Site-specific nitrate guidelines for Hawke's Bay

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Authors/Contributors:
C.W. Hickey

For any information regarding this report please contact:

Dr C.W. Hickey
Principal Scientist

+64-7-856 1713
chris.hickey@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road
Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest
Hamilton 3251
New Zealand

Phone +64-7-856 7026
Fax +64-7-856 0151

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Reviewed by

C. Depree

Approved for release by

T. Hume

Formatting checked by

1 Introduction

Hawke's Bay Regional Council (HBRC) is currently developing information to incorporate into a Plan Change for the Tukituki River catchment to respond to the requirements of the National Policy Statement for Freshwater Management, 2011. As part of that process, HBRC are seeking advice on appropriate nitrate concentration thresholds to be incorporated in that plan change.

This report responds to a detailed brief requested by HBRC in their letter of 11 July 2012 (Ref: RMP25/8) as received from Helen Codlin, Group Manager Strategic Development. The brief is as follows:

Brief

Toxicity Guidelines – General

1. Provide a brief summary of the Nitrate Toxicity guidelines and how they are intended to be used.

2. Comment on whether or not the proposed framework is consistent with how the nitrate toxicity guidelines are intended to be used.

3. Discuss the new data for rainbow trout toxicity. Describe rainbow trout sensitivity to nitrate as compared to Lake Trout (which is the most sensitive species).

4. Discuss the new data for inanga toxicity. Describe inanga sensitivity to nitrate as compared to Lake Trout (which is the most sensitive species).

5. Discuss the new data for mayfly toxicity. Describe mayfly sensitivity to nitrate as compared to Lake Trout (which is the most sensitive species).

6. Provide recalculation of the revised acute and chronic guidelines with inclusion of these test species.

7. Advise if there is any additional toxicity data with respect to brown trout.

8. Comment on the appropriateness of setting a limit based on a single species (such as inanga if that has been determined to be the most critical species for a particular catchment or part of catchment) versus setting a limit based on the most sensitive species. Comment on how particular species can be referenced in relation to the most sensitive species.

Proposed Framework

1. Comment on the use of average Nitrate N concentrations as a comparison to the Proposed Limits in light of the characteristics of the dataset for the Tukituki water quality sites. What would be the minimum dataset needed for determining an average?

2. Comment on the use of the Threshold Effect Concentration (TEC) (geometric mean of NOEC and LOEC) as a chronic maxima. Provide recommendations on the appropriate

concentration statistic (e.g., 90th or 95th percentile) to be compared with these chronic maxima limits. Calculate the TEC to complete the table.

3. Each management class is based on the 99%, 95%, 90% and 80% species protection respectively. Describe the effects that nitrate can have on fish and invertebrate species, individually and on population health; describe those effects in the context of the proposed concentration limits. Describe in terms that can be easily understood by non-specialists. As a comparison, also comment on lethal concentrations.

4. Comment on whether nitrate concentrations present a barrier to migratory fish. Comment on whether there is a pathway for nitrate to affect trout eggs or hatching rates.

2 Background

Nitrate occurs naturally in the environment and is produced and consumed through the processes of the nitrogen cycle, and anthropogenically produced for agricultural use as a fertilizer. The major anthropogenic sources of nitrate to surface waters are agricultural runoff, municipal and industrial wastewaters, urban runoff and groundwater inputs. Nitrate concentrations are an important indicator of agricultural enrichment and ecological health. As such, they form an important component of the management of freshwaters, requiring robust guideline values to support environmental planning and management.

Since the last revision of the freshwater nitrate trigger values (TVs) for toxicity in 2000 [1], errors were identified in the derivation and new data have become available. The revised 2009 guideline trigger value is significantly lowered from the 2000 value (changing from 7.2 mg NO_3-N /L [2] to 1.7 mg NO_3-N /L for 95% species protection [3]). Subsequent to the 2009 review, Environment Canada has released a revised freshwater nitrate water quality guideline [4], which included new acute and chronic data for several freshwater species. Recent chronic nitrate toxicity studies have also been undertaken for two New Zealand freshwater species (juvenile and sub-adult inanga, *Galaxias maculatus*; mayfly, *Deleatidium* sp.; [5, 6]), and the New Zealand strain of rainbow trout (42 d early life-stage test, *Oncorhynchus mykiss*; [6]), which further expanded the database for local species. The chronic nitrate guideline values reported here are based on 22 species, including the new New Zealand data, and are summarised in Appendix A. This updated database and guideline derivation will form the basis for the ANZECC interim revised nitrate guidelines scheduled to be completed in 2013.

