SUPPLEMENTARY EVIDENCE OF ANTONIUS HUGH SNELDER ON BEHALF OF WELLINGTON REGIONAL COUNCIL

TECHNICAL - REGIONAL WATER QUALITY TRENDS

22 February 2018

Introduction

1. At the hearing for the Proposed Natural Resources Plan for the Wellington Region on Thursday 15th February 2018, the commissioners asked me for additional evidence concerning regional water quality trends. This document provides that additional evidence and should be regarded as an extension to my evidence and additional analyses that I undertook in response to rebuttal of my evidence by Doctor Canning and Ms McArthur.

Scope

2. The commissioners asked me to provide tables, charts and maps that describe the confidence in water quality trend direction at sites within the individual Whaitua (i.e. sub-regions defined for management purposes) that make up the Wellington region. In addition, to produce an analysis at the Whaitua level that is consistent with my original region-level analysis, I have tested for 'overall' Whaitua-trends (i.e., evidence that there are more improving or degrading trends within a Whaitua than would be expected by chance). I was also asked to provide commentary on what can be inferred about water quality trends in each individual Whaitua. This document provides the requested information.

Methodology

3. The statistical methods that have been used to produce the analysis presented in this document are as for my original evidence and the regional trend report (Snelder 2017a). However, the spatial units of analysis reported here are the five individual Whaitua that make up the Wellington region, rather than the region itself. There are five Whaitua in the region: East Wairarapa Whaitua, Kapiti Coast Whaitua, Porirua Harbour Whaitua, Ruamahanga Whaitua and Wellington Harbour Whaitua.
4. This analysis considered trends in the same 18 water quality variables investigated by Snelder (2017a) at up to 62 water quality monitoring sites and the ten-year and five-year time-periods. Three separate analyses were performed for the ten and five-year periods. First, the maps were produced showing the statistical confidence that trends were improving for each of the

monitoring sites and each water quality variable. The confidence was expressed using the categorical descriptors defined by Snelder (2017a). Second, tabulations were made of the proportion of sites in each Whaitua for which improving water quality trends have specific levels of statistical confidence. Third, an analysis of the 'overall' trend in each Whaitua was made using a binomial test. The p-values for the binomial tests were adjusted for false discovery within each Whaitua. Adjustment for false discovery was applied to the original 'overall' trend test within the region of Snelder (2017a) in response to rebuttal of my evidence by Dr Canning.

5. It is noted that the number of sites and variables differs by Whaitua due to the geographic distribution of the monitoring network. In addition, as for the original study (Snelder 2017a) trends were not analysed for some variables and some sites due to missing data. Only raw trends have been considered in this analysis because this maximises the number of sites. It was shown by (Snelder, 2017a) that conclusions differ little if flow adjusted trends are used. Maximising the number of sites is particularly important in this analysis because of the analyses are based on the Whaitua, some of which have few monitoring sites.

Results

Ten-year trends

6. Regional maps showing the statistical confidence that ten-year trends were improving for each of the monitored variables are provided by Figure 1. The boundaries of the five Whaitua are superimposed on the maps. The mapped patterns indicate that improving trends that are inferred with high confidence (green colours), and low confidence (red coloured sites, indicating high confidence that these sites have degrading trends) are mostly randomly distributed geographically. With the exception of the *E. coli* variable, no Whaitua has a predominance of improving trends of low confidence (i.e., indicating degrading trends). There are a higher proportion of degrading trends (i.e., orange to red coloured sites) for some variables (e.g., *E. coli*, periphyton and invertebrate variables) as noted in my original evidence but these are generally randomly distributed over the Whaitua. The only noteworthy exception is a predominance of degrading *E. coli* trends in the Kapiti Coast and Porirua Harbour Whaitua.
7. The proportion of sites in each Whaitua for which the statistical confidence that ten-year trends represent improving water quality is tabulated in Table 1. In general (i.e., across all water quality variables), more than 50% of sites have trends that are at least as likely as not to be improving. However, in each Whaitua there are some variables for which fewer than 50% of sites are at least as likely as not to be improving. Across all variables, the mean proportion of sites for which trends were at least as likely as not to be improving ranged between 63% (Kapiti

Coast and Porirua Harbour Whaitua), 70% (Ruamahunga Whaitua), 73% (Wellington Harbour Whaitua) and 79% (East Wairapa Whaitua). These values are all close to the ten-year regional mean proportion of sites that at least as likely as not to be improving (68%) that I reported in my evidence.

8. Analyses of overall Whaitua ten-year trends indicated only three significant overall trends (Table 2). This was fewer than regional analyses and occurs because of reduction in statistical power when sites are aggregated by Whaitua rather than region. There were overall improving trends in clarity and TN in the Ruamahunga Whaitua and overall improving trends in TN in the Wellington Harbour Whaitua. There were no degrading overall trends in any Whaitua (Table 2).

