions (total volume 1180m^3 and 1270m^3) are to be constructed for the SH58 interchange at Lanes Flat (within the Pauatahanui catchment) and one (total volume 1980m^3) at the James Cook interchange (Duck Creek catchment).

2.5 PROPRIETARY DEVICES

Proprietary devices are underground structures, typically pre-cast concrete, with filtration measures/media which treats stormwater to remove contaminants such as total suspended solids TSS with heavy metals attached. They are useful in constrained areas where more natural forms of treatment are not possible or practical.

Stormwater 360 (SW360) was the main proprietary device considered for application to this project. SW360 treatment devices (Stormfilter) are known to remove 75% TSS without any need for additional treatment. SW360 has been accredited by Washington State Department of Ecology, New Jersey Department of Environmental Protection and for use under ARC TP10 2003. They have also been used for stormwater treatment in numerous NZTA highway projects to date.

Stormwater 360 devices have been specified due to space constraints at the downstream end of the Kenepuru interchange drainage systemas well as the roundabout intersection near the end of the Kenepuru Link Road (Porirua catchment).

2.6 TREATMENT TRAIN APPROACH

It should be noted that the various measures and devices discussed above are often used in a "treatment train" approach where several measures are combined in series, that is used sequentially. . For example, a vegetated batter may be followed by a vegetated swale, or even natural vegetation, where the vegetated batter is not considered sufficient to achieve an appropriate level of TSS removal. The NZTA (2010) formula to establish treatment train efficiency was used. That is overall treatment train efficiency = primary treatment efficiency A% + secondary treatment B% - A% x B%.

3 ASSESSMENT APPROACH

3.1 GENERAL

There is a certain degree of uncertainty in the data and theories for estimating treatment removal efficiencies using different treatment measures. Uncertainty also exists in the underlying parameter assumptions. Two alternative methods were therefore utilised to assess the relative TSS treatment removal efficiency of the various treatment measures proposed for this project. These methods are:

1) Spreadsheet calculations based on the approach outlined in NZTA (2010).

2) Detailed MUSIC modelling of the pollutant build-up (generation) and wash-off (rainfall-runoff) processes using long term historical rainfall data for the areas surrounding the project.

3.2 SPREADSHEET CALCULATIONS (NZTA 2010 APPROACH)

A detailed spreadsheet has been developed to assess the performance of the overall proposed treatment measures for TSS removal efficiency. The spreadsheet considers the contribution of primary and secondary treatment measures as well as the combined "treatment train", including primary and secondary, outcomes.

The spreadsheet calculations are based on the information and guidelines set out in the references "Stormwater Treatment Standard for State Highway Infrastructure" NZTA May

2010. The NZTA approach uses a peak design event water quality flow based on the 90th percentile storm to assess the instantaneous treatment performance.

Two separate spreadsheets have been established to represent the TG northbound (NB) and southbound (SB) carriageways. The spreadsheet template was automated as much as possible to undertake the calculations efficiently and consistently.

3.3 MUSIC MODELLING

MUSIC was first developed in Australia by the Cooperative Research Centre (CRC) for Catchment Hydrology and then enhanced later by the eWater CRC. It represents an accumulation of the best available knowledge and research into urban stormwater management in Australia as well as the international research literature. It is used extensively in Australia by State highway authorities to establish stormwater treatment effectiveness.

MUSIC estimates stormwater flow and pollution generation. It simulates the performance of stormwater treatment devices individually and as part of a group of stormwater management measures, configured in series or in parallel to form a “treatment train”. By simulating the performance of stormwater quality improvement measures, MUSIC provides information at a conseptual level on whether a proposed system would achieve flow and water quality targets.

The adoption of a continuous simulation approach is recommended in modelling stormwater management systems. It allows examining the hydrologic and pollutant removal performance of treatment systems over a range of climatic conditions, not just design events.

Owing to the intermittent nature of stormwater rainfall over a range of rainfall events from low intensity long duration to high intensity short duration, MUSIC was developed to improve the understanding of the build-up and wash-off of contaminants over the longer term. Physical processes associated with detention for sedimentation and filtration, either through vegetated systems or through an infiltration medium, are the principal mechanisms by which stormwater contaminants are first intercepted. This is represented along with the differing rainfall either for specific storm events or a long term continuous series of rainfall.

Hydraulic loading, vegetation density and areal coverage, hydraulic efficiency and the characteristics of the target pollutants, for example particle size distribution, are considered to largely influence the differences in performance between the various treatment processes modelled under actual rainfall conditions. Two basic modelling procedures are adopted in the unified model. These include hydrologic routing to simulate the movement of water through the treatment system and a first order kinetic model to simulate the removal of pollutants within the treatment system.

When a parcel of water carrying materials such as suspended solids, phosphorus, or nitrogen enters a treatment measure such as a pond or wetland, the water quality of the parcel begins to change. Several physical processes are involved, and the detailed behaviour can be very complex. The overall effect is contaminant concentrations in the parcel tend to move as a result of an exponential decay process towards an equilibrium value for that site at that time. This behaviour can be described by the first order kinetic (or k-C*) model, in which C* is the equilibrium value or background concentration, and ‘k’ is the exponential rate constant.