Background information on nitrate as a toxicant can still be sourced from ANZECC/ARMCANZ (2000) [1] (Volume 2, Section 8.3.7.2) and Environment Canada (2012) [7].

3 Responses to Brief

1. *Provide a brief summary of the Nitrate Toxicity guidelines and how they are intended to be used.*

The ANZECC (2000) guidelines provide a methodology to derive risk-based trigger values (TVs) for surface waters using no observed effect concentration (NOEC) sensitivity values for aquatic species. The TVs are based on a dataset describing chronic (long term) effect (i.e., growth, reproduction) for a range of species groups (e.g., fish, invertebrates, amphibians) which are representative of the ecosystem.

The ANZECC (2000) guidelines provide a statistical derivation procedure for differing levels of ecosystem protection. The ANZECC descriptors recognise three broad ecosystem conditions:

1. High conservation/ecological value systems (99% species protection[1]) — effectively unmodified or other highly-valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations. While there are no aquatic ecosystems in Australia and New Zealand that are entirely without some human influence, the ecological integrity of high conservation/ecological value systems is regarded as intact.

2. Slightly to moderately disturbed systems (95% species protection) — ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Typically, freshwater systems would have slightly to moderately cleared catchments and/or reasonably intact riparian vegetation; marine systems would have largely intact habitats and associated biological communities. Slightly to moderately disturbed systems could include rural streams receiving runoff from land disturbed to varying degrees by grazing or pastoralism, or marine ecosystems lying immediately adjacent to metropolitan areas.

3. Highly disturbed systems (80-90% species protection). These are measurably degraded ecosystems of lower ecological value. Examples of highly disturbed systems would be some shipping ports and sections of harbours serving coastal cities, urban streams receiving road and stormwater runoff, or rural streams receiving runoff from intensive horticulture.

The site-specific framework for Hawke's Bay replaces these general descriptors with regional descriptors applicable to nitrate management within the catchments and sub-catchment areas.

The TVs which form the basis of the guideline values used in this report use the ANZECC derivation methodology and the updated species database as described above. The site-specific components include: (i) guideline derivation using NOEC and threshold effect

[1] The percentage species protection refers to a statistically-derived numeric value which is calculated from the chronic toxicity sensitivity data for the species groups. These species are assumed to be representative of the "ecosystem" of species in the receiving environment.

concentration (TEC)[2] values for all species; (ii) consideration of the relative sensitivity of key species and life-stages; (iii) incorporation of water quality factors which affect nitrate toxicity (specifically water hardness) into the decision-making framework; and (iv) application to site-specific management units within the greater Tukituki catchment.

A summary of the available NOEC and TEC sensitivity data for the species used in guideline derivation is provided in Appendix A. These include data for 22 species, including 9 fish, 8 invertebrates, 4 amphibians and 1 alga. Seven of the species in the database are resident in New Zealand. The dataset spans a 224-fold range in sensitivity, with Lake Trout (*Salvelinus namaycush*; resident in Lake Pearson, Canterbury) the most sensitive (NOEC of 1.6 mg NO_3-N/L,TEC 3.2 mg NO_3-N/L) for both growth and development endpoints measured after a 146-day exposure. In general, the chronic fish data indicate higher exposure sensitivity, although both fish and invertebrates show wide ranges in sensitivity. The most sensitive invertebrate NOEC (a freshwater crayfish, *Astacus astacus*) was 9x less sensitive than the most sensitive fish NOEC. Rainbow trout, the mayfly *Deleatidium* sp., and juvenile inanga were all markedly less sensitive than the most sensitive species (by 16x, 13x and 7x respectively; corresponding to 57th, 48th and 29th percentiles of the chronic dataset (Table A-1)).