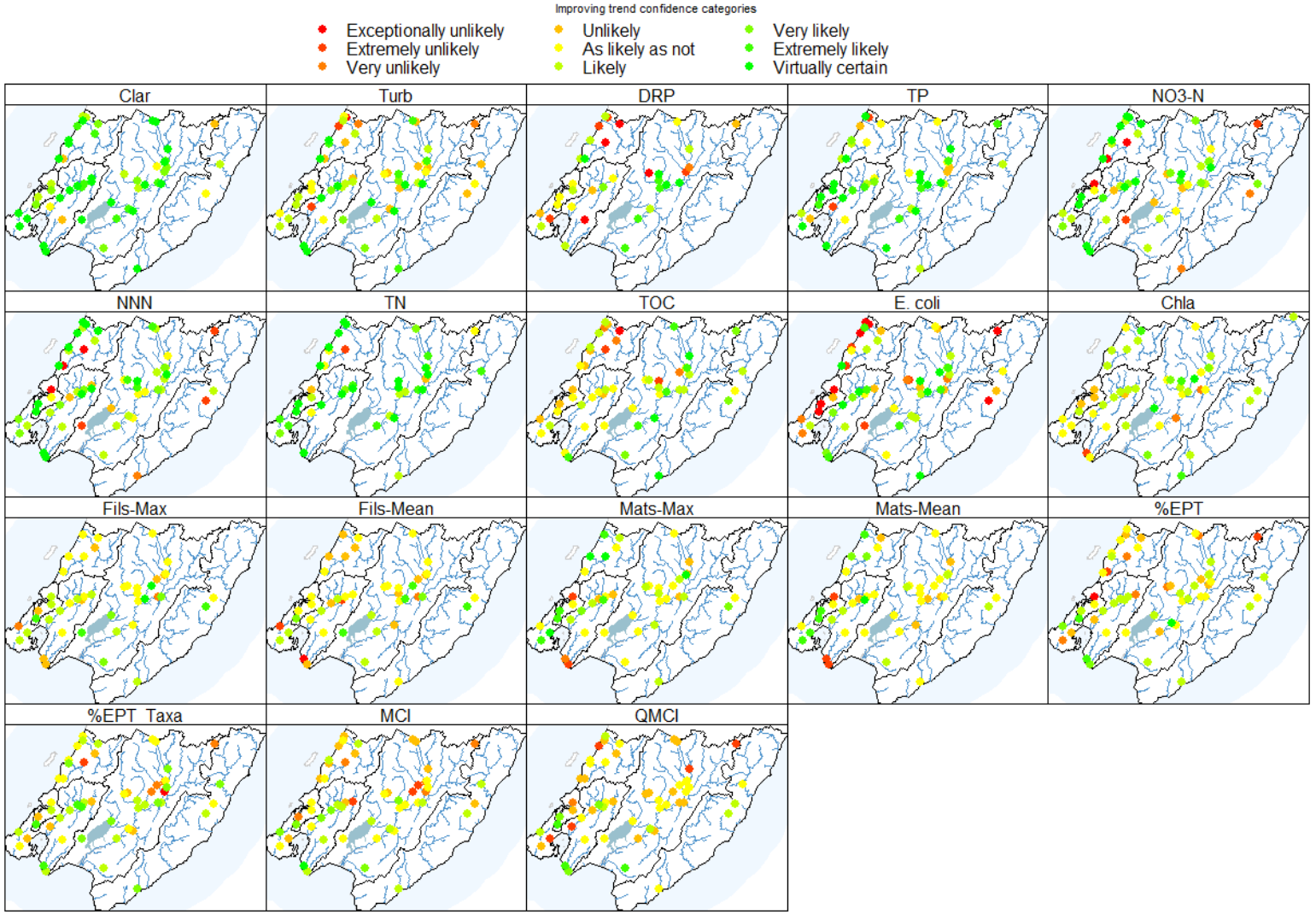

Figure 1. Maps showing statistical confidence that ten-year trends indicate improvement by water quality variable. The boundaries of the five Whaitua are superimposed on the region

Table 1. Cumulative proportion of sites (%) with ten-year improving raw trends with at least the level of confidence indicated.

