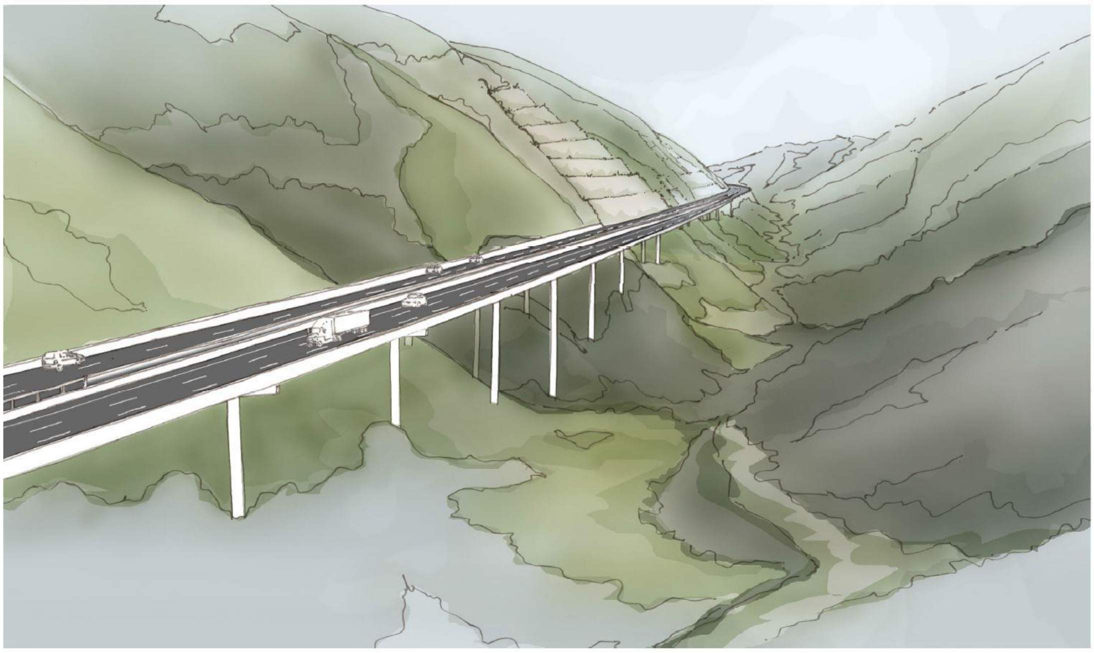
2014

Transmission Gully

Environmental Impact Assessment on the Pauatahanui Inlet



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Executive Summary

To support the resource consent application to construct the Transmission Gully Motorway (TGM) we present the environmental impact assessment study of vehicle contaminants and road runoff expected to affect the Pauatahanui Inlet Catchment Area (PICA). The report is presented to the Porirua City Council that is the legal authority responsible for resource management in the area. To conduct our assessment, data was taken from previous sediment studies and was extrapolated using the PICA as a limiting boundary. Average data from the New Zealand Transport Agency (NZTA 2006 - 2009) was used to estimate the traffic loading affecting the PICA. Vehicle contaminant load models and emission factors developed for other New Zealand aquatic environments were also used. From our analysis we conclude the following:

The total length of roads that affect the inlet will increase from 33 km to 56 km. Projected data from the NZTA predicts a reduction in Annual Average Daily Traffic Volume (AADT). However traffic loading expressed as vehicles kilometres travelled (VKT) will increase by 116% once the motorway is operational (year 2026).

The sedimentation history analysed by Swales et al. (2005) describes the inlet as an extremely dynamic sedimentary environment. Current sediment accumulation rates are 4.6 mm year^{-1} and sediment loading is 17,000 tonnes at a rate of 160 tonnes per km^{-2} year^{-1}.

Zinc, copper, lead and polycyclic aromatic hydrocarbons (PAHs) are the main contaminants coming from vehicles and road runoff. Copper is found in 8 – 13 mg kg^{-1}, lead is 15 – 26 mg kg^{-1} and zinc presents the highest concentration ranging from 55 – 90 mg kg^{-1} (Swales et al. 2005). These concentrations are currently well below Interim Sediment Quality Guideline (ISQG) trigger values for New Zealand. Total contaminant loads present in the top 5 cm surface of the inlet's sediment are

estimated to be in the range of 1,843 -2,995 kg for copper; 3,455 – 5,990 kg for lead and 12,671 - 20,734 kg for Zinc.

Current contaminant loads deriving from road runoff are estimated to be in the range of 6 – 15 kg yr^{-1} km^{-1} of copper, 5-11 kg yr^{-1} km^{-1} of lead, 17-220 kg yr^{-1} km^{-1} of zinc and 1-8 kg yr^{-1} km^{-1} of PAHs. These are considered as the baseline values without the TGM. Contaminants loading from road runoff once the TGM is operational are expected to be in a range of 12-33 kg km^{-1} yr^{-1} for copper, 9-22 kg km^{-1} yr^{-1} for lead, 37-475 kg km^{-1} yr^{-1} for zinc and 2-16 kg km^{-1} yr^{-1} for PAHs. This represents a twofold increase from the baseline values.

The relative contribution of copper and lead from road runoff in the PICA represents less than 0.5 % of the total contaminant load found in the top 5 cm of the inlet's sediment. Once the TGM is constructed these values will increase but will not exceed 1% of the total. For zinc the relative contribution from road runoff to the inlets sediment currently is 1%, and this could increase to 2% once the TGM is operational. Evidence of the pesticide DDT is also reported for some of the streams in PICA originating from urban runoff (Blaschke, 2010).

Increments in contaminants loads will not reach toxic levels and could be diluted over the catchment area. However, long term exposure to heavy metals can be a threat to depositional ecosystems. It has been shown that first flush from rainfall events present metal concentrations above ISQG trigger values that can be toxic to benthic organisms (Milne & Watts, 2008). For this reason we recommend that a number of mitigation measures are implemented, as well as a constant water quality and sediment monitoring program.

Introduction

The Pauatahanui Inlet is a coastal estuarine ecosystem that has been recognized as an important area of conservation. Due to the isolated nature of New Zealand, estuaries play an important role as transition zones between marine and terrestrial environments. Ten of the most populated cities were built around estuaries which have been the focus of economic activities (Woods & Kennedy, 2011). The Pauatahanui Inlet is part of the Porirua Harbour, and even though development has been carried out in the outer part of the harbour, it has not affected the Inlet. However the completion of the Transmission Gully Motorway is expected to change the traffic loads from vehicles that transit roads running through the inlet catchment area. Consequently this event will affect the amount of pollutants that drain into the inlet by stormwater runoff. Currently there is no baseline scenario for the contaminant loading in the inlet's sediment. Therefore, information will be necessary for monitoring programs to assess the present versus the future state of the sediment contaminant loads affecting the inlet.

In order to assess the effects of the Transmission Gully Motorway (TGM) we present the results from the environmental impact assessment study conducted for the Porirua City Council. The report presents a brief biophysical description of the Pauatahanui Inlet, which was taken mostly from literature reviews. We then show the current and expected traffic loading that will affect the Pauatahanui Catchment Area due to the construction of the transmission gully. Earlier studies of sedimentation in the inlet provide historical sedimentation accumulation rates and concentration values for heavy metals. From these values we extrapolate and estimate the contaminant loadings present and expected to occur as a result of the TGM. The significance of these contaminants and their relative contribution to the current contaminant loads are discussed. Finally the conclusions from these analyses are presented accompanied by some mitigation measures as recommendations. The appendices contain all the data used and calculation procedures used throughout this report.

This report presents information on sedimentation and contaminants that could arise as a result of the construction of the TGM. It will be used to support the resource consent application process demanded by the Porirua City Council which is the legal authority in charge of administering the environmental quality of the Pauatahanui Inlet.

Background Information

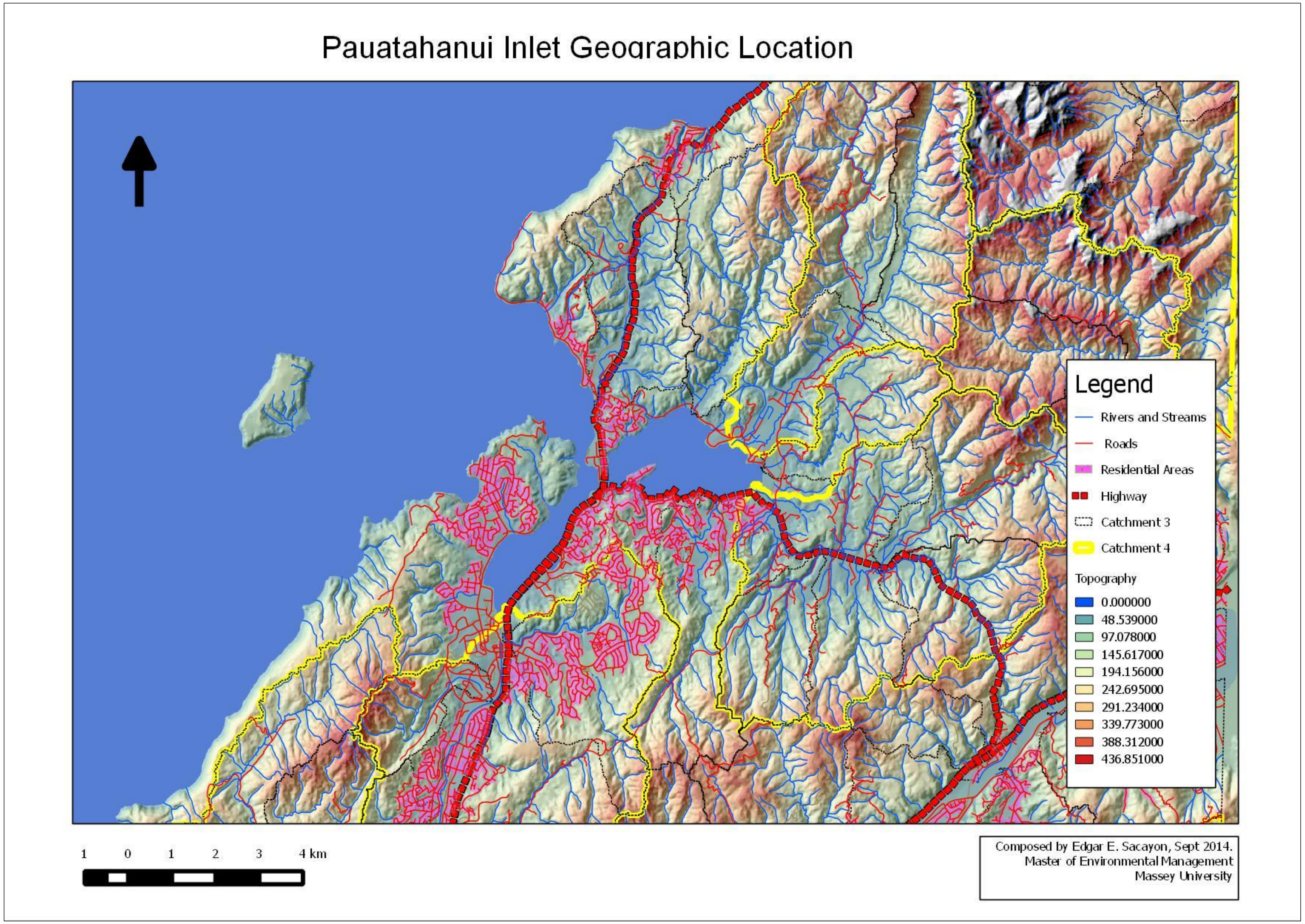
Pauatahanui Inlet Biophysical Description

The Pauatahanui Inlet is located in the northwest part of the Wellington Region. Together with the Onepoto Arm, they form the Porirua Harbour. The catchment total area is 109 km^2 and is composed of six major sub-catchments, Duck Creek, Ration Point, Horokiri, Kakaho, Browns Bay and Pauatahanui, with rivers that drain each catchment into the inlet (Blaschke, 2010). The topography ranges from heights between sea level to 530 meters. The Pauatahanui inlet area is approximately 4.6 km^2 and its shoreline is about 13.2 km. The whole catchment is 25 times bigger than the inlet.

Porirua City is one of the four cities of the Wellington metropolitan area and the residents in the Porirua harbour are estimated to sum 85,000 which are distributed in suburbs and villages surrounding the harbour (Blaschke, 2010). State Highway 1 crosses Porirua City from north to south and links Wellington with the Kapiti Coast. From west to east State Highway 58 links Paremata with the Hut Valley. Other minor roads connect suburbs with small roads around both arms of the harbour. The inlet is a subtidal estuary with less than 25% of tidal flats (Blaschke, 2010). More than 65% of its area is underwater at low tides. Several salt marshes have being filled by human activities but most of the Pauatahanui inlet is now protected (Blaschke, 2010).

The catchment bedrock dates back to the late Triassic and early Jurassic (255-170 million years ago). Composed mainly by greywacke and argillite that form a grey sandstone-mudstone sequence with north-northeast orientation (Blaschke, 2010). Basalt and chert are also part of the rock components. The unconsolidated beach dates back to the Quaternary, with alluvial, fluvial, loess and fan deposits, confined to the harbour fringes (Blaschke, 2010). Terraces from the Quaternary are evident in the catchment topography and it is believed that their origin is related to interglacial periods (Blaschke, 2010). Three fault lines can be identified in the catchment in a northeast to southwest arrangement. The Pukerua, Moonshine and Ohariu faults, have influenced the tectonic uplift of the area which is estimated at around 0.3mm/yr, and are the cause of the significant earthquake hazard of the area (Blaschke, 2010; Swales et al., 2005)

Annual rainfall is estimated to be around 1200mm, being wetter in the winter from May to October. The mean annual temperature is 12.9^{o}C. Four ecodomains, a classification system based on topography, climate and geology, are reported for the Pauatahanui Inlet Catchment Area (Blaschke, 2010). These factors determine the vegetation cover of the Severe salt belt in the coast, the Nikau belt, the Cool tops and the Inland hills and basins. It is believed that before colonization (pre-1850's) native hardwood and podocarp forest associations prevailed (Blaschke, 2010). Other studies report Tawa, Pine, Rewa Rewa and Pukatea on the shores of the inlet. The Pauatahanui Inlet can be considered as an estuary. Recognized ecological values include the Pauatahanui Wildlife Management Reserve which comprises 43 ha, Duck Creek Scenic reserve of 1 ha, Horokiri Wildlife Management Reserve of 5ha and a wildlife refuge of 169 ha. Pauatahanui has been protected as a Site of Special Wildlife Interest (SSWI) because of its ecological value (Blaschke, 2010).



Map 1. Pauatahanui Inlet Geographic Location.

Transmission Gully

The Transmission Gully Motorway[1] is a public-private partnership project to construct a new 27km four-lane vehicle highway between MacKays crossing and Linden. It is expected to offer a new gateway to the city of Wellington which at present only possesses one western highway. Concerns about the dangers of SH1 being blocked reducing communications have sparked the initiative which is expected to begin in the third quarter of the present year. The Wellington Gateway partnership will be in charge of the design, finance, construction, operation and maintenance of the motorway during a 25 year period. The motorway is expected to be fully operational in 2020. Connections to State Highway 58, Whitby, Eastern Porirua and Kenepuru roads will become effective once the Transmission Gully is operational. Two new roads will be constructed. Whitby Link Road will connect with 0.9 km the James Cook Interchange with Navigation Drive and James Cook Drive. Waitangirua Link Road will be aproximately 2.5km long and will connect the James Cook Interchange with the intersection in Niagara Street. This will reduce traffic loads in States Highways and will probably leave a segment of the State Highway 1 along the coast as a scenic route with less traffic volume and reduced traffic speeds. These changes could affect the inlet's catchment area with runoff from roads carrying pollutants into the waters and sediments, particular if this becomes the main route.

Resource Management Act

Because of the potential for environmental degradation, under the Resource Management Act 1991 (RMA), New Zealand's Environmental Regulatory Law, the construction of the TGM requires approval from four district councils affected by the development of the project. A Notice of Requirement (NOR) to designate land and resource consents from Kapiti Coast, Upper Hut, Porirua, Wellington and Hutt City, district councils are required.

[1] http://www.nzta.govt.nz/projects/transmission-gully/index.html

Figure 1. Transmission Gully. Source: NZTA Website.

Traffic Loading

One of the most important factors that affect road runoff is the level of traffic (Gardiner & Armstrong, 2007a). The amounts of contaminants that will deposit on a road are determined by the configuration, terrain and level of traffic congestion (Gardiner & Armstrong, 2007a). To understand the effects of traffic on aquatic environments it has been suggested that the Vehicle Kilometres Travelled (VKT) at catchment or subcatchments levels be used (Gardiner & Armstrong, 2007a). The underlying assumption is that vehicle emissions deposited in the roads will be drained by stormwater runoff into the catchment and will make their way into the aquatic ecosystem.

VKT is a measure of the daily traffic volume for a given road length. It is estimated by multiplying the Annual Average Daily Traffic Volume (AADT) by the road length of the particular site.

$$VKT \ = AADT\ x\ Road\ Length$$

AADT = Average Daily Traffic Volume
VKT = Vehicle Kilometre Travel

In the present study the VKT for the Pauatahanui Inlet catchment area was estimated. Five main roads and their length within the catchment were included in our analysis (Table 1). The length of the road was measured in QGIS[2]. The road network geographic information was obtained from the Land Information New Zealand data portal [3]. For State Highway One (SH1) only two kilometres were considered to affect the inlet, which is why this is the road length used for traffic loading estimation. The AADT is estimated by telemetry sites over one week intervals four times per year. In the present study AADT values for the year 2006 - 2009 were used (NZTA, 2009).

[2] Quantum Geographic Information System, is an open source software to analyse geospatial data.
[3] https://data.linz.govt.nz/

Present Traffic Loading

The present traffic loading affecting the PICA was estimated at 72,100 vehicles per day and a total of 261,832 VKT. The total length of roads going through the PICA is almost 33 km. Table 1 presents the results of current traffic within the PICA.

Table 1 Traffic Loading for the Pauatahanui Catchment Area

Without Transmission Gully				
Roads	**Average Daily Traffic Volume**		**Km**	**VKT**
SH1 Mana Esplanade	32,600		2.00	65,200
SH58 East of Paremata	18,100		4.91	88,817
Grays Road, East of SH1	5,500		5.59	30,745
SH58 West	14,600		3.80	55,480
Paekakiriki Hill Road	1,300		16.61	21,590
Total	**72,100**		**32.91**	**261,832**

Expected Traffic Loading

Using the traffic modelling data from the New Zealand Traffic Agency for the year 2026 it is expected that a total of 70,900 vehicles per day and a total of 566,123 VKT will be affecting the Pauatahanui Inlet Catchment Area. Table 2 presents the estimation for each of the roads expected to be functional in year 2026. Note that Whitby Link Road and Waitangirua Link Road are part of the Transmission Gully new infrastructure. Even though the AADT is expected to decrease the VKT when the motorway is operational will have an increase of 116%.

Table 2 Estimated Traffic Loading for Year 2026

With Transmission Gully				
Roads	**Average Daily Traffic Volume**		**Km**	**VKT**
SH1 Mana Esplanade	20,500		2.00	41,000.00
SH58 East of Paremata	12,600		4.91	61,828.20
Grays Road, East of SH1	1,900		5.59	10,621.00
SH58 West	8,700		3.80	33,060.00
Paekakiriki Hill Road	500		16.61	8,304.00
Transmission Gully	20,000		20.00	400,000.00
Whitby Link Road	3,400		0.90	3,060.00
Waitangirua Link Road	3,300		2.50	8,250.00
Total	**70,900**		**56.31**	**566,123.20**

Sedimentation and contaminants in the Pauatahanui Inlet

Sedimentation

Sedimentation is a natural process in estuaries because these are considered as depositional ecosystems (Woods & Kennedy, 2011). Sedimentation is usually caused by natural geological and water processes, flooding or tidal changes. Sediments play an important role in the ecology of estuaries since they transport nutrients, minerals and also pollutants. Sediments can be classified as suspended and deposited. Deposited sediments are found on the inlet bed and suspended sediments are transported in the water column (Bartram & Ballance, 1996). Sediment accumulation can be harmful to sensitive aquatic environments because it reduces light, it changes the bed condition, it alters electrolytes and reduces survival rates on some aquatic organisms like mussels (Ellis, 1936). Sediment accumulation rates (SAR) are used to evidence the impacts of sediment runoff in aquatic ecosystems.

Swales et al. (2005) determined the sedimentation history of the Pauatahanui Inlet using pollen dating and Beryllium, Caesium, and Lead radioisotope analysis in sediment cores. Radioisotopes concentrations were estimated by high resolution, low level gamma ray spectrometry (Swales et al. 2005). For their analysis Swales et al. (2005) describe four time periods: pre-1850, from 1850-1950, 1950-1985 and post 1985. In their study Swales et al. (2005) determined that the Pauatahanui Inlet is an extremely dynamic sedimentary environment, evidenced by the rapid mixing of the upper 5 cm subtidal sediments by physical and biological processes. They also found that accumulation rates have already increased. Before human intervention (pre-1850) SAR were estimated to be 1mm/yr. During the 150 years of the New Zealand’s colonization period SAR increased to 3.4mm/yr, and in the last 20 years (Post-1985) SAR reached 4.6mm/yr. Consequently sediment loading has also increased (Table 3). Sediment loads for the Pauatahanui inlet are 17,000 tonnes per year at a rate of 160 tonnes per km^2 (Swales et al., 2005).

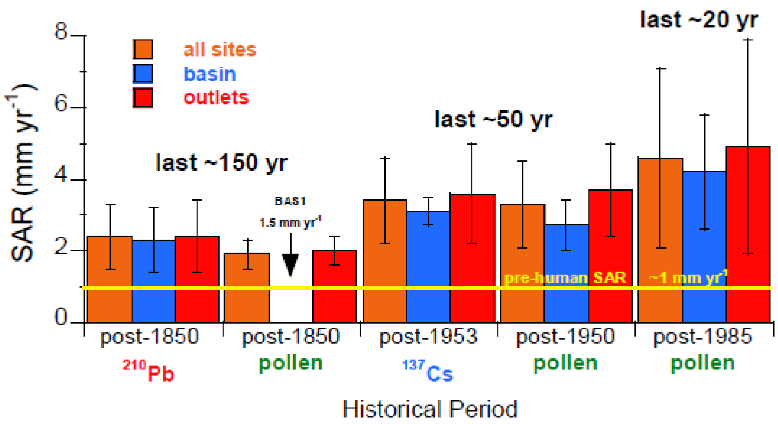


Figure 2. Sediment accumulation rates. Source: Swales et al. (2005)

Table 3. Sedimentation Accumulation Rates and Sediment Loading. Source: Swales et al. (2005)

Time Period	SAR ($mm\ yr^{-1}$)	Sed. Volume (m^3)	Dry Bulk[1] Density ($g\ cm^{-3}$)	Sed. Load (tonnes)	Sed. Load [2] ($t\ km^{-2}\ yr^{-1}$)
Pre-1850	1	3700	1.37 (*0.14, 24*)	~5,000	~50
Post-1850	2.4	8900	1.09 (*0.28, 83*)	~9,700	~90
Post-1950	3.4	12600	1.05 (*0.28, 55*)	~13,000	~120
Post-1985	4.6	17000	1.01 (*0.30, 39*)	~17,000	~160

Gibb (2011) described the sedimentation zones of the inlet and their sources (Figure 3). He found that the largest sedimentation zone is the central mud basin, which is affected by mixed suspended sediment flowing from streams during floods. The other zones have less sedimentation rates than the central mud basin.

These findings show that the Pauatahanui Catchment sedimentation processes are being strongly impacted by the land cover changes in the catchment. Even though urban land cover is estimated to be less than 4% of the total catchment area, it is expected that the forestry industry also have the potential to increase sediment loading to the inlet in the next 15 years (Swales et al., 2005).

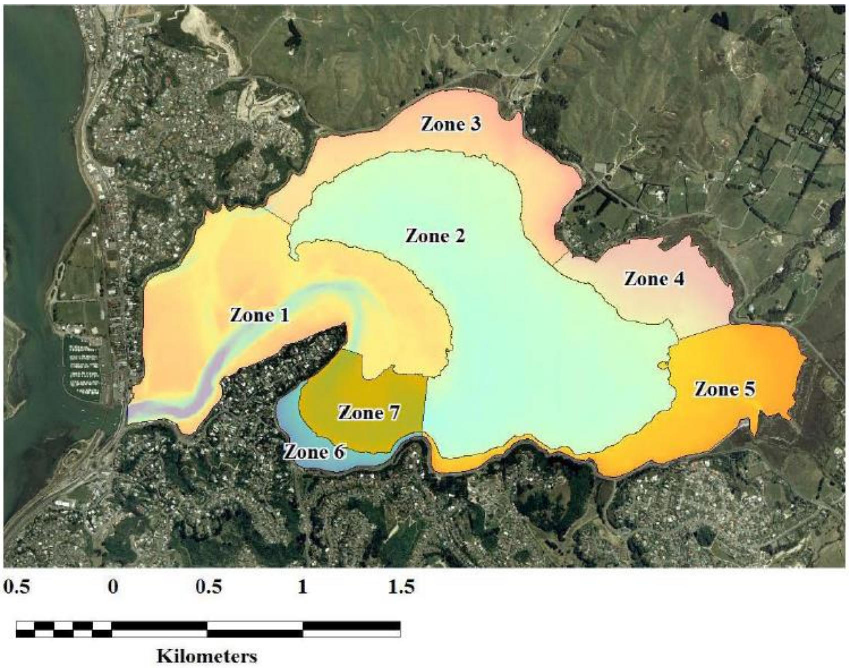


Figure 3. Sedimentation Zones described by Gibb 2011, Zone 2, the central mud basin presents the highest sedimentation rates.

Table 4. Sedimentation Zones and their Relative Size to the Inlet. Source: Gibb (2011).

Zones	Area m2	% Inlet Area	Major Sediment Source
1	1,171,437	25.4%	Ebb-Tide delta
2	1,746,993	37.9%	All Streams
3	482,226	10.5%	Kakaho
4	317,345	6.9%	Horokiri
5	520,382	11.3%	Pauatahanui Stream
6	104,575	2.3%	Browns Bay
7	264,806	5.7%	Browns Bay
Total Area	**4,607,764**		

Contaminants from Road Runoff

Road runoff is a major source of organic and inorganic contaminants affecting aquatic environments. Road runoff carries particles from motor vehicles, road surface, , buildings, construction, house roofs, as well as organic debris from industrial and human activities (Mills & Willliamson, 2008). Particulates will accumulate depending on the depositional characteristics of the ecosystem (Gardiner & Armstrong, 2007a). If the environment is depositional and subject to reduced water movement, it will be prone to accumulate contaminants at ecologically significant levels (Gardiner & Armstrong, 2007a). Identifying the sources of contaminants allows application of mitigation measures to reduce and manage contaminants loads and impacts on downstream ecosystems (Mills & Willliamson, 2008).

Inorganic contaminants

Heavy metals are present in road surfaces, vehicle paints, engine additives, brake wear, tyres, fuels, oils and exhaust emissions (Gardiner & Armstrong, 2007b). Heavy metals can travel dissolved in stormwater runoff chemically or physically attached to sediment particles (Gardiner & Armstrong, 2007b). Kennedy (2003) has extensively described the inorganic contaminants deriving from road runoff which are summarized in Table 5. These studies indicate that most of the copper present in road runoff comes from brake wear and Zinc derives from tyre wear.

Table 5. Inorganic contaminants from vehicles present in stormwater road runoff. Based on Kennedy (2003)

Source	Contaminants
Fuel	Cd, Cr, Ni, Zn and V coming from petroleum.
Engine	Oil, grease and additives. Coolants, air conditioning refrigerants, Hydraulics, sealants. (metals found on these include Fe, Cd, Cu, As, Hg and Pb
Brake pads	These are complex source due to the variety of pads in the market, but the most important are Ba, Cu, Cr, Ni and Zn. Other elements are Pb, Sb, Ti and Zr.
Tyres	Zn is the most significant inorganic element in tyres.
Catalytic converters	Pt, Pd and Rh are used to reduce emissions from hydrocarbons and NOx and CO.
Road surface	Concrete from walls contains Ni, Cr, Ag and Tl. Bitumen has a fairly amount of Cr, Cu, Ni.
Vehicle body	Plasticisers, paintwork, metal corrosion, windscreen washer, wax, battery fluids and cargo losses.

Heavy Metal Concentrations in the Pauatahanui Inlet

The key contaminants from road runoff found in the Pauatahanui Inlet sediment are the heavy metals Zinc, Copper, and Lead. Concentration values shown in Table 7 represent the range from lower to upper concentrations of the metals found presently in sediment. The concentrations were obtained by Swales et al. (2005) using Inductively-Couple Plasma Mass Spectrometry from acid extractions of 1 gm dried sediment samples. These values appear to be well below the recommended Interim Sediment Quality Guidelines (ISQG) for freshwater ecosystems shown in Table 8 (ANZECC, 2000).

Table 6. Concentration of Heavy Metals found in the sediments of the Pauatahanui Inlet. Source: Swales et al. 2005

Heavy Metal Concentration in mg/kg		
Cu	8 – 13	mg/kg
Pb	15 – 26	mg/kg
Zn	55 – 90	mg/kg

Table 7. Interim Sediment Quality Guidelines. Source. ANZECC, 2000

Metal	ISQG - Low	ISQG - High
	mg/kg dry wt	
Cu	65	270
Pb	50	220
Zn	200	410
PAH µg/kg	4000	45000

Organic contaminants

Combustion emissions are the main source of Polycyclic Aromatic Hydrocarbons (PAHs) and volatile organic compounds (VOCs) (Kennedy, 2003). PAHs include a wide variety of five and six carbon ringed molecules that are severely harmful to the environment. They are carcinogenic, mutagenic and toxic for reproduction (ATSDR, 1995). PAHs result from incomplete combustion of fossil fuels and can bioaccumulate on aquatic organisms. PAH of low molecular weight have a high solubility in water although the bigger molecules are lipophilic in nature.

Other contaminants

Road dust can potentially be a source of particulate contaminants. It has been shown that road dust can contain significant concentrations of heavy metals PAHs, PCBs and DDTs. Even though the use of DDT was banned in the 1970's Blaschke (2010) reports DDT concentrations in several streams in the Porirua Catchment above the ANZECC "low" trigger value. It is assumed that urban areas where the chemical was still used in the 1980's could be a significant remaining source that is likely to continue to input into the inlet. Other important pollutants could be organochlorine pesticides, fertilizers, particulate debris from rubber and ferromagnetic material. These are listed in Table 6.

Table 8. Other Important Sources of Contamination in Road Runoff from Urban Environments. Based on Mills & Williamson, 2008.

Potential Sources of Contaminants affecting the Pauatahanui Inlet Catchment Area.	
Metals	Cd, Fe, Cr, Ni, Sb, Pt, Mo
Herbicides, pesticides, fungicides	Dieldring
	Chlordane
	Lindane
	heptachlor
	DDT
Plasticisers	PCBs have also been used in wide range of products such as plasticizers, surface coatings, inks, adhesives, flame-retardants, paints, and carbonless duplicating paper
Particulates	Fragments of rubber and metals (rust and ferromagnetic material). Paper, glass, plastic and other debris
Hydrocarbons	Polybrominated diphenyl ethers PBDE, chlorinated dioxines and furans.

Microbial contamination from rural runoff could also be affecting the Inlet (Blaschke, 2010). Streams draining the Porirua catchment into the inlet carry nutrients and faecal coliforms from stock, piggeries and chicken farms. The other major source of microbial contamination is sewage. Blaschke (2010) reports occasional high counts of faecal contamination in several streams of the Pauatahanui Inlet catchment, and attributes it to uncontrolled leaks from sewage piping.

Toxicity

Copper, lead and zinc are considered toxic elements because they can bioaccumulate in aquatic organisms (El-Nemr, 2010). Because they are part of biochemical process in living organisms, they can have negative effects in high quantities (El-Nemr, 2010). PAHs are considered carcinogenic (ATSDR, 1995). Even though the fraction of road runoff might be significantly low in terms of toxicity, long-term exposures may pose a risk to freshwater organisms. It has been tested that the first flush after a rainfall event has the highest toxicity potential for aquatic environments (Milne & Watts, 2008). In the Pauatahanui inlet the cockle community has been used as an indicator species of pollution (Michael & Wells, 2014). So far the studies show that cockle populations are stable and increasing. This suggest that the environmental conditions of the Pauatahanui inlet are in good state (Michael & Wells, 2014).

Contaminant Load in the Pauatahanui Inlet

To estimate the current contaminant loading on the inlet we used the volumetric mass density equation. The volume for the 0.05 m of the inlet surface was estimated using an area value of 4.607 km^2 reported by Gibb, (2011). Sediment density was assumed to be $1gm/cm^3$.

$$CL = [metal]\ x\ \ \rho\ x\ V$$

ρ= density $1gm/cm^3$
V = volume 230,338 m^3
[metal] = concentration
CL = contaminant load

The total contaminant load estimated for the Pauatahanui Inlet is presented in Table 9. These values represent the baseline amount in Kg of contaminants that have been deposited in the Inlet. The specific source of the present contaminant loads cannot be assessed but are assumed to be urban and rural runoff. Zinc is the metal present in highest quantities that range from 12,671 - 20,734 kg. Lead is present in the range of 3,455 – 5,990 kg and copper is currently present in a range of 1,843 - 2,995 kg.

Table 9. Present contaminant load in the Pauatahanui Inlet for high and low concentrations values for a volume of 230,338 m^3.

Contaminant Loads		
[Cu] -	**1,843.11**	**kg**
[Cu]+	**2,995.05**	**kg**
[Pb]-	**3,455.82**	**kg**
[Pb]+	**5,990.09**	**kg**
[Zn]-	**12,671.35**	**kg**
[Zn]+	**20,734.94**	**kg**

Contaminant Loads from Road Runoff

To assess the impacts of the road runoff on aquatic environments, vehicle contamination load models have been developed for New Zealand (Mills & Willliamson, 2008). These models use vehicle emission factors as a function of traffic density expressed in units of mg per VKT. Vehicle emission factors are estimations of the amount of contaminants (Cu, Pb or Zn) deriving from engines, exhausts and brake pads from a vehicle per kilometre of road. Emission factors have been estimated for the New Zealand vehicle fleet by Kennedy (2003). Estimations on vehicle emission factors have a degree of uncertainty which is why for the purpose of our analysis we use the lowest and highest values reported in the literature. Table 10 shows the emission factors used in the present study.

Here contaminant load is estimated as the product of the AADT by the road length and the vehicle emission factors. The contaminant load from road runoff is a measure of annual mass loads in kg per VKT per year (Gardiner & Armstrong, 2007a). An example of the procedure for the estimation of the vehicle contaminant load is presented in appendix 1.

$$VCL \ = AADT\ x\ Road\ Length\ x\ \ V.E.F.$$

VCL = Vehicle contaminant load
AADT = Average Daily Traffic Volume
VEF = Vehicle Emission Factors

Table 10. Vehicle emission factors. Source: Kennedy (2002) and Timperley (2003).

Vehicle emission factors		
Cu -	0.06	mg/km
Cu +	0.16	mg/km
Lead -	0.05	mg/km
Lead +	0.11	mg/km
Zinc -	0.45	mg/km
Zinc +	0.18	mg/km
PAH -	0.014	mg/km
PAH +	0.06	mg/km

Present contaminant loads from road runoff

The results from the Vehicle Contaminant Load estimation are presented in Figure 4. The complete dataset is included in the appendix. Currently the annual contaminant contribution from road runoff to the inlet is estimated to be in the range of 6 – 15 kg km^{-1} yr^{-1} of copper, 5-11 kg km^{-1} yr^{-1} of lead, 17-220 kg $km^{-1}yr^{-1}$ of zinc and 1-8 kg km^{-1} yr^{-1} of PAHs.

Expected contaminant loads from the construction of transmission gully.

Based on the projected data for 2016, a two fold increase in heavy metals and PAHs is expected from road runoff as a result of the construction of the Transmission Gully Motorway (Figure 4). The expected annual contaminant loads that will affect the inlet are in a range of 12-33 kg km^{-1} yr^{-1} for copper, 9-22 kg km^{-1} yr^{-1} for lead, 37-475 kg km^{-1} yr^{-1} for zinc and 2-16 kg km^{-1} yr^{-1} for PAHs.

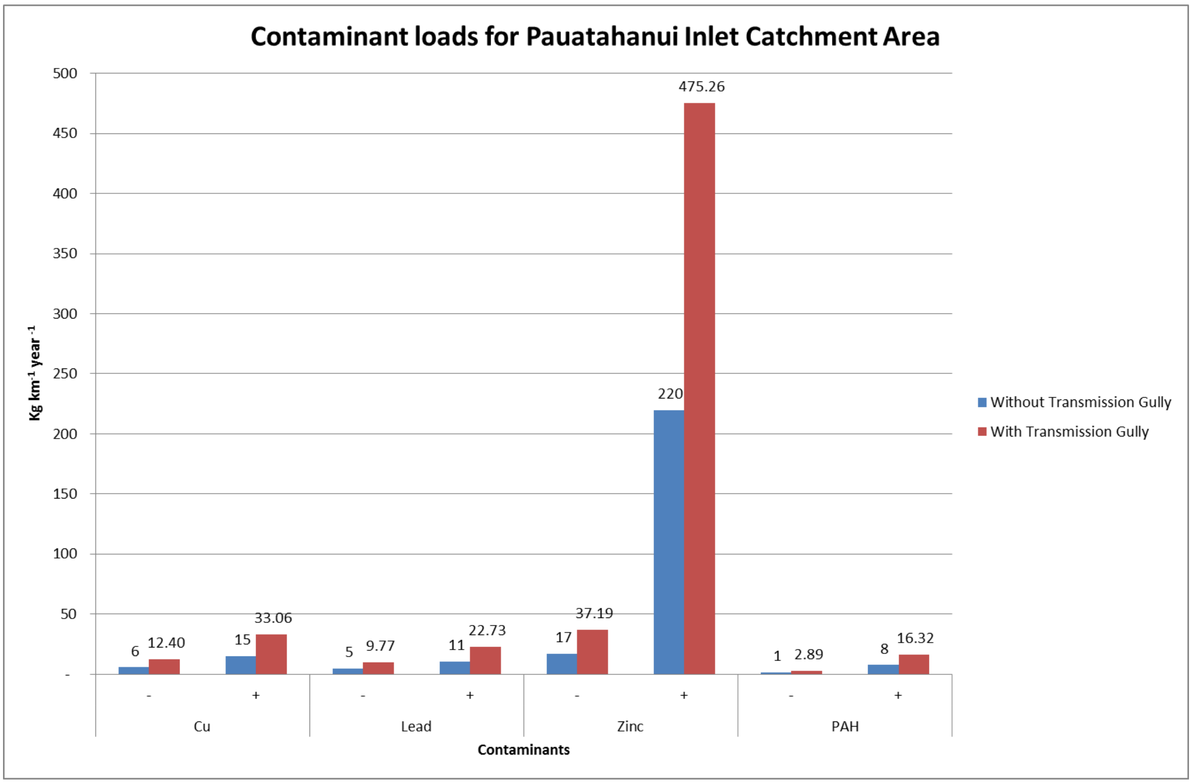


Figure 4. Expected contaminant loads from the construction of the Transmission Gully Motorway. Plus and minus signs represent highest and lowest values respectively.

Discussion

Presently urban and rural runoffs are the main sources of contaminants into the Pauatahanui inlet. Stormwater runoff from urban areas carries most of the contaminants of concern that are affecting the Pauatahanui Inlet. Heavy metals, Zinc, Lead, and Copper as well as PAHs are the quantitative significant contaminants present in road runoff. The sources of these are vehicle emissions deposited in roads and particles deriving from urban infrastructure.

The evidence found by Swales is helpful describing the inlet's sedimentation process. From his analysis it can be seen that the inlet is an active depositional environment with sediment accumulation rates of 4.6 mm $year^{-1}$. The sediment load to the inlet is 17,000 tonnes at a rate of 160 tonnes km^{-2} $year^{-1}$.

The present heavy metal concentrations found in the inlet are well below the Interim Sediment Quality Guidelines for New Zealand (ANZECC, 2000). From these, the most significant contaminant is Zinc and is found in concentrations of 55 – 90 mg/kg. Reported ranges of concentrations in other studies that breach ISQG are in the range of 130 – 2700 mg/kg of zinc. High levels of zinc in the Pauatahanui Inlet could originate from the present traffic loading, galvanized house roofs and other urban elements. This has also been suggested for the aquatic environments in Auckland (Mills & Willliamson, 2008). It can be concluded that the environmental quality of the inlet is in good state. The increase in cockle population could also provide evidence because cockle are sensitive to environmental changes in the sediment (Michael & Wells, 2014).

The relative contribution of copper and lead from road runoff in to the PICA is currently less than 0.5 % of the total contaminant load found in the 5 cm of the inlet's sediment. For zinc the current relative contribution is 1%.

An increment of 116% in vehicle kilometres travelled is expected to occur once the Transmission Gully Motorway is constructed; consequently a twofold increment in the heavy metal and PAHs contaminant loads is expected to affect the Pauatahanui Inlet Catchment Area. This increment represents less than 1% of copper and lead of the baseline contaminant load found in the inlet currently. For Zinc it could represent up to 2%. PAHs baseline values could not be obtained, but the estimated contaminant loads deriving from road runoff are expected to double. Figure 5 shows the relative contribution of the present and expected vehicle contaminant loads to the current contaminant load of the inlet.

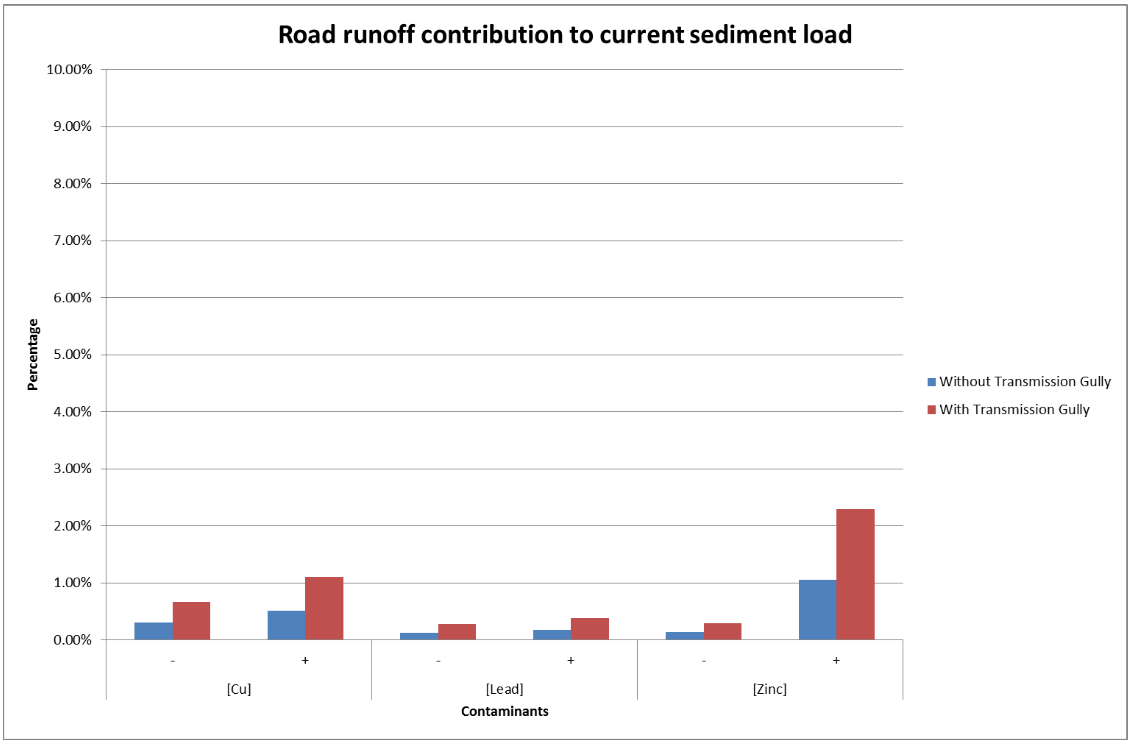


Figure 5. Road runoff contaminant loads contribution to the inlet sediment.

The current and expected values for the PICA are very low and would not have potential toxic effects, however vehicle contaminant load models are influenced by road characteristics, drainage, climate, rainfall, driving conditions, the pathway taken by the road runoff, and assumptions on pollutants emission factors which were not considered in the present analysis. Vehicle emission factors have a high degree of uncertainty which is why these results are presented in ranges instead of average data.

Also contaminants loads from road runoff would be diluted over the catchment area. This could mean that actual loads reaching the inlet would be lower. However, long term exposure to heavy metals can be a threat to depositional ecosystems and It has been shown that first flush from rainfall events present metal concentrations above ANZECC ISQG trigger values that can be toxic to aquatic organisms (Milne & Watts, 2008). Recommendations for mitigation measures are presented in the recommendation section of this report.

As for other contaminants found in this study the rivers in the catchment deliver most of the organic contaminants product of changes in land use. Evidence of DDT has been found in some rivers affecting the inlet and it has been suggested that traces of this compound used in urban areas after it was banned could be still contributing to the area (Blaschke, 2010).

Conclusions

1. The total length of roads that affect the inlet will increase from 33 km to 56 km. Projected data from the NZTA predicts a reduction in AADT. However traffic loading expressed as VKT in the PICA will increase in 116% once the motorway is operational (year 2026).
2. The sedimentation history analysed by Swales et al. (2005) describes the inlet as extremely dynamic sedimentary environment. Sediment accumulation rates are 4.6 mm year^{-1} and sediment loading is 17,000 tonnes at a rate of 160 tonnes per km^{-1} year^{-1}.
3. The key contaminants coming from vehicles and roads affecting the Pauatahanui Catchment Area are lead, copper, zinc and polycyclic aromatic hydrocarbons. The concentrations values for these contaminants are below the ANZECC ISQG trigger values for New Zealand.
4. Total contaminant loads present in the 5 cm surface of the inlet's sediment are estimated to be in the range of 1,843 -2,995 kg for copper; 3,455 – 5,990 kg for lead and 12,671 - 20,734 kg for Zinc.
5. Current contaminant loads deriving from road runoff are estimated to be in the range of 6 – 15 kg yr^{-1} km^{-1} of copper, 5-11 kg yr^{-1} km^{-1} of lead, 17-220 kg yr^{-1} km^{-1} of zinc and 1-8 kg yr^{-1} km^{-1} of PAHs.
6. Contaminant loading expected to be available for road runoff as a result of the construction of the Transmission Gully Motorway are in a range of 12-33 kg km^{-1} yr^{-1} for copper, 9-22 kg km^{-1} yr^{-1} for lead, 37-475 kg km^{-1} yr^{-1} for zinc and 2-16 kg km^{-1} yr^{-1} for PAHs
7. The relative contribution of copper and lead from road runoff in the PICA represent less than 0.5 % of the total contaminant load found in the 5 cm of the inlet's sediment. Once the TGM is constructed these values will increase but will not exceed 1% of the total. For zinc the relative contribution from road runoff to the inlets sediment currently is 1% but this will increase to 2% once the TGM is operational.

8. Increments in contaminants loads expected from TGM will not reach toxic levels however it has been shown that first flush from rainfall events increment heavy metal concentrations in stormwater runoff to levels higher than trigger values.
9. Evidence of DDT has been found in some rivers affecting the inlet and it has been suggested that traces of this compound used in urban areas after it was banned could still be contributing to runoff draining into the inlet (Blaschke, 2010).

Recommendations

To reduce the probability of contaminants and sedimentation increasing in the rivers and streams of the Pauatahanui Inlet Catchment Area, it is suggested that several mitigation measures are taken. These can be categorized as point source devices near the Transmission Gully Motorway and sedimentation control devices near rivers and streams. Point source devices are suggested as the most important mitigation measures because they are the first stage in the reduction of contaminants from first flush rainfall events. These can be integrated into the motorway infrastructure using landscaping methods. Catchpits are usually the most common sediment traps in roads and stop objects and debris to drain into the stormwater runoff. Culverts are transport devices to conduct stormwater runoff under the roadway and are also used to allow natural streams to pass under a motorway. Artificial Wetlands**,** are constructed shallow ponds with vegetation which remove contaminants through biological processes. Swales and grass channels are effective in sites with gentle slopes and they remove stormwater contaminants through the slow movement of stormwater through vegetation. Rain Gardens function as filtration devices that use plants and soil to remove contaminants from urban stormwater and can be incorporated into the landscaping architecture of a highway. Filtration systems made of concrete tanks with filtration media like sands, can be used to collect stormwater in a settling chamber.

As a secondary measure to protect rivers and streams water quality that drain into the Pauatahanui Inlet it is suggested that sediment traps near streams and rivers should be constructed. Also water quality ponds can be constructed to store temporary runoff after rain events and remove contaminants through sedimentation. As an additional measure a sediment and water quality monitoring program is should be maintained in the Pauatahanui Inlet Catchment Area to detect any important changes in water quality that may breach ANZECC IQGS trigger values.

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Appendix 1 Calculations

Calculations for contaminant loads

The contaminant load for copper in the upper 5 cm of the inlet sediment including unit conversions is:

$$CL = [metal]\ x\ \ \rho\ x\ V$$

ρ= density 1gm/cm^3
V = volume 230,338 m^3
[metal] = concentration
CL = contaminant load

$$CL_{Cu} = \frac{8\ mg\ Cu}{kg\ sed.}\ x\ \frac{1gm\ Cu}{1000mg\ Cu}\ x\ \frac{1gm\ sed}{cm^3}\ x\ \frac{1kg\ sed}{1000gm\ sed}\ x\ \frac{1{,}000{,}000cm^3}{1m^3}\ x\ 230{,}338\ m^3$$

$$CL = 1{,}843.11\ kg$$

Estimation of vehicle contaminant loads using AADT, Road Length and Vehicle Emission Factors.

$$VCL\ = AADT\ x\ Road\ Length\ x\ \ V.E.F.$$

$$VCL_{SH1} = 20{,}500\ vehicles\ x\ 2\ km\ x\ \frac{0.06\ mg}{km} = 2460\ \frac{mg}{km \cdot day}$$

$$= 2460\ \frac{mg}{km \cdot day}\ x\ 365\ days$$

$$= 0.89\ \frac{kg}{km \cdot yr}$$

Where SH1 = portion of state highway 1 in the catchment area.

Appendix 2 Datasets

Data Inputs		
Inlet Total Area	4,607,764.00	m^2
Height	0.05	m
Sediment density	1.00	g/cm^3
1 m3 =	1,000,000.00	cm^3
1 gm =	1,000,000.00	µg
Inlet Volume	230,388.20	m^3

Heavy Metal Concentration		
Cu	8.00	µg/g
Cu	13.00	µg/g
Pb	15.00	µg/g
Pb	26.00	µg/g
Zn	55.00	µg/g
Zn	90.00	µg/g

Contaminant Loads = [Metal] x Sediment Dens. x Volume				
[Cu]	1,843,105.60	gm	**1,843.11**	**kg**
[Cu]	2,995,046.60	gm	**2,995.05**	**kg**
[Pb]	3,455,823.00	gm	**3,455.82**	**kg**
[Pb]	5,990,093.20	gm	**5,990.09**	**kg**
[Zn]	12,671,351.00	gm	**12,671.35**	**kg**
[Zn]	20,734,938.00	gm	**20,734.94**	**kg**

Without Transmission Gully				**Contaminant Load per VKT**							
	Average Daily			**Cu**		**Lead**		**Zinc**		**PAH**	
Roads	**Traffic Volume**	**Km**	**VKT**	**-**	**+**	**-**	**+**	**-**	**+**	**-**	**+**
SH1 Mana Esplanade	32,600	2.00	65,200	3,912	10,432	3,084	7,172	11,736	149,960	913	5,151
SH58 East of Paremata	18,100	4.91	88,817	5,329	14,211	4,201	9,770	15,987	204,278	1,243	7,017
Grays Road, East of SH1	5,500	5.59	30,745	1,845	4,919	1,454	3,382	5,534	70,714	430	2,429
SH58 West	14,600	3.80	55,480	3,329	8,877	2,624	6,103	9,986	127,604	777	4,383
Paekakiriki Hill Road	1,300	16.61	21,590	1,295	3,454	1,021	2,375	3,886	49,658	302	1,706
Total	**72,100**	**32.91**	**261,832**	15,710	41,893	12,385	28,802	47,130	602,214	3,666	20,685
Total Kg per Year (total x 365)				**5.73**	**15.29**	**4.52**	**10.51**	**17.20**	**219.81**	**1.34**	**7.55**

With Transmission Gully				**Contaminant Load per VKT**							
	Average Daily			**Cu**		**Lead**		**Zinc**		**PAH**	
Roads	**Traffic Volume**	**Km**	**VKT**	**-**	**+**	**-**	**+**	**-**	**+**	**-**	**+**
SH1 Mana Esplanade	20,500	2.00	41,000.00	2,460	6,560	1,939	4,510	7,380	94,300	574	3,239
SH58 East of Paremata	12,600	4.91	61,828.20	3,710	9,893	2,924	6,801	11,129	142,205	866	4,884
Grays Road, East of SH1	1,900	5.59	10,621.00	637	1,699	502	1,168	1,912	24,428	149	839
SH58 West	8,700	3.80	33,060.00	1,984	5,290	1,564	3,637	5,951	76,038	463	2,612
Paekakiriki Hill Road	500	16.61	8,304.00	498	1,329	393	913	1,495	19,099	116	656
Transmission Gully	20,000	20.00	400,000.00	24,000	64,000	18,920	44,000	72,000	920,000	5,600	31,600
Whitby Link Road	3,400	0.90	3,060.00	184	490	145	337	551	7,038	43	242
Waitangirua Link Road	3,300	2.50	8,250.00	495	1,320	390	908	1,485	18,975	116	652
Total	**70,900**	**56.31**	**566,123.20**	33,967.39	90,579.71	26,777.63	62,273.55	101,902.18	1,302,083.36	7,925.72	44,723.73
Kg per Year (total x 365)				**12.40**	**33.06**	**9.77**	**22.73**	**37.19**	**475.26**	**2.89**	**16.32**