The site-specific numeric nitrate guideline values for Hawke’s Bay were based on NOEC and TEC effect thresholds. These are summarised together with narrative descriptors in Table 3-1. Background to the thresholds derivation procedure is provided in Appendix D. The terms “Grading” and “Surveillance” are derived from the compliance descriptors applied to microbiological standards. The Grading values are derived from the species NOEC values and it is recommended that compliance should be based on the annual median concentrations. The Surveillance values are derived from the species TEC values and it is recommended that compliance should be based on the annual 95th percentile of the monitoring data. The TEC value is a conservative measure to protect from seasonally high concentrations in that it is lower than the statistically derived lowest observed effect concentration (LOEC) for each species.

[2] The threshold effect concentration (TEC) is the geometric mean of the no observed effect concentration (NOEC) and the lowest observed effect concentration (LOEC). The TEC value is below the lowest statistically significant effect concentration.

Table 3-1: Proposed Framework for managing Nitrate risk for Aquatic Species.

Management Classification (ANZECC protection threshold)	Grading Nitrate concentration (mg NO_3-N /L)	Surveillance Nitrate concentration (mg NO_3-N /L)	Description of Management Class
Excellent (99%)	1.0	1.5	Pristine environment with high biodiversity and conservation values.
Very Good (95%)	2.4	3.5	Environments which are subject to a range of disturbances from human activities, but with minor effects.
Good (90%)	3.8	5.6	Environments which have multiple disturbances from human activities and seasonally elevated concentrations for significant periods of the year (1-3 months).
Fair (80%)	6.9	9.8	Environment which are measurably degraded and which have seasonally elevated concentrations for significant periods of the year (1-3 months).
Monitoring statistic:	Annual median	95^{th} percentile	

2. *Comment on whether or not the proposed framework is consistent with how the nitrate toxicity guidelines are intended to be used.*

The proposed framework outlined in Table 3-1 is based on and consistent with the ANZECC (2000) guidelines [1] risk-based methodology to provide various levels of ecosystem protection. The proposed compliance monitoring basis provides species protection for both average long-term exposure and seasonal maximum concentrations. The proposed site-specific application also considers water quality factors such as hardness, which may modify the nitrate toxicity to key species (see response to Question 3). The basis for the protection levels is discussed further in Appendix D and the adequacy of protection is addressed for key species and species groups below (Question 11).

The ultimate decision on the level of environmental protection involves both technical and community input, which must consider and balance resource use and value judgements on development and potential degradation, together with abstractive uses. The technical assessment for protection from nitrate toxicity involves consideration of potential toxicity effects thresholds and consideration of the existing water quality (i.e., nitrate concentration and factors which affect toxicity), together with information on the management objective for a specific catchment area. Table 3-2 provides a summary of fisheries management objectives and proposed appropriate levels of protection for the Nitrate Management Zones in the Tukituki catchment. A qualitative assessment of risk to these species groups is provided in **Table 3-3** and addressed in response to Question 11.

Table 3-2: Proposed nitrate toxicity thresholds for the Tukituki with appropriate levels of protection.

Zone [a]	Management objective [b]	Appropriate level of protection [c]
N1 (Lower Tukituki)	Migrating whitebait, rainbow trout	95% [d]
N2 (Ruataniwha Plains north)	Rainbow trout / native fish	90% [e]
N3 (Ruataniwha Plains south)	Rainbow trout / native fish	90% [e]
N4 Upper Tukituki/Waipawa)	Biodiversity/ high conservation value	99% [f]
N5 (Papanui/Otane)	Native fish	90% (?) [g]

[a] Nitrate Management Zones shown in Appendix B;
[b] Primary proposed fishery management objective (HBRC);
[c] Proposed level of protection based on management objective and existing water quality. See Table 3-1for numeric values associated with protection levels. Table 3-3 provides a qualitative risk summary for the target management group.
[d] To provide a high level of protection for larval migratory fish in the absence of specific sensitivity information;
[e] Rivers with high degree of seasonality of nitrate concentration, or in the absence of seasonality having moderate to moderately-high hardness (which reduces toxicity sensitivity). Provides a good level of protection for adult rainbow trout and native fish, as well as providing adequate spawning conditions for rainbow trout;
[f] Relatively pristine environment with high conservation values. Highest level of protection;
[g] Current nitrate concentrations relatively low. Highly modified catchment with intensive cropping in high nutrient (phosphorus) and potential contaminant run-off. Currently limited information on the existing fishery.