Whaitua	Variable	No. sites	Virtually certain	Extremely likely	Very likely	Likely	Likely as not
East Wairarapa	Clar	3	33	33	33	67	67
	Turb	4	0	25	25	25	25
	TP	2	0	0	0	100	100
	NO3-N	3	0	0	33	33	33
	NNN	3	0	0	0	33	33
	TN	2	0	50	50	100	100
	TOC	4	25	25	50	75	100
	E. coli	4	25	25	25	25	50
	Chla	5	0	20	20	100	100
	Fils-Max	3	0	33	33	67	100
	Fils-Mean	3	0	33	33	33	67
	Mats-Max	3	0	0	33	67	100
	Mats-Mean	3	0	0	0	33	100
	%EPT	4	0	0	0	75	100
	%EPT_Taxa	4	0	0	50	75	100
	MCI	4	0	0	0	75	75
	QMCI	4	0	0	0	50	100
Kapiti Coast	Clar	10	40	60	70	90	90
	Turb	11	18	27	27	45	55
	DRP	8	12	12	12	50	50
	TP	9	22	22	33	56	78
	NO3-N	11	55	55	55	82	82
	NNN	11	55	55	55	82	82
	TN	8	62	62	62	62	88
	TOC	11	0	0	0	27	36
	E. coli	11	9	18	18	36	45
	Chla	6	0	17	17	83	100
	Fils-Max	6	0	0	0	0	67
	Fils-Mean	6	0	0	0	0	33
	Mats-Max	6	33	50	50	67	100
	Mats-Mean	6	0	17	50	50	83
	%EPT	10	0	0	0	10	50
	%EPT_Taxa	10	0	0	10	30	40
	MCI	10	0	0	0	20	30
	QMCI	10	0	0	0	10	30
Porirua Harbour	Clar	4	0	0	50	100	100
	Turb	4	0	0	0	50	75
	DRP	4	0	0	0	25	100
	TP	4	75	100	100	100	100
	NO3-N	4	50	50	50	50	50
	NNN	4	50	50	50	50	50
	TN	4	50	50	50	75	75
	TOC	4	0	0	0	0	50
	E. coli	4	0	0	0	0	0
	Chla	4	0	0	0	25	25
	Fils-Max	4	0	25	25	75	75
	Fils-Mean	4	0	0	25	25	75
	Mats-Max	4	0	50	50	50	75
	Mats-Mean	4	0	50	50	50	75
	%EPT	4	0	25	25	50	50
	%EPT_Taxa	4	0	25	25	50	50
	MCI	4	0	0	25	25	50
	QMCI	4	0	25	50	50	50

Table 1. Continued.

Whaitua	Variable	No. sites	Virtually certain	Extremely likely	Very likely	Likely	Likely as not
Ruamahanga	Clar	21	43	62	81	90	95
	Turb	23	17	30	43	57	65
	DRP	14	21	50	50	64	71
	TP	18	39	61	61	72	89
	NO3-N	20	10	15	35	60	65
	NNN	23	9	22	30	65	74
	TN	16	38	56	62	88	94
	TOC	20	10	30	40	65	90
	E. coli	23	13	26	30	52	65
	Chla	19	11	16	32	53	63
	Fils-Max	19	11	16	32	37	84
	Fils-Mean	19	0	16	21	37	58
	Mats-Max	19	5	5	5	32	79
	Mats-Mean	19	0	0	0	16	74
	%EPT	23	4	4	4	35	52
	%EPT_Taxa	23	0	0	22	48	61
	MCI	23	0	0	9	22	52
	QMCI	23	0	4	4	9	22
Wellington Harbour	Clar	14	71	86	86	86	86
	Turb	14	29	29	36	71	86
	DRP	9	0	0	11	33	56
	TP	12	25	42	50	67	83
	NO3-N	12	33	42	58	92	92
	NNN	14	29	29	57	86	86
	TN	10	40	70	90	90	100
	TOC	12	0	8	8	33	83
	E. coli	13	15	31	54	69	77
	Chla	13	0	0	0	38	62
	Fils-Max	13	0	0	0	46	62
	Fils-Mean	13	0	0	0	31	46
	Mats-Max	13	8	23	31	46	69
	Mats-Mean	13	8	23	23	38	62
	%EPT	13	0	8	23	62	62
	%EPT_Taxa	13	0	23	23	62	77
	MCI	13	8	8	31	62	62
	QMCI	13	0	8	23	38	54

Table 2. Ten-year overall Whaitua trends based on raw site trends and binomial tests. Note that this table classifies trends as increasing and decreasing. For clarity and the four invertebrate variables (%EPT, %EPT_Taxa, MCI and QMCI) an increasing trend indicates improvement but indicates degradation for all other variables.

Whaitua	Variable	No_sites	No_Decreasing	No_Increasing	Binomial_p	Whaitua trend magnitude	Adjusted_p_value	Adjusted whaitua trend
East Wairarapa	Clar	3	1	2	1	1.85	1.00	Not significant
	Turb	4	1	3	0.625	0.63	0.97	Not significant
	TP	2	2	0	0.5	-2.07	0.97	Not significant
	NO3-N	3	1	2	1	2.77	1.00	Not significant
	NNN	3	1	2	1	2.92	1.00	Not significant
	TN	2	2	0	0.5	-1.83	0.97	Not significant
	TOC	4	4	0	0.125	-1.34	0.53	Not significant
	E. coli	4	1	2	1	1.29	1.00	Not significant
	Chla	5	5	0	0.062	-14.78	0.53	Not significant
	Fils-Max	3	2	0	0.25	-1.33	0.71	Not significant
	Fils-Mean	3	1	1	1	0	1.00	Not significant
	Mats-Max	3	2	0	0.25	-21.01	0.71	Not significant
	Mats-Mean	3	2	1	1	0	1.00	Not significant
	%EPT	4	0	4	0.125	9.29	0.53	Not significant
	%EPT_Taxa	4	0	4	0.125	7.53	0.53	Not significant
	MCI	4	1	3	0.625	0.76	0.97	Not significant
	QMCI	4	0	3	0.625	0.6	0.97	Not significant
Kapiti Coast	Clar	10	1	9	0.021	3.66	0.28	Not significant
	Turb	11	5	5	1	0	1.00	Not significant
	DRP	8	4	4	1	0.85	1.00	Not significant
	TP	9	6	3	0.508	-0.42	0.82	Not significant
	NO3-N	11	9	2	0.065	-3.01	0.29	Not significant
	NNN	11	9	2	0.065	-3.14	0.29	Not significant
	TN	8	6	2	0.289	-3.36	0.62	Not significant
	TOC	11	4	7	0.549	0.73	0.82	Not significant
	E. coli	11	4	6	1	1.79	1.00	Not significant
	Chla	6	6	0	0.031	-10.27	0.28	Not significant
	Fils-Max	6	3	3	1	0	1.00	Not significant
	Fils-Mean	6	1	5	0.219	9.18	0.62	Not significant
	Mats-Max	6	5	1	0.219	-13.17	0.62	Not significant
	Mats-Mean	6	4	2	0.687	-8.82	0.95	Not significant
	%EPT	10	6	4	0.754	-0.1	0.97	Not significant
	%EPT_Taxa	10	6	3	0.344	-0.09	0.62	Not significant
	MCI	10	7	3	0.344	-0.49	0.62	Not significant
	QMCI	10	7	3	0.344	-0.26	0.62	Not significant

