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Dear Zefanja

Human Health Effects Arising from Overflow Events from 2012 to 2014

1.0 Introduction

1.1 Background

Christchurch City Council (CCC) currently holds resource consent CRC092692 to discharge wastewater, groundwater and stormwater into the Avon and Heathcote Rivers and tributaries, and into drains entering the Avon-Heathcote Estuary. The consented discharge shall only occur as a result of wet weather events overloading the wastewater network, and only occur at the consented overflow locations.

As part of the consent compliance requirements an assessment of the human health effects arising from the overflow events shall be prepared following the third full year from the date of the consent commencement (condition 15). URS New Zealand Limited (URS, acquired by AECOM Consultancy Services in late 2014, hereafter referred to as AECOM) was engaged by CCC to undertake this work. The receiving environment for each consented overflow location was identified within the consent CRC092692, as specified in Table 1 below.

1.2 Purpose

This brief letter report outlines AECOM's findings of this public health assessment, as per condition 15 of the resource consent (CRC092692). Key information sources and assessment methodology adopted are also summarised in this report. A detailed quantitative public health risk assessment is beyond the scope of this study, as a quantitative microbial risk assessment (QMRA) of the modelled wet weather overflows for the sewage network was already completed by NIWA in 2009.

This report is therefore based on a qualitative comparison against relevant NZ recreational water quality guidelines (i.e. Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas, MfE 2003).

2.0 Overflow Records

Overflow records between 2012 and 2014 were provided by CCC, which shows information obtained for each overflow event (both dry weather and wet weather) such as overflow site, start time, end time, affected water body, average flow rate, and total overflow volume, etc. This is required as condition 9 of the resource consent (CRC092692).

The observed overflow frequencies need to be calculated using a field-calibrated computer model incorporating actual rainfall records, comparing the actual records with the previously-modelled annual overflow event frequencies and volumes (Condition 14). However, this work was not made available to AECOM for the purpose of this assessment. In absence of the overflow modelling calculation, AECOM has simply categorised the annual overflow frequencies from 2012 to 2014 based on the overflow records provided and compared them with the consented frequencies. This provides an important factor in assessing the potential public health risks, considering the pathogen load generally carried by sewage overflow.

2.1.1 Wet Weather Overflow

The consented discharge shall only occur as a result of wet weather events overloading the wastewater network, and only occur at the consented overflow locations. The locations of the consented overflow sites are summarised in Table 1.

Table 1 Consented Overflow Locations and Receiving Environment

Overflow Pump Station ID	Location	Receiving Environment
PS1/11	River Road	Avon River
PS1/15	St Andrews Square	Avon River
PS1/16-1	Fendalton Road Bridge	Avon River
PS1/16-2	Fendalton Road Bridge	Avon River
PS36/1	Pages Road	Avon River
PS1/21	Grassmere Street	Avon River (via Dudley Creek)
PS7/1	Slater Street	Avon River (via Dudley Creek)
PS7/2	Warden Street	Avon River (via Dudley Creek)
PS41/1	Westminster Street	Avon River (via Dudley Creek)
PS40/1	Joy Street	Avon River (via Horseshoe Lake)
PS19/1	Beckford Road	Heathcote River
PS20/2	Waltham Road	Heathcote River
PS20/3	Tennyson Street	Heathcote River
PS20/4	Fisher Avenue	Heathcote River
PS22/1	Eastern Terrace	Heathcote River
PS23/1	Sandwich Road	Heathcote River
PS15/1	Alport Place	Heathcote River
PS11/1	Ferry Road	Heathcote River
PS60/1	Halswell Road	Heathcote River (via Cashmere Stream)
PS42/2	Sparks Road	Heathcote River (via Cashmere Stream or open drain)
PS09/1	Chelsea Street	Avon-Heathcote Estuary (via Linwood Avenue Canal)
PS10/1	Linwood Avenue	Avon-Heathcote Estuary (via Linwood Avenue Canal)

The total annual overflow event frequency across the consented overflow sites are summarised in Table 2.

Table 2 Consented Annual Overflow Event Frequencies

Receiving Environment	Annual Overflow Frequency (at commencement of the consent)	Annual Overflow Frequency (2015)
Avon River	8.4	7
Heathcote River	14.2	8
Avon-Heathcote Estuary	0.86	0.87

Based on the overflow records provided to AECOM (data provided on 16 February 2015), the approximate wet weather overflow occurrences and total volumes of the overflows are summarised in Table 3 below. As mentioned above, a computer-modelled calculation and comprehensive review of the overflow records have not been completed for the purposes of this report. The computer model will take into consideration rainfall records and will provide explanations for any discrepancies between modelled overflow scenarios and observed overflow records. Nevertheless, the simple records provided in Table 3 indicate that the observed annual occurrences of overflows at consented sites exceeded consented annual frequencies for all the receiving water bodies. The expected reduction in annual overflow frequencies from the commencement of the consent to 2015 has not been achieved. In addition, there have been wet weather overflows occurring in a number of un-consented locations for both Avon River and Heathcote River catchments.

Table 3 Summary of Wet Weather Overflows

Receiving Environment	Items	2014*	2013*	2012*	Consented Annual Overflow Frequency
Avon River	Total No. of overflow	20	21	11	8.4
	No. of overflow at consented sites	14	15	8	8.4
	No. of overflow at non-consented sites	6	6	3	0
	Total overflow volume (m^3)	149,763	146,421	22,616	-
Heathcote River	Total No. of overflow	28	21	10	14.2
	No. of overflow at consented sites	25	18	8	14.2
	No. of overflow at non-consented sites	3	3	2	0
	Total overflow volume (m^3)	77,160	84,437	17,026	-
Estuary	Total No. of overflow	2	0	2	0.86
	No. of overflow at consented sites	2	0	1	0.86
	No. of overflow at non-consented sites	0	0	1	0
	Total overflow volume (m^3)	2,429	0	64,200	-

*: Calendar year.

In addition to the total consented annual wet weather overflow frequencies specified for each receiving environment (listed in Table 2), the current consent authorises up to 2 per year wet weather overflows to occur at any individual site. Locations of the frequent wet weather overflows are summarised in Table 4. Overflows in excess of 2 per year have occurred at a number of locations including Beckford Rd, Fisher Avenue, Grassmere St, Halswell Rd, Jack Hinton, Joy St, St Andrew Sq, Tennyson St, and Waltham Rd. Up to 4 per annum wet weather overflow events occurred at five pump stations between 2012 and 2014, including Fisher Av, Halswell Rd, Jack Hinton, Tennyson St, and Waltham Rd.

Table 4 Locations with Wet Weather Overflow Annual Frequencies of Greater Than 2 per Year

Sites	2014*	2013*	2012*
Beckford Rd. PS19/1	2	3	
Eastern Terrace PS22/1		2	
Fendalton North PS1/16-1		2	
Fendalton North PS1/16-2		2	
Fisher Avenue PS20/4	4	3	
Grassmere St. PS1/21	3	2	

Sites	2014*	2013*	2012*
Halswell Rd PS60/1	3	4	
Jack Hinton PS36/2	4	2	2
Joy St. PS40/1	2	2	
Pages Rd PS36/1			2
River Rd PS1/11		3	2
St Andrew Sq. PS1/15	3	2	
Tennyson St. PS20/3	3	4	4
Valley Rd. PS23/2	3		
Waltham PS20/2	3	4	

*: Calendar year.

2.1.2 Dry Weather Overflow

The previous public health risk assessment (NIWA 2009) did not consider any dry weather overflows occurring within the sewage network, because no dry weather overflow was expected to occur based on current network capacity (GHD 2008). Consequently the current consent does not authorise any dry weather overflows. In reality however, dry weather overflow may occur due to pipe damage, drain blockage, pump failure or power outage. From the overflow records provided by CCC, the occurrence of dry weather overflow events within the network can be as frequent as wet weather overflows due to various asset maintenance issues, although the overflow volumes may not be as significant as wet weather overflows. The Christchurch earthquake in 2011 has also had a significant impact on the network assets. The high dry weather overflow volume recorded in 2013 for Avon River catchment was mainly due to the pump failures experienced at PS36 which overflows at Jack Hinton. The new PS 136 has resolved this issue.

Directly in response to the consent requirements, this study is focused on wet weather overflow public health impact assessment only. A detailed assessment of the public health risks associated with dry weather overflows is outside the scope of this study. In general terms during dry weather conditions, there would be a higher likelihood of recreational contact (e.g. walking along the river banks, kayaking, etc.) by the local community, and the dilution factors would be lower during dry weather period when the sewage overflow reaches the streams. These factors, although hard to quantify, may potentially result in elevated public health risks. Christchurch City Council is required to follow the response procedure relating to each overflow event (including both dry weather and wet weather overflows) set out in a Response Plan (Christchurch City Council 2007). This includes monitoring and reporting in a timely manner, and erection of public health warning signs. The stipulated response procedure may adequately lower the public health risk associated with any dry weather overflow event, considering the current degraded amenity values in some areas of the rivers and the recorded low overflow volumes under dry weather circumstances. Nevertheless, it is the Council's responsibility to reduce the dry weather overflows by proactively maintaining the network assets so that the consent requirements regarding no dry weather overflows can be met.

Table 5 Summary of Dry Weather Overflows

Receiving Environment	Items	2014*	2013*	2012*
Avon River	Total No. of overflow	19	16	13
	No. of overflow at consented sites	0	4	6
	No. of overflow at non-consented sites	19	12	7
	Total overflow volume (m^3)	1,336	129,091	979
Heathcote River	Total No. of overflow	24	15	13
	No. of overflow at consented sites	1	2	2
	No. of overflow at non-consented sites	23	13	11
	Total overflow volume (m^3)	1,524	1,687	6,066

Receiving Environment	Items	2014*	2013*	2012*
Estuary	Total No. of overflow	9	1	0
	No. of overflow at consented sites	0	1	0
	No. of overflow at non-consented sites	9	0	0
	Total overflow volume (m^3)	7.7	4.5	0

*: Calendar year

The higher-than-consented wet weather overflow frequencies, in addition to dry weather overflows, indicate a considerable pathogen load carried by sewage overflow into the receiving water bodies, subject to a certain level of dilution within the receiving waterways. Based on the findings of a previous investigation (Suren 2010), significant dilution can be achieved when the overflow reaches the receiving water bodies. For instance, a median dilution factor of 1:334 can be achieved immediately when the overflow reaches both Avon and Heathcote Rivers under low flow circumstances (Suren 2010).

Notwithstanding the pathogen loads within the sewage overflows, it shall be noted that the public health implication of the overflow events for the community (Christchurch city residents in this case) needs to be assessed within the framework of the general water quality of the receiving water bodies, with considerations given to the potential public exposure pathways and probabilities. This is further discussed below.

3.0 Water Quality Status of the Receiving Waterways

3.1.1 Water quality survey

Recently, an annual water quality monitoring report for Christchurch City was completed in 2015. This report summarises water quality analytical results at 44 sites across the major river catchments of the city, including both Avon River and Heathcote River (Margetts and Marshall 2015). These samples were collected monthly, mostly during base flow conditions with occasional sampling carried out during storm events. Therefore the monitoring results provide an overall status of water quality of the studied waterways, irrespective of wastewater overflows.

Consistent with previous monitoring, the 2014 monitoring results indicated that the both Avon and Heathcote rivers showed degraded status in terms of water quality, typical of urban streams. Most monitored sites failed to comply with MfE guideline level of 550 cfu/100ml E. coli (95 percentile, Action/Red mode), unsuitable for direct recreational water contact.

In addition to the monthly water quality monitoring, CCC has proposed pathogen monitoring (*E.coli.*) to be undertaken during each overflow event, within 100 m upstream of the discharge (or group of discharges) and within 200 m downstream. The monitoring procedures, along with key contacts and their respective roles and responsibilities, are stipulated in the updated Response Plan: CCC's WW-003: Manage Sewer Overflow, dated 2013. The monitoring results between 2013 and 2015, in response to each overflow event during this period, were recorded by CCC and reviewed by AECOM as part of this assessment. Relatively high E. coli levels have been found in a large number of upstream sampling locations, masking the actual impact of overflows on the downstream water quality.

Apart from raw domestic wastewater carried in overflows, urban streams such as Avon River and Heathcote River are subjected to various contamination sources, including stormwater and other inputs such as waterfowl and dog faeces. For instance, the Halswell Retention Basin is known to attract a significant number of waterfowl, whose contribution of pathogens such as faecal coliforms is well documented (Tipler 2010). Non-sanitary urban runoff alone can be a significant contributor to the aquatic environment pathogen load. AECOM understand that a comprehensive faecal tracking investigation is current underway, which will provide additional insight on the source of pathogens within these receiving waterways.

4.0 Public Health Effects Assessment

4.1.1 Potential Public Exposure Pathways and the Respective Risks

An important step in the assessment of public health risks of certain pathogen is the establishment of public exposure routes to the pathogen sources. Potentially the exposure routes to the pathogens existent in wastewater overflows involves consumption of contaminated drinking water and mahinga kai, or direct recreational contact.

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Of these exposure routes, drinking water source contamination can be ruled out because urban Christchurch drinking water is not sourced from surface water. Urban Christchurch has one of the best water supplies in the world, sourcing directly from deep aquifers with extremely high quality and requiring no treatment. General compliance with the requirements of Drinking-water Standards for New Zealand (2005, amended in 2008) and the Health Act (1956, amended in 2007) has been demonstrated in previous and the most recent drinking water quality survey (MoH 2015).

Mahingai kai is not officially reported to be harvested from the waterways and estuary due to the current degraded status of the water bodies (NIWA 2009). In addition, the human pathogens of concern are not expected to infect fish. Therefore the risks of people who eat the fish being brought into contact with human pathogens will be very low. Cooking is also expected to further reduce this risk. Therefore the threat of infectious disease following consumption of mahinga kai can be considered to be no more than minor at the current time.

Direct recreational contact of the local public with the surface water network at a community level is hard to quantify. This assessment assumes that recreational use of the rivers may occur on a very rare basis. The potential recreational activities that may result in the public exposure to the wastewater overflow include the following:

a) Direct immersion in water leading to ingestion of water (e.g. swimming, surfing):

   This is considered to have the highest degree of exposure and therefore represent the highest risk.

b) Accidental immersion in water (e.g. fishing, canoeing, kayaking):

   The level of exposure and health risk is considered to be low, as this requires people falling from canoes or kayaks into the water

c) No direct immersion in water (e.g. walking, dog-walking):

   The level of exposure and health risk is considered to be low. For instance, infections may result from any potential pathogen transfer from dogs that had immersed into the contaminated water to the dog owner who happened to ingest pathogens by touching the dog and his/her food subsequently.

Due to the low risks associated with exposure pathway (b) and (c), the following estimation of public health risk arising from wet weather overflows is focused on pathway (a) swimming only.

A quantitative microbial risk assessment (QMRA) was undertaken in 2009; assessing the accumulative individual human health risks associated with random bathing or shellfish collection within the rivers during overflow events (including both six-month Annual Recurrence Interval (ARI) and 2-yr ARI storm events) (NIWA 2009). Based on the individual infection risks calculated by NIWA (2009), the observed wet weather overflow frequencies, and considering the community's potential recreational water use pattern (swimming only for the worst case scenario estimate), the community gastrointestinal infection risks may be estimated as indicated in Table 6:

Table 6 Estimated probability of direct recreational water contact (annually, for the community) at any overflow location

Item No.	Factor	Probability	Comments
A	Worst potential individual infection risk (IIR)	0.15-0.18 (from NIWA 2009)	Estimated for Halswell Rd pump station (PS60/1), when individuals choose to swim during a storm event. This is the worst case scenario as the calculated individual infection risks (IIRs) for the majority sites are blow 0.02 (2%).
B	Annual overflow frequency	0.077	Calculated by 4/52, assuming 4 overflows per year and the average overflow duration being 1 week. This is the observed highest wet weather overflow annual frequency (from 2012 to 2014). Records showed that average overflow duration is approximately within a couple of days, therefore this estimate should be considered conservative.
C	Probability of swimming during storm events	0.0001	- Assuming 1% probability that any individual will choose to swim in the river while overflow is occurring. - Assuming 1 in 100 people within the community will

Item No.	Factor	Probability	Comments
			choose to swim in the river while overflow is occurring. - This is postulation only, however should be considered very conservative, as swimming is not identified as a recreational activity in both Avon River and Heathcote River catchments. In addition, public warning signs are erected whenever an overflow event occurs (for both dry and wet weather overflows), hindering public water contact.
D	Estimated community annual infection risk potentially arising from recreational water use of Avon or Heathcote River	1.15-1.34 $\times10^{-6}$	This is calculated by multiplying item A, B, and C (i.e. $0.15\times0.077\times0.0001 = 1.15\times10^{-6}$) Equivalent to 0.1 case per 100,000 population
E	Rate of Gastroenteritis* in 2013 for Canterbury District Health Boards	3.7×10^{-5}	Equivalent to 3.7 cases per 100,000 population Data were obtained from Notifiable and Other Diseases in NZ: Annual Report 2013 (ESR 2014).

*: Gastroenteritis: Refer to acute gastroenteritis from a common source or foodborne intoxication.

The estimated community gastrointestinal infection rate is approximately 0.1 cases per a population base of 100,000 (Item D in Table 6 above). Considering that not all infections result in actual diseases, the actual risks of community gastroenteritis as a result of recreational water use during wet weather overflow events (swimming within Avon or Heathcote River when overflow occurs) would be much lower.

It was reported that an average NZ community has a background risk of gastrointestinal infections in the order of approximately 6% (McBride 1998), while the current reported gastroenteritis rate alone within Canterbury DHB is approximately 3.7 cases per 100,000 population (0.0037%; Item E in Table 6) (ESR 2014). This is due to the level of risk associated with everyday exposure to potential pathogens such as dining at an unsanitary restaurant, or consuming contaminated food from the fridge, etc. This rate was calculated based on reported illness cases, which ought to be lower than the actual number of total gastroenteritis cases within the community (including both reported and non-reported cases), and much lower than the number of total gastrointestinal infection cases (including infection cases that did not result in sickness). As can be seen, the potential infection risk for the community arising from the wet weather overflows (0.1 case of infection per 100,000 population), estimated as conservatively as it has been, is significantly lower than the background level of health risk to the community from everyday life (3.7 cases of infection per 100,000 population).

In summary the public health risks associated with current wet weather overflow within the Avon and Heathcote Rivers are expected to be remote.

4.1.2 Public Health Risks of Existing Catchments

In this section, the level of public health risks associated with contact with the Avon and Heathcote Rivers is qualitatively assessed based on current pathogen levels existing in the stream. This assessment is focused on public health risks posed by the bacteriological pathogen (*i.e.* using *E. coli.* and Enterococci as indicative microorganism) only. Viral or other pathogens occurrence data are not available and therefore have not been considered in this assessment.

Water quality monitoring carried out between 2006 and 2009 indicated relatively high level of faecal coliforms (Suren 2010). An estimated risk of infection, based on comparing the observed 95 percentile *E. Coli* concentrations during bathing season against the guideline established in the current MfE guideline (MfE 2003), was found to be higher than 5%. This indicates that the rivers are unsuitable for recreational contact (NIWA 2009).

Table 7 outlines the microbial assessment category (MAC) and various action mode levels identified in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE 2003). We understand that the saltwater influence is known to extend well upstream in both Avon and Heathcote catchments, as far upstream as the Avon River at Avondale Bridge and Heathcote River at Opawa Road/Clarendon Terrace (Margetts and Marshall 2015). Hence both marine water and freshwater MAC levels are provided in Table 7 below.

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The median levels of *E. coli* and Enterococci monitored historically (NIWA 2009) and in the last monitoring year (Margetts and Marshall, 2015) are shown in Table 8. Consistently high levels of *E. coli* and enterococci (where tidal influence is observed) were reported within most sites within both Avon and Heathcote river catchments during low flow condition, which is considered to be mainly caused by the urban runoff in vicinity of the stream and faecal inputs from waterfowl. A large number of monitoring sites within the Avon and Heathcote catchments may be graded as poor or very poor, and are in breach of the Action/Red Mode category for freshwater, therefore representing a significant risk for public health, should the public be in direct (i.e. swimming) contact with the aquatic environment.

Table 7 Microbiological Assessment Categories and Relevant Levels for Marine and Freshwater for Contact Recreation

Items	Marine Water	Fresh Water
Bacteriological Indicators	Enterococci	*E. coli*
Microbiological Assessment Category (MAC)	**A: Sample 95 percentile ≤ 40 enterococci/100 mL** B: Sample 95 percentile 41–200 enterococci/100 mL C: Sample 95 percentile 201–500 enterococci/100 mL D: Sample 95 percentile > 500 enterococci/100 mL	A: Sample 95 percentile ≤ 130 E. coli per 100 mL B: Sample 95 percentile 131–260 E. coli per 100 mL C: Sample 95 percentile 261–550 E. coli per 100 mL D: Sample 95 percentile >550 E. coli per 100 mL
Acceptable/Green Mode	No single sample greater than 140 enterococci/100 mL	No single sample greater than 260 *E. coli*/100 mL
Alert/Amber Mode	Single sample greater than 140 enterococci/100 mL	Single sample greater than 260 *E. coli*/100 mL
Action/Red Mode	Two consecutive single sample greater than 280 enterococci/100 mL	Single sample greater than 550 *E. coli*/100 mL

Table 8 Range of Median Levels of Microbial Pathogens within Avon and Heathcote Rivers Monitoring Sites

Parameters	Avon River	Heathcote
E. Coli (median, in cfu/100mL, 2006-2009)*	45-800	160-790
E. Coli (median, in cfu/100mL, 2014) §	120-1300	10-745
Enterococci (median, in cfu/100mL, 2006-2009)*	85-18000	18-554

*: Data from NIWA (2009).
§: Data from Margetts and Marshall (2015)

5.0 Conclusion

A large number of overflow events, including both wet weather and dry weather events, have been recorded for the current CCC sewage network from 2012 to 2014. Both the total number of annual wet weather overflow frequencies for the receiving environment (Avon River and Heathcote River) and for individual locations have exceeded consented levels. Also, the expected reduction in wet weather overflow annual frequencies was not achieved. Dry weather overflows are not covered by the current consent CRC092692.

Although more-frequent-than consented wet weather overflows have occurred in the sewage network, the potential public health risks associated with the observed wet weather overflow events were estimated to be very low. This is largely based on the fact that public exposure pathways to the waterways in proximity of the overflow locations are relatively limited, particularly during storm events, and the estimated potential risks (i.e. community infection probability) for the community are significantly lower than the background community disease or infection rates.

However the public health risks arising from public contact with Avon River or Heathcote River can be assessed in the context of the existing microbial quality of the waterways only. The microbial water quality of the Avon and Heathcote River is shown to be poor upstream of the overflow discharge sites. This is shown in the recent monitoring results produced by CCC (Margetts & Marshall, 2015) and previous investigations conducted in the catchment (NIWA 2009). These results showed that monitored samples within the whole catchments generally exceed MfE guidelines for microbial water quality for recreational areas (Action/Red Mode category). Therefore the wider catchment microbial inputs should be investigated, and any direct recreational water contact such as swimming should be considered to pose significant health risks.

Yours faithfully

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6.0 References

Christchurch City Council, 2007, Sewer Overflow Response Plan.

ESR, 2014, Foodborne disease in New Zealand 2013 Annual Report. Report prepared for Ministry of Primary Industries.

GHD, 2008, System performance assessment report for truck sewer strategy, Report prepared for Christchurch City Council.

Margetts, B. and Marshall, W., 2015, Surface water quality monitoring report for Christchurch City waterways: January – December 2014. Christchurch City Council, Christchurch.

McBride G B, et al. 1998, Health effects of marine bathing in New Zealand. International Journal of Environmental Health Research 8: 173-189.

MfE, 2003, Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas.

NIWA, 2009, Quantitative microbial risk assessment associated with sewer discharges to the Avon and Heathcote River catchments.

MoH, 2015, Annual Report on Drinking-Water Quality 2013-2014, Wellington: Ministry of Health.

Suren, A. 2010, Statement of Evidence before the Canterbury Regional Council, in regards to the resource consent application (CRC092692) by the Christchurch City Council to discharge water and contaminants to water from overflow points in the Christchurch wastewater network as a result of wet weather events.

Tipler, C. 2010, Statement of Evidence before the Canterbury Regional Council, in regards to the resource consent application (CRC092692) by the Christchurch City Council to discharge water and contaminants to water from overflow points in the Christchurch wastewater network as a result of wet weather events.