BEFORE COMMISSIONERS APPOINTED BY THE NELSON CITY COUNCIL

IN THE MATTER OF	Applications for resource consent under the Resource Management Act 1991
AND IN THE MATTER OF	The aberrational discharge of sewage from Nelson Sewerage Business Unit (NSRBU) Pump Stations

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STATEMENT OF EVIDENCE OF NEALE ALAN HUDSON

Dated 27 November 2017

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1 INTRODUCTION

1.1 My full name is Neale Alan Hudson. I am an Environmental Chemist at the National Institute of Water and Atmospheric Research Limited.

1.2 I have a PhD in Environmental Chemistry from Queensland University of Technology, and more than 20 years' experience in the areas of emission processes, water quality, waste management and environmental management.

1.3 I was the first author of Hudson and McBride (2017), Hudson (2017), and Hudson and Wadhwa (2017).

1.4 I have read the Code of Conduct for expert witnesses issued as part of the Environment Court Practice Note. I agree to comply with the Code of Conduct. I am satisfied that the matters addressed in this statement of evidence are within my expertise. I am not aware of any material facts that have either been omitted or might alter or detract from the opinions expressed in this statement of evidence.

2 SUMMARY

2.1 I confirm that the findings and approach summarised in the technical reports associated with this consent application - Hudson and McBride (2017), Hudson (2017), and Hudson and Wadhwa (2017). are still current and valid.

Key findings from Hudson and McBride (2017)

<u>Quantitative Microbial Risk Assessment (QMRA)</u>

2.2 Using QMRA, it is possible to estimate the human health risk arising from discharge of raw sewage from pump stations for several scenarios according to:

(a) Selected model pathogens (in this case norovirus);

(b) Typical virus concentrations in raw sewage;

(c) Commonly-accepted water ingestion rates for recreational water users (swimmers), adjusted for child receptors, and

(d) A range of relative sewage dilution rates.

2.3 The Individual Illness Risk levels calculated for a group of recreational users exposed on any random occasion indicate:

(a) If negligible virus inactivation and attenuation occurs,

(i) at least 15,000× dilution is required to reduce the concentration of virus below the “no observable adverse effects level” (NOAEL) of 1% gastrointestinal illness (GI) risk,

(ii) at least 2,500× dilution is required to reduce the concentration of virus below the level of 5% GI risk, and

(iii) approximately 800× dilution is required to reduce the concentration of virus below the level of 10% GI risk.

(b) These risk levels are consistent with those defined in Section H of the MfE/MoH (2003) guidelines for marine waters containing:

(i) Less than 40 enterococci/ per 100 mL (NOAEL)

(ii) 40 to ≤ 200 enterococci per 100 mL (1-5% GI risk), and

(iii) 201 to ≤ 500 enterococci per 100 mL (<10% GI risk), respectively.

(iv) Should virus aggregation occur, at least 150x dilution is required to reduce the concentration of virus below the same “no observable effects level” of 1% gastrointestinal illness risk.

2.4 Combining the risk levels arising from pathogen concentrations with the output of a calibrated hydrodynamic model, enabled me to represent the mixing, dilution and advection of contaminants within and adjacent to the

Waimea Inlet. These results were summarised in Hudson and Wadhwa (2017), summarised in Section 2.8.

Receiving Environment

2.5 Separately, available microbiological monitoring data (using enterococci, a Faecal Indicator Bacteria (FIB) species) were assessed to characterise the receiving environment (Hudson 2017):

(a) Recreational water quality data indicate:

(v) the illness risk associated with undertaking contact recreation in the Waimea Inlet and other sites in the Nelson City Council jurisdictional area is generally in a range from 1-5% risk (GI illness), increasing at times to 5-10% GI illness risk.

(vi) These illness risks are general illness risks, unrelated to specific events, i.e., they indicate that undertaking recreation in these waters generally has a measurable risk, and these waters would be graded either B or C in terms of the MfE/MoH 2003 guidelines.

(vii) The Guidelines also recommend that a Sanitary Inspection is undertaken when grading recreational water quality. The Sanitary Inspection further qualifies the microbiological results by taking proximity to an urban area, where storm water discharges are likely to increase health risks.

(b) Assessment of data derived from storm-event sampling in creeks and streams discharging into the Waimea Inlet suggest that the load of FIB discharged into the Inlet may be of similar magnitude to that discharged from the Bell Island WWTP, and is likely to impact adversely on recreational water quality in the Inlet.

(c) Data collected to characterise microbiological water quality in the Waimea Inlet during winter 2017 indicated that 32% of samples exceeded the 'Amber" single sample threshold (140 enterococci per 100 mL), and 25% exceeded the "Red" single sample threshold (280 enterococci per 100 mL). [1] Recreational survey results of this nature would elicit follow-up response (resampling), and if necessary, erection of signs or other appropriate responses.

Key findings from Hudson and Wadhwa (2017):

2.6 Using several variables to define a series of highly conservative aberrational discharge events, the spatial extent of the concentration contours defined in Section 2.3 were estimated using a calibrated hydrodynamic model (described by MetOcean (2017)).

2.7 The model scenarios are summarised in Table 1.

(a) Two river conditions were selected for the modelling – wet and dry catchment conditions (90th and 15th percentile flow estimates).

(b) "Peak" and "dry flow" discharge rate estimates were selected for the four pump stations as well – these were equivalent to the largest estimated discharge from each of the pump stations under wet- and dry weather flow conditions.

(c) In all cases the duration of discharge selected was four hours, which was as large or larger than historical discharges from any of the pump stations.

2.8 My assessment indicates:

[1] These guideline values are not legislated standards with which compliance is required. "Green" status indicates that the water is highly likely to be uncontaminated, and suitable for bathing. "Amber" indicates potential contamination, and signals that further investigation is required to assess suitability for recreation. "Red" indicates that water is highly likely to be contaminated, highly likely to be unsuitable for recreation, and signals that urgent action is required from resource managers, such as public warnings (MfE/MoH 2003 guidelines, page C3).

(a) Illness risks associated with pump station discharges are generally likely to be less than 1% (the No Observable Adverse Effects Level, NOAEL) across most of the Inlet, both during and following a discharge event, i.e., contamination tends to be localised.

(b) Under conditions created by selected discharge scenarios, and for discharges from specific pump stations, the illness risks may exceed the 1% effects level threshold, at specific locations:

(i) High illness risk (>10% GI illness) areas were primarily associated with drainage channels and depressions where untreated sewage may accumulate, i.e., the spatial extents were relatively small. These tended to occur close to the discharge point, extending along the drainage channels.

(ii) Moderate illness risk (5-10% GI illness) was associated with the drainage channels, and some areas of the adjacent intertidal flats. Factors such as tidal stage and wind increasingly determines the extent to which the inter-tidal flats are contaminated. These levels of dilution may occur along the shoreline under specific conditions.

(iii) Low illness risk (1-5% GI illness) was associated with the intertidal flats, and drainage channels distant from the discharge points. These areas were also most prone to tidal stage and wind effects. They also occurred in areas likely to be accessible to the public, including the southern shoreline of the Monaco Peninsular, the southern shore of the Waimea inlet, and the north-eastern corner of the inlet, along Wakatu Drive and Point Road.

3 KEY FINDINGS IN TERMS OF MICROBIAL RISK ASSESSMENT

Measured microbial water quality

3.1 Available water quality data for the Waimea Inlet indicate that measurable health risk exists at a representative site in Waimea Inlet and at several down-current sites used for recreational bathing. These risks are not excessive – in recent seasons, these sites have generally been classified as B and C in terms of the Microbiological Assessment Category (MAC) guidelines (MfE/MoH 2003).

3.2 Although I do not have access to a recent Sanitary Inspection Category (SIC), known contaminant sources (urban runoff, streams draining catchments with some stock etc.) are likely to impair water quality during storm events. Recent storm sampling of runoff demonstrated significant FIB loads (NCC 2013, Hudson 2017) and identifies potential sources of faecal contamination, and requires assessment of the likelihood of an effect.

3.3 Combining the MAC with the SIC provides an overall suitability for recreation grade (MfE/MoH 2003). Sites with generally low FIB concentrations but which may be subject periodically to storm runoff are generally downgraded in terms of suitability for recreation, say from "Good" to "Fair". Such downgrading is common to urban areas. Resource managers and health agencies react to these periodic impairment events through increased surveillance monitoring, and notification of water users and community groups when such events occur.

Discharge scenarios selected for modelling

3.4 The discharge scenarios selected were purposefully conservative, representing i) discharge durations greater than the longest one known to have occurred, ii) rates of sewage discharge greater than the largest known discharge rate for each pump station, iii) high contaminant loading within the wastewater, and iv) ignoring on-site wet-well storage capacity.

3.5 The ambient conditions selected for the dispersion modelling also represent moderate and more extreme conditions, the latter intended to allow risks to be assessed for infrequent events. For example, river flow conditions represent dry weather flows, as well as extreme wet weather flows – the latter are known to mobilise particulate materials (including pathogens) from urban and rural catchments, e.g. (NCC 2013, Hudson 2017).

3.6 Incorporating these assumptions into the dispersion modelling scenario designs predicts pathogen concentrations conservatively (i.e. biases predictions toward the high end of likely pathogen concentrations), while ensuring that they remain realistic. This approach is appropriate given the nature of the potential contaminants (pathogenic organisms), and severe health sequelae arising from exposure, infection and illness.

The QMRA process

3.7 The QMRA allows the risk arising from exposure to potentially contaminated water to be assessed for a range of potential aberrant discharge scenarios – as detailed in sections 3.4 and 3.5, conservative scenarios were purposefully selected.

3.8 The QMRA process is also purposefully conservative, recognising the severe health sequelae associated with exposure to pathogens. This was done by i) assuming that the concentrations of the model pathogen were equal to dry-weather wastewater treatment plant inflow concentrations, (which are known to be substantially diluted during peak wet weather flow events), ii) selecting ranges of virus concentrations to represent highly skewed concentration data (i.e. recognising that infrequently, very high pathogen concentrations may occur), iii) incorporating long exposure times (swimming events lasting up to four hours duration were incorporated in the model), and iv) allowing for ingestion of large volumes of potentially contaminated water (using ingestion rates ranging up to 270 mL/hour).

3.9 Incorporating these assumptions into the QMRA scenario designs makes the risk assessment conservative, while ensuring that they remain realistic.

Assessment of areas likely to be contaminated

3.10 QMRA is generally performed for specific locations, where various activities (e.g. shellfish gathering, contact recreation) are known to occur. It might mistakenly be concluded that there is no risk associated with water use at other sites. For the assessment of aberrational discharges however, the likely concentration "footprint" associated with the plume of potentially contaminated water was tracked through time and space. This provided a very detailed view of the areas of the inlet that may potentially be contaminated, as well as the duration over which concentrations that exceeded specific thresholds were likely to occur.

3.11 This presentation of material allowed the likely maximum extent of various concentration contours to be estimated. This approach was chosen because of the very specific, event-based nature of these discharges.

3.12 The dispersion modelling indicates:

(d) Contaminant concentrations (and therefore exposure to high concentrations of contaminants) are greatest near the pump station discharge points and associated drainage channels, decreasing with distance from the discharge points along these channels.

(e) Under calm conditions, contaminants tend to be confined to the channels draining the inlet, in which they remain in diluted but relatively high concentrations, rather than spreading laterally across the intertidal flats to create large areas of contamination.

(f) Under windy, full tide conditions, contaminants are increasingly dispersed locally across the intertidal flats, creating the potential for larger areas of contamination (but at lower concentrations), and for contamination along the Inlet margins.

(g) Dilution and dispersion of the contaminated waters within the Inlet (and therefore of Illness risks) will be influenced by weather conditions at the time of the discharge, to a slightly lesser extent by the tidal stage, and to a much smaller extent, the river flows discharging into the Inlet.

(h) Although relatively elevated pathogen concentrations may occur in the drainage channels and shallow grade areas at the point of discharge, the depth of water in which these concentrations will occur will be relatively shallow under low tide conditions (likely to be less than 500 mm along most of the drainage channel lengths – see Figure 1 for an illustrative example). Exposure to these relatively high concentrations in the channels is therefore likely to be via hand-to-mouth transmission, rather than immersion and ingestion.

3.13 The approach followed demonstrated that discharges from the four pump stations were quite different in terms of the likely extent and duration of effect. This information is considered invaluable to guide planning for the specific management actions that will be required for responses to discharges from any or all of the pump stations.

4 RESPONSES TO S42A REPORTS

4.1 Ms Lojkine and Ms McArthur acknowledge that the approach followed for determining the extent of the plume and associated health risk associated with each of the discharges is reasonable.

4.2 They also acknowledge the 1-5% GI illness risk that generally exists in and near the Inlet, e.g., at Monaco and Tahunanui Beach sites.

4.3 It appears, however, that the very infrequent nature of these aberrant discharges and the very conservative scenario conditions that were selected to describe the dispersion and dilution of the contaminant plume have been under-recognised. Section 3.4 explains why the modelling scenarios selected are conservative (i.e. are biased toward the extremely low probability, large consequence events). The scenario conditions selected also ignore several known mitigation factors, further biasing them toward extremely low probability, large consequence events:

(a) Discharge volumes are very likely to be considerably smaller than those used for these estimates (i.e. the number of pathogens discharged is likely to be considerably smaller, and actual concentrations after dilution much lower).

(b) The duration of the discharge events are likely to be far shorter than the four hours allowed (considerably decreasing the volume of contaminated material and likely concentration of pathogens after dilution).

(c) The scenarios selected do not take into account the wet-well storage that exists at each pump station, which will immediately reduce the volume of contaminated material discharged to the Inlet.

4.4 What was presented in the technical report (Hudson and Wadhwa 2017) and in supplementary materials were the extreme worst-case scenarios. For example, the figure representing the extent of areas likely to be impacted by aberrant discharges (reproduced as Figure 5) is the total area likely to be impacted by the combined contaminant plume arising from a concurrent, worst-case scenario discharge from all four pump stations. The likelihood of such a discharge event occurring is so extremely small that it should be ignored. Further consideration of the different scenario conditions confirms that the contours presented in Figure 5 could not realistically occur – several of the scenario conditions could not co-occur (e.g. discharge under high tide and low tide conditions, southerly and northerly wind directions, wet and dry catchment and sewer flow conditions).

4.5 I consider that the plume extents and durations derived from the QMRA and dispersion modelling should be regarded as indicative of what **could possibly** occur, rather than as predictions of what will realistically occur. When viewed in this light, it alters the likely impact associated with the discharge from the Saxton pump station, for example. Ms McArthur considers it is "high risk" (point 83, page 121) in terms of potential for microbial illness risk effects. This is only true if the highly conservative nature of the modelling, the low frequency of discharge, and the mitigation and management responses are ignored. Once these factors are considered, the likely human health risk is likely to be reduced considerably, and these risks should be manageable using provisions such as those identified in the MfE/MoH guidelines (2003) and the other techniques explained in the evidence of Mr Molloy.

4.6 Both Ms Lojkine (point 5.62, page 29) and Ms McArthur (point 87, page 122) and Mr Molloy consider the use of signage, public notification and other actions identified in the MfE/MoH guidelines to be appropriate. I support this response, but recommend that additional monitoring effort be included as well. Ms McArthur (point 87, page 122) suggests that the inlet may need to be closed for extended periods following a discharge event. This action may be taken following a discharge event, but the duration of closure is best determined from an appropriate monitoring response, similar to what is done for recreational beaches following an exceedance of amber or red threshold concentrations. Once red or amber thresholds are exceeded, follow-up monitoring is undertaken until the illness risk has receded. A similar approach could be implemented following a sewer discharge event.

4.7 Ms McArthur notes that shellfish were not included in the assessment, but comments that reason for excluding shellfish assessment was based on the response of few individuals. I agree that this is the case. However, the proximity of all waters in the Inlet to urban runoff and discharges from streams where rainfall-event faecal contamination occurs suggests that consumption of shellfish from the Inlet is generally likely to have some level of illness risk. Currently no water quality monitoring data exist to demonstrate the level of faecal contamination.

4.8 I note that Mr Molloy has provided further evidence on the efficacy of the public health and response protocols. From his evidence it appears that the low risk that may eventuate can be adequately managed by the relevant authorities. However, it would be prudent to carefully consider whether shellfish gathered downstream of urban storm water drains should ever be considered safe. Although monitoring may indicate compliance with the current MfE/MoH guideline values (median faecal coliform concentration of 14 per 100 mL, and fewer than 10% of results exceeding 42 per 100 mL), the Guidelines note: "These guidelines should be applied in conjunction with a sanitary survey. <u>There may be situations where bacteriological levels suggest that waters are safe, but a sanitary survey may indicate that there is an unacceptable level of risk</u>**"** (MfE/MoH 2003, p F2, my <u>emphasis</u>).

5 MONITORING CONDITIONS

5.1 I agree that additional monitoring is required to establish the general microbiological condition in the Waimea Inlet. Currently water quality information in Waimea Inlet is limited to measurement of summer enterococci concentrations at Monaco Peninsula only.

Microbiological water quality monitoring of Waimea Inlet

5.2 Section 8 of Ms Lojkine's report describes sampling intended to characterise the receiving environment. The seasonal monitoring proposed should include assessment of Faecal Indicator Bacteria (FIB), specifically enterococci and faecal coliforms.

5.3 Ms Lojkine proposes the monitoring of transects associated with locations likely to be impacted by aberrant discharges, plus one control site. The control site should be selected to represent inlet or nearshore waters subject to urban runoff (i.e. stormwater discharges), but where aberrant sewer discharge is unlikely. Monitoring of this site would provide a control data set, against which the other data could be compared.

5.4 The extent of water monitoring proposed appears excessive. Ms Lojkine proposes three replicate (6) samples should be collected from each of two (2) transects comprising three (3) sample points for each of the four pump station discharge points plus one control site (4+1). This requires analysis of 6×2×3×5

= 180 samples quarterly. Much of these data would be redundant – samples collected in close proximity (i.e. replicates) are likely to represent essentially the sample body of water at each site on each sampling occasion.

5.5 I recommend that a similar approach be followed as for the recreational water quality sampling, where a single sample (possibly in replicate) is collected from each site, but if the enterococci concentration exceeds a defined threshold, additional samples are collected and analysed on the next (and subsequent) day(s) if required. This approach will allow the duration of relatively poor microbiological quality events to be assessed. I understand that these amendments are reflected in the conditions marked up by the applicant for the hearing.

5.6 Under conditions where threshold values are not exceeded, valuable baseline data and information would be obtained from 5 or 10 samples, spread across 5 sites on each sampling occasion.

5.7 It would be more useful to sample these five sites monthly (minimum of 120 samples annually).

(a) Even if follow-up samples were to be collected, it is unlikely that 200 samples would be collected annually.

(b) Even though fewer samples would be collected, more information regarding receiving environment conditions would be obtained, including the duration of impairment.

5.8 I agree that additional monitoring should commence immediately after a discharge event occurs. The location of sampling sites for this event-response monitoring should have two objectives:

(a) Determining the spatial extent of the contaminant plume (to guide the public notification response), and

(b) To determine the duration of the contamination event (i.e. for how long should signage be displayed etc.).

6 RESPONSES TO SELECTED SUBMISSIONS

6.1 The following submissions raise points addressed in this evidence:

Human health risk – Submissions 4; 9; 10; 14; 15; 28

6.2 Available data indicates a measurable health risk exists at present, even when aberrant discharges do not occur.

6.3 The QMRA process has allowed the extent of contamination and level of risk to be estimated for highly unlikely, worst-case discharge conditions.

6.4 While some level of risk is indicated, quantifying the risk and the spatial extent of contamination allows development of appropriate management plans, thereby minimising the actual health risk.

6.5 It is reasonable to respond to potential health risks arising from aberrant discharges in the multi-faceted manner proposed by NRSBU:

(a) Improvement of infrastructure, development of procedures to minimise the volume and duration of discharges by involving industrial sources of wastewater, and reduce the amount of infiltration to the sewer system by removing infiltration and inflow through illegal connections.

(b) However good these measures might be, the potential always exists that multiple failures may coincide, or factors outside of the NRSBU's control may occur, leading to aberrational discharges.

(c) In the unlikely event that these rare circumstances occur, it will be essential to have robust emergency management and response plans in place. These will result in actions such as erection of signs, communication with other agencies, and appropriate monitoring. From the evidence of Mr Molloy it seems that the applicant is well prepared in that regard.

Increasing incidence and/or duration of unsafe conditions – Submissions 19; 21; 22

6.6 This assertion is not substantiated by available data.

6.7 The MfE/MOH recreational water quality guidelines describe how water quality may be categorised using (in part) a Microbiological Assessment Category (MAC), which requires approximately 100 data collected over five-year period.

6.8 Data were available to me for four seasons (more than 80 results/site). These data are summarised in Figure 2 and Figure 3.

(a) Considering 95th percentile concentrations alone for all sites (Figure 2), microbiological water quality in 2016/17 was better than in most earlier years. Improvement has been greatest at the Monaco site, where the 95th percentile concentration has decreased by a factor of 10 relative to that measured in 2013/14.

(b) This trend is confirmed when the full data set for each site for each bathing season is considered (Figure 3). The variability in concentrations (indicated by the height of the box and spread of the whiskers) is smaller for the three urban sites in 2016/17 than in earlier years, indicating generally lower enterococci concentrations.

6.9 The number of sewer pump station discharges has also decreased over time, as illustrated in the evidence of Mr Thiart and in the Data Bundle.

6.10 The human health risk associated with recreational contact is likely to also decrease as concentrations of faecal indicator bacteria decrease.

Use of treatment wetlands – Submission 29

6.11 Treatment wetlands have a place in wastewater treatment (e.g., Kadlec and Wallace 2009).

6.12 They are generally used to treat relatively small low-volumes of domestic sewage from single dwellings, marae, or small communities, rather than as primary treatment of municipal or industrial wastewater, for which they are not really suited, particularly for raw sewage.

6.13 They have relatively low capacity to deal with variations in flows arising from sub-divisions with significant storm water infiltration or where industrial wastewater sources exist.

6.14 The large areas that would be required to effectively deal with the volumes of wastewater would create significant odour emission sources, and would create environments where insect (flies) and rodent (rats) vectors could conceivably increase exposure of inhabitants to pathogenic organisms.

7 CONCLUSIONS

7.1 Aberrant discharge of raw sewage from pump stations to the Waimea Inlet is likely to result in a measurable health risk. Following use of dispersion/dilution modelling (to predict the likely spatial extent and duration of contamination), and Quantitative Microbial Risk Assessment to estimate illness risk associated with ingestion of contaminants, the levels of risk were estimated. These risks were expressed in similar manner to the MfE/MoH guidelines, to allow comparison with risk levels established for recreational waters.

7.2 Both the dispersion/dilution modelling and the QMRA modelling are conservative, biased toward low probability, serious consequence events. In particular, the scenarios selected for dispersion/dilution modelling were not intended to represent normal, everyday circumstances – they represent low probability, very rare events. This approach is appropriate because it allows the upper bound of risk to be estimated, and guides the development of appropriate risk response/management plans.

7.3 The location and extent of the area of greatest risk (at the point of discharge, and along drainage channels downgradient of these discharge points) will be determined by event-related conditions, notably tidal stage and wind speed and direction at the time of discharge.

7.4 Although weather, river flow and tidal conditions are out of the control of NRSBU, robust contingency planning has considerably reduced the probability that such discharges occur, and reduced the scale and duration of these discharges, should one occur.

7.5 Available data indicate that measurable health risk associated with contact recreation exists in the Inlet generally. This risk is likely to increase following a sewer discharge event. It is essential that a management/response plan is developed for these events of extremely low probability, that have the potential to increase the human health risk. These health risks are considered serious, but not extreme.

7.6 The management/response plan should include immediate reaction (signage, public notification), as well as sampling. The signage and public notification will minimise risk to recreational users, and the sampling will help determine when waters may be considered safe for recreational use. Several agencies are generally involved in these response activities, guided in part by the MfE/MoH recreational water quality guidelines, as well as other emergency response plans.

7.7 Provided adequate steps are taken to reduce the likelihood and size of an aberrant sewer discharge event, and that a robust plan exists to respond adequately to a discharge event of this nature (extremely low probability, moderate risk), the overall health risk to local communities will be very low.

Neale Alan Hudson

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APPENDIX A

A

B

Figure 1: Distance from Songer Street pump station to standing water under low tide conditions (A) and highwater conditions (B). The yellow line indicates approximately 370 m distance from the discharge point to standing water in the drainage channel, at this stage of the tidal cycle. The blue arrow indicates a storm water discharge point.

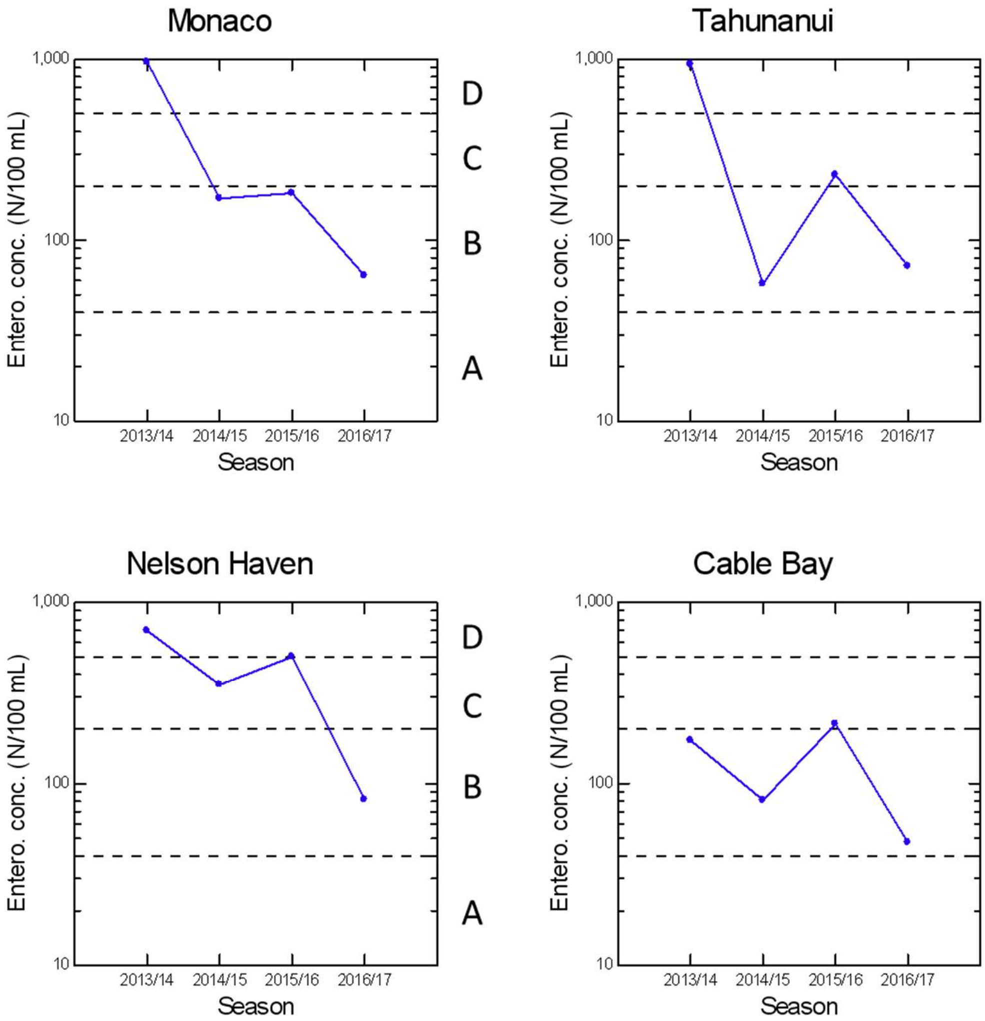

Figure 2: Ninety-fifth percentile enterococci concentrations for the 2013/14 through 2016/17 bathing seasons. The horizontal broken lines indicate 40, 200 and 500 enterococci/100 mL, the thresholds for the A/B, B/C and C/D for the Microbiological Assessment Categories defined in the NZ microbiological water quality guidelines (MfE/MoH 2003).

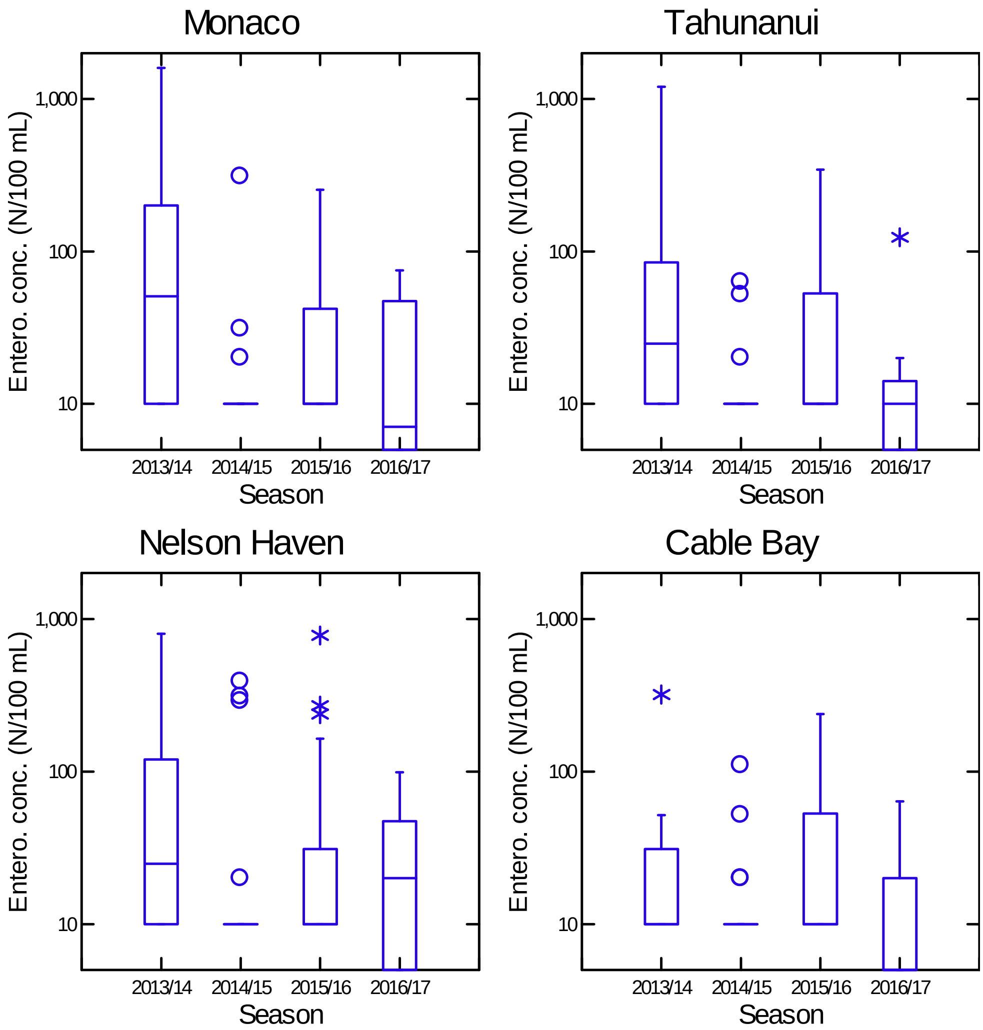

Figure 3: Enterococci concentrations for the 2013/14 through 2016/17 bathing seasons. The horizontal lines within the boxes indicate the median concentration (where not visible, these coincide with the lower edge of the box). An explanation of a box and whisker plots is provided in **Figure 4**.

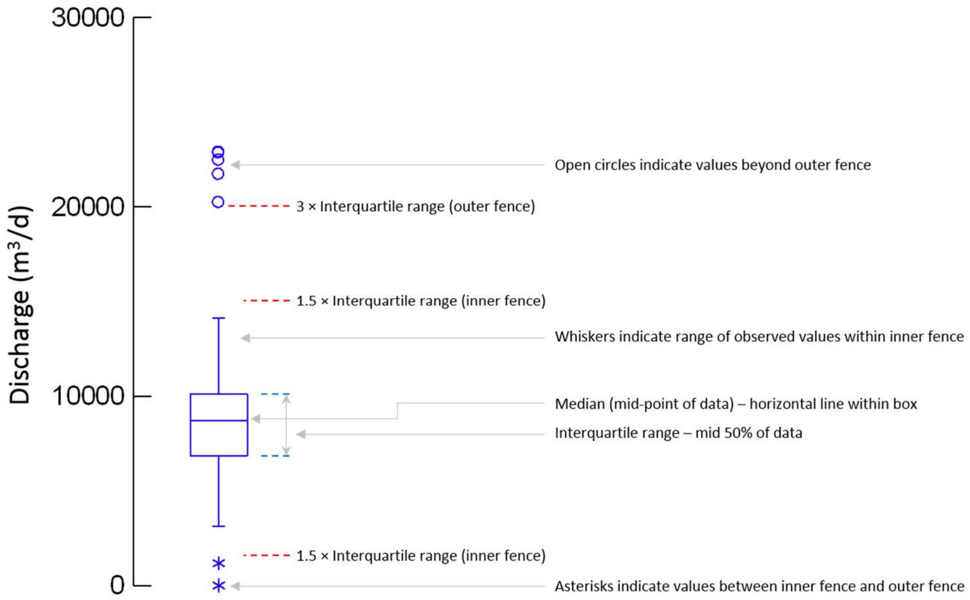

Figure 4: Explanation of the symbols used in box and whisker plots produced using Systat statistical software. Box and whisker plots provide a convenient way of summarising and comparing data for several sites or periods of time, while also indicating the distribution of data.

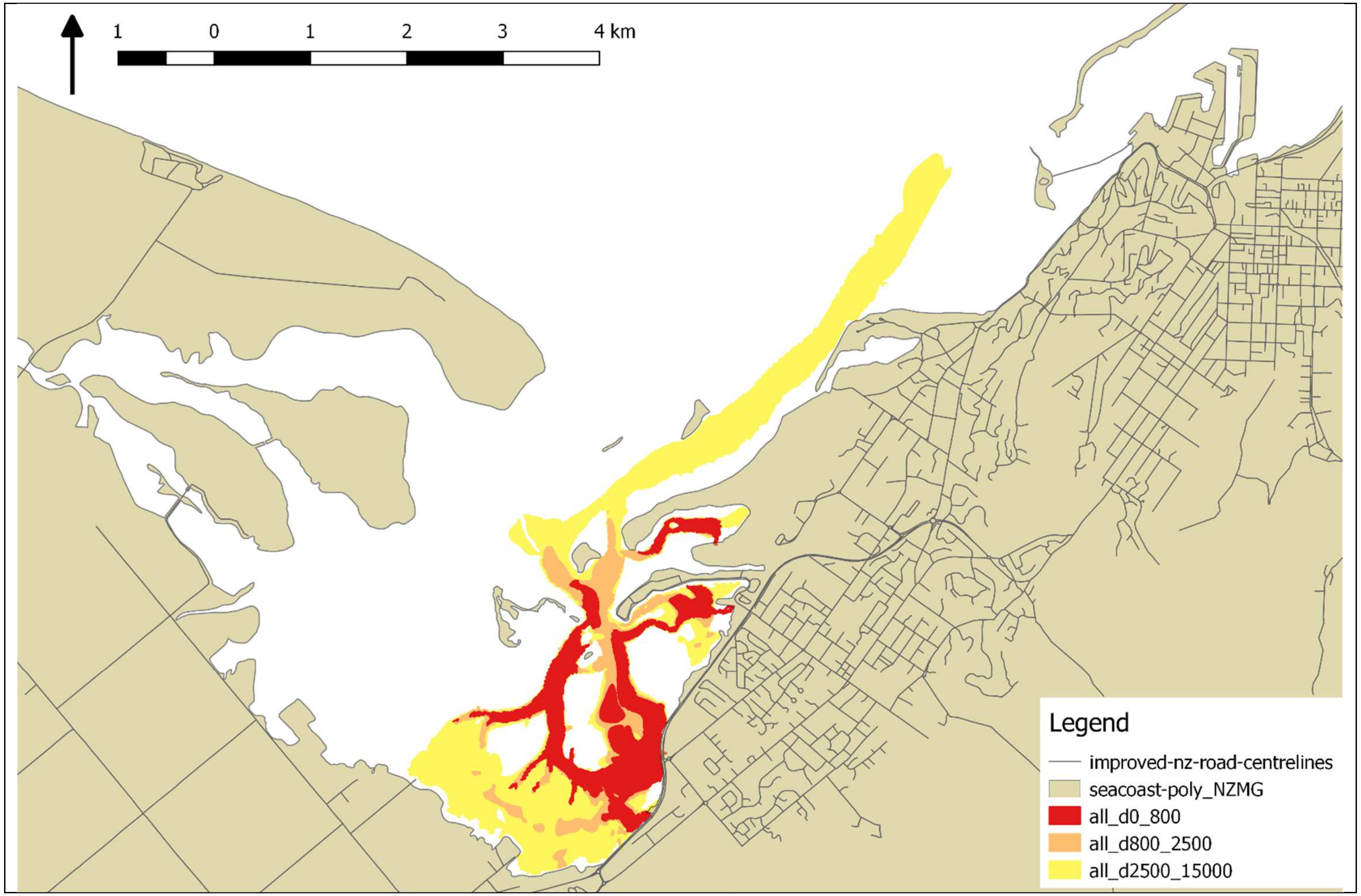

Figure 5: Extent of spatial footprint of three dilution thresholds for all pump stations combined. These contours represent the **theoretical** footprint were all four pump stations to discharge untreated sewage according to the worst-case scenarios defined for the dispersion modelling. "all_d0_800" represents the extent of area where GI illness risk is likely to exceed 10%, "all_d0_800_2500" represents the area where 5-10% GI illness risk is likely to exist, and "all_d0_2500_15000" represents the area where 1-5% GI illness risk is likely to exist.

Table 1: Scenarios for which contaminant dilution was estimated. "Weather" indicates the catchment condition in terms of rainfall, where "Wet" indicates infiltration possible, and "Dry" indicates infiltration unlikely, "MHW" indicates discharge of contaminants into Waimea Inlet under high tide conditions, "MLW" indicates discharge of contaminants into Waimea Inlet under low tide conditions, "22.5°" wind indicates northerly wind, and "135°" indicates southerly wind. Stream discharge values (90^{th} and 15^{th} percentile) indicate very high and low flow runoff conditions. From MetOcean Solutions Limited (2017).

Weather	Tide	Winds		Stream discharge rate (Percentile)	Sewer flow condition
		Direction (°)	Speed (km/h)		
Wet	MHW	22.5	9	90^{th}	Peak
		135	8.5	90^{th}	Peak
		Zero wind	0	90^{th}	Dry
	MLW	22.5	9	90^{th}	Peak
		135	8.5	90^{th}	Peak
		Zero wind	0	90^{th}	Dry
Dry	MHW	22.5	9	15^{th}	Peak
		135	8.5	15^{th}	Peak
		Zero wind	0	15^{th}	Dry
	MLW	22.5	9	15^{th}	Peak
		135	8.5	15^{th}	Peak
		Zero wind	0	15^{th}	Dry
Number of scenarios per pump station				12	