3. *Discuss the new data for rainbow trout toxicity. Describe rainbow trout sensitivity to nitrate as compared to lake trout (being the most sensitive species)*.

The Environment Canada nitrate guidelines published in 2012 [4, 7] included new chronic studies on the sensitivity of rainbow trout to nitrate. These studies ranged from 30 day exposures, including a range of water hardness concentrations [8] to 64 day exposures through eggs, alevin and fry life-stages [9].The hardness response data showed a decreasing toxicity with increasing hardness for rainbow trout [8] and several other species [10]. A similar response to hardness has also been found for chronic toxicity to juvenile inanga [6]. However, the quantity of available information was not sufficient to incorporate a hardness-modifying function in the Environment Canada guidelines [7]. The most sensitive species in the nitrate dataset (Lake Trout, Appendix A) was tested in very low hardness water (10-16 mg $CaCO_3$ /L) and was considered a conservative measure.

A study was recently completed of the sensitivity of the New Zealand strain of rainbow trout exposed to nitrate in moderate hardness (40 mg $CaCO_3$ /L) water [6]. The early life-stage test involved a 42 day exposure of eggs through to fry, with delayed development being the most sensitive endpoint. The NOEC and TEC values for these tests were 99 mg NO_3-N /L and 200 mg NO_3-N /L respectively. These results showed a 3.8-fold lower nitrate sensitivity than the averaged rainbow trout data incorporated in the guideline derivation (geometric mean NOEC 26.3 mg NO_3-N /L, Table A-1). Comparison of the rainbow trout NOEC values with the proposed guideline values given in Table 3-1 indicates a high protection level in all potential management classes.

An analysis of the hardness monitoring data for the Tukituki catchment is summarised in Appendix C. The average hardness in the Hawke's Bay rivers is higher at sites receiving increased groundwater contributions, which also have elevated nitrate; hardness is generally 30 to 40 mg $CaCO_3$/L at sites draining the Ruahine Ranges; moderate hardness occurs in the main Tukituki and Waipawa rivers Zones 1, 2 and 3. Higher hardness provides an additional margin of safety for site-specific guideline application to the higher level management classes.

4. *Discuss the new data for inanga toxicity. Describe inanga sensitivity to nitrate as compared to Lake Trout (which is the most sensitive species)*.

The inanga (*Galaxias maculatus*) tests were undertaken for 31 days using sub-adult life-stage fish [5], and with juveniles for 40 days for growth in both soft and moderate hardness waters [6]. The growth of juvenile inanga was the most sensitive chronic measure, with results showing significant sensitivity differences between the two hardness levels tested. Juvenile inanga in the low hardness water were 3.5x more sensitive to nitrate than in moderate hardness water (NOECs: 6.0 mg NO_3-N/L c.f. 20.9 mg NO_3-N/L), indicating that site-specific guidelines for low hardness waters may require use of appropriately selected data. Growth reduction was greater in the soft water test (average 11% at the NOEC concentration of 6.0 mg NO_3-N/L and 20% at the TEC concentration of 11.0 mg NO_3-N/L) than the moderate hard water test (average 5% at the NOEC concentration of 20.9 mg NO_3-N/L and 10% at the TEC concentration of 47.4 mg NO_3-N/L). Chronic survival was also significantly reduced at concentrations which resulted in growth reductions, however, the growth response was a more sensitive endpoint. A geometric mean value of 11.2 mg NO_3-N/L was calculated from the growth data for soft and moderately hard water NOEC values and used for guideline derivation. This effects threshold equates to the 29th percentile of the dataset (Figure A-1, Table A-1).