The parameter 'k' combines the influence of a number of predominantly physical factors on the removal of stormwater pollutants. A higher k means a faster approach to equilibrium, and hence a higher treatment capacity. Similarly a lower C* means that concentrations can be reduced, resulting in improved treatment efficiency. Treatment efficiency of many stormwater management measures decreases with increasing inflow rates and increases with increasing inflow pollutant concentration.

The selection of appropriate k and C* values for MUSIC is an important consideration in simulating any proposed treatment measure. The default k and C* values used in MUSIC for swales and vegetated batters are shown in Table 1 along with a recommended upper and lower bound range.

Table 1 - MUSIC modelling parameters for swales and vegetated batters

MUSIC Modelling Parameters	Default Parameter Value	Recommended Range of Values
Exponential decay rate constant, k	8,000 m/yr	4,000 to 15,000 m/yr
Equilibrium or background concentration, C*	20 mg/L	10 to 30 mg/L

3.4 MUSIC MODEL INPUT

Rainfall and PET

Ten years of continuous historical rainfall time series data at Whenua Tapu at Taupo and Blue Gum Spur at Whakatiki near the Transmission Gully project were used in MUSIC modelling investigations. The mean annual rainfall ranges from 994mm at Whenua Tapu to 1750mm at Blue Gum Spur. The rainfall time series data from five minute intervals was collected from the Greater Wellington Regional Council. The rainfall time series data was converted in six minute intervals for input into the MUSIC model. Monthly Potential EvapoTranspiration (PET) data at Paraparaumu Aero extracted from NIWA CLIFLO database were used in MUSIC modelling investigations. Rainfall and PET time-series data are presented in Figure six and seven respectively.

Pollutant Generation Parameter Values

Analysis by Duncan (1999) found event mean concentrations of TSS, TP and TN to be approximately log-normally distributed for a range of different urban land-use. MUSIC uses a stochastic generation approach to derive concentrations for TSS, TP and TN at each time-step from the log-normal distribution described by the mean and standard deviation of each pollutant for different urban land-use.

A mean annual stormwater TSS concentration of 80 mg/L from the Auckland Regional Council (ARC) Contaminant Load Model Development Manual (ARC, 2010) for roads with 20,000 to 50,000 vehicles per day was used to generate the TSS pollutant load in MUSIC modelling investigations. The traffic values for the TG project are estimated to be around 20,000 vehicles per day.

Figure 6 - 10 years continuous rainfall and PET time-series data at Whenua Tapu

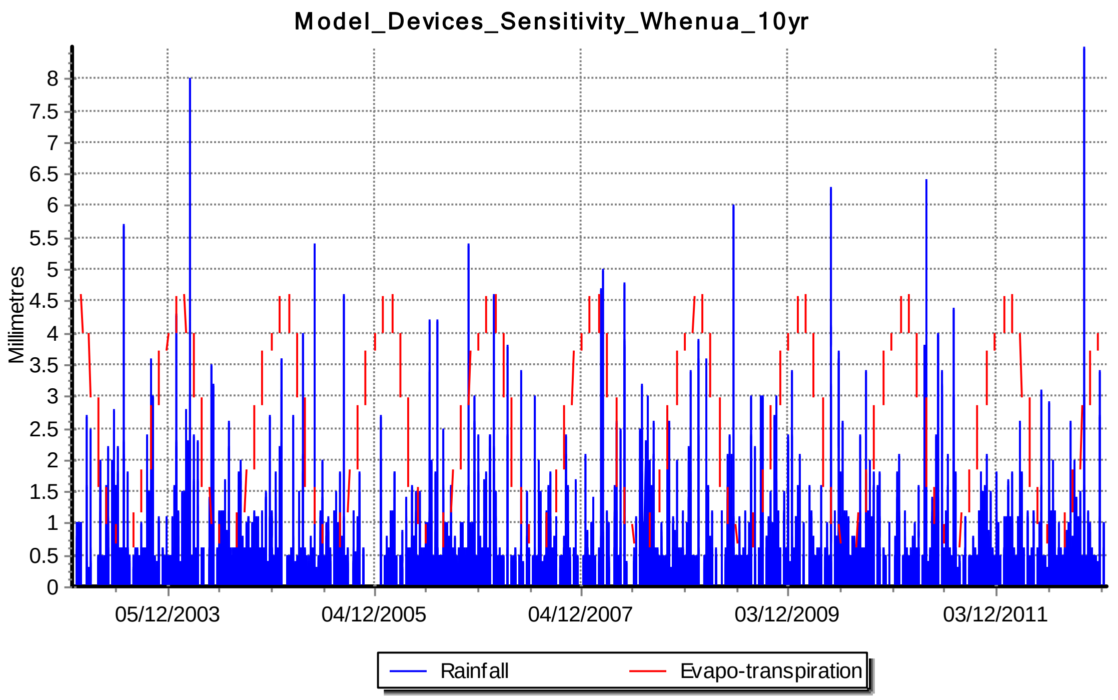
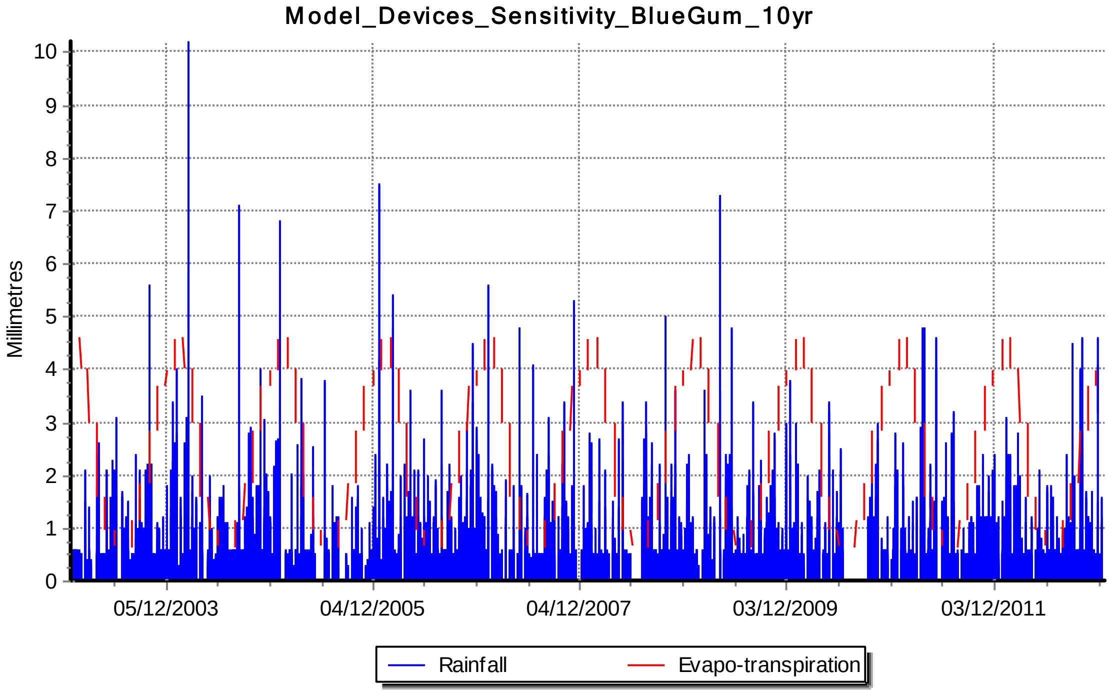


Figure 7 - 10 years continuous rainfall and PET time-series data at Blue Gum Spur



Since the buildup of pollutants is not a limiting factor in determining washoff loads (Duncan 1999), in general the load of suspended solids in stormwater runoff is proportional to the volume of runoff. Based on the mean annual stormwater TSS concentration value (80 mg/L), Whenua Tapu rainfall gauge generates a lower mean annual TSS loads (90 gm/m2/year) compared to a higher TSS loading (160 gm/m2/year) in case of Blue Gum Spur rainfall gauge. Wheareas ARC Contaminant Load Model (ARC, 2010) shows a TSS genartion rate of 96 gm/m2/year in Auckland based on annual rainfall of 1200mm per annum.

TSS load time-series data for Whenau Tapu and Blue Gum Spur rainfall gauges are presented in Figure 8 and 9 respectively.

For comparison, a higher stormwater TSS concentration value of 270 mg/L, derived by Fletcher et al. (2004) for NSW conditions, was also used for sensitivity analyses.

Rainfall-runoff Modelling Parameter Values

The default rainfall-runoff parameter values in MUSIC for impervious and pervious areas were used in MUSIC modelling investigations. A rainfall threshold of 1mm/day has been used for depression storage in the impervious area which defines the minimum daily rainfall before surface runoff would occur from the impervious area. For the Transmission Gully Project runoff from impervious areas (road) is the main concern as it generates the major pollutant loads.

Figure 8 - 10 years continuous TSS Load time-series data at Whenua Tapu from 1 ha road area

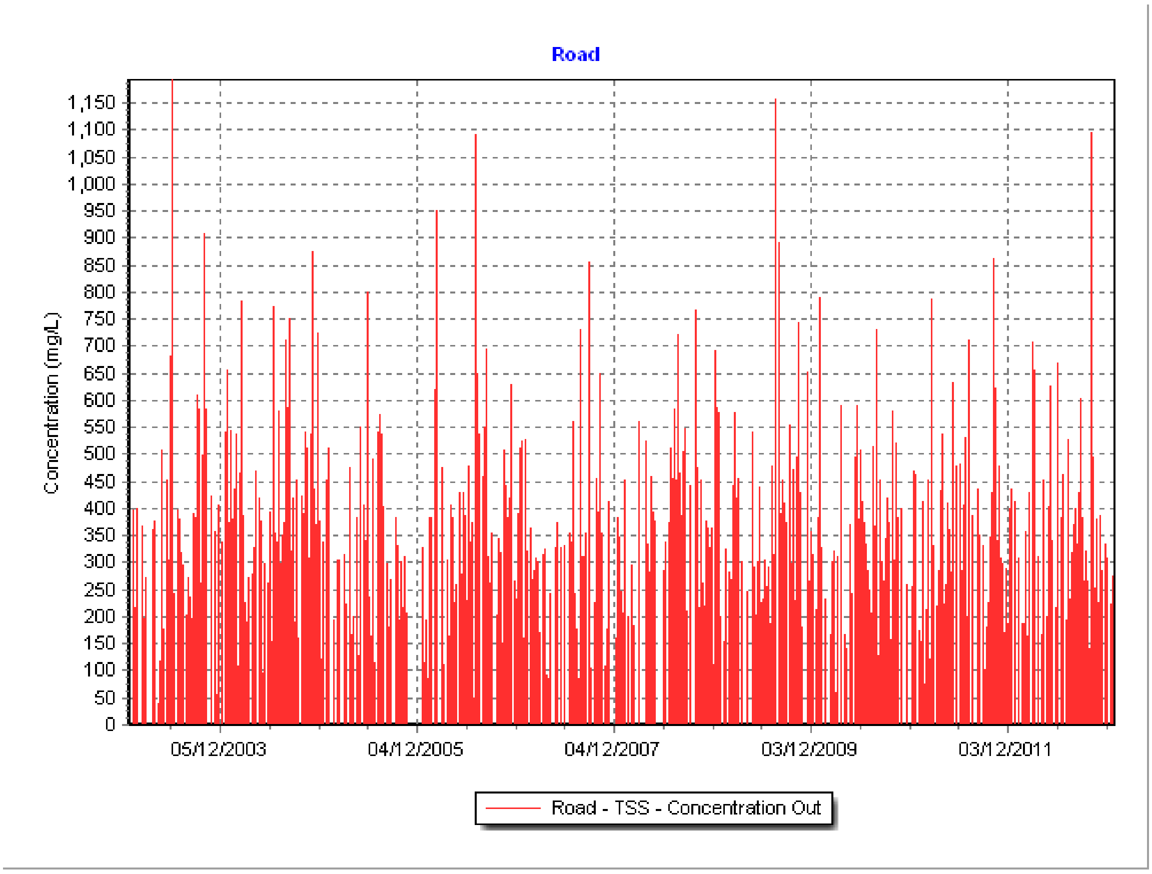
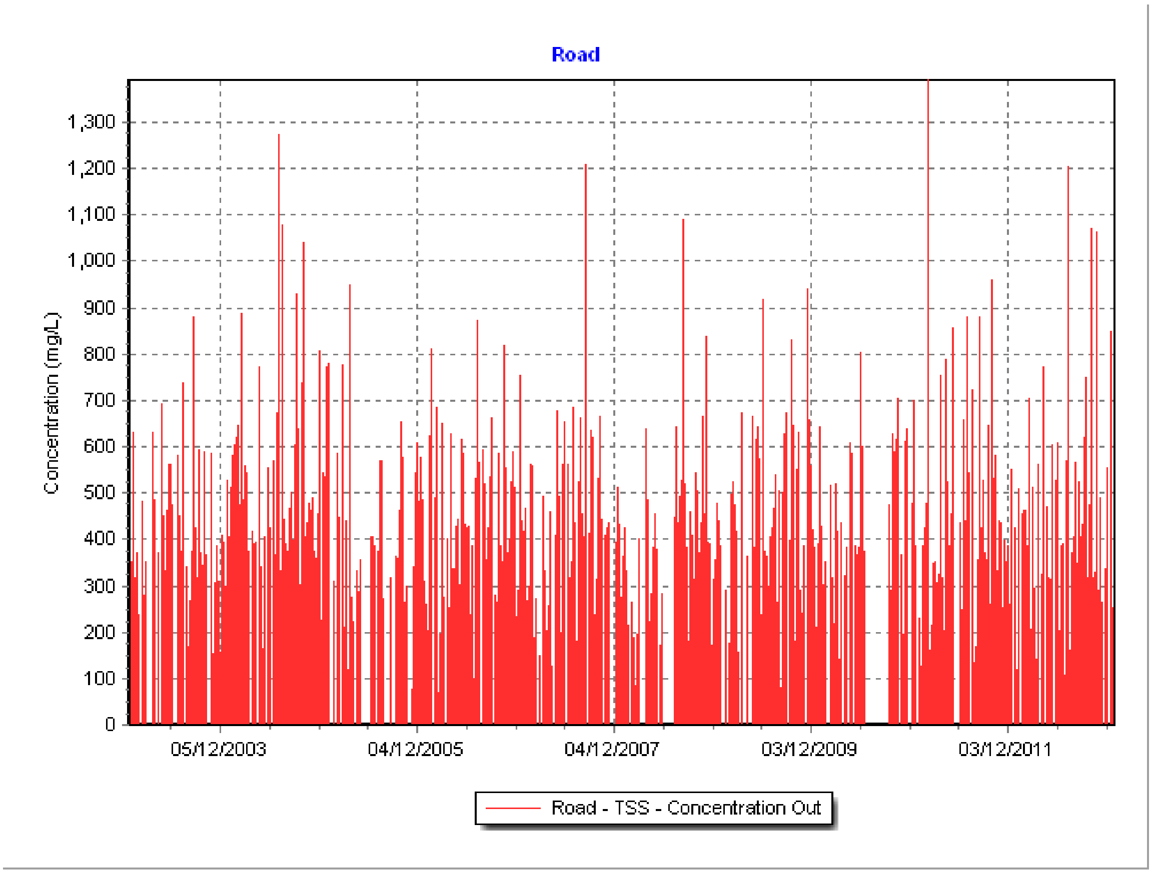


Figure 9 - 10 years continuous TSS Load time-series data at Blue Gum Spur from 1ha road area



Stormwater Treatment Modelling Parameter Values

The recommended ranges of k and C* parameter values provided in MUSIC manual were used in the current modelling investigations to account for the variability and uncertainty in parameter estimates (refer to Table 1). As the recommended ranges of k and C* parameter values provided in the MUSIC manual are based on typical particle size distribution of suspended solids in Australian conditions and in general the particle size distribution of suspended solids found in New Zealand are similar to that in Australia, it is expected that the k and C* parameter values would be within the recommended ranges provided in MUSIC model.

3.5 SENSITIVITY ANALYSIS FOR VARIOUS TREATMENT MEASURES

Sensitivity analyses were carried out for various treatment measures using the recommended ranges of k and C* parameter values provided in MUSIC manual (refer to Table 1). Sensitivity analyses were also carried out for ARC and NSW stormwater TSS concentration values (80 mg/L and 270 mg/L). Initial sensitivity analysis shows similar TSS removal efficiencies for the two rainfall gauges although the mean annual rainfall differs significantly between the gauges but the mean flows over the 10-year period are similar. Finally the higher rainfall time-series data at Blue Gum Spur gauge were used for all sensitivity simulation runs.

Vegetaed Buffer Strip

Vegetated buffer strips are commonly used as a source control measure, particularly for management of diffuse runoff. The treatment process in a vegetated buffer strip is modelled in MUSIC by a set of simple transfer functions, derived from a review of worldwide literature. MUSIC only allows the use of a vegetated buffer with an area up to 50% of the upstream impervious area that drains into it. Sensitivity simulation runs were carried out for smaller buffer areas as presented in Table 2. It shows the TSS removal efficiency is not sensitive to the vegetated buffer area.

Table 2 - Predicted TSS removal efficiency as function of vegetated buffer strip areas

Buffer Area as % of Upstream Impervious Area	TSS Removal Efficiency (%)
50.0%	72.8%
40.0%	72.5%
30.0%	72.2%
20.0%	71.8%
10.0%	70.9%
5.0%	69.7%

Grass Swale

Vegetated swales are open channel systems which utilise vegetation to aid removal of suspended solids. As for buffer strips, the vegetation can assist in reducing peak flows for a range of events. A grass swale with base width of 1m, side slope of 1:2, bed slope of 3%, and vegetated with grass height of 150mm was used for sensitivity simulation runs. A contributing catchment area of 0.26ha was assumed to be discharging laterally from the road (100m long and 26m wide) to the swale, therefore the average length of the swale treatment used in the MUSIC model was half of the actual length, that is 50meters. The predicted long-term average TSS removal efficiencies for different treatment parameter and stormwater TSS concentration values are presented in Table 3.

Calculation of Manning's roughness coefficient in grass swales in MUSIC is based on an empirical model developed by Kouwen (1988), Kouwen and Li (1980) and Kouwen and Unny (1973). The model is based on determining the roughness of flexible vegetation for a defined flow depth.The aim of the model is to reproduce the bending of the vegetation at higher discharges and the consequent reduction of the bed roughness. Manning's roughness coefficient n varies with vegetation type and height relative to flow depth, as well as slope. The MUSIC model estimated Manning’s roughness coefficient for a typical swale as function of flow depth is shown in Figure 10.

Figure 10 - Manning's roughness coefficient n as function of flow depth for a typical grass swale with 1m base width, 1:2 side slope and 150mm grass height

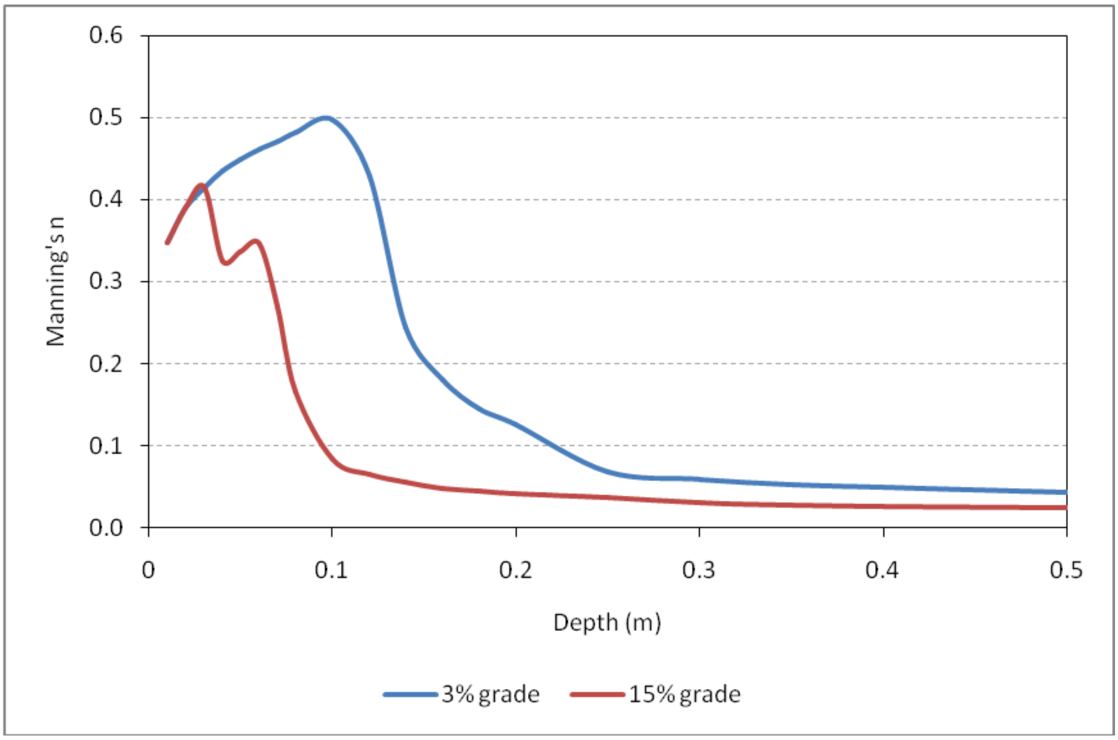


Table 3 - Predicted TSS removal efficiency of grass swale for different parameter values

Exponential Decay Rate Constant, k (m/yr)	Equilibrium Concentration, C* (mg/L)	TSS Removal Efficiency (%)		Notes
		ARC TSS Loading (80 mg/L)	NSW TSS Loading (270 mg/L)	
4000	30	64.4%	81.9%	Low Parameter Values
4000	10	81.3%	86.9%	
8000	20	78.3%	90.8%	Default Parameter Values
15000	30	71.0%	90.6%	
15000	10	89.7%	96.1%	High Parameter Values

Notes: default parameter values in MUSIC for grass swale: k = 8000 m/yr and C* = 20 mg/L and recommended parameter values for grass swale: k = 4000 to 15000 m/yr and C* = 10 to 30 mg/L.

Hydraulic Residence Time Estimation

Table 3 shows a high level of TSS removal efficiency for grass swale (64 to 96%) compared to the NZTA method result of 52% for grass swale. The difference can be attributed to the different approaches of the two methods. The NZTA method estimates the TSS removal efficiency based on single peak flow estimate (rationale method) using the 90-percentile rainfall (24.2mm). The MUSIC model estimates the long-term average TSS removal efficiency based on 10 years of continuous historical rainfall time series data as shown in Figure 11. Figure 12 shows the flow duration curve of the computed 10-year flow data from 0.26 ha road impervious area considering only non-zero flows.

Figure 11 - Runoff from 0.26ha road impervious area for the 10-year period, 2003 to 2012

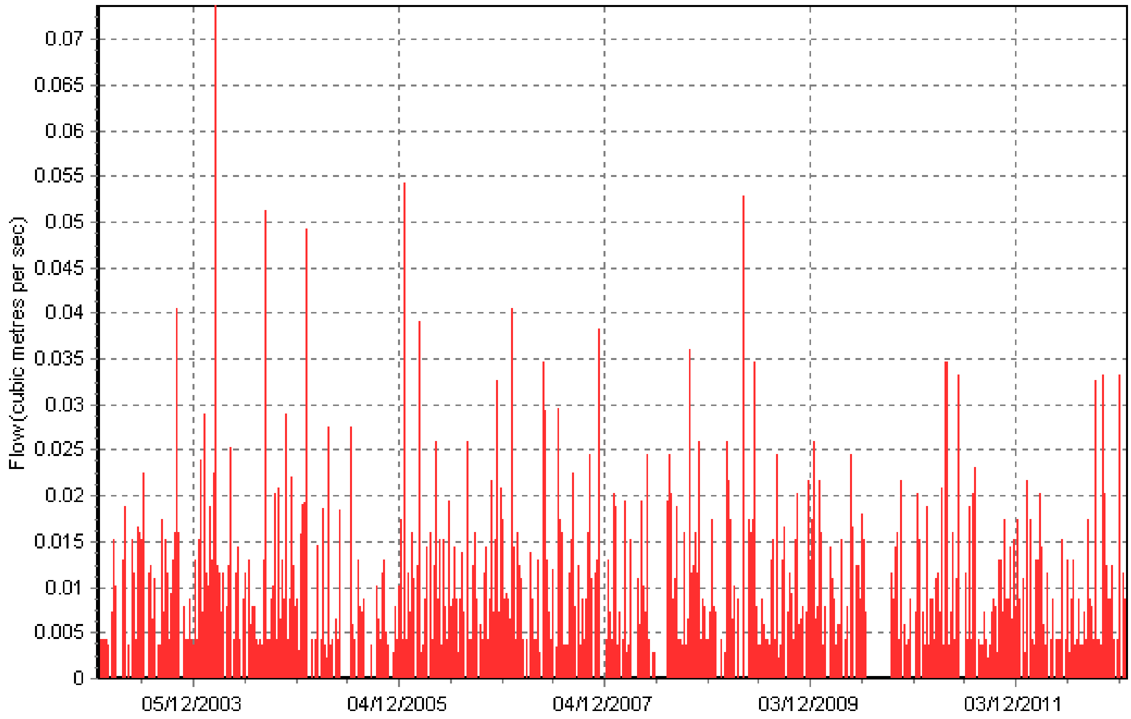
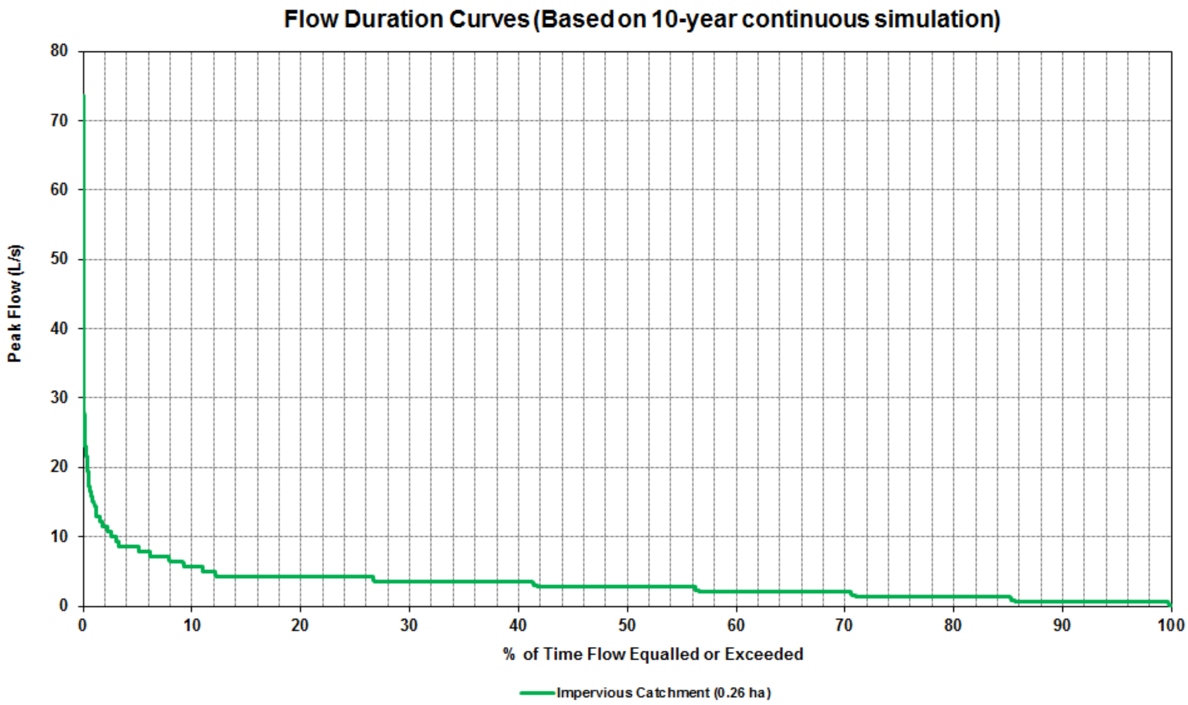


Figure 12 - Flow duration curveof the computed 10-year flow data considering only non-zero flows. Mean flow = 3.3 L/s; 90-percentile flow = 5.8 L/s; Maximum flow = 73.7 L/s (0.26 ha catchment)



A mean flow of 3.3 L/s, 90-percentile flow of 5.8 L/s and maximum flow of 73.7 L/s is estimated from the computed 10-year flow data from the 0.26 ha road impervious area. Using the flow statistics, hydraulic residence times are estimated for grass swale as shown in Table 4. Considering the long-term average flow, the estimated hydraulic residence time for grass swale is about three times greater than that based on water quality storm flow (Twoyear, onehour storm of 24.2mm). Based on hydraulic residence time estimates and considering a nine minute residence time would provide 75% removal efficiency, it is expected that the TSS removal efficiency for grass swale would be more than 80% similar to that predicted by the MUSIC model.

Table 4 - Estimated hydraulic residence time for different flow data for grass swale

Flow Type	Flow, Q (m3/s)	Flow Velocity, v (m/s)	Swale Length (half of actual length), L (m)	Hydraulic Residence Time, v/L (min)
Mean Flow	0.0033	0.049	50	17.0 (10.6)[1]
90-Percentile Flow	0.0058	0.060	50	13.9 (8.5)
Maximum Flow	0.0737	0.319	50	2.6 (2.3)
Water Quality Storm Flow (NZTA method)	0.0166	0.144	50	5.8

1. The bracketed values are for the NZTA Manning's n value of 0.25 compared to the value calculated by MUSIC which is higher for shallow flows.Catchment Area = 0.26 ha; 100m long & 26m road width.

One of the key points to note from the results in Table 4 is the difference in estimated residence time depending on the assumed Manning's n value. The MUSIC model approach allows for a higher n value at shallow depths compared to the 0.25 assumed for the NZTA approach and MUSIC also automatically adjusts the n value with the changing flow depth (refer to Figure 10).

4 TSS REMOVAL EFFICIENCY RESULTS

For the purposes of alternative assessment, several segments of TG alignment with a range of treatment measures and performance have been modelled. This enables comparison to the spreadsheet calculation results rather than developing a model of the entire project alignment. A 10 year period of historical rainfall data at the Blue Gum Spur rainfall gauge was used to assess the long term water quality processes (pollutant build-up and wash-off) and TSS removal efficiency.

Many of the parameters used in the model are based on Australian experience but they are considered to be very similar to NZ conditions. For example, particle size distribution and rainfalls. A range of sensitivity analyses have also been undertaken to quantify the potential variation in treatment performance results and thereby gain a level of confidence in the overall outcomes.

A comparison of the MUSIC modelling results for the three segments of alignment are summarised in Table 5 along with the equivalent results obtained from the spreadsheet approach based on NZTA (2010) manual.

The results indicate that the differences between the two methods compare favourably for the three sections of alignment chosen. The spreadsheet calculations based on the NZTA approach are considered to provide a lower bound estimate of removal efficiency while the MUSIC results indicate an upper bound estimate. Overall it is believed that the actual result lies somewhere in between.

Table 5 – Compariosn of MUSIC model and Spreadsheet analysis results

Carriageway Section	Chainages		Estimated TSS removal efficiency		
			NZTA 2010	MUSIC modelling results[1]	
	Start	End		ARC TSS Loading (80 mg/L)	NSW TSS Loading (270 mg/L)
Northbound	9,480	10,230	65%	69% (54 to 85%)	88% (82 to 94%)
Southbound	13,650	14,850	74%	68% (56 to 79%)	81% (76 to 85%)
Southbound (includes James Cook on/off ramps)	19,540	20,905	65%	66% (49 to 77%)	84% (75 to 92%)

1. The bracketed TSS removal efficiency results for MUSIC show the possible range of results using the low to high parameter values. Results for the recommended default values are un-bracketed.

5 CONCLUSIONS

The alternative long term assessment using the MUSIC modelling approach with 10 year continuous actual historical rainfall data, 1,750mm per annum on average, indicates a treatment performance in the range of 84% to 88%. This MUSIC result potentially provides an over-estimate of the treatment performance, an upper bound estimate. Other sensitivity analyses have also been undertaken to test the MUSIC modelling assumptions and default input parameters. The results suggest that by comparison, the NZTA 2010 spreadsheet approach appears to provide more conservative results as it uses a single higher peak water quality storm flow rate with consequent lower estimated TSS removal efficiencies. Given all of the above and the uncertainty surrounding the theory and variability of parameters assumed, it is considered that the actual result lies somewhere in between.

REFERENCES

ARC (2010), Development of the Contaminant Load Model, Technical report No. 2010/004, Auckland Regional Council, 2010.

Duncan, H.P. (1999), Urban Stormwater Quality: A Statistical Overview, Report 99/3, Cooperative Research Centre for Catchment Hydrology, February 1999.

Kouwen N. and Li, R. M., (1980), "Biomechanics of Vegetative Channel Linings", Journal of the Hydraulic Division, Proceedings of ACSE, Vol 106, No. HY6, June 1980, pp. 1085.

Kouwen, N. and Unny, T. E., (1973), "Flexible Roughness in Open Channels", Journal of the Hydraulic Division, Proceedings of ACSE, Vol 99, No. HY5, May 1973, pp. 713 – 728.

Kouwen, N., (1988), "Field Estimation of the Biomechanical Properties of Grass", Journal of Hydraulics Research, 26(5), 559 – 568.

NZTA (2010), Stormwater Treatment Standard for State Highway Infrastructure, New Zealand Transport Agency, 2010.