Table 2. Continued.

Whaitua	Variable	No_sites	No_Decreasing	No_Increasing	Binomial_p	Whaitua trend magnitude	Adjusted_p_value	Adjusted whaitua trend
Porirua Harbour	Clar	4	0	4	0.125	2.13	0.75	Not significant
	Turb	4	2	1	0.625	-0.93	0.94	Not significant
	DRP	4	3	1	0.625	-0.38	0.94	Not significant
	TP	4	4	0	0.125	-3.28	0.75	Not significant
	NO3-N	4	2	2	1	-1.51	1.00	Not significant
	NNN	4	2	2	1	-1.43	1.00	Not significant
	TN	4	3	1	0.625	-1.19	0.94	Not significant
	TOC	4	1	3	0.625	0.34	0.94	Not significant
	E. coli	4	0	4	0.125	7.66	0.75	Not significant
	Chla	4	1	3	0.625	6.59	0.94	Not significant
	Fils-Max	4	3	1	0.625	-8.66	0.94	Not significant
	Fils-Mean	4	3	1	0.625	-0.79	0.94	Not significant
	Mats-Max	4	2	1	0.625	-28.51	0.94	Not significant
	Mats-Mean	4	2	1	0.625	-34.38	0.94	Not significant
	%EPT	4	2	2	1	3.01	1.00	Not significant
	%EPT_Taxa	4	2	2	1	0.86	1.00	Not significant
	MCI	4	2	2	1	-0.04	1.00	Not significant
	QMCI	4	2	2	1	0.81	1.00	Not significant
Ruamahanga	Clar	21	1	20	0	4.18	0.00	Improving
	Turb	23	15	8	0.21	-1.47	0.42	Not significant
	DRP	14	9	4	0.18	-1.42	0.41	Not significant
	TP	18	15	4	0.031	-2.88	0.11	Not significant
	NO3-N	20	12	7	0.263	-1.3	0.47	Not significant
	NNN	23	16	6	0.035	-1.43	0.11	Not significant
	TN	16	14	1	0.001	-1.89	0.01	Improving
	TOC	20	17	4	0.012	-1.2	0.05	Not significant
	E. coli	23	14	10	0.678	-1.34	0.87	Not significant
	Chla	19	12	7	0.359	-8.18	0.59	Not significant
	Fils-Max	19	13	6	0.167	-0.48	0.41	Not significant
	Fils-Mean	19	9	10	1	0	1.00	Not significant
	Mats-Max	19	10	9	1	0	1.00	Not significant
	Mats-Mean	19	9	11	0.648	0	0.87	Not significant
	%EPT	23	11	12	1	0.06	1.00	Not significant
	%EPT_Taxa	23	9	14	0.405	1.52	0.61	Not significant
	MCI	23	11	11	1	0	1.00	Not significant
	QMCI	23	18	5	0.011	-0.79	0.05	Not significant

Table 2. Continued.

Whaitua	Variable	No_sites	No_Decreasing	No_Increasing	Binomial_p	Whaitua trend magnitude	Adjusted_p_value	Adjusted whaitua trend
Wellington Harbour	Clar	14	2	12	0.013	5.28	0.06	Not significant
	Turb	14	11	3	0.057	-2.05	0.21	Not significant
	DRP	9	4	5	1	0	1.00	Not significant
	TP	12	9	3	0.146	-2.08	0.33	Not significant
	NO3-N	12	11	1	0.006	-1.57	0.05	Not significant
	NNN	14	12	2	0.013	-1.19	0.06	Not significant
	TN	10	10	0	0.002	-2.15	0.04	Improving
	TOC	12	7	5	0.774	0	1.00	Not significant
	E. coli	13	9	3	0.092	-2.85	0.24	Not significant
	Chla	13	8	5	0.581	-1.97	0.87	Not significant
	Fils-Max	13	7	7	1	0	1.00	Not significant
	Fils-Mean	13	5	9	0.267	1.7	0.53	Not significant
	Mats-Max	13	8	6	1	0	1.00	Not significant
	Mats-Mean	13	7	6	1	0	1.00	Not significant
	%EPT	13	5	8	0.581	0.75	0.87	Not significant
	%EPT_Taxa	13	3	10	0.092	0.95	0.24	Not significant
	MCI	13	5	8	0.581	0.38	0.87	Not significant
	QMCI	13	6	7	1	0.05	1.00	Not significant

Five-year trends

9. Regional maps showing the statistical confidence that five-year trends were improving for each of the monitored variables are presented in Figure 2. The boundaries of the five Whaitua are superimposed on the region. The mapped patterns indicate that improving trends that are inferred with high confidence (green colours), and low confidence (red coloured sites, indicating high confidence that these sites have degrading trends) are mostly randomly distributed geographically. There are a higher proportion of degrading trends (i.e., orange to red coloured sites) for some variables (e.g., periphyton and invertebrate variables) but these are randomly distributed over the Whaitua.
10. The proportion of sites in each Whaitua for which the statistical confidence that five-year trends represent improving water quality is tabulated in Table 3. In general, more than 50% of sites have trends that are at least as likely as not to be improving. However, in each Whaitua there are some variables > 50% of sites are as likely as not to be degrading. Across all variables, the mean proportion of sites for which trends were at least as likely as not to be improving ranged between 56% (Kapiti Coast), 62% (Wellington Harbour Whaitua) 65% (Ruamahunga Whaitua), 73% (Porirua Harbour Whaitua), and 78% (East Wairapa Whaitua). For all Whaitua, these values are all close to the five-year regional mean proportion of sites that at least as likely as not to be improving (66%) that I reported in my evidence.
11. Analyses of overall Whaitua five-year trends indicated only six significant overall trends (Table 4). This was fewer than regional analyses and occurs because of reduction in statistical power when sites are aggregated by Whaitua rather than region. There were overall improving trends in clarity in the Kapiti Coast, Wellington Harbour and Ruamahanga Whaitua, and overall improving trends in turbidity in the Ruamahanga Whaitua and overall improving trends in TOC in the Ruamahanga and Wellington Harbour Whaitua. There were no degrading overall five-year trends in any Whaitua (Table 4).

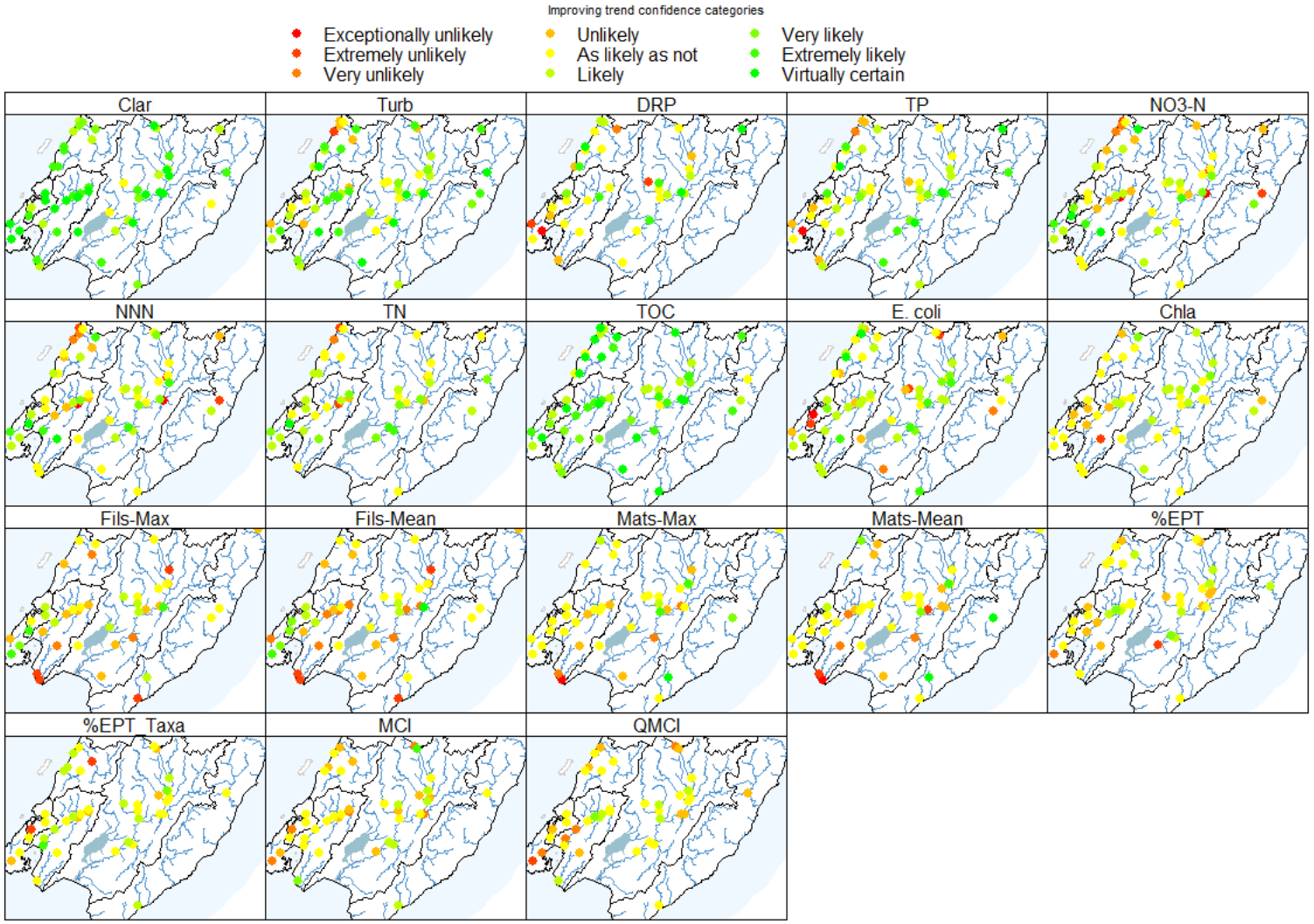

Figure 2. Maps showing statistical confidence that five-year trends indicate improvement by water quality variable. The boundaries of the five Whaitua are superimposed on the region

Table 3. Cumulative proportion of sites (%) with ten-year improving raw trends with at least the level of confidence indicated.

Whaitua	Variable	No. sites	Virtually certain	Extremely likely	Very likely	Likely	Likely as not
East Wairarapa	Clar	3	0	33	67	67	100
	Turb	4	25	50	75	100	100
	TP	2	0	50	50	100	100
	NO3-N	3	0	0	33	33	67
	NNN	3	0	0	0	33	67
	TN	3	0	0	33	67	100
	TOC	4	25	50	50	75	100
	E. coli	4	0	25	25	50	50
	Chla	3	0	0	0	33	67
	Fils-Max	5	0	0	0	20	60
	Fils-Mean	5	0	0	0	0	60
	Mats-Max	4	25	25	50	50	100
	Mats-Mean	4	50	50	50	50	100
	%EPT	2	0	0	0	50	50
	%EPT_Taxa	2	0	0	0	50	100
	MCI	2	0	0	0	50	50
	QMCI	2	0	0	0	0	50
Kapiti Coast	Clar	10	0	40	70	100	100
	Turb	11	9	36	36	55	55
	DRP	9	11	22	22	44	78
	TP	9	11	22	22	44	56
	NO3-N	10	10	10	10	30	40
	NNN	11	0	9	9	27	45
	TN	8	0	0	0	25	62
	TOC	11	55	64	64	82	91
	E. coli	11	18	18	18	45	73
	Chla	6	0	0	17	17	33
	Fils-Max	4	0	0	0	0	25
	Fils-Mean	4	0	0	0	0	25
	Mats-Max	4	0	0	0	25	100
	Mats-Mean	4	0	0	25	25	50
	%EPT	6	0	0	0	17	50
	%EPT_Taxa	6	0	0	0	50	67
	MCI	6	0	0	0	0	33
	QMCI	6	0	0	0	0	33
Porirua Harbour	Clar	4	50	75	75	100	100
	Turb	4	0	0	0	50	100
	DRP	4	0	0	25	25	75
	TP	4	0	25	25	25	25
	NO3-N	4	25	25	50	50	100
	NNN	4	25	25	25	50	100
	TN	4	25	25	25	75	75
	TOC	4	25	25	50	100	100
	E. coli	4	0	0	25	50	50
	Chla	4	0	0	0	0	50
	Fils-Max	4	0	25	25	100	100
	Fils-Mean	4	0	0	50	100	100
	Mats-Max	4	0	0	0	25	100
	Mats-Mean	4	0	0	0	25	100
	%EPT	4	0	0	0	0	75
	%EPT_Taxa	4	0	0	0	0	0
	MCI	4	0	0	0	0	0
	QMCI	4	0	0	0	0	75

Table 3. Continued.

Whaitua	Variable	No. sites	Virtually certain	Extremely likely	Very likely	Likely	Likely as not
Ruamahanga	Clar	20	40	55	60	90	100
	Turb	22	18	32	41	68	86
	DRP	15	13	27	27	47	80
	TP	16	19	38	50	69	81
	NO3-N	20	0	5	15	35	75
	NNN	22	0	9	23	41	77
	TN	15	0	13	33	47	67
	TOC	20	25	55	70	95	100
	E. coli	22	0	14	27	55	68
	Chla	19	0	0	11	53	68
	Fils-Max	17	0	6	6	29	53
	Fils-Mean	17	6	6	6	18	59
	Mats-Max	16	0	12	12	19	69
	Mats-Mean	16	0	6	12	12	44
	%EPT	17	0	0	6	29	35
	%EPT_Taxa	17	0	0	6	29	41
	MCI	17	0	6	6	35	53
	QMCI	17	0	0	0	18	29
Wellington Harbour	Clar	14	50	86	86	100	100
	Turb	14	7	43	50	79	79
	DRP	9	0	11	11	11	44
	TP	13	0	0	8	38	77
	NO3-N	13	8	23	23	54	62
	NNN	14	7	21	29	50	64
	TN	12	0	0	25	58	75
	TOC	13	15	54	77	100	100
	E. coli	14	0	7	7	79	86
	Chla	13	0	0	0	15	46
	Fils-Max	13	0	8	15	23	31
	Fils-Mean	13	0	8	15	23	31
	Mats-Max	13	0	0	0	0	62
	Mats-Mean	13	0	0	0	0	46
	%EPT	12	0	0	8	25	67
	%EPT_Taxa	13	0	8	8	31	62
	MCI	13	0	0	8	8	38
	QMCI	13	0	0	8	31	38

Table 4. Five-year overall Whaitua trends based on raw site trends and binomial tests. Note that this table classifies trends as increasing and decreasing. For clarity and the four invertebrate variables (%EPT, %EPT_Taxa, MCI and QMCI) an increasing trend indicates improvement but indicates degradation for all other variables.

Whaitua	Variable	No_sites	No_Decreasing	No_Increasing	Binomial_p	Whaitua trend magnitude	Adjusted_p_value	Adjusted whaitua trend
East Wairarapa	Clar	3	0	3	0.25	5.65	1.00	Not significant
	Turb	4	4	0	0.125	-12.73	1.00	Not significant
	TP	2	2	0	0.5	-19.05	1.00	Not significant
	NO3-N	3	1	1	1	0	1.00	Not significant
	NNN	3	2	1	1	-0.3	1.00	Not significant
	TN	3	3	0	0.25	-4.74	1.00	Not significant
	TOC	4	4	0	0.125	-5.49	1.00	Not significant
	E. coli	4	2	2	1	0.88	1.00	Not significant
	Chla	3	2	1	1	-26.93	1.00	Not significant
	Fils-Max	5	2	3	1	0	1.00	Not significant
	Fils-Mean	5	2	3	1	0	1.00	Not significant
	Mats-Max	4	3	2	1	0	1.00	Not significant
	Mats-Mean	4	3	2	1	0	1.00	Not significant
	%EPT	2	1	1	1	7.69	1.00	Not significant
	%EPT_Taxa	2	0	2	0.5	10.08	1.00	Not significant
	MCI	2	1	1	1	0.77	1.00	Not significant
	QMCI	2	1	1	1	6.51	1.00	Not significant
Kapiti Coast	Clar	10	0	10	0.002	8.38	0.04	Improving
	Turb	11	6	5	1	-3.42	1.00	Not significant
	DRP	9	6	4	1	0	1.00	Not significant
	TP	9	4	4	1	0	1.00	Not significant
	NO3-N	10	4	6	0.754	1.03	1.00	Not significant
	NNN	11	5	6	1	0.95	1.00	Not significant
	TN	8	4	4	1	0	1.00	Not significant
	TOC	11	10	1	0.012	-7.72	0.11	Not significant
	E. coli	11	7	3	0.227	-4.61	1.00	Not significant
	Chla	6	2	4	0.687	19.38	1.00	Not significant
	Fils-Max	4	0	3	0.625	16.02	1.00	Not significant
	Fils-Mean	4	0	3	0.625	12.21	1.00	Not significant
	Mats-Max	4	3	0	0.125	-11.4	0.75	Not significant
	Mats-Mean	4	2	2	1	7.81	1.00	Not significant
	%EPT	6	3	2	0.687	-0.87	1.00	Not significant
	%EPT_Taxa	6	2	4	0.687	6.07	1.00	Not significant
	MCI	6	4	2	0.687	-1.78	1.00	Not significant
	QMCI	6	4	2	0.687	-0.51	1.00	Not significant

Table 4. Continued.

Whaitua	Variable	No_sites	No_Decreasing	No_Increasing	Binomial_p	Whaitua trend magnitude	Adjusted_p_value	Adjusted whaitua trend
Porirua Harbour	Clar	4	0	4	0.125	13.16	0.25	Not significant
	Turb	4	4	0	0.125	-2.71	0.25	Not significant
	DRP	4	2	2	1	0	1.00	Not significant
	TP	4	1	3	0.625	0.49	0.87	Not significant
	NO3-N	4	4	0	0.125	-0.98	0.25	Not significant
	NNN	4	4	0	0.125	-1.1	0.25	Not significant
	TN	4	3	1	0.625	-2.25	0.87	Not significant
	TOC	4	4	0	0.125	-5.2	0.25	Not significant
	E. coli	4	2	2	1	4.68	1.00	Not significant
	Chla	4	2	2	1	14.77	1.00	Not significant
	Fils-Max	4	4	0	0.125	-18.96	0.25	Not significant
	Fils-Mean	4	4	0	0.125	-26.81	0.25	Not significant
	Mats-Max	4	3	2	1	0	1.00	Not significant
	Mats-Mean	4	3	2	1	0	1.00	Not significant
	%EPT	4	1	3	0.625	2.28	0.87	Not significant
	%EPT_Taxa	4	4	0	0.125	-3.37	0.25	Not significant
	MCI	4	4	0	0.125	-1.89	0.25	Not significant
	QMCI	4	1	3	0.625	0.47	0.87	Not significant
Ruamahanga	Clar	20	0	20	0	6.71	0.00	Improving
	Turb	22	19	3	0.001	-5.24	0.01	Improving
	DRP	15	9	5	0.302	0	0.43	Not significant
	TP	16	12	3	0.021	-6.54	0.09	Not significant
	NO3-N	20	14	7	0.263	-0.33	0.43	Not significant
	NNN	22	16	6	0.052	-1	0.19	Not significant
	TN	15	10	5	0.302	-1.29	0.43	Not significant
	TOC	20	19	0	0	-6.88	0.00	Improving
	E. coli	22	14	7	0.134	-5.52	0.37	Not significant
	Chla	19	13	6	0.167	-18.62	0.38	Not significant
	Fils-Max	17	8	10	0.629	0	0.75	Not significant
	Fils-Mean	17	9	9	1	0	1.00	Not significant
	Mats-Max	16	8	8	1	0	1.00	Not significant
	Mats-Mean	16	4	11	0.21	1.39	0.42	Not significant
	%EPT	17	11	6	0.332	-2.12	0.43	Not significant
	%EPT_Taxa	17	10	6	0.332	-0.51	0.43	Not significant
	MCI	17	8	9	1	0.01	1.00	Not significant
	QMCI	17	12	5	0.143	-1.25	0.37	Not significant

Table 4. Continued.

Whaitua	Variable	No_sites	No_Decreasing	No_Increasing	Binomial_p	Whaitua trend magnitude	Adjusted_p_value	Adjusted whaitua trend
Wellington Harbour	Clar	14	0	14	0	11.68	0.00	Improving
	Turb	14	11	3	0.057	-5.65	0.26	Not significant
	DRP	9	3	6	0.508	0.35	0.65	Not significant
	TP	13	7	5	0.581	0	0.65	Not significant
	NO3-N	13	8	5	0.581	-1.27	0.65	Not significant
	NNN	14	8	5	0.424	-1.29	0.65	Not significant
	TN	12	8	4	0.388	-2	0.65	Not significant
	TOC	13	13	0	0	-8.76	0.00	Improving
	E. coli	14	11	2	0.013	-6.15	0.08	Not significant
	Chla	13	6	7	1	0.5	1.00	Not significant
	Fils-Max	13	3	9	0.267	13.33	0.65	Not significant
	Fils-Mean	13	3	9	0.267	15.5	0.65	Not significant
	Mats-Max	13	7	7	1	0	1.00	Not significant
	Mats-Mean	13	4	9	0.267	4.12	0.65	Not significant
	%EPT	12	4	8	0.388	0.54	0.65	Not significant
	%EPT_Taxa	13	5	8	0.581	1.36	0.65	Not significant
	MCI	13	8	5	0.581	-1.09	0.65	Not significant
	QMCI	13	8	5	0.581	-0.78	0.65	Not significant

Conclusions

12. The Whaitua-level analysis presented above is generally consistent with the results of the region-level analysis that is described in Snelder (2107a) and was previously presented by me in evidence. The analyses indicate that water quality generally improved (i.e., at a majority of sites) in each of the five Whaitua (sub-regions) that make up the Wellington region over the past decade.
13. The results for the ten and five-year trends, indicate relatively little variation among the Whaitua in the proportion of sites that are at least as likely as not to be improving. In addition, for both time periods, a predominance of improving water quality trends is evident in all of the individual Whaitua and there is no evidence of general water quality degradation (i.e. systematic and consistent) in any individual Whaitua.
14. I reiterate four caveats of my earlier evidence and reports and additional caveats that arose in expert conferencing between myself and Doctor Canning and Ms McArthur and which are detailed in our joint witness statement. First, although the predominant water quality change across the region and within individual Whaitua represents improvement, some attributes of water quality are degrading at some sites. Second, there are particular sites for which more than five water quality variables exhibited trends that were likely to be degrading. These have been detailed in my evidence and in the joint witness statement. Third, data collected from the network of sites used in this analysis are imperfect representation of water quality for the region as a whole and of the individual Whaitua. Forth, the analyses and results above are based on aggregating across up to 62 sites and 18 water quality variables. As such, the results are a very general picture and all sites and water quality variables have been given equal weight. Particular sites may be more 'significant' (in the sense of being 'important' rather than statistically significant) than others and some water quality measures may also be considered more important than others. This analysis has provided data for all sites and variables but has not made any judgement about relative significance or importance of sites and variables.

References

Snelder, T., 2017a. Analysis of regional-scale river water quality trends in the Wellington region; Period 2007 to 2016. LWP Client Report: 2017-07, Christchurch.

Snelder, T., 2017b. Analysis of Water Quality Trends for Rivers and Lakes of the Wellington Region. LWP Client Report: 2017-01, Christchurch.