The inanga growth sensitivity in moderate hardness water is the most suitable for site-specific application to the Tukituki catchment. The juvenile inanga NOEC and TEC values in moderate hardness water are markedly higher than the Grading and Surveillance guidelines for all management classes (Table 3-1). The NOEC value of 20.9 mg NO_3-N/L for juvenile inanga in moderate hardness water value is 13-times higher (i.e., lower toxicity) compared with the most sensitive Lake Trout. The juvenile inanga in moderate hardness water are at the 48th percentile of the suite of species used for nitrate guideline derivation and would be well protected by the derived guidelines which include more sensitive fish species.

5. *Discuss the new data for mayfly toxicity. Describe mayfly sensitivity to nitrate as compared to Lake Trout (which is the most sensitive species)*.

The mayfly (*Deleatidium* sp.) test was undertaken for 20 days using early life-stage larvae [5]. At test completion a NOEC value of 20.3 mg NO_3-N /L and TEC value of 35 mg NO_3-N /L were established based on organism survival. This NOEC value is 13x higher (i.e., lower toxicity) compared with the most sensitive Lake Trout. The larval mayfly are at the 48th percentile of the suite of species used for nitrate guideline derivation (Appendix A).

6. *Provide recalculation of the revised acute and chronic guidelines with inclusion of these test species*.

Revised acute guidelines have been updated with recently published data and inclusion of the New Zealand mayfly data [11]. The revised datasets supported the previous observations that invertebrates were the most acutely sensitive to nitrate and fish were more chronically sensitive. The mayfly, *Deleatidium* sp., was the most acutely sensitive and comparable with sensitive amphipod species. The acute guideline remained at 20 mg NO_3-N/L after inclusion of new species data. The results of the chronic threshold measurements for inanga and mayfly were incorporated into the revised site-specific guideline derivation (Table 3-1).

7. *Advise if there is any additional toxicity data with respect to brown trout*.

To the author's knowledge, there is no additional work presently being undertaken with brown trout. Additional long-term (>100 day) testing is presently being undertaken in Canada with Lake Trout for a range of water hardness concentrations.

8. *Comment on the appropriateness of setting a limit based on a single species (such as inanga if that has been determined to be the most critical species for a particular catchment or part of catchment) versus setting a limit based on the most sensitive species. Comment on how particular species can be referenced in relation to the most sensitive species*.

The available data for chronic toxicity to nitrate indicates that fish are markedly more sensitive than invertebrates (Appendix A). Thus it may be appropriate to base site-specific limits on protection of a key fish species resident in that catchment, providing supporting data are available for protection of other resident fish species.

The sensitivity data for sub-adult and juvenile inanga is available from the native species testing. These data showed that inanga growth sensitivity in moderate hardness water is the most suitable for site-specific application to the Tukituki catchment, with NOEC and TEC values being markedly higher than the Grading and Surveillance guidelines for all management classes (Table 3-1). The use of guidelines based on the highly sensitive Lake Trout would be expected to provide suitable protection for juvenile inanga (see response to Question 4).

9. *Comment on the use of average Nitrate-N concentrations as a comparison to the Proposed Limits in light of the characteristics of the dataset for the Tukituki water quality sites. What would be the minimum dataset needed for determining an average?*

The compliance monitoring for nitrate should be annual median concentrations for grading (i.e., based on NOEC data) and 95th percentile concentrations for surveillance (i.e., based on TEC data) (Table 3-1).

Monthly monitoring would generally be adequate to provide a compliance dataset, as sub-lethal responses provide the basis for guideline derivation. Acute lethality thresholds are markedly higher than the regional river water nitrate concentrations (acute guideline, 20 mg NO_3-N /L [3, 11]).

10. *Comment on the use of the Threshold Effect Concentration (TEC) (geometric mean of NOEC and LOEC) as a chronic maxima. Provide recommendations on the appropriate concentration statistic (e.g., 90th or 95th percentile) to be compared with these chronic maxima limits. Calculate the TEC to complete the table*.

