False and misleading?

A review of the cost benefit assessment of 'Action for healthy waterways'

October 2020

tailrisk economics

te maha hoki o nga pihikete

About Tailrisk economics

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False and misleading?

Part one: Introduction

The primary purpose of this report is to review the quality of the economic analysis supporting the decisions made on the fresh water proposals announced in May 2020, and summarised in a table in the Cabinet paper 'Actions for Healthy Waterways'. The Cabinet paper was supported by a set of 20 regulatory impact assessments which added to and drew on analysis set out in the earlier paper 'Interim Regulatory Impact Analysis for Consultation: Essential Freshwater Part II: Detailed Analysis'.

The headline result is that the present value of the benefits of the measures is $7 billion, and the costs have a present value of $3.2 billion for a net gain of $3.8 billion. Most of the benefits come from the health benefits of stock exclusion from waterways ($2.4 b) and from the preservation of wetlands ($3.9 billion).

The Cabinet paper paints the following picture of the supporting analysis and science.

Our recommendations on Action for healthy waterways are supported by comprehensive impact analysis, much of which was undertaken since consultation and in response to submitters' feedback. Officials assessed the impacts of individual policies, as well as the cumulative impacts of policies, that will have significant environmental and economic effects.

New Zealand's leading research institutes, universities, and private sector firms contributed to this effort. They produced numerous studies of national as well as catchment- and farm-level policy impacts on key groups (Māori, farmers and regional councils) and analysis of industry, regional and national costs and benefits. Officials commissioned peer reviews of many reports in order to ensure the quality of the data that informed their advice.

Quality assurance of the regulatory assessements was provided by a panel of MfE. MPI and Treasury. This is the summary of their conclusions.

The panel considers that overall, the package "partially meets" the quality assurance (QA) criteria. Within the individual RIA, twelve "meet" the QA criteria and eight "partially meet". 156. The "partially meets" rating for the individual RIA and the overall package, reflects *information and data constraints. The Ministry's approach to the analysis is generally sound and is based on relevant available data.*

This picture of a robust process is mostly misleading. While there may have been good science at the bottom of some of the assessments, in many cases the results were distorted or misused as they went up the analytical chain. In some cases the science was dubious. We found that the estimates of the size of the major benefits were not supported by both good science and credible economic modelling.

In particular:

- The health benefits from stock exclusions from waterways were not based on data that showed that there would be a very limited impact on the disease vector. Our assessment showed that contrary to popular belief contamination by stock does not cause many illnesses and that the health benefits from the stock exclusion measures will be tiny.
- The estimate of $3.9 billion for the wetland protection benefits was not based on any analysis at all. Instead a single nonsensical number was plucked from an environmental journal. The implication of the assumption is that if a farmer converted a single hectare of farmland worth say $15,000 into wetland it would generate economic value of $50,000 a year, and be worth $1,500,000.

More generally we found many cases where:

- Numbers were simply made up at the last minute.
- Evidence was ignored (when inconvenient), exaggerated or misundertood.
- There was no obvious or strong link from the reported benefit and cost numbers to the underlying analysis.
- Strong conclusions were drawn from personal or institutional predispositions or prejudices rather than the science.

We were particularly concerned about Treasury's role. They should not have been part of a panel where they were in a one on two situation with the agencies that were defending their work. They should have conducted their review function independently. While they would not have been in a position to enquire too deeply into the detailed science and analysis of many of the proposals, there was no such excuse for the wetland protection benefits estimate. At $3900 million this was the 'big ticket' item. It was based on a number in a single foreign journal, which could have been read and absorbed in 30 minutes, and should have been written off as a nonsense. Treasury should have been aware that there was nothing that would pass as an analytical framework in the Regulatory Impact Assessment supporting the wetlands proposals. But they let it pass, perhaps as a'partially meets'the quality assurance criteria.

Table one : Cost and benefit calculations in Cabinet paper

Benefits	**Annual $'m**	**PV $'m**	
Swimmability benefits from stock exclusion	138	2366	Reduced human health risks
Water clarity benefits from stock exclusion	13	104	
Ecosystem health benefits of MCI bottom lines	79	661	Assumes Action for healthy waterways provides 50% of total benefits, with the current NPS-FM providing the rest; assumes achievement of MCI bottom lines by successfully implementing the costed policies. This has not been modelled
Wetland econsystem services	450	3900	Assumes that replacing lost wetlands with infrastructure like flood barriers and dams would cost about $50,000 per hectare of wetlands lost per year
	359	**7031**	
Costs			
Stock exclusions	61	1092	Outlays begin in 2023 and marginal impact ceases by 2050
Farm plan costs	22	253	Assumed marginal impact from 2025 to 2035
Mitigation costs from reducing nitrogen pollution due to toxicity policy	30	217	Assumes periphyton is managed to 20% spatial exceedance and includes the net opportunity cost of land use change. This is in addition to the cost of reducing nitrogen for the current NPS-FM, estimated to be $3,579 million
Water measuring and reporting related costs	10	196	
Additional costs for local authorities	76	1490	
Total Costs	**166**	**3249**	

This report is structured as follows:

Part two presents our key findings.

Part three discusses the evidence from Ministry of Health reports on the health risk posed by the loss of farm animal effluent into waterways. The evidence strongly suggests that the public health costs are low and that the benefits from excluding animals from waterways are correspondingly low.

Part four examines the 'swimmability' of river definitions that lie behind the MfE's claims that 80 percent of New Zealand's rivers in pastoral areas are 'unswimmable'. It goes back to review in detail the original science that was used to support the risk assessments.

Part five examines the modelling of heath cost benefits generated by the stock exclusion proposal.

Part six assesses the estimate of the benefits from protecting wetlands.

Part seven discusses the science and logic of the nitrate bottom line and their costs and benefits.

Part eight reviews the rationale for and the cost benefit analysis of the proposed sedimentation in water limit.

Part nine presents a summary of our assessment of the cost and benefit numbers.

Part two: Key findings

The net value of the benefits is negative

The present value of the net monetized benefits are minus $3.2 billion dollars. The estimate in the cabinet paper was a positive value of $3.8 billion. The difference is largely explained by omitting the $3.9 billion benefit from protecting wetlands, which was just a fanciful number introduced at the last minute to boost the numbers; and reducing the health benefits from stock exclusion from $2366 million to $2 million.

Benefits from wetlands protection fanciful

The estimate PV benefits of $3.9 billion from wetland's projection appears to have been made up at the last minute for the Cabinet paper. There is no reference to the number in any of the MfE papers and there was no peer review. The estimate is based on a number in a single paper in an overseas journal that claimed, without any supporting analysis, that the economic value from wetlands is NZ $50,0000 per hectare a year. The number is simply fanciful and should not have been used. Applying the discount rate of 3 percent used in the MfE analysis this suggests that the value of a hectare of wetland is about $1,500,000 and that New Zealand could become wealthy by reconverting all of its converted farmland back to wetlands. This is obviously nonsense.

Health Benefits from stock exclusion very low

Our assessment of the NPV benefits of $1 million excluding stock from waterways was based on:

- A realistic assessment of the number of notifiable cases currently caused by infections from cattle effluent getting into waterways of about 500 a year.
- A best estimate of the average cost of illness of $700. As most cases are not notified and do not require medical attention, the cost is largely driven based on an illness that lasts about four days.
- NIWA modelling that suggests that stock exclusions will reduce the number of illnesses by only 7 percent or about 90 cases.

The MfE's estimate of the present value cost to farmers is $1092 million.

MfE modelling of health benefits was unsound

The MfE estimate was not based on an assessment of the reduction in the number of illnesses from waterways contamination. Rather it used an economic technique called a Choice Experiment. This involved providing a large sample of respondents with freshwater health, ecological and water clarity outcomes and seeing whether they were prepared to pay a certain amount for those outcomes. From that a figure was calculated for the amount thay were prepared to pay for a one percent improvement in the risk of getting sick from a freshwater swim. The problem was that the respondents were given grossly exaggerated pictures of both the risk of freshwater swimming and the amount of improvement that could have been expected from the policy intervention. These biases invalidated the results and they should not have been used.

The MfE also made some errors in calculating the cost of an illness, increasing the cost from around $700 a case to $2500, which blew up the PV number by a factor of 3.5.

Number of freshwater contact illnesses overstated

The MfE overstated the number of freshwater illnesses. The headline number in the Regulatory Impact Assessment, based on misleading reporting of the Ministry of Health's notifiable disease data, rated up to account for unreported cases, was 100,000 a year. Our estimate is about 1300 a year.

The modelling of the risk of illness from freshwater not based on sufficient evidence to generate robust conclusions and overstates the true risks

The modelling behind the assessments used to generate 'unswimmability' assessments is based on some flimsy data and appears to overstate the risks. The sole data source for the critical relationship between the level of campylobacteria in the water and the probability of becoming infected was a laboratory experiment that showed that 5 out of 10 subjects became infected when given a dose that was around 200 times higher than the trigger point that is now used to assess the swimmability of rivers. There was also a flaw in the 'sense testing' of the modelled results against notifiable disease numbers that resulted in an overstatement of the level of risk by a factor of, perhaps, 10 to 20. The comparison was with the total number of cases, not the possible number of cases from freshwater sources.

As a consequence the MfE's statement that 80 percent of rivers and streams in pastoral farming areas are unswimmble is exaggerated and alarmist.

Part three: Health effects from animal effluent in fresh water

Thoughout the consultation documents, regulatory impact statements and the cabinet paper, there is a running narrative that a large proportion of New Zealand rivers are not safe to swim in; that run-off from farm land is a major cause of the problem; and that this is a problem that needs to be, and can be, fixed. The health benefits from the stock exclusion policy alone are valued at $2366 million.

The detailed RIA made the case in its summary of the policy issue as follows:

The high levels of E. coli in many rivers and lakes indicate that people who are in contact with the water, particularly where there is a high incidence of ingestion or inhalation of water and water vapour, have an unacceptable risk of infection or illness. This situation is getting worse in some rivers and current direction in regional plans and the NPS-FM is not driving sufficient improvements.

The incidence of water borne notifiable diseases has not changed much over the last ten years. Recreational water contact was the fourth most commonly cited risk factor for campylobacteriosis (6482 cases) in 2017. Recreational water contact is also cited as a risk factor for salmonellosis (1,119 cases), giardiasis (1,648 cases), and cryptosporidiosis (1,192 cases). Health professionals estimate the actual number of cases to be at least ten times higher than the notified cases.

Action for healthy waterways proposed to address this issue by directing regional councils to identify primary contact sites in their regional plans, and improve water quality at those sites so that it is at least better than the proposed national bottom line for E. coli set out in proposed Table 23.

As an assessment of the policy problem this was inadequate and misleading. The figures presented on notifiable illnesses are the total number of notifiable illness from all sources, not the number that might possibly be attributable to illnesses from freshwater sources, as the issue discussion implies. The uninformed reader is lead to think that there were more than 10,000 notified cases, due to freshwater contact, and that the total of notified and unnotified cases was over 100,000. The reality is that the number of cases that could possibly be linked to recreational water contact is a small fraction of this number.

This part examines the evidence, from the notifiable disease data, that farm effluent is a significant cause for concern. Our estimate of the annual economic cost of illnesses caused by farm animals is under $500,000 per annum. Because the stock exclusion policy will not be a very effective mitigant the present value of the benefits is less than $1 million.

Preliminary Regulatory Impact Assessment

There was a more detailed discussion of the notifiable disease evidence in the preliminary Regulatory Impact Assessment.

The starting point for the initial RIS consideration of the incidence of illness is the Health Ministry's notifiable disease report[1]. The exposure to risk factors for campylobacteriosis (which accounts for over 60 percent of notifiable illnesses that could be caused by farm effluent) is shown in their table 5 below. In 2017 recreational water contact was reported as a risk factor in 427 cases. This was 6.6 percent of the total of 6482.

Table two: Notifiable disease risk factors

Table 5. Exposure to risk factors associated with campylobacteriosis, 2017

Risk factor	Yes	No	Unknown	Percentage (%) [a]
Consumed food from retail premises	1016	1192	4274	46.0
Contact with farm animals	1004	1431	4047	41.2
Consumed untreated water	589	1588	4305	27.1
Recreational water contact	427	1970	4085	17.8
Contact with faecal matter	341	1904	4237	15.2
Contact with other symptomatic people	268	1900	4314	12.4
Travelled overseas during the incubation period	271	2808	3403	8.8
Contact with sick animals	171	1955	4356	8.0

[a] Percentage refers to the number of cases who answered "yes" out of the total number of cases for which this information was known. Some cases had more than one risk factor recorded.

The table shows that the recreational water risk factor was reported in only about a third of cases. To calculate the total number of risk factors, the MfE assumed two possibilities. The first is that **all** of the 4085 'cause unknown' cases were associated with recreational water contact. This generates an estimated number of risk factors of 4512. The second assumption is that **none** of the unknown cases are associated with recreational water contact so the estimate is the actual reported number, 427 giving an estimate in the range of 427 to 4512. The same approach is used with the three other notifiable, potentially waterborne, illnesses to produce a risk factor range of 1031-6874.

[1] ESR Notifiable Disease Report 2017

Scaling for non-reporting of illnesses

The second step in the MfE analysis was to multiply the reported illness numbers by a factor of 10, citing an analysis[2] of the Havelock North campylobacteriosis outbreak in 2016 that the number of cases '*could have been as many as 7,326, but there were only 964 notifications*'. This is a ratio of estimated to reported cases of about 7.5.

The mean estimate of the number of cases in the Sapere study was 5500, a ratio of about 6 times the reported number. The number cited by the MfE was the upper bound of the confidence interval around that central estimate. The central estimate should have been used.

The MfE then, for good measure, further blew the ratio up to 10.

'*the number of people getting sick from campylobacteria annually after contact with recreational water, could be between 4,000 and 45,000.*

Extending this methodology to the other reported waterborne illnesses then the number of people getting *'a serious illness after recreational contact with water could be 10,000 to 70,000'.*

There are a number of issues with the analysis. We critique the MfE analysis and then present our own estimates. Note that we present our analysis in terms of campylobacteria illnesses and then scale up by a factor of 1.5 for the other three illnesses at the end of the discussion.

Presentation of a range of numbers

When the risk factors are not reported the best approach would have been to assume that the reported cases are an unbiased estimate of the unreported cases. The reported cases, 427, should have been scaled up by the factor of total cases to unreported cases. This factor was 2.7 so the number of cases with a recreational water risk factor would have been 427 x 2.7 =1153.

There is a big sample and there is no reason to expect that this would be too far from the true number. It is not valid to assume that none, or all, of the unreported cases had reported recreational water risk factors. The only reason you would assume that the risk factor in all unreported cases was due to recreational water contact, would be to blow up the reported highest estimate. You could say that cases were up to 70,000, implying that this was a limit that had been calculated

[2] Sapere Research Group 2017 The Economic Costs of the Havelock North August 2016 Waterborne Disease Outbreak David Moore, Rebecca Drew, Preston Davies, Rebecca Rippon

using some robust statistical analysis, when the truth is that the probability that this is the true number is infinitesimally small.

Our estimate: 1153

A risk factor does not signify cause

It is important to understand that the data in the table records just possible risk factors, it does not mean that the risk factor was the source of the infection. In many cases there are multiple risk factors, but only one will have been the cause of the illness. The total number of reported risk factors in the above table was 4087 (the 'yes' sum in table two) but there were only about 2300 actual reports. Then we have to consider biases in the reporting. The number of reports of retail food as a risk factor was 1016 - less than 50 percent of cases. However, retail food will have been a risk factor in most cases, as people have to eat. With recreational water contact, however, people will mostly remember the event and there will be less under-reporting.

To move from the reported number of risk factors to the actual expected number of cases it is necessary to divide the reported number by the ratio of the number of risk factors (4087/2300) to the number of reports. The MfE did not do this. We have used a ratio of two, making a conservative adjustment for under-reporting of food consumption risks.

Our estimate: 1153/2 = 577

Scaling for non-reporting of illnesses

The second step in the MfE analysis is to scale up the number of reported cases to account for unreported cases. This assessment was based on the Sapere Havelock North campylobacteriosis outbreak analysis, which it was claimed, reported a ratio of total to notified cases of 7.5.

The mean estimate of the number of cases in the Sapere study was 5500, a ratio of about 6 times the reported number The number cited by the MfE was the upper bound of the confidence interval around that central estimate. The central estimate should have been used.

In our calculation we have used a ratio of 6 as this is the most objective reported number.

Our estimate: 577 x 6 =3462

Reporting of total illnesses misleading

The statement that there were up to 70,000 serious illnesses was misleading in two more respects. First, it is an estimate of all recreational water contacts, not fresh water contacts. All contacts is not the relevant data, because it is only contacts in rivers, lakes and streams that is relevant. Recreational contacts includes saltwater, pool and spa contacts. It is mentioned that these are recreational water contacts but the casual reader would not understand that the freshwater figure would be much lower.

Second, describing all of the cases as serious illness is misleading, because on their assumption, 90 percent were not serious enough to warrant treatment by a doctor.

The MfE did attempt to adjust for freshwater contacts but only when they scaled down the calculations of the cost of illness by half, in that section of their analysis. The logic was as follows:

Some of these people may have been swimming in the sea, or in rivers not monitored by the councils. With nearly half of New Zealand's population living within 20 km of a monitored recreational site (2.2 million people), and assuming that this equates reasonably well with the proportion of people who have become sick after contact with recreational freshwater, the estimated benefits of reduced illness that would result from improving water quality in rivers and lakes as indicated by E. coli would be in the range of $10 million to $80 million annually.

It is a bit difficult to follow the logic here. Half the population might live within 20 km. of a monitored river site, but equally, perhaps 90 percent, or more, might live within 20 km. of the sea, swimming pools and spa pools. This does not prove that these sources were responsible for 90 percent of the illnesses.

It is difficult to say what proportion of illnesses were from streams, rivers and lakes, but there is some relevant information on the matter. Until 2015 some data was reported in the notifiable disease reports on the number of disease outbreaks (not all campylobacteriosis), broken down by swimming pools and spas, and other water contact. Over 2013-2015[3] the numbers were about even. 49 illnesses related to pools and spas, and 43 to 'other' (sea and freshwater).

There is also evidence that seawater swimming may be more risky than freshwater swimming. The following is the relevant discussion in a WHO document.[4]

[3] ESR reports

[4] WHO 2005 'Water Recreation and Disease'

Dufour (1984) discussed the significant differences in swimming-associated gastrointestinal illness rates in seawater and freshwater swimmers at a given level of faecal index organisms. The illness rate in seawater swimmers was about two times greater than that in *freshwater swimmers. A similar higher illness rate in seawater swimmers is observed if the epidemiological study data of Kay et al. (1994) and Ferley et al.(1989) are compared, although it should be noted that the research groups used very different methodologies. At the same intestinal enterococci densities, the swimming associated illness rate was about five times higher in seawater bathers (Kay et al., 1994) than in freshwater swimmers (Ferley et al., 1989).*

Given this evidence and the likelihood that a much larger proportion of the population are exposed to risks in the sea and in swimming pools and spas, we have assessed the share due to freshwater contacts at 25 percent.

Our estimate: 3462 x .25 =866

Adjusted for all reported illness: 866 x 1.5 = 1300

A natural experiment

Our estimates will appear low to some who have been brought up with the idea that many of New Zealand's rivers are unswimmable, but the results are supported by the outcome of a natural experiment.

In the 2000's there was an epidemic of campylobacteriosis caused by infections in chickens getting into the food chain. When the authorities got on top of the problem the number of notifications fell sharply from 12,700 in 2007 to 6700 in 2008.

In the cases where recreational water contact was reported as a possible cause of illness, there should not have been a drop in these numbers as it is unlikely that chickens were contaminating recreational waters. But that is not what happened. Table three below shows the total campylobacteriosis notifications and the reported recreation water risk factor notifications. Comparing four years of the epidemic (2004-2007), with the four post epidemic years (2008-2011), overall notifications fell by 50 percent. The number of water risk factor notifications fell by 54 percent.

What this suggests is that it may not have been the fresh water contact that was the source of a reported infection in many cases. Rather it could have been the home prepared chicken salad, which was thoroughly toxic by the time it was consumed at a riverside picnic several hours later.

Table three: Campylobacteriosis notifications 2004-2017

	Notifications	Recreational water contact
2004	14286	766
2005	13839	566
2006	15873	473
2007	12736	337
2008	6693	179
2009	7176	234
2010	7346	281
2011	6692	284
2012	7031	405
2013	6837	366
2014	6776	403
2015	6218	370
2016	6250	357
2017	6492	427

Unfortunately this is not a perfect natural experiment. At the time there was a practice of spreading chicken droppings on farms, and while this was not widespread, it may have been a vector for campylobacteriosis though a recreational water route that could have affected the data.

MfE's estimate of economic cost of freshwater recreational contact-driven illness

The Ministry calculated the economic cost of water borne illness as follows:

The total economic costs associated with the Havelock North campylobacteriosis outbreak in 2016 were estimated to be $21,029,288, for an estimated 5,088 households. The costs included costs to hospitals, households, and businesses.[5] *Subtracting costs to local and central government and non-government organisations of responding to the outbreak ($4,774,233), and costs to households of buying or boiling water ($3,489,574) leaves a total cost of $12,765,481, or $2,509 per household.*

The $2509 cost is then scaled up by the estimates of the number of illnesses to:

[5] Sapere ibid.

'suggest that illnesses caused by contact with recreational water could be costing New Zealand $25 million - $175 million annually'.

But as noted above this is then scaled down by 50 percent to generate freshwater cost estimates of $10 million to $80 million per annum.

Issues with the cost estimate

There are a number of issues with the estimate of $2509.

- The estimate is based on the cost per household, not the cost per illness. There were cases where there were multiple illnesses in households.
- The Havelock North demographic is more elderly than the demographic of people likely to become sick swimming so the illness cost would have been higher.
- The costs to businesses due to the disruption of the water supply does not appear to have been deducted.
- The largest cost to households was an estimate of the time spent away from normal activities due to the outbreak, derived from survey information. It was not clear, in the Sapere study, the extent that this was due to disruptions due to the lack of a secure water supply in the town, and disruptions due to personal illness. If it is due to the lack of a secure water supply this is not relevant to the cost of a normal recreational contact campylobacteriosis illness. If it refers to the direct cost of the illness then this would be double counting. This cost was already captured by the calculation of the QALY estimate in the medical cost section of the report. Illnesses were estimated to cost 4 days if no doctor was involved, and 9 days with medical treatment. The cost per day was taken from the standard Pharmac estimate of $50,000 per year.

Using these figures, and including the Sapere estimates of the direct health costs we calculate the average cost of an illness to be about $700.

The burden of freshwater contact diseases

The MfE estimated the annual burden of the disease to be $10-80 million. Using their methodology the mean estimate would have been about $25 million.
Our estimate is 1300 cases X $700 = $910,000. The reasons for the difference are:

- MfE did not correctly interpret the cost per illness in the Sapere report and overstated the costs by a factor of 3.5
- We assumed streams, rivers and lakes accounted for 25% of illnesses. MFE assumed 50 percent.
- We adjusted for the multiple reporting of risk factors. MfE did not.

- We scaled by a factor of 6 for under-reported cases. The MfE used a factor of 10. As no one knows the true number, neither estimate is right or wrong.

Share of illnesses due to livestock contamination

The MfE did not calculate the share of infections due to livestock, because as we describe in Part 5, they used a different approach to calculate the impact of stock exclusion. Our preferred approach is to work from the health burden data to estimate the expected benefits.

There are three main sources of infections in fresh water: bird life; point sources and livestock. Again it is difficult to attribute cases to these sources, but from the available evidence and discussions with a knowledgeable source in the local authority sector, livestock does not appear to be the obvious major source. For example McBride et al[6], reported that in catchments dominated by bird effluent (gulls, waterfowl etc.) the level of e-coli contaminant was significantly higher than in catchments dominated by dairying.

One reason why livestock effluent poses a lesser risk to swimmers than it might appear from river contamination numbers, is that the effluent is mostly released into rivers when people are not swimming. In a paper that suggests that stock exclusion fencing will largely be a waste of resources Muirhead[7] reported that the amount of effluent removed in high rainfall events is 95-99 percent of the annual load. In those events people are unlikely to be swimming because it is raining, which doesn't make for a good picnic, and because they are aware that a swollen river could be dangerous and could pose a health hazard (there are official warnings not to swim for a few days after a high rainfall event). This view is not universally shared however. Some commentators have noted that there does not appear to be an obvious link between river flow readings and e-coli readings.

There is no right answer here but for illustrative purposes we have assumed that the livestock affected by the new stock exclusion policy is responsible for forty percent of illnesses. The number of illness falls to 520 and the annual cost is $364,000.

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[6] McBride, G.; Till, D.P.; Ryan, T.; Ball, A.; Lewis, G.; Palmer, S.; Weinstein, P.(2002). Pathogen occurrence and human health risk assessment analysis. New Zealand: freshwater Microbiology research Programme, Ministry for the Environment,

[7] Muirhead RW, Monaghan RM, Donnison AM and Ross C (2008). 'Effectiveness of current best management practices to achieve faecal microbial water quality standards'

Impact of fencing on illness cases

The last step is to calculate the benefit, in terms of the reduction in health costs of the exclusion policies.

Here we have relied on a 2016 catchment load model built by the National Institute of Water and Atmospheric Research (NIWA), in partnership with AgResearch. The key ouput of the model was the impact of various stock exclusion proposals on swimming quality. The results in terms of the change in the kilometres of swimmable rivers and streams, are presented in their table 14, which we have reproduced as a screenshot below. The most relevant scenario is option 7.

The obvious take-out from the model is that the stock exclusion policy will have very limited benefits. The percentage of waterways below a 'minimum swimmable standard' falls from the baseline 42.7 percent to 39.6 percent, an improvement of about 7 percent. The percentage of waterways in the highest swimmability band increases from 48 percent to 50 percent, a 4 percent improvement.

If we assume that the 7 percent reduction in waterways below the minimum swimmable standard is reflected in the number of infections, then that number will fall by 91 a year (1300 x .07). The annual monetary benefit will be $63700. The present value of this benefit through to 2050, will be about $2 million. Even if we were more generous with our assumptions it is hard to come up with a number of over $5 million. This is a long way short of the $2366 million in the Cabinet paper.

How the MfE could come up with an estimate of $2366 million we address in part five.

Figure one: NIWA e-coli change estimates

Table 14: Proportion of Accord waterways nationally within each National Objectives Framework *E. coli* band for primary contact recreation (based on 95th percentile *E. coli* concentrations) for each stock exclusion option

Option	Description	Swimmable bands A	Swimmable bands B	Below minimal acceptable standard
1	Baseline Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	47.96% (147 182)	9.41% (28 887)	42.62% (130 805)
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	47.99% (147 269)	9.43% (28 951)	42.58% (130 653)
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	47.99% (147 275)	9.44% (28 968)	42.57% (130 631)
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	48.0% (147 312)	9.45% (29 008)	42.54% (130 553)
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	48.32% (148 282)	9.69% (29 723)	41.99% (128 868)
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	48.33% (148 324)	9.69% (29 742)	41.97% (128 807)
7	Exclude dairy, beef and deer into steep country (slopes up to 28 degrees) for Accord waterways only	49.99% (153 417)	10.41% (31 948)	39.60% (121 508)

Note: Accord waterways are deeper than 30 centimetres and wider than 1 metre. Non-Accord waterways are smaller than this.
A and B bands refer to the National Objectives Framework (NOF) bands. For a waterway to be safe to swim in, the *E. coli* load should be within the A or B band. The numbers in brackets are the length of stream kilometres in each NOF band.

Part four: The measurement of 'swimmability'

The official risk assessments

The official risk assessments by class presented on the MfE website are shown in table four.

Table four: Risk by attribute states

Catetegory	**Percent exceedance over 540**	**Percent samples over 260**	**Median**	**95th percentile**	**Risk description**
A	<5%	<20%	<130	< 540	For at least half the time the estimated risk is less than 0.1% Average is 1%
B	5-10	20-30	<130	<1000	Average infection risk is 2%
C	10-20	20-30	<130	<1200	Average 3 %
D	20-30	>34%	>130	>1200	Av >3%
E	>30	>50	>260	>1200	Av >7%

On the face of it these estimated risks seem to imply a much higher number of illnesses from fresh water contact in rivers and stream than the 1300 we estimated in part three. If, say, there were one million swims a year and the average risk was 2.5 percent then there would be 25,000 infections a year. A higher number of swims would increase the number of infections.

However, there are several factors that close the gap. They are:

- The difference between infections and illness rates.
- The risk measures assume that people swim when there are warnings against swimming in place.
- The underlying modelling is not robust and could overstate the risk by a large margin.

Illness rates rather than infection rates

The risk measures are infection rates, and not all infections result in illnesses. McBride[8] says that the illness rate is less than 50 percent, and the WHO have settled on a 33 percent conversion rate. As it is illness, not infection that matters from a public risk perception perspective (and illness is the metric for the reporting of marine water risk), the risk should have been presented in terms of illness probabilties.

The reason for not making this adjustment was that the risks are based on Campylobacteriosis infection rate modelling and that there other waterborne illnesses that would add to the risk. However, in the most authoritative study on the issue, Mcbride reported that other waterborne pathogens were seldom found at swimming sites.

Making some adjustment for other illnesses would still reduce the illness rate to perhaps half of the infection rate.

Weather state and warnings ignored

The predicted infection rates assume that people swim at the same rate regardless of the weather and whether there is a swimming advisory notice in force. As noted in part 3 this will bias infection rate estimates upwards.

The MfE produced a table that included (right hand column) their estimate of the effect of avoiding swiming when river flows are high. This appears to reduce the risk by about forty percent. Note that the description of normal risk in the table, is a little misleading. The figures refer to three times the normal flow, not the normal flow.

There is no assessment of the reduction in risk if people do not swim when advisory warnings are in effect.

Table 5: Average risk from each swimming category

Category	Average theoretical risk across all time (assessed by Massey University)[1]	Average theoretical risk across all time (assessed by NIWA)[2]	Average risk per exposure at monitored sites[3]	Average risk during normal flows[4]
Excellent	0.9%	1.0%	0.4%	0.3%
Good	1.9%	2.4%	1.7%	1.3%
Fair	3.1%	3.1%	2.6%	2.0%
Intermittent	More than 8.0%	More than 3.1%	More than 6.8%	More than 5.4%
Poor	More than 15.0%	More than 3.1%	More than 11.7%	More than 10.6%

[8] Mcbride ibid.

If we assume that the risk is overstated by a factor of, say four, this still leaves a large gap between our estimate and the official modelling.

Modelling results not robust

The most important issue is the robustness of the modelling underpining the official risk calculations. They are based on modelling by McBride for the Freshwater Microbiological Research Programme (FMRP), which was based on a major testing exercise of waterborne pathogens in a range of freshwater swimming sites. The model works by first calculating a relationship between the level of canphylobacter in the water and infection rates and then translating this to an estimate of level of e-coli in the water. The E-coli levels are used as the measure of swimming quality. E-coli is an indicator variable. it does not (except rarely) cause illnesses. The translation from camphylobacter to e-coli is done by percentile matching.

Some summary results from the analysis (by infections per 1000 swims) are shown in table six, The overall risk is just over 4 percent. Interestingly the risk posed in dairy areas, which have been associated as a source of poor swimming quality was not much higher than than the risk posed by forested areas.

Table six: Risk (infections per 1000 swims) by land type

	All	All (swimming season)	Birds	Dairy	Forests	Municipal	Sheep
Mean risk	41.2	32.1	45.5	33	27.4	42.5	55

The 75th percentile, equating to a camphylobacter dose rate of about 4 and e- coli values of 175-500 (depending on the land types) was identified as the trigger point where infection rates rise steeply from low levels for individual swimming sites and became the basis of the risk threshold recommendations.

Table seven: Risk by percentile of observations

Percentile of individual sites	Risk full year:infections per 1000	Risk swimming season: infections per 1000
55th	0	0
60th	1	0
65th	3	2
70th	9	4
75th	18	10
80th	26	19
85th	72	32
90th	131	91
95th	329	217
Maximum	491	505

Weak empirical support

The problem with this modelling is that it is supported by some very weak evidence . It is based on the only available empirical evidence (Blackwell 1988), which was a laboratory test of the effect of measured doses of a strain of camphylocbacter on a group of 72 volunteers. The results as presented in McBride are shown in figure 3. Only one of the dose experiments, involving just 10 participants (5 of whom became ill) is relevant to the assessment of freshwater swimming risk. The dosage level was 800 organisms per 100ml, which is much higher than observed in rivers and lakes. The median observation in the New Zealand testing was 0.6 per 100ml (and 0.2 in dairying areas).

The other tests (10,000 and above) were of dosage levels which are extremely unlikely every to be observed. From this 800 dosage point a relationship was drawn down to zero. This is depicted in figure 3 which shows the estimated curve from the Black data, and figure 4, which shows the estimated curve in the study from 800 down to zero. The problem with the analysis is that it is entirely contingent on the assumed curve because there is no supporting evidence for dose rates of under 800. It would have been plausible to draw a curve that had a close to zero risk up to say 50 and then curved up more steeply to the 800 observation point. An alternative curve could have readily generated an overall risk that was one tenth or one twentieth of the McBride estimate of 4 percent.

Figure two: Modelled dose response curve 100 plus

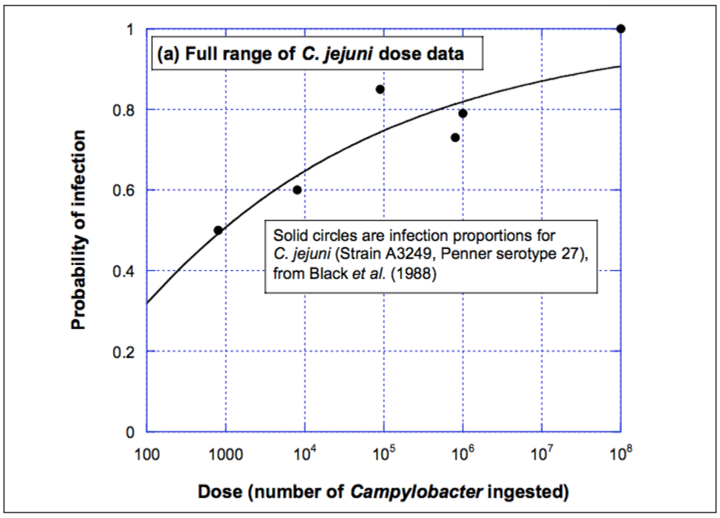
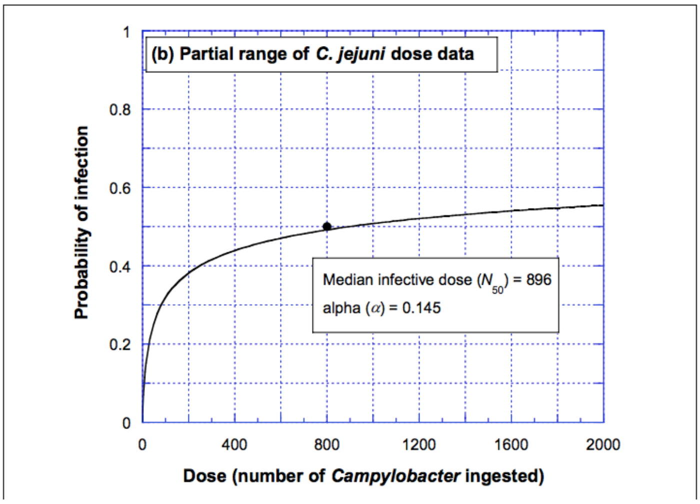


Figure three: Modelled dose response curve 0- 2000



There are other issues with this dose-response relationship.

- Figure 4 above shows that the infection rate at 100 is about 30 percent. In the modelling of the infection rate in table seven the maximum assumed dose rate of 100 had an infection rate of 50 percent. This discrepancy in the rate probably had something to do with the way the data was manipulated because the infection/dose distribution was not well behaved.
- The 10 subjects of the 800 dosage test is a very small sample, so the confidence bounds would be relatively wide. The 'true' number falling ill

could well be two or three rather than five, which would have drastically changed the McBride results.

- The Black study used a single strain of the pathogen, which may not be indicative of the infectiousness of strains encountered in New Zealand.
- A further uncertainty in the modelling is around the amount of water ingested when swimming. A midpoint of 50mls (with a distribution around that) was assumed, but we don't really know how much water is typically ingested in a river swim.
- There is uncertainty around the relationship between the indicator variable – the amount of e-coli - and the presence of the camphylobacter pathogen. The correlation between the two is only around 0.3, which adds further noise into the mix. Other pathogens had weak relationships with e-coli. McBride says that the correlation for camphylobacter is stronger at higher dose rates, but the more relevant test is the correlation at measured readings of 3-10, which is where the infection rates pick up. If there is only weak correlation here then the 'correlation matching' technique flounders.

Sense testing the results

The reality is that the modelling probably does not provide very robust estimates of the relationship between measured e-coli and illness rates. The authors of the report were obviously aware of this and conducted a kind of 'sense testing' exercise. They looked at the empirical evidence on the number of campylobacteriosis infections, and must have concluded that this independent evidence showed infection rates roughly similar to those produced by their modelling. Hence the model had been correctly calibrated and was fit for purpose.

The discussion was as follows:

Of the three infections modelled (campylobacteriosis, adenovirus, enterovirus) only the first is a notifiable disease in New Zealand. The notified case rates for this illness are reported regularly in the New Zealand Public Health Reports, and have typically averaged about 300 per 100,000 per annum in recent years (approximately 400 in the summer months).
From surveys of recreational water use (McBride et al. 1996) one can estimate that about 250,000 people go for at least one swim at a freshwater site each year (MfE 1998b). Further, most folk have been observed to immerse the head while swimming (McBride et al. 1996). From the risk analysis reported herein, the median or mean campylobacteriosis infection rate spread over all recreational sites is approximately 0.04 (i.e., 40/1,000—see Table A3.7.3).30 Therefore the typical number of infections per annum equates to 0.04 x 250,000 = 10,000.

Accordingly, for the country's population of about 4 million, the water-recreation infection rate is 250 per 100,000 persons per annum. If we assume that the notified illness rate reflects

13% of actual illness rate, the summertime illness rate is around 3,000 per 100,000 persons per annum. Furthermore, the infection rate is held to be double actual rate, i.e., 6,000 /100,000 persons per annum.

We won't go through the detail of the discussion because there is a fundamental error at the beginning, which is immediately apparent. The starting point was the **total** number of campylobacteriosis infections (which at 300 per 100,000 of the population is about 12,000 per year – which reconciles with the notification data), **not** the number that could be ascribed to river and lake sources.

As we demonstrated in section three this would have been only a few hundred a year. Elsewhere in the document they say that recreational water illnesses were only 4 percent of the total. If they had gone though the same exercise we did, they should have concluded that their model was over-estimating. They could have re-estimated the dose response curve to produce results that would have more closely matched the case evidence data.

We do not know why they did not do this. Perhaps it simply didn't occur to them. However, the context was that the clients were convinced that there was a big illness issue to be addressed and may not have been open to modelling results that were telling them that their mindset was not supported by the evidence, or that it was not possible to produce a standard because the evidence was not robust. The clients had funded an expensive research programme so a result would have been expected.

Not withstanding the fragility of the results the analysis was picked up by a Health Department/MfE Working Group review of freshwater swimming risk in 2003 and the risk numbers have been part of the official narrative since then.

The New Zealand approach contrasts with that of the Australians. They do not set limits on freshwater swimmability because they believe that there is insufficient information to base a standard on. On the evidence we have seen they were right.

The limitations of the FRMP modelling were discussed in a recent MfE paper[9]. They were identified as follows:

- There was no modelling of age group susceptibity.
- Different strains of campylobacter could produce different results.

[9] Swimming categories for E. coli in the Clean Water package A summary of the categories and their relationship to human health risk from swimming MFE 2017

- The study only looked at e-coli and campylobacter link. It didn't look at how well e-coli indicated the presence of other pathogens.

The last point was not true. The study found that other pathogens were rare and were not correlated with e-coli.

There was no mention of the fragility of the infection estimates or of the lack of an appropriate analysis of the correlation between campylobacter and e-coli.

It appears that others have picked up on this weakness. The problem was identified in at least one consultation submission and made it into the submissions summary document. However, it does not appear to have had any impact on official thinking. If it did there was a risk that the whole testing framework could be undermined.

'Non swimmability' assessment is misleading

We now return to the Environment Aotearoa claim that 82 percent of New Zealand rivers in pastoral areas are not suitable for swimming.

For 2013–17, 82 percent of the river length in the pastoral land-cover class was not suitable for activities such as swimming, based on a predicted average Campylobacter infection risk of greater than 3 percent (NOF bands D and E respectively – the two highest risk categories).

The source information[10] for this statement is presented in figure four. Obviously the definition of what is 'swimmable' will be critical in determining swimmability. It appears that a very tough test has been set. Twenty percent of streams and rivers in native forest areas are not 'swimmable' on the official test.

Figure four: Swimmability data by landuse class

Table 4-3: River monitoring sites in the ECOLI attribute states specified in the NPS-FM. Values are numbers of river monitoring sites, and proportions of sites within each attribute state in parentheses).

Attribute State	Land-cover class				Total
	Exotic forest	Natural	Pastoral	Urban	
A	7 (8.9%)	54 (68.4%)	18 (22.8%)	0 (0%)	79
B	3 (7.3%)	12 (29.3%)	25 (61%)	1 (2.4%)	41
C	0 (0%)	1 (16.7%)	5 (83.3%)	0 (0%)	6
D	3 (2.6%)	14 (12.3%)	92 (80.7%)	5 (4.4%)	114
E	1 (0.7%)	3 (2.2%)	94 (69.6%)	37 (27.4%)	135

10 Water quality state and trends in New Zealand rivers Analyses of national data ending in 2017 NIWA Prepared for Ministry for the Environment December 2018

The swimmability criteria were set out in table six above. All of the criteria must be met for a river reach to fall into the A, B and C swimmable categories. In many cases the defining criteria will be the 95th percentile tests. This means that if there are, say, 60 readings over a three or four year measurement period, there need to be only four high readings of over 1200 from a rain-driven flush: a dead animal upstream; a spike in human or animal excrement, or a collection of water birds, before the site fails the test and is defined as unswimmable. The other 95 percent of the time the site might have low e-coli readings, and not pose an appreciable risk.

The rationale for using the 95th percentile is that it is recommended by the World Health Organisation. Not all countries stick to this advice. The US uses a geometric monthly average, and the EU allows up to 15 percent of readings to be discarded if they represent transitory events.

So the 'poor' performance of New Zealand rivers is partially an artifact of swimmable/ unswimmable definition.

New Zealand also takes a tougher position on acceptable risk .

In international Guidelines (WHO 2003) the tolerable illness risk thresholds at these boundaries are 1%, 5% and 10% respectively. The New Zealand Guidelines for freshwater reduced these to infection levels of 0.1%, 1% and 5%, in the recognition that pathogens other than Campylobacter (e.g., human enteric viruses) may also cause infection and subsequent illness (Hewitt et al. 2013). At first sight these risk levels are high, but there is often inherent risk in being immersed in environmental waters subject to some faecal contamination from human and animal sources.[11]

The reality is that there will always be some risk from swimming in streams and rivers. The stock exclusion policy will not make much difference; councils will be required to work harder to reduce point source contamination, but there is nothing that can be done about contamination from birdlife. The MfE's suggested solution in the Regulatory Impact Statement is that councils might have to put up permanent signs. This is obviously a cheaper solution than requiring farmers to spend more than $1 billion to exclude livestock.

[11] Technical Background for 2017 MfE 'Clean Water' Swimmability Proposals for Rivers NIWA Report: FWWQ1722 May 2017

Part five: Stock exclusion benefit calculation

In this part we examine the modelling that was used to calculate the benefits for the stock exclusion initiatives, and the water clarity component of the benefits from the sedimentation reduction policy. This is a rather tortuous process because the modelling and analysis is sometimes not clear and has changed over time.

The starting point is economic modelling of the benefits of the stock by Tait et al.,[12] using a using a technique called choice experiment (CE) modelling. The modelled benefits were improvements in health outcomes; improvements in environmental quality; and the value of better water clarity. This analysis was imported into a 2016 cost benefit study by the MPI.

There were some obvious flaws in the modelling, which must have at least partially been picked up in a later review or in the consultation process. So the modelling was reworked by Environment Economics[13] with some different inputs to produce the benefit numbers presented in the cabinet paper. These estimates still basically relied on the Tait CE modelling.

The Tail CE modelling

The CE modelling approach is explained in Tait as follows:

CEs are a survey-based method in which respondents are presented with a series of choice tasks. For each choice task, respondents choose between at least two broad options. In this study, the options represent alternative scenarios for stock exclusion policy. Each option is described by a number of attributes describing water quality outcomes resultant from stock exclusion e.g. improved human health risks, or ecological quality. In each choice task, the combinations of attributes are systematically varied to denote different management options. Respondents are asked to choose the option with the combination of outcomes they prefer.

These outcomes are

- lower health risk of swimming in lakes, streams and rivers
- improved ecological quality

[12]

[13] Environment economics

- better water clarity.

As we understand it the respondents were provided with the following quantitative information on the water quality attributes. There are also qualitative descriptions of the attributes in the report which are reproduced below. It is not clear what qualitative information was provided to respondents but there were interviews designed to assist their understanding of the process.

Health risk

Quantitative

Share of swimming spots percent	Chance of getting sick
30	10%
10	5%
10	!%
50	<1 %

Qualitative

Farm animals produce significant quantities of waste that contains bacteria that cause disease and make people sick. Keeping farm animals out of waterways helps limit the amount of waste that reaches the waterway. This results in a reduced risk of people becoming sick.

Ecological quality

Quantitative

	Share of sites %
Poor MCI score <80	40
Moderate MCI score 80 - 90	20
Good MCI score >100	40

Qualitative

Ecological quality was measured using Macroinvertebrate Community Index (MCI) scores, which are based on the presence (or absence) of different kinds of invertebrates such as insects, worms and snails that respond to changes in habitat condition. Higher index scores indicate healthier waterbodies. We assessed median MCI scores for 876 monitored sites throughout New Zealand, between 2012 and 2013.

Preventing farm animals from entering waterways can enhance the range of species living within the freshwater environment (biodiversity) and provide food and habitat for flora and fauna. This is achieved by enabling the establishment of overhanging vegetation creating shade and helps keep water temperatures more stable. This also provides shelter and safety *from predation for aquatic life. The vegetation improves the range of habitats available for aquatic life to occupy and thrive in.*

Water clarity

Quantitative

Visibility m.	**Share of sites %**
Poor 1.1 or less	60
Medium 1.2-2.4	20
Good -Over 2.5	20

Qualitative

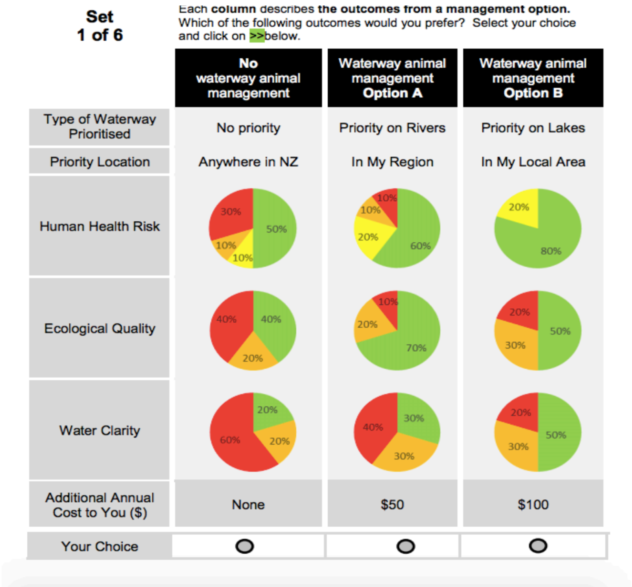
Fences prevent farm animals from accessing waterways and causing damage to banks and beds of water bodies. Erosion of banks and river beds introduces extra sediment into the waterway. Sediment in waterways reduces water clarity and visibility, and settles on beds. This can smother aquatic life and prevent vital biological processes from functioning normally, and destroy spawning areas. Raised river or stream beds can increase the risk of flooding. High levels of sediment also make swimming and other recreation activities unpleasant and unsafe.

The choices

The respondents were then required to make a number of choices. One of the six choice set was presented in the document. The repondent can stick with the status quo, and pay nothing, or pay $50 or $100 per annum and choose one of the other options to improve water quality outcomes by the amounts shown in the pie graphs.

The modelling also has outcomes attributes designed to elicit preferences for the priorities that should be given to improvements in different water bodies (lakes, rivers and streams)

Figure five: Choice experiment example



Statistical analysis

The second step is to use the statistical information derived from the six choice tasks answers from over 2000 respondents to calculate the monetary value they placed on a programme that generates the positive outcomes.

The key results were:

Health

- *$0.70 for each 1% increase in the proportion of waterbodies that achieve a 1:20 Health Risk level*
- *$1.15 for each 1% increase in the proportion of waterbodies that achieve a 1:100 Health Risk level*
- *$3.31 for each 1% increase in the proportion of waterbodies that achieve a 1:1000 Health Risk level*

Ecological quality

- *$2.14 for each 1% increase in the proportion of waterbodies that achieve Moderate Ecological quality*
- *$5.68 for each 1% increase in the proportion of waterbodies that achieve Good Ecological quality*

Water clarity

- *$4.13 for each 1% increase in the proportion of waterbodies that achieve Moderate Clarity quality*
- *$7.39 for each 1% increase in the proportion of waterbodies that achieve Good Clarity quality.*

These numbers are then multiplied by the percentage point improvement in the attributes to produce the following amounts an individual will pay. The results are shown in figure x for the vatious stock exclusion options. The one that matters is number 7 with a 'most likely' willingness to pay of $128 .1 per person per year.

Figure six: Per person benefit from stock exclusion

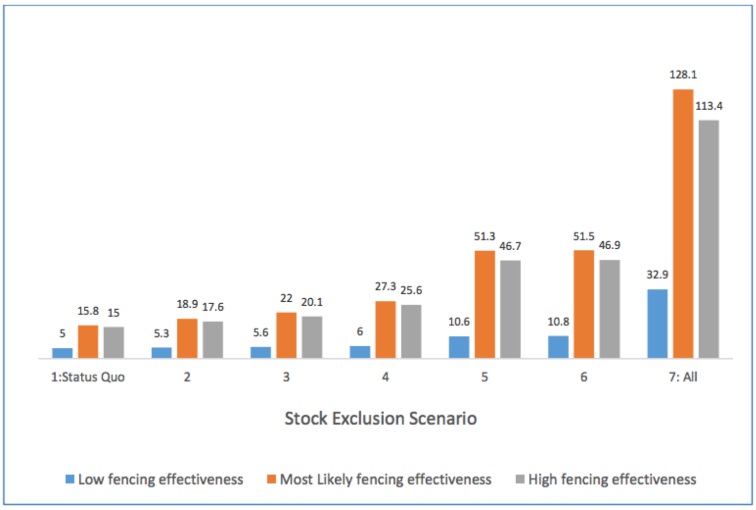


Figure 14. Average annual per person willingness to pay for policy scenarios

This number is then scaled up by the adult population (multiplied by 0.79 to account for the proportion of the respondents who refused to pay anything for the improvements). The aggregate annual benefits over 25 years were converted to present values using a discount rate of 8 percent.

These results are presented in the following table. The net present value of the benefits of option 7 was $4233.4 million.

There is an obvious, but unexplained, oddity in the results. The most likely outcome has a PV of $4233 million. The PV of the'high' estimate is $3868 million.

Table seven: Aggregate benefits from stock exclusion policies

Policy scenarios – stock to be excluded			reducing E.coli load to waterways Low	Most Likely	High
1	Status Quo:	Current fencing, including regional requirements to be implemented by July 2017	265	863.6	837.1
2	Status Quo, PLUS:	Dairy cattle on dairy platforms by 2017	272.6	928.9	916.7
3	Scenario 2, PLUS:	Dairy cattle grazing on land owned by dairy farmers by 2020	279.5	996.9	992.8
4	Scenario 3, PLUS:	Dairy cattle grazing on land owned by a third party by 2025	290.3	1,121.4	1,143.7
5	Scenario 4, PLUS:	Beef cattle excluded by 2025 on flat land, and 2030 on rolling land (slopes less than 16 degrees)	424.8	1,8375	1,787.9
6	Scenario 5, PLUS:	Deer excluded by 2025 on flat land, and 2030 on rolling land	426.6	1,8470	1,793.9
7	ALL	Steep Hill Country Scenario: Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	1,062.8	4,233.4	3,868.6

Criticisms of the modelling

CE models are a game

Our first observation is that CE modelling is just a game. People are not paying real money. They are just ticking boxes, and it costs nothing to tick a virtuous box. Who wouldn't tick the box for 'better health', a better environment and clearer rivers when you are not really paying for it? The authors' response to this kind of criticism was as follows:

There has been some criticism of using choice experiments to form monetary estimates of people's preferences on the basis that it uses stated preferences rather than market observations. The contention is that this approach can introduce hypothetical bias, whereby respondents may overstate their true willingness to pay. Tests of external validity that can assess the legitimacy of these concerns are difficult to form and only possible where concordant market data are available. While observed market data is unlikely to ever be available regarding water quality, in contexts such as food product choices, external validity has been tested by comparing results with market data. These studies suggest that CE does not bias values compared to market data. Examples include findings that: CE and scanner data for milk choices are equally good predictors of consumer choice (Brooks and Lusk, 2010); food values are significantly related to actual grocery store purchases (Lusk, 2011); estimated premiums are reasonable when comparing existing market prices(Mørkbak and Nordström, 2009). In other contexts CEs have been shown to accurately predict consumer behaviour over transport mode (Beaton et al., 2007), health care product choices (Mark and Swait, 2004) and recreation site choice (Haener et al., 2001).

The food product and other products contexts are very different from broader environmental contexts. With food choices people are well informed about product attributes and prices. With water quality attributes they are not.

Results consistent with other studies?

A second supporting argument for the robustness of the results is that they are consistent with those in other CE studies:

The individual marginal WTP(willingness to pay) results found here are consistent with those of comparable choice experiment studies, finding significant public support for enhancement of freshwater environments. Miller et al. (2015) estimate that Canterbury residents are WTP about $0.60 per one per cent increase in the number of monitored sites suitable for swimming in the region. Their swimming quality classification concords with the 1:100 human health risk category used in this study. Our estimate of $1.15 is consistent with the results obtained by Miller et al. (2015); while being higher reflects the difference in scale between regional and national outcomes employed across studies.

Phillips (2014) provides another comparison with our estimates of WTP for the 1:1,000 human health risk category. The author estimates that Waikato residents are WTP about $2.00 per one per cent increase in the proportion of monitored sites with less than one infection per 1,000 swimmers.

We don’t want to get diverted into a detailed discussion of these studies but we have couple of comments on the large scale Phillips (Waikato catchment) study. First, the willingness to pay for improving swimmability model results would have been influenced by the information the respondents were given. They appear to have been told that the probability of being infected from swimming in lower quality sites was thirty percent. This was a gross overstatement.

Second are the results of their revealed preference model, which was based on how people actually behave. It showed that ‘swimmability’ as defined by the Ministry, was not valued at all. This might reflect respondents’ actual experience. If they were not getting sick after swimming in supposedly high risk swimming sites, then they would not have modified their behaviour and avoided those sites.

Why use a CE approach with the health improvement attributes

With the health attribute there was information on the extent of the problem, and the impact of the stock exclusion policy on the level of illnesses that could have been used to calculate an expected value of the health cost savings. The MfE calculated the size of the health burden at $10-80 million a year. Our best estimate was under $1 million. Tait and the MPI had access to information that stock exclusion would have only a minimal effect on that outcome. At the least they should have explained why their CE results were so different from the expected cost savings evidence.

A counter-argument is that an expected value calculation does not capture the full welfare gains from the policy measures because people are likely to be risk adverse and be willing to pay a premium over the expected cost to reduce the risk of an illness. They are paying for a form of insurance. However, this might explain a willingness to pay a moderate multiple (say 2 or 3 times) over the expected cost. But it does not explain why a rational, informed person would be willing to pay a multple in the thousands. We are not talking about extreme events like death that might generate higher risk aversion. The average outcome is an unpleasant experience for 4 or 5 days, with an economic cost of $700.

The nub of the issue, which we discuss below, was whether the survey respondents were full informed about the status quo and the difference stock exclusion would make. We show very clearly that they were misinformed and that this almost certainly had an impact on the results.

The distinction between a present value approach and a CE approach with uninformed respondents can be illustrated as follows. Assume that a bogus medical company is doing a survey for a new product called 'Snake Oil' using the CE technique. It provides a number of exaggerated statements about the prevalance and severity of the diseases 'Snake oil' will cure. And it makes exaggerated claims about the effectiveness of the product. A bottle of Snake Oil costs $5 to produce and it does have some mildly positive effects with an expected value of $ 1. However, because 'Snake Oii' is claimed, amongst other things, to reduce the risk of cancer by over 90 percent, potential purchasers are prepared to pay $200 a bottle.

The conventional economist does a cost benefit analysis and assesses the net benefit at minus $4 a bottle. She concludes that there is likely to be a welfare loss if the product is sold. The CE analysis shows that there is a gain of $195. The promoters conclude that society will be better off by that amount and proceed to market 'Snake Oil' in the self-righteous belief that they are doing it for the good of the country.

Risks in the status quo overstated

The status quo risks from swimming (presented above) were overstated by a large margin. In 30 percent of waterways the risk of visitors getting sick is put at 10 percent.

- The risk is presented in terms of the risk of visitors to freshwater sites getting sick. Even if you just paddle about in the edge of the water a bit, this is the risk. However, the risk figures were loosely based on the official risk assessments (which overstate the risk by a large margin as argued above), which are the risk of **infections** for full immersion swimming. As noted above the number of sicknesses is likely to be less than half the number of infections, and only a fraction of visitors to lakes, rivers and streams will go for a full immersion swim.

- Respondents were not informed that the risks assume that swimmers will continue to swim when there is bad weather that flushes contaminants through the river, and when warning signs are in place.
- Respondents are not told how serious the illness is. There is a difference between a tummy bug and some thing that poses a material risk of death. As discussed above the sicknesses in question are at the lower end of the severity range.

Benefits overstated

The authors had access to the companion study from NIWA (results presented in figure one) that showed that the stock exclusion option no. 7 would increase the percentage of waterways in the highest band from 48 percent to 50 percent, an improvement of just 4 percent. However, respondents were told that the share of high quality sites would increase from 50 to 80 percent, an improvement of 60 percent. The true share below the 'minimum acceptable' standard falls from 42.6 to 39.6 percent, but respondents were told it would fall from 30 per cent to zero.

The situation is similar for the water clarity benefit. Later NIWA modelling (which was not available at the time) puts the increase in the share of the clearest waterways at about 2 percent. The respondents were told that there would be a 150 percent increase in sites with good water clarity.

Estimate of benefits not based on the scientific evidence

It seems that the NIWA evidence on water swimmability was ignored when calculating the benefits, and the made-up number of a sixty percent was used instead. This estimate was false and misleading. If the NIWA improvement estimates were used the annual benefits per head would have been about $7 rather than $128.

Individual willingness to pay estimate not mathematically possible

if every respondent, willing to pay, chose the $100 option then the maximum per head benefit is $79 (because 21 percent were not prepared to pay anything and were excluded). However, the estimated benefit per head is $128.

Willingness to pay outcomes not rational from a public health perspective
Respondents are willing to pay more for small improvements in the already reasonably safe sites but much less for improvements in the riskiest sites. Moving from the highest risk site (10 percent risk) to a site with a 5 percent risk, improves the odds by 5 percentage points and is valued at $0.70. However, moving from a risk of 1:100 to 1:1000 improves the odds by 0.9 percentage points but is valued at $3.31. The implication is that the lower risk sites should be improved first, but this does not make sense if the public health objective is to reduce the number of illnesses at least cost. The respondents are willing to pay more than 25 times more to avoid an illness by improving a 1:100 risk site than to improve a highest risk site.

The respondents' preferences are not uncommon. The behavioural economics literature is full of cases where people are not able to make complex risk assessments and choose economically irrational outcomes. It is a reason for basing public health decisions on professional analysis rather than being driven by the preferences of people with a poor understanding of the risks.

Ecological quality
With the ecological quality variable there is a strong bias in the description of the ecological quality states. A MCI score of 80 is described as poor, 90 is moderate and 100 is good. Applying these descriptors will have a powerful influence on respondents willingness to pay. Who wouldn't sign up for good as opposed to just moderate or poor ecological quality.

However, if respondents were just told more neutrally that:

- The MCI is a measure of the mix of different macroinvertibrates such as worms and small flies that they probably would not be able to perceive.
- The MCI is regarded as an indicator of 'environmental' quality but there is no evidence that there is any correlation between the MCI index over the range from 80 to 100, and any environmnetal attributes that they would be able to perceive and would value;
- There is no evidence that there is a relationship between stock exclusion policies and the MCI (see part 7).

Then we suspect the willness to pay for any 'improvement' would have slumped.

A freshwater scientist might, after some investigation, be able to spot some wider differences, and might also place an intrinsic value on a slightly more 'appropriate' macroinvertibrate mix, but in a choice experiment their opinions would not be valued any more than the average citizen's.

Arbitrary pricing could affect williness to pay estimates

The willingness to pay might have been influenced by the payment values which were set rather than chosen. As the values were set by by what was perceived to be a trusted party, respondents might have taken the prices of $50 and $100 as a good indicator of value, and this would have influenced their willingness to 'pay'. If the payments had been set at, say, $5 and $10, then it is likely that much lower WTP results would have been obtained.

An evidence based Choice Experiment

If the choice experiment information was based on the best evidence then the pie graphs would have been depicted very differently. If the cut-off for the lowest risk segment for swimming was set at a risk of less that 1:1000 (assuming no swimming against advice and when the river was high) then a high proportion of waterways (perhaps 90 percent) could have fallen into that category.

And if stock inclusion resulted in only a very small improvement that would have been almost imperceptible in the pie graph, then it is likely that a much higher proportion of respondents would not have been prepared to pay $50 or $100 for the improvement. There will be some. There is a proportion of the population who are mathematically challenged, or who will sign up, at least theoretically, to any measure that they think will 'improve' the environment, no matter how small the benefit.

MPI estimates

The Tait model was picked up in the Ministry of Primary Industry paper[14], without any comment on the logic of the analysis or the robustness of the estimates. The estimated health benefits however did change a little. The net present value was $3370 million. The NPV of the cost was $1434 million. It was implied that the water clarity and ecolological benefits, while not monetised, would be greater than this. The basis for this statement appears to have been that the dollar values per one percent improvement were higher.

Resource Economics Essential Freshwater Package: Benefits Analysis

The direct source of the health, environment and water benefit estimates in the Cabinet paper was a paper covering most of the monetised benefits prepared by

[14] Grinter J and White J 2016' National Stock Exclusion Study: analysis of the costs and benefits of excluding stock from New Zealand waterways'. MPI.

Resource Economics[15]. The paper was not referenced in the Regulatory Impact Statement, and is dated 30 April 2020. It is both a review of the earlier benefit analysis and an attempt at rescuing some of the flawed analysis that appeared in the preliminary regulatory impact assessments. There was a companion paper that reviewed the costs estimates.

The following is an assessment of this benefit review and the new estimates. Notably, there was no assessment of the largest contribution to the benefits, the Wetlands retention value of $3,900 million. Possibly this was because the estimate was indefensible and MfE did not wish to embarrass themselves by subjecting it to any review.

The discount rate

A discount rate of 3 percent is used, which boosts the present value estimates. It is explained that the 3 percent rate is recommended by Treasury for sensitivity testing around their recommended central discount rate of 6 percent. The conceptual bases for discounting are discussed, distinguishing between the social rate of time preference (SRTP) and the social opportunity cost of capital (SOC) approaches. The Treasury's recomended 6 percent rate is based on the SOC approach which captures risk as well as pure time preference.

There is also reference to the use of lower rates in some New Zealand studies:

Some studies in New Zealand have attempted to measure the SRTP, including a (real) rate of 4.4% estimated in 2006 for the national energy strategy, a range of 2.7 to 4.2% developed in the context of decisions on investments in the national electricity transmission grid, and 3% in a study relating to transport infrastructure investments. Auckland Council adopted a rate of 4% for CBAs, building on advice from NZIER for a rate of between 3% and 4%.

The justication for the three percent rate was:

It reflects analyses of the SRTP in New Zealand and uses the low rate used by Treasury in its CBAx model.

This is not really a justification. This is a (very) risky project so some accounting for risk is appropriate using a SOC approach would be appropriate. Simply stating that

[15] Denne T. 2020 'Essential Freshwater Package: Benefits Analysis. Report prepared for Ministry for the Environment'. Resource Economics.

the Treasury's low sensitivity analysis rate was used is not a justification. Nor can a low rate be justified because this is an 'environmental' project with irreversibilities. The bulk of the benefits are health benefits and if a future generation wishes to very slightly improve their health outcomes with a stock exclusion policy then they are free to do so.

Number of recreational water illnesses and the cost burden of the disease
The report repeated, but did not critically review, the Ministry's estimates of the number of recreational water-linked illnesses, and their costs. It noted, however, that the the MfE assessment of the benefits in Regultory Impact Statement 7, between $10 million to $80 million, was flawed because it was a measure of the total burden of disease rather than an estimate of the impact of the policy on that burden.

It noted that using this MfE analysis as a starting point was an option, but preferred the Tait CE analysis in part because could be applied to the ecological and water clarity benefits as well as the health benefits. This doesn't make sense. The avoided health risk approach could be taken for health, and the Tait analysis applied to the other benefit estimates. The other reason was:

Our preference is for the results using the WTP (willingness to pay*) study as it would be expected to include the full set of benefits that people obtain from improvements in the quality of swimming water, including those that accrue to those who don't visit the freshwater sites but benefit from knowing it is clean.*

There was a detailed description of the WTP modelling presented in the Tait paper. The revealed preference modelling in the Philips paper was mentioned. However,one of the key results, that safer swimming sites were not valued, was not reported.

The Tait model
The most important part of the report was its review and adaptation of the Tait model. The review was mainly just a description of the model. There was no critical assessment. However, it must have become obvious at some point that the health risk estimates were indefensible. In particular it was not possible to reconcile the the NIWA estimates of e-coli concentration changes with the estimated benefits. The report also noted that Tait did not provide benefit values for ecological quality and water clarity. It attempted to fill this gap.

Human health
To calculate the health benefits, the approach taken was to combine the results of a new (2020) NIWA report on the impact of livestock exclusion on e-coli values, with the Tait values of the benefits of a marginal change in swimmability.

The problem with the 2016 NIWA study is that it could not generate high benefit outcomes. The solution was to commission NIWA to produce a report that focused on just 400 km. of waterways. The results are shown in table x. The percentage of water ways moving into the highest quality category changes from 4 percent to 27 percent.

The new NIWA report has not been publicly released so we do not know precisely what explains the difference. The only explanation given in this report is that the 2016 study calculated the percentage change in the number of streams in the different categories, and was an estimate of the nationwide impact. The new study uses percentage changes in stream length. This, in itself, should not have changed the results drastically. What would have changed the results is restricting the analysis to 400 km (see table eight below) of stream length and cherry picking which lengths were included in the 400 km. The NIWA study is not publicly available but it seems obvious that the lengths were selected on the basis of a high estimated e-coli impact. If that is the case then the results cannot be used for a nationwide assessment. Resource Economics skates over this problem with the following comment:

Unlike the original study, which used percentage change in the number of streams in the different categories, this uses percentage change in stream length. We use this as a proxy for percentage improvement in number of streams (or assume that people will value this improvement equally)

It is not a proxy for the whole New Zealand population. It should have only been applied to the subset of the population with reasonable access to the 400 km. of waterways.

Table eight; Impact on stream lengths by risk catergory

	A	B	C	D	E
Baseline	107.2	92.4	50.5	83.4	66.5
Scenario 3b	135.9	102.6	65	70.5	26.1
Change	28.7	10.2	14.5	-12.9	-40.4

Source: Semadeni-Davies et al (2020)

With the 27 percent change in the proportion of kilometres in the second risk category the calculation of the individual benefits is straightforward. The 27 percent is multiplied by the Tait value of $1.22. The individual values are then scaled up by the New Zealand population numbers to produce a New Zealand-wide figure. Assumptions are made about the rate at which the benefits emerge over time and a discount rate of 3 percent applied. The PV is $2366 million. At the standard Treasury discount rate of 6 percent it is $1609million. The former figure was reported in the Cabinet paper.

Table nine : **Swimming site improvement calculations**

Band	% improvement	% points	Median Value (range)	Total – Median value ($/person)	Low ($/person)	High ($/person)
1:100	27%	26.8	$1.22 ($0.69 - $1.75)	$32.73	$18.47	$46.85
1:20	5%	5.2	$0.74 ($0.23 - $1.36)	$3.88	$1.20	$7.09
Total				$36.61	$19.67	$53.94

Water clarity

The value of the improvement in visual clarity for the stock exclusion policy was calculated from a NIWA assessment of the impact of the policy which is set out in table ten. The first two columns are straightforward. The meaning of the two columns on the right is described as follows:

The two columns on the right show the percentage of segments that are predicted to meet the bottom lines in terms of their starting levels of water clarity, ie in Auckland 4.7% of those that will change to meeting the bottom lines after the policy is introduced are starting from a position of moderate water clarity and 95.3% are starting from poor water clarity.

Table ten: Improvements in water clarity

Locality	Compliance before mitigation	% improvement	%mod	%Poor
Auckland	87.07	0.57	4.7	95.3
BOP	97.92	0.09	96.3	3.7
Canterbury	95.65	2.62	99.96	.04
Gisborne	94.42	.02	100	0
Hawkes Bay	97.47	1	99.71	0.29
Manawatu Wanganui	76.16	1.47	67.9	32.1

Marlborough	97.22	.09	100	0
Northland	90.69	2.86	23.9	76.1
Otago	83.9	1.94	72.1	27.9
Southland	77.4	3.04	37.1	63
Taranaki	96.7	1.76	0	0
Tasman	99.38	.05	70.9	29.1
Waikato	66.4	2.42	100	0
Wellington	90	0.37	40.1	59.9
West Coast	95.5	0.32	91.4	8.6
New Zealand	86.2	1.62	1.61	

The value of the improvements is calculated as follows:

To estimate the benefits of improvements we use an equation of the following form:
VWC = P × Z × PPI × PSS × WTP
P = adult pop in region or NZ
Z not interested
PPI percentage point of improvement in compliant
PSS Percentage of segments moving to compliance by starting date
WTP Willingness to pay for 1 percent improvement

The willingness to pay figures for a 1 percent improvement from Tait are: Moderate $4.13; Good $ 7.39.

The annual benefits are about $12 million and the present value is $221 million.

It is not at all clear how the aggregate benefit number was derived. We do not know how the PSS variable was calculated, other than it appears to have something to do with the starting share of the moderate and poor observations. There is no walk through of one of the regional calculations to make this clearer. It is not possible to calculate a regional breakdown of the aggreagte figure, which would assist in making a judgement of the plausibility of the estimates.

In short this is something of a black box, and little weight should be placed on it given the issues with the Tait figures which underpin the calculations.

The nub of the issue is this. Would a rational government be prepared to invest up to $221 million in a national project that improves water clarity (which is already on average pretty good) by less than two percent? Or would they identify the areas where water clarity is an issue and spend less on interventions that are more clearly targeted to the outcome.

The same methodology was used to estimate the water clarity benefit from the sediment bottom line policy.

Ecosystem health

The explanation of the approach is as follows:

River ecosystem health is estimated to improve as a consequence of a number of different policies, but we examine it here as the benefits of achieving the MCI bottom lines. These are compared with current monitoring data to estimate changes in the number of rivers that will improve to higher categories of ecosystem health. This can be combined with the Tait et al (2016) values to quantify the benefits.

We use an equation of the following form:
VEH = P × Z × WTP × PImod
Where: VEH = value of ecological health improvement
P = Population in the region or NZ
Z = Proportion of population with a zero WTP, ie 0.79
WTP = willingness to pay for improvement from class D to C, assumed to be $2.27
PImod = Percentage of rivers improving from class D to C.

For example, in Northland (population estimated at 134,112 in 2020), where there is a 5.26 percentage point improvement, the equation is as follows: VEH = 134,112 × 0.79 × $2.27 × 5.26 = $1,265,806

The methodology, if it can be called that, is simply to assume that the stock exclusion scheme will shift all of the rivers below the MCI bottom line to above the bottom line. There is no reason to believe that this will happen. The effect of this assumption is most apparent in Auckland. This is a highly urbanised area with relatively few cattle, and it is unlikely that runoff from cattle farming is the big driver of Auckland's relatively low compliance with the national MCI bottom line.

But it is assumed that the stock exclusion policy will somehow, magically, fix everything. And Auckland dominates the results. The annual value of the improvements is calculated as follows: 1.15 m x 0.79 x 2.27 x 54 = $111 million Auckland accounts over over 60 percent of the national value estimate. All from fencing to exclude a relatively small number of cattle.

Table eleven: Ecological bottom line compliance by region.

Region	A	B	C	D	Total	% improve-ment
Northland	3	12	3	1	19	5%
Auckland	3	2	13	21	39	54%
Waikato	15	27	17	16	75	21%
Bay of Plenty	8	38	19	9	74	12%
Gisborne	0	1	0	0	1	0%
Taranaki	12	9	32	6	59	10%
Manawatu-Wanganui	5	33	35	10	83	12%
Hawke's Bay	2	19	26	21	68	31%
Wellington	7	21	20	9	57	16%
Tasman	1	11	2	6	20	30%
Nelson	4	7	9	6	26	23%
Marlborough	0	15	9	2	26	8%
West Coast	3	23	11	1	38	3%
Canterbury	1	35	69	29	134	22%
Otago	0	10	21	10	41	24%
Southland	1	27	31	13	72	18%
Total	65	290	317	160	832	19%

Source: MfE

The annual calculations, are mutitiplied by 0.5 to account for the share of the benefits that can be ascribed to the policy and the benefits are assumed to emerge with a lag. This produces a present value of $661 million.

Assessment of ecological benefits

We think that this analysis is a nonsense designed to drum up a heathy looking benefit figure.

While it is just possible that there may be some broader environmental benefit from the stock exclusion policy, these are uncertain and unlikely to be perceived by many people. There are so many issues with the monetisation analysis that it is best deleted from the cost benefit assessment. To summarise:

- The Tait figures are extremely dubious .
- The link from nitrogen run-off to the MCI is weak (see part seven).
- MCI is a weak indicator of environmental improvements that people value.
- The Resource Economic assessment of the improvement in the MCI index grossly overstates the likely effect.

Part six: Preservation of wetlands

This part analyses the largest benefit item, the preservation of wetlands. The annual benefits are $450 million and the net present value is $3900 million.

There was no estimate of the costs even though there was some discussion on costs in the Regulatory Impact Assessment.

The discussion of the wetland protection benefits in the Cabinet document was as follows:

Officials have assessed benefits of protecting the 30,000 hectares of unprotected inland wetlands on fertile land. These provide ongoing ecosystem services such as flood mitigation, nutrient cycling, and water storage. Based on New Zealand assessments, to replace the services these wetlands provide, for example, with engineering infrastructure like flood barriers and dams, it would cost about $50,000 per hectare of wetlands lost per year. When capital stocks decrease (wetland area), the flow of benefits received from them are lost forever.

The statement that New Zealand assessments put the cost of lost wetland services at $50,000 per hectare per year, was, to put it bluntly, false. There was no New Zealand assessment in the RIA, or any reference to an assessment in any other document. The RIA simply took the figure from the reported number in a single academic paper. We discuss this paper below.

The idea that once a wetland is lost the benefits that derive from them are lost 'forever' is mostly wrong. Farmland can be converted back to wetlands or a replacement wetland constructed in a different location.

New Zealand has lost on average 300 hectares of these valuable ecosystems each year for the last decade. There has been no substantial slowdown since the NPS-FM was introduced in 2011, and in the absence of further regulation, officials see no reason for this trend to change.

It is not explained where this 300 hectare loss figure came from and why it is not consistent with the figure of 1247 hectares over the 15 years from 2001-16 that was also presented in the Cabinet paper. This represented an annual loss of 83 hectares a year. The source for this information appears to be a Landcare Research report for the MfE dated 2016. Based on reviews of satelite images it was reported that:

- 214 wetlands totalling 1247 hectares out of a total of 14,600 (250,000 hectares) had disappeared. The loss rate was 1.5 percent, or 0.1 percent per year.
- 5 percent of wetlands had a 'partial loss'. There was no measure of how many hectares had been lost, in part because it is difficult to define with precision a wetland boundary, and there were a large number of errors in the starting data.
- There was no assessment of the rate of change from 2011.

The report did not assess whether there had been any wetland gains.

There is no mention of 300 hectares being lost per year in the RIA, nor is there any discussion and assessment of how much will be lost in the future. However, conveniently, just in time to make the Cabinet paper, the information came to light. Most likely the 300 hectare figure was simply made up at the last moment to boost the benefit number.

The key issue here is not the amount of loss, which could be readily be replaced it the government was prepared to purchase farmland and convert it to wetland, or allows developers to create replacement wetlands, but the valuation of wetland benefits, which is extremely high. If the estimate were true then it would 'pay' to convert as much New Zealand farmland as possible to wetland .

It is acknowledged that benefits of $50,000 per hectare per year is substantially higher than many other land uses. However, international research suggests that despite covering only 1.5% of the earth's surface, wetlands provide disproportionately high ecosystem service benefits – roughly 40% of the total.

'Substantially higher' is an understatement. With benefits of $50,000 per year and a discount rate of 3 percent, wetlands are worth about $1.5 million per hectare. At that value the Government could convert two million hectares of farmland to wetlands at, say, $50,000 a hectare (allowing for some planting and drainage changes on farmland worth $15,000 a hectare) and we would be $2,900 billion better off. This would dwarf the expected increase in debt due to the covid-19 recession.

The Regulatory Impact assessment

Most of the Regulatory Impact Assessment was a response to objections raised by the mining sector.

Some in the mining sector also raised opposition to the proposal. They consider their operations to be of economic significance, (Ocean Gold for example considers that the proposal has the potential to leave 4 million ounces of gold (~1 billion NZD equivalent) un-minable and have a functional need to be located where resources are found. They stated a non-complying status is unworkable and without the ability to mitigate, offset and compensate it could bring a halt to their business.

We do not know the costs associated with unmined minerals as these permits are across multiple companies and are for a variety of different minerals. However, based on the wetland extents identified, MBIE estimate in 2018 approximately $1million was spent on exploration of mineral deposits classified as wetlands and likely impacted by the proposed policies. For large mining permits that contain wetlands, it is estimated the value of the minerals impacted by the proposal is at least $600 million. This is a lower-bound estimate as it includes only coal reserves, due to data availability.

While the issue of the costs was raised it is then forgotten. There was no attempt to estimate the economic costs (they could, for example, have assessed the net economic value of the $1 billion gold reserves, or the coal reserves (though that may not be much). Instead the issue was waved away because the wetlands are so 'valuable'.

The estimated annual value of the ecosystem services provided by the wetlands potentially impacted by active mining permits alone (excluding prospecting and exploration) is in the order of $66.2 million per year (2019 NZD) for active permits and $41.9 million per year for those under mining permit application.

On other costs the argument was:

Unknown potential costs to landowners but not expected to be high because of the small proportion of non-protected wetlands on fertile land.

This does not necessary follow. We are still talking about 30,000 hectares of private land, which are mostly scattered about, and there will be occasions where an effective prohibition on developing wetlands could be very costly, particularly if it precludes the development of, or access to, a larger site, or requires an expensive road diversion.

Wetland valuation

The critical issue is the valuation of the wetlands, which was explained in more detail in the Interim RIA.

A recent global study gives an indicative value of ecosystem services for inland wetlands to be approximately $25,600 (2007 USD) per hectare (ha) per year and approximately $193,800 (2007 USD) per ha per year for coastal wetlands. These values have been adjusted for inflation and converted to 2019 NZD257 to give approximate values of $48,640 per ha per year for inland wetlands and $368,220 per ha per year for coastal wetlands.

The translation to New Zealand dollars and the updating for inflation was the full extent of the Ministry's analysis.

These estimates are based on 'ecosystem values' presented in a paper by Costanza et al.[16] This paper is based on a collation of data from 665 local case studies across the world to produce average estimates of the value, to people, of eco system services for a range of land and water types. The wetland figure is an average of a particularly large number (168) of studies.

The problem with this 'analysis' is that we have no idea about the content of the studies. We do not know what the locations were; what the valuation methodologies were; whether the authors were economically literate; or whether they were just pumping the numbers as part of their environment agenda; and especially, the relevance of the studies to all wetlands. For example, a study of a residential development might well have found that leaving half a hectare as a wetland was an effective enginneering solution with asthetic co-benefits, and with a high dollar value. But this does not mean that every hectare of wetland in the world has the same value.

This is the basic error in the Costanza paper when they calculated global values for environmental services. Based on these numbers in the studies they concluded that the value of environmental services in 2011 was $125 trillion dollars. This is not a value based on some assessment of the intrinsic worth of the environment. It is the sum that would otherwise have to be spent to replace the services that were being provided by the natural capital. The $125 trillion is greater than current world GDP of $81 trillion.

Although they don't realise it, Australians are especially blessed. The value of services from the Great Barrier reef are $12 trillion per year.

16 Costzanza et. al 2014 'Changes in the global value of ecosystem services'

What we know about the results is that they can vary wildly from paper to paper and over time. The wetland values ranged from US$3000 to US$105000 per hectare.

In terms of the source of contribitions the main elements (in US $) per hectare were:

Cultural	1992
Food	614
Raw materials	539
Recreational	2211
Climate regulation	488
Water regulation	9000
Erosion control	2600
Nutrient recycling	1700
Waste treatment	3015

As we mentioned above new wetlands can be created, without too much cost and effort, if they are so valuable. Indeed there are cases when they were created without any effort at all. We were told about the experience of a South Island farmer who, some time ago, constructed a water storage dam at an isolated spot on his isolated farm. Over time water seepage promoted the growth of some flaxes and rushes. Eventually the local council spotted the growth in a satellite photograph and demanded that an area of about four hectares be fenced off to protect it. They offered to pay for fencing materials, but the farmer had to do the fencing and lost productive land worth $30,000. The farmer refused to do it, not realising that he was failing to protect natural capital worth $6 million and that he risked losing food, recreational and cultural services alone worth $30,000 a year, as well as other benefits.

As an aside, the Ministry's claim that wetlands contribute 40 percent of the world's natural capital services value was wrong. The correct number was 1.2 percent.

The foreign study is basically useless as an assessment of the benefits of protecting wetlands in New Zealand. If the MfE were serious about the subject then they should have conducted a survey of the costs and benefits of a sample of the wetlands that have been converted over the last decade or so. They would be able to assess, amongst other things, whether conversions did indeed result in costly expenditures on flood protection, dams and so on as they were claiming. We would expect that the numbers would vary from place to place, but strongly suspect that the aggregate numbers would not be high. And they should have made a serious effort to cost the net value of mineral resources.

But the Ministry was not serious and the only purpose they were serving was to pump the benefit numbers, apparently late in the piece. There was no 'independent' review of the estimates. Apparently there are some things that even a consultant will not do.

Our assessment

We have assessed the net benefits at zero, though a case could be made with more information that they are negative.

Part Seven: Nutrient Limits

Introduction

One of the most controversial measures that went to consultation was a proposed limit of 1 mg. of dissolved inorganic nitrate (DIN) per litre. This was a reduction from the existing standard of 6.9. This limit was based on toxicity to small animals, (including some fish) At 20 mg./l there could be an impact on the most senstive animals.

The main impact of the limit would have been on soft bottomed streams and rivers. The issue of most obvious concern to the public, the growth of slime on hard bottomed waterways was already covered by periphyton limits which are estimated to cost farmers $3.7 billion.

The additional 1mg./l limit would have been very costly. The Ministry did not do an overall economic cost assessment but case examples illustrated that the only path to compliance in some areas was to close the dairy industry. A dairy industry assessment put the eventual revenue loss to the industry at up to $6 billion a year.

In the event the Minister for the Environment backed off the 1 mg./l limit and a new limit of 2.4 mg./l was set. But this was a temporary response awaiting further evidence on the science and the economic and social costs.

The increase in the limit from 1 to 2.4 mg/l was estimated by MfE to reduce the present value of the costs by $2 billion. The reduction from 6.9 mg./l to 2.4 mg/l is estimated to cost just $30 million a year with a present value cost of $217 million.

We will comment only briefly on the present value cost estimate noting that it is probably understated.

The main focus in this part is on the logic and science behind the recommended 1 mg./l limit. It was presented as the best science on the subject, developed and recommended by the Scientific and Technical Advisory Group (STAG). As the DIN limit will be an ongoing issue it is important that there is a wider understanding of how robust the STAG recommendation was.

Present value of costs

The reasons for the low present value of the costs are:

- The bottom line is assumed to be imposed only gradually over the 30 years to 2050, so the costs are weighted to the future. The costs per year are by 2050 are substantially higher than the $30 million.
- Costs of farm conversions have not been taken into account.
- There was no estimate of the cost of applying a national cap on nitrogen applications of 190 kg./ha/year.Officials estimate that roughly 2,000 of the 11,000 current dairy farms may need to reduce synthetic fertiliser application, with the vast majority of these being in the South Island, especially in Canterbury and Southland.
- The cost of Action for healthy waterways will depend on how the total costs of AHW and NPS –FM are allocated between the two. There have been suggestions that some costs have been disproportionately loaded into the NPS-FM, thereby reducing the AHW costs.

The modelling has been reviewed at a high level by Infometrics and Sense Partners, who found that generally the model structure was plausible and that the results were in the 'right ball park'.

As we do not have sufficent information to make an estimate of the cost of the DIN 2.4 bottom line we have only noted that the costs are likely be higher than the $217 million estimate,

The Scientific and Technical advisory Group

The Scientific and Technical Advisory Group (STAG) was a collection of academic, consulting, and two regional authority, scientists. As it had to cover a wide range of topics, there was not necessarily a representation of the breadth of experience and perspectives of the wider science community on each topic. Thus the advice on particular topics could be driven by a small number of members with strong views on the subject.

Initially the group was meant to be, primarily, a technical advisory group for the MfE. In the event the STAG went further, taking a more proactive approach, particuarly on the DIN bottomline and released its own report and recommendations publicly. From their report:

We were tasked specifically with providing expert advice on existing science, ensuring officials were interpreting the science accurately, and identifying data gaps to direct future focus/research efforts. The STAG was not engaged to develop attributes or policy responses appropriate for amending the NPS-FM.

We have chosen deliberately, however, to follow the same format and use the same terms as the NPS-FM to emphasise that the measures and thresholds we are recommending in this report are of equal importance to the existing measures and thresholds currently included within the national framework for managing fresh water

Having gone beyond their initial mandate, they shied away, however, from taking any responsibility for the consequences.

We recognise that recommendations in this report could, depending on the way they are incorporated into policy, have very significant economic and social implications for individuals and communities in some parts of New Zealand. At the same time, they will require substantial investment in both capacity and capability in freshwater science and management in New Zealand, especially in relation to regional council monitoring and reporting. However, it is explicitly not within our remit to consider such implications in developing our recommendations.

At the outset the Minister set the direction. Members were told not to worry about the social and economic impacts. The Minister would deal with that. From the 29 November 2018 minutes:

Some group members indicated the importance of economic analysis of policy options, this has been clarified with the Minister, who said we shouldn't be inhibiting our thinking with economic considerations, but these can be considered.

STAG, as a group, does not appear to have thought about economic consequences, and given the composition of the group were ill-equipped to do so. Nevertheless despite their claim above that the economic and social effects were not within their remit, they could have taken these considerations into account if they wanted to.

Given the STAG mindset the results were almost pre-determined. If the cost was irrelevant, and a return to a more 'natural' state was in some sense good, then the answer was, obviously, to set a DIN limit to about as low as you think you can get away with.

The Minister also said that he wanted quick action with results within 5 years. He did not want to see an extinction 'on his watch'. It was not clear what the Minister had in mind here, but it may have been fish extinctions that exercised his mind. New Zealand has around 50 native freshwater species, and one is recorded as having becoming extinct over the past 200 years. So on the odds he is probably fairly safe over the next five years.

The scientific support

The basic technical task is to set a bottom line, in terms of an acceptable level of the environmental impact and then set a DIN limit that is consistent with that bottom line. This bottom line is defined by the boundary of grade C, which is acceptable and grade D that is not.

Grade C is defined as follows:

Ecological communities are impacted by moderate DIN elevation above natural reference conditions, but sensitive species are not experiencing nitrate toxicity. If other conditions also favour eutrophication, DIN enrichment may cause increased algal and plant growth, loss of sensitive macroinvertebrate & fish taxa, and high rates of respiration and decay.

Grade D reads:

Ecological communities impacted by substantial DIN elevation above natural reference conditions. In combination with other conditions favouring eutrophication, DIN enrichment drives excessive primary production and significant changes in macroinvertebrate and fish communities, as taxa sensitive to hypoxia and nitrate toxicity are lost.

Obviously these definitions do not provide a very firm boundary between the C and D grade but should, in principle, provide a starting point for an assessment. This would not be a trivial exercise. For example the sedimentation bottom line assessments were part of the document that extended to almost two hundred pages.

Lack of clarity on the basis for the STAG recommendations

The scientific basis for identifying the C/D threshold was very unclear. A paper by Death et al[17] was mentioned in the preliminary Regulatory impact assessment and an early version was available on line. It was explained that an updated paper was forthcoming.

A combination of real and modelled data were sourced from a variety of publications and agencies and threshold limits were determined by weighting each line of evidence based on whether the effects were direct or indirect. More detail on the data sources used and the methodology to derive the nutrient thresholds can be found in (Death et al., in prep).

The early Death paper appeared to show a bottom line of 1.66 mg/100, on a

[17] Death R. G., Magierowski, R., Tonkin, J. D., and Canning, A. D. (in pr Clean But Not Green: A Weight-of-Evidence Approach for Setting Nutrient Criteria in New Zealand Rivers.

weighted basis, and 2 on a weighted basis. Submitters to the consultation, might have had access to that paper but would have had to guess at what could have been driving the 1 mg. results.

The prelimary paper results are shown in figure x. They are dominated by MCI and the DIN limits vary from 0.2 to 9. A limit of 0.2 would probably wipe out much of the dairy industry. With a limit of 9 there would be no effect since the current toxicity limit of 6.9 would be binding.

Figure seven: Preliminary DIN study results

Table 2. Numerical nutrient thresholds (mg/l) for annual median nitrate and DRP concentrations for inclusion in the National Policy Statement for freshwater state (A-D) derived from multiple lines of evidence. Weighting of each piece of evidence is provided along with regression statistics (F statistic, degrees of freedom, probability value and r^2) when relevant. PCI = public conservation land, MCI = Macroinvertebrate Community Index, QMCI= Quantitative Macroinvertebrate Community Index, EPT animals=Percent animals that are Ephemeroptera, Plecoptera or Trichoptera, EPT taxa=Percent taxa that are Ephemeroptera, Plecoptera or Trichoptera, IBI = Fish Index of Biotic Integrity, Chl a = Chlorophyll a concentration.

Ecological metric	n/a	n/a	MCI	QMCI	MCI	QMCI	EPT animals	EPT taxa	MCI	QMCI	MCI	QMCI	IBI	n/a	Chl a	Chl a	
NO_3																	
Relationship Equation	n/a	n/a	ln y = ln (x+1)	ln y = ln (x+1)	y = ln x	y = ln x	y = ln x	y = ln x	y=lnx	y=lnx	y=x	y=lnx	y=lnx	n/a	log10(max Chl a) = x	See Mathes on et al 2016	Weighted mean
Weight of evidence	1	1	2	2	2	2	2	2	2	2	2	0	1	2	2	2	
A/B threshold	0.03	0.08	0.02	0.00	0.11	0.10	0.11	0.20	0.06	0.09	0.00	0.00	0.00	0.17	0.12	0.43	0.11
B/C threshold	0.06	0.12	0.45	0.29	0.58	0.34	0.30	0.47	0.53	0.33	0.60	0.13	0.21		0.43	2.77	0.58
C/D threshold	0.28	0.20	1.22	0.77	3.01	1.09	0.87	1.09	4.36	1.20	1.60	9.10	1.54	0.44	0.90	4.84	1.66
r^2			0.53	0.54	0.35	0.27	0.28	0.29	0.37	0.27	0.08	0.04	0.09		0.3		
F			632224	653084	513	363	377.6	390.6	51.72	32.66	6.78	3.85	3775				
df			1,566548	1,566548	1,961	1,961	1,961	1,961	1,86	1,86	1,62	1,62	1,392543				
p			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.01	0.05	<0.0001				
DRP																	
Relationship Equation	n/a	n/a	ln y =x	ln y =x	ln y = x	ln y = x	ln y = x	y=x	y=lnx	y = lnx	y=x	Y=lnx	lny=lnx	n/a	$\log_{10}$(max chla) = x	See Mathes on etal 2016	Weighted mean

STAG was little better off. All they were provided with was a short piece that provided them with a one paragraph explanation:

Each regression of the datasets was used to determine the numerical nutrient limits for each ecological state (Table 1). The final nutrient limits were determined by calculating a weighted average of those nutrient limits for each dataset / line of evidence multiplied by their allocated weighting. Following (Smith & Tran, 2010), direct linkage relationships between ecosystem health measures and nutrients were allocated a weighted value of 2 in the analysis and purely statistical or less direct linkages were allocated a weighted value of 1 (e.g. percentile analysis and Fish IBI). Where relationships were not significant they were not included as a line of evidence i.e. they were allocated a weighted value of 0.

In the event STAG did not receive a final version of the paper until 17 April 2020 and it turned out to be very different to the preliminary paper. The final paper is discussed below.

What do Macroinvertebrate indices describe?

Macroinvertebrate indices are frequently used as an indicator of river and stream health so a word on what they mean might be helpful. Basically they are measures of the extent to which macroinvertebrate presence and prevalence have departed from a natural, prehuman condition. They can be a noisy indicator because invertebrate communities vary naturally, seasonally and geographically and in different river systems. Even if accurately measured all the indices are saying is that the ecology of the river is different from some modelled 'more natural' state. From some recreational river users perspective a higher index number is more likely a bad rather than a good thing. Higher scores can mean more swarms of mayflies, which can be particularly annoying for picnickers.

But higher MCIs can be imbued with more significance by some scientists. Differences become a measure of the river's 'health'. A river may look perfectly 'healthy' to a lay person, but to the 'scientist' the river system is in poor or indifferent health because it a bit different from its 'natural' levels. This is not a scientific judgement. It is a value judgement based on the view that any departure from the natural condition caused by humans is intrinsically undesirable and in varying degrees is 'unhealthy'.

The STAG minutes

From the STAG minutes it seems that at least one member expressed disquiet at what was being presented and this prompted a discussion of the robustness of the DIN bottom line.

One member expressed concern that the proposed attribute is a proxy for general water quality and habitat degradation. Recent work in Environment Bay of Plenty suggests there's no relationship between nitrate and MCI within that region. It's not known if that is specific to a region. It is not certain whether these relationships break down at smaller scales.

And the outcome was:

The point we've agreed to is that there is a general gradient of ecosystem health and nitrate is not the main driver, but is an indicator.

The one thing that farmers can control very finely is nitrogen. If you give them a nitrogen target, they will change their nitrogen. But if nitrogen is not the cause, changing the nitrogen will not make a difference. Managing nitrogen is necessary but not sufficient. The intent of having a nitrogen number is that farmers will tweak their operation to manage nitrogen.

The discussion here is revealing. Reducing nitrogen won't make much difference to environmental indicators but it still must be done, because, for some unexplained reasons it is 'necessary'. STAG was determined to make farmers reduce nitrogen inputs almost regardless of the evidence. Nitrogen reduction had become an end in itself, with the Group quite oblivious, or indifferent, to the economic harm their recommendation would cause. With a DIN limit of 1 it is not just a case for many farmers of 'tweaking' their operations. For a number the only option is to exit the business at a high economic and social cost.

The report finally appears

After the consultation process STAG was reconvened and produced a supplementary report in April 2020. It finally included the report on the DIN bottom line of 1mg/100 ml.

The majority of members stuck by the recommendation in the primary report

Recommendation 13 should be retained without amendment – the methodologies and data sets used to derive the proposed criteria, bottom lines and thresholds for DIN and DRP for rivers are scientifically rigorous, well explained and well justified, have been discussed at length by the STAG and peer reviewed independently by Professor David Hamilton who generally supported the approach adopted.

A minority strongly disagreed in an appendix to the report.

- *the evidence provided to establish nationally applicable bands and bottom lines is insufficient to provide confidence that a given DIN or DRP concentration will achieve the desired improvement in ecosystem health or ensure that the target of a specific ecosystem health metric will be met.*
- *There are concerns about the reliability and effectiveness of nationally-applied nutrient criteria in managing for ecosystem health, given they have been derived from weak relationships that vary spatially. This could have the effect of not triggering a management response in rivers where this is necessary to protect ecosystem health and vice versa.*

The minority group outlined an unsatisfactory process:

An update on progress with the supplementary technical report, along with several graphs and tables, was presented to the STAG at its meeting on 22/23 January 2020. On 3 February, a draft of the supplementary technical report on the development of DIN and DRP attributes was circulated to the STAG for review and comments provided. At that time the subgroup who previously identified concerns developed a table detailing remaining concerns as well as additional commentary and shared that with the report author. A final version of the supplementary technical report (now Appendix 6) was provided to the STAG on 16 April 2020 *and this subgroup have accordingly reviewed and modified their paper to form this document (now Appendix 7).*

The report that the majority relied on is described below. In our view the minority was right. The thresholds were not 'scientifically rigorous, well explained and well justified'. The reference to the support from the peer review by Professor David Hamilton might be misleading. A draft paper did not exist until early 2020. The review was of an earlier and possibly different analysis.

The report: Nutrients in NZ Rivers and Streams[18]

The ecosystem 'health'metrics used in the line of evidence approach to setting the nutrient bottom line are set out in figure eight.

Figure eight: STAG study health metrics

Table 1. The ecosystem health metrics using the in MLoE derivation of nutrient criteria, the number of sites and the relationship used.

	Ecosystem health metric	Number of sites	Relationship
Periphyton	Chlorophyll *a* (Matheson et al, 2016)	871-981	Quantile regression
	Chlorophyll *a* (Biggs, 2000)	30	Log regression
Macroinvertebrates	Macroinvertebrate community index (MCI)	388	Piecewise regression
	Quantitative macroinvertebrate community index (QMCI)	293	Piecewise regression
	Macroinvertebrate average score per metric (ASPM)	388	Piecewise regression
Fish	Fish index of biotic integrity (F-IBI)	2922	Quantile regression
Ecosystem processes	Ecosystem respiration	83	Log-log regression
	Gross primary production	83	Log-log regression
	Cotton decay	83	Log-log regression

The key outputs are set out in their table five in figure nine below. Excluding the periphyton analysis, which is not really relevant to soft bottom rivers and streams, and which does not affect the result, the 1.0 mg limit is an average of the 3 macroinvertebrate measures (1.47); the single fish IBI measure (0.76): and the three ecosystem process measures (0.77). Fortuitously they average 1mg./L

All of the results depend on a judgment on the C band bottom line shown in their table 4. If lower C bands had been selected then the DINs would be correspondingly higher. Despite the obvious criticality of these judgments there is no sustained

[18] Canning D. 2020 Nutrients in NZ Rivers and Streams

discussion in the document justifying these selections against some independent criteria. Within limits, the data almost becomes irrelevant, a DIN of 1 mg/l can be readily obtained if the C/D boundary is selected appropriately.

Figure nine: STAG DIN study inputs and results

Table 4. The bands used for each ecological metric used in nutrient band derivation.

Band	Chlorophyll a	MCI	QMCI	ASPM	IBI	GPP	ER	Cotton K dd
A	50	130	6.5	0.6	36	3.5	5.8	0.0009
B	120	110	5.5	0.4	28	5	7	0.0019
C	200	90	4.5	0.3	20	7	9.5	0.00395

Table 5. Nutrient criteria for each trophic group and the overall average (mg/L).

Nutrient	Band	Periphyton	Invertebrates	Fish	Ecosystem processes	Average	Average (excluding periphyton)	Most stringent
DIN	A	0.11	0.01	0.50	0.35	**0.24**	**0.29**	**0.01**
	B	0.53	0.33	0.63	0.50	**0.50**	**0.49**	**0.33**
	C	1.00	1.47	0.76	0.77	**1.00**	**1.00**	**0.76**
DRP	A	0.004	0.001	0.013	0.008	**0.006**	**0.007**	**0.001**
	B	0.009	0.009	0.016	0.009	**0.010**	**0.011**	**0.009**
	C	0.016	0.028	0.019	0.010	**0.018**	**0.019**	**0.010**

Macroinvertebrate metric

The issue the minority group had with the data is that the correlations are generally low and vary markedly by region. This is illustrated for the MCI indicator in table twelve below.

Table twelve: MCI/DIN correlations by region

Region	Rsq
Northland	0.48
Auckland	0.33
Taranaki	0.1
Hawkes Bay	0.0
Waikato	0.04
Manawatu	0.26
Wellington	0.33
Tasman	0.32
Marlborough	0.23

Canterbury	0.18
Westcoast	0.26
Otago	0.21
Southland	0.60

The fish IBI metric

The issues with the fish IBI were that it was based on a single paper by the STAG and was not fully empirically based. Estimated rather than actual nutrient levels were used and this may have significantly affected the results.

There is some more robust and transparent modelling available that might be relevant. A study produced for the Horizons Regional Council [19] found that lowland pasture had the best, not the lowest, Index of Biotic integrity score. The mean was 63.3 compared to 58.1 for native forest. If farm runoff was the problem for fish then the order would have been reversed.

Figure ten: Horizon IBI scores

Table 2. Statistics for IBI scores for main REC land-cover classes

	Urban	*Exotic forest*	*Tussock*	*H-pasture*	*Scrub*	*Native forest*	*L-pasture*
Mean	28.73	41.30	42.48	45.35	53.82	58.13	63.25
Standard Error	5.31	2.38	3.68	0.70	1.59	0.91	5.67
Median	24	34	34	50	60	64	70
Mode	0	34	34	0	34	64	34
Minimum	0	0	0	0	0	0	24
Maximum	72	88	78	88	88	88	88
Count	22	80	25	807	177	454	16

The ecosystem process metric

There was very little discussion of the content and logic of the three ecosystem process metrics. This is the entirety of the discussion.

Three metrics of ecosystem processing were used, being gross primary production (GPP), ecosystem respiration (ER) and cotton cellulose decomposition potential. The data used comprised 84 sites across three main bioregions of NZ, as described by Clapcott et al (2010). Bands for GPP and ER were derived from those proposed by Young et al (2008) and recommended by STAG in the ecosystem metabolism attribute. For cotton decomposition,

[19] A Fish Index of Biotic Integrity (IBI) For Horizons Regional Council Joy 2015

there were no previously suggested bands, instead the 25th, 50th and 75th percentiles comprised the A, B and C bands respectively. Log-log transformations were applied to all metric and nutrient relationships, and all were statistically significant (Table 3)

On the information provided it is difficult to say what meaning can be attached to these relationships. There appears to a positive relationship between gross primary production and DIN. Does this mean that primary production is intrinsically bad and that a desirable outcome would be reducing that production by reducing DIN levels? In any event these indicators had almost no statistical relationship with DIN levels. The R-sqs were: GPP 0.15; ER 0.13; and 'Cotton' 0.15. These indicators appeared to be there just to make up the numbers in the line of evidence approach.

Majority group response to minority concerns

The majority group responded to the minority report with a further paper which didn't really engage with the technical scientific differences and comes across as somewhat evangelical.

We, the majority …… believe that there is sufficient evidence available now, as summarised in Appendix 6, to support the introduction of nationally applicable bottom lines and thresholds for DIN and DRP. We are mindful that successive state of the environment reports produced by the Ministry for the Environment, including the Our Freshwater 2020 report released in April, have concluded that water quality in New Zealand's rivers continues to degrade, threats to New Zealand's freshwater fish and ecosystems continue to grow and the health of these ecosystems continues to decline. We believe we cannot wait for every residual uncertainty in the evidence to be resolved before taking action.

Part eight: Sedimentation bottom lines

The Cabinet paper did not include the benefits and costs from the sedimentation policy in its overall assessment of the costs and benefits. The reasoning, which is quite correct, is that it is difficult to separate the benefits from 'carbon farming' of trees that will happen anyway in response to the economic incentives of the carbon price, from the additional benefits that will be driven by the sediment bottom line policy.

However, because the apparently very favorable net benefits were still presented, and might be trotted out, from time to time, to support the argument that there is a large net economic benefit from the policies as a whole, we examine the estimated benefits from the sediment bottom line.

The benefits calculations that were presented in the cabinet paper are set out in table thirteen.

Table thirteen: Sedimentation bottom lines benefit estimates

Monetised impacts	Annual impact by 2050 $m p.a.	PV of cumulative impact by 2050, 3% discount rate $m	Comments
Water clarity benefits from sediment policy	46	383	
Savings from reduced dredging	20	392	
Avoided erosion cost	4	68	
Net profit impacts assuming land use change and carbon revenues	253	4,958	
Sediment policy $m	297	**5,801**	This is the upper limit of net benefits

The big benefit is the $4958 million present value from converting farmland to forestry. This estimate was generated by some complex cost benefit modelling by Landcare Research[20]

The modellers first had to estimate, at a fine spatial level of detail, the areas that were generating 'excessive' sedimentation based on the sedimentation bottom lines.

[20] Neverman A, Djanibekov U, Soliman T, Walsh P, Spiekermann R and Basher L 2019 'Impact testing of a proposed sediment attribute: identifying erosion and sediment control mitigations to meet proposed sediment attribute bottom lines and the costs and benefits of those mitigations'. Landcare Research Contract Report: LC3574. Prepared for the Ministry for the Environment.

They then calculated the amount of additional afforestation that is required to comply with the national bottom line. While farmers can use 'whole of farm' plans to meet the sedimentation requirements, these are hardly ever adopted because they are less effective and more costly.

The next step is to calculate the amount of afforestation that will occur just as a response to the value of the carbon credits. This becomes the baseline and is deducted from the amount of afforestation required to meet the sedimentation bottom line. This is the amount of afforestation generated by the policy.

The next step is to calculate the value of the marginal afforestation, which is the value of carbon credits less the value of reduced pastoral farming profits. As 'carbon farming' is much more financially profitable than pastoral farming this generates the large present value in the benefit assessment

There are a number of issues with the robustness of this net benefit calculation.

- There is uncertainty around future carbon prices.
- There is uncertainty about how the carbon price will affect the conversion rates from farmland to forest. Farmers will differ in how they respond to the price signal. Some might adopt a hard-nosed commercial approach, maximizing their financial income. Others will place a value on farming as such. At a personal level they will be prepared to accept a lower monetary income to be a farmer, and some may value the retention of a farming community. They do not want the farming community they have grown up with replaced with forests with no community life.

- The modellers addressed the issue of the uncertain conversion rate by making carbon farming artificially less profitable. They assumed that the investment in carbon farming would be funded by bank loans at a 20 percent interest rate because of the high risk of these investments. This had the effect of reducing the baseline conversion rate and meant that the sedimentation policy had a greater effect. The 20 percent interest rate was a nonsense that grossly overstated the cost of capital for carbon farming.
- The different preferences for commercial returns over other personal values means that it is difficult to make an assessment of the impact of higher carbon prices on the rate of afforestation, particularly over the small geographical areas that matter in modelling the rate of allowable sedimentation. There might be half a dozen farms in a river reach. If they are all driven by strictly financial considerations then all of them might convert to carbon farming (or sell to someone who will). Or if they are all driven by a broader conception of value then none of them will convert.

- The modelling of the benefits of the sedimentation-driven conversions is wrong. It does not value the lifestyle and broader benefits that farmers get from continuing to farm. There is an imputed income here that should be valued.

  We can put the idea in concrete terms. Suppose that a hectare of land is worth $10,000 as farmland, and $15,000 as an input into carbon farming. However, the land as farmland is worth $20,000 to the farmer for the reasons discussed above. He will not sell until the land price reaches that point.

  In the model it is assumed that when the state coercively forces the farmer to convert to carbon farming there is a gain of $5000 a hectare ($15,000 less $10,000). The correct valuation should have been a loss of $5000 ($20,000 less $15,000). It would only be appropriate to ignore the farmer's preferences if the farmer was mentally incapable, and the state had to intervene to force a decision in the farmer's best interests (so they would be $5000 a hectare better off in financial terms). This assumption was not made in the cost benefit modelling and we do not believe it is an assumption that can reasonably be made.

The upshot is that all of the benefits in the cost benefit model from forcible conversion should be ignored and, theoretically, some estimate should have been made of the welfare costs.

Other avoided costs

Of the other avoided costs, the benefits of $383 million for water clarity can largely be ignored, because they are based on the dubious Choice Experiment modelling that we critiqued in Part five. Some credible analysis went into the 'reduced dredging of hydro lakes', but to the extent that the estimate was driven by reduced dredging of harbours the numbers look dubious. The avoided erosion costs may well be reasonable but the numbers are small. The overall 'other benefits' may well balance out the welfare costs of forced conversion and the costs to farmers who take the 'whole of farm' plan approach.

Was there really a problem to be solved?

Quite apart from the issue of whether the net benefits are really positive there is a question of whether a national bottom line was really necessary.

Problem will be naturally be addressed

As noted the more pronounced erosion problems will probably be largely mitigated by the economic incentive to convert to carbon farming.

The current state may be better than thought

A recent report [21] reviewed more up to date information on river sedimentation. It showed a much more positive picture than the dated information used in MfE reports used to develop the bottom lines. The Regulatory impact statement noted:

Predictive models estimate that current deposited sediment levels are worse than the proposed thresholds in river reaches shown in Figure 2 below (approximately 37% of segments). However, the most recent state of the environment data (where they are available) show a more refined and less negative picture of the current state of rivers in relation to the proposed thresholds.

The more refined and less negative Cawthron summary was:

*Overall, 23.3% of monitoring sites had Habitat Quality Scores indicating Excellent habitat condition, 51.4% were in Good condition, 24% were in Fair condition and no sites were in Poor condition. (*It was not clear whether poor condition referred to those below the national bottom line.) *The national median deposited fine sediment cover was 4.5 percent….. When compared to the reference condition based on model predictions by Franklin et al. (2019), 85% of sites were below reference values, indicating good stream health.*

This suggests that the sedimentation modelling used to define the bottom lines might not have been very robust.

CBA results raise issues about robustness of modelling threshold levels

The cost benefit modelling raises issues about the robustness of the modelling that purports to identify a natural state of sedimentation. Of the 1,000,000 hectares that converted to forestry the bottom line was not achievable in catchments covering 400,000 hectares, even when all farmland had been converted. As full conversion should closely replicate a natural environment this suggests that the modelled

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21 Clapcott J, Casanovas P, Doehring K 2019. Indicators of freshwater quality based on deposited sediment and rapid habitat assessment. Prepared for Ministry for the Environment. Cawthron Report No. 3402. 21 p. march 2020

‘natural’ sedimentation rate is too low and that accordingly the bottom line is too low.

Uncertainty on whether the a bottom line can be meaningfully defined
The bottom line is meant to represent a safe level before an ecological tipping point.

The derivation of a ‘bottom line’ value for application as National Objectives Framework (NOF) standards in the NPS-FM seeks to identify a threshold level of protection which is protective of a ‘tipping point’ for environmental decline of key biotic characteristics (e.g., biodiversity, key functional or endangered species) of the environment[22]

The report commissioned by the MfE[23] attempted to do that but it was not clear that they came to a convincing conclusion. A mass of evidence was discussed, which often pointed in different directions and little suggested clear cut-off points. And the bottom lines were based on the impact of sediments on macroinvertebrates rather than fish, because they were thought to be more sensitive to sediment. The evidence did not suggest that there was a clear bottom line as it is described in the attribute table below. Attribute state D is meant to be distinguishable from state C because there is a:

High impact of suspended sediment on in-stream biota. Ecological communities are significantly altered and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.

But if we look at the relationship in some of the figures presented in the report we do not see a marked deterioration in macroinvertebrate health as the amount of sediment in the water increases (note the dark green lines are the median relationship).

The suggestion that species are at risk of actually being ‘lost’ does not appear to be supported by the evidence. Sediment even at extremely high loads is not toxic.

A laboratory study investigated acute effects of suspended sediment on stream invertebrates (Suren et al. 2005), which investigated responses of five common native stream insects and a

[22] Development of ecosystem health bottom-line thresholds for suspended and deposited sediment in New Zealand rivers and streams Prepared for Ministry for the Environment
May 2018

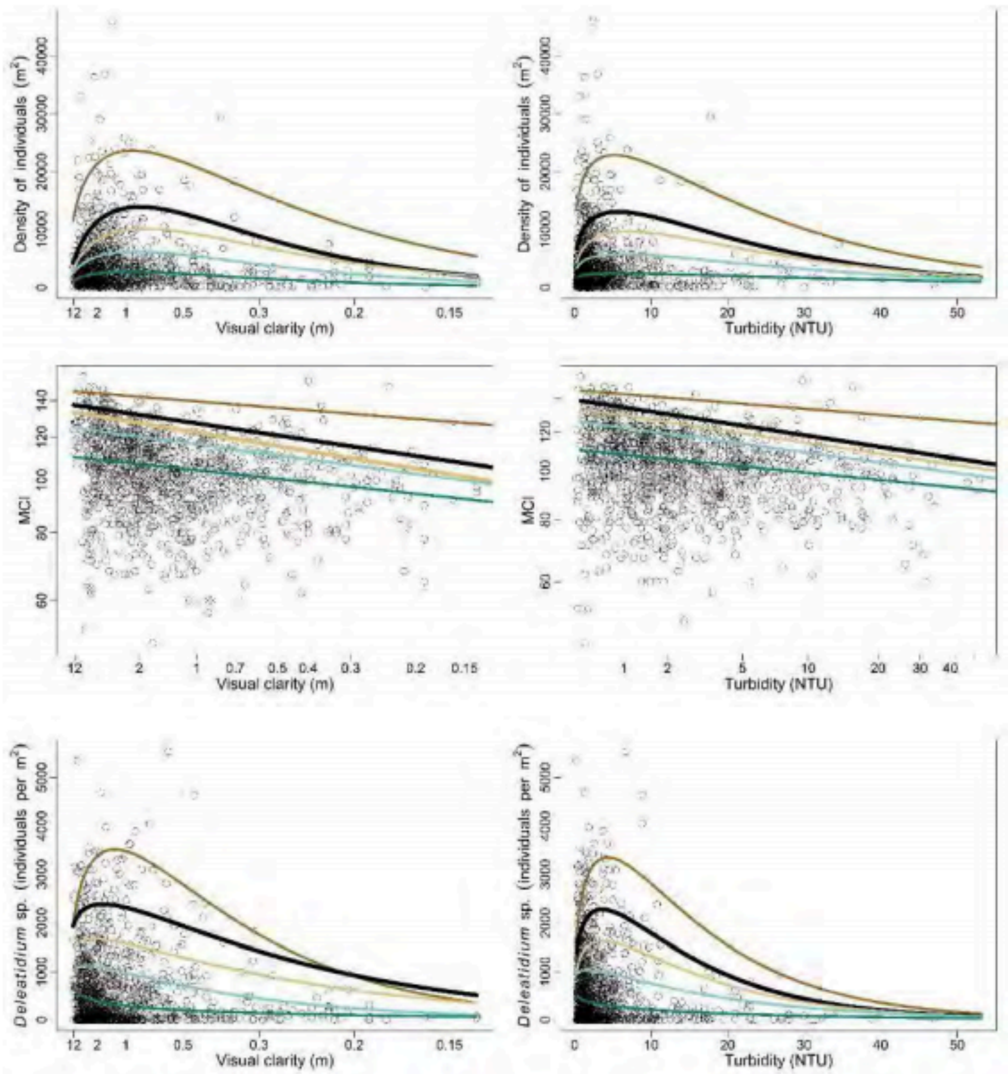
[23] ‘Development of ecosystem health bottom-line thresholds for suspended and deposited sediment in New Zealand rivers and streams Prepared for Ministry for the Environment
May 2018

native crayfish that are supposedly sensitive to fine sediment. They showed that even very high clay concentrations (up to ~20,000 NTU), were not toxic over relatively short durations (24 hr). Furthermore, there were no detectable toxic effects on the mayfly Deleatidium compared to controls with exposure to 1000 NTU of clay in 4-hr 'pulses' for up to 14 days.

Table fourteen: Attribute states by catchment type

Attribute state	1	2	3	4
A Minimal impact of suspended sediment on in-stream biota. Ecological communities are similar to those observed in natural reference conditions.	>1.78	>0.93	>2.95	>1.38
B Low to moderate impact of suspended sediment on in-stream biota. Abundance of sensitive fish species may be reduced.	1.78	0.93	2.95	1.38
C Moderate to high impact of suspended sediment on in-stream biota. Sensitive fish species may be lost.	1.55	0.76	2.57	1.17
D High impact of suspended sediment on in-stream biota. Ecological communities are significantly altered and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.	<1.34	<0.61	<2.22	>(sic)0.98

Figure ten: Sediment/macroinvertibrate relationships



Part nine: Summary of impacts

Table fifteen below presents the original Cabinet paper estimates together with our assessments. The MfE net benefit estimate of $3782 million becomes a net loss of $3233 million. The big drivers of the change are the reduction in the value of swimmability benefits to reflect the likely impact based on a realistic assessment of the actual health data; and the removal of the wetland ecosystem benefit. The latter benefit was little more than a sham number probably introduced at the last minute to boost the benefit numbers.

Table fifteen : NPV summary table

	MFE		Tailrisk
Benefits	**Annual $'m**	**PV $'m**	**PV $m**
Swimmability benefits from stock exclusion	138	2366	2
Water clarity benefits from stock exclusion	13	104	Low. Benefits not likely to be perceptible
Ecosystem health benefits of MCI bottom lines	79	661	Low Impacts minor and not likely to be highly valued
Wetland econsystem services	450	3900	Low. Valuable wetlands alrady likely to be protected Allows for conversions to wetlands
	359	**7031**	**300** A generous order of magnitude estimate
Costs			
Stock exclusions	61	1092	1092 No change
Wetland opportunity costs		0 Not assessed	200 Order of magnitude
Farm plan costs	22	253	253 No change
Mitigation costs from reducing nitrogen pollution due to toxicity policy	30	217	300 Moderate increase in MfE figure
Water measuring and reporting related costs	10	196	196
Additional costs	76	1490	1490

for local authorities			
Total Costs		**3249**	**3533**
Net Benefits		**3782**	**-3233**

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