The TEC provides a conservative sub-lethal measure of a species tolerance which is less than the statistically-derived LOEC concentration. For example, the TEC value for the most sensitive species, Lake Trout in soft water, is 3.2 mg NO_3-N /L for growth reduction and developmental delay, while the LOEC for this species is 6.25 mg NO_3-N /L. The LOEC value represents an 11.5% reduction in growth for this species after a 146 day exposure [12]. The mortality NOEC for Lake Trout was 100 mg NO_3-N /L and TEC 200 mg NO_3-N /L based on survival of fry (% of initial embryos).

The TEC for juvenile inanga in moderate hardness water was 47.4 mg NO_3-N /L for growth and survival, with 10.3% and 8.2% responses respectively [6]. The LOEC value of 108 mg NO_3-N /L represents a 23% growth reduction and a 51% survival reduction. All proposed guidelines are well below the TEC effect thresholds for juvenile inanga in moderate hardness waters.

The proposed use of the TEC value for seasonal maxima is conservative in that it is below the LOEC and would only occur for a relatively short period of the year.

The use of the 95th percentile of the monitoring data is recommended as a measure of concentration to compare with the TEC-derived Surveillance values (Table 3-1).

11. *Each management class is based on the 99%, 95%, 90% and 80% species protection respectively. Describe the effects that nitrate can have on fish and invertebrate species, individually and on population health; describe those effects in the context of the proposed concentration limits. Describe in terms that can be easily understood by non-specialists. As a comparison, also comment on lethal concentrations.*

The ANZECC (2000) guideline methodology has been applied to derive a range of nominal species protection levels based on the nitrate species sensitivity database (Appendix A). These will generally be conservative because NOEC and TEC values used in the derivation of the numeric guidelines that are below significant effects thresholds. However, lower levels of nominal protection may include some species which experience some chronic effects. Information on the level of protection for groups which are not well represented in the database may have higher uncertainty.

Table 3-3 provides an assessment of risks and potential impacts on species groups at the various protection levels. All effects considered are sub-lethal (i.e., development, growth, reproduction, see Table A-1) and occur at concentrations markedly lower than the lethality thresholds (Figure A-1). This assessment is based on the narrative criteria provided in **Table 3-3** (see footnotes) and the species sensitivity data from Table A-1. The relative acute lethality and sub-lethal chronic sensitivity distribution for all species is shown in Figure A-1.The analysis indicates that most species groups have a negligible risk and that any impacts resulting from exceedance would be insignificant. The indication of low risk with moderate effects for Lake Trout, which are not resident in the catchment, would equate to a 10% growth reduction for that species and be 16x below the lethality threshold for the fry.

The “minor” impact threshold for rainbow trout relates to concentrations below the LOEC values for this species.

Table 3-3: Qualitative risk summary for revised nitrate toxicity species protection levels.

Target group	Level of protection - Level of risk / Impacts			
	99%	95%	90%	80%
Fish eggs [1]	Negligible/Insignificant	Negligible/Insignificant	Negligible/Insignificant	Negligible/Insignificant
Native fish larvae/fry	Negligible/Insignificant	Negligible/Insignificant	Negligible(?)/Insignificant(?)	Negligible(?)/Insignificant(?)
Mature native fish	Negligible/Insignificant	Negligible/Insignificant	Negligible/Insignificant	Negligible(?)/Insignificant(?)
Lake Trout fry/fingerlings [2]	Negligible/Insignificant	Very low / Minor	Low / Moderate	Low / Moderate
Rainbow trout fry/fingerlings	Negligible/Insignificant	Negligible/Insignificant	Very low / Minor	Very low / Minor
Mature rainbow trout	Negligible/Insignificant	Negligible/Insignificant	Negligible/Insignificant	Negligible/Insignificant
Aquatic invertebrates	Negligible/Insignificant	Negligible/Insignificant	Negligible/Insignificant	Negligible/Insignificant

[1] Descriptors:

Risk (relates to the number of species exposed): Negligible = all target group protected for all conditions; Very low = only most sensitive species affected; Low = several sensitive species affected; Moderate = several sensitive species from multiple target groups; High = several species affected, including key local environment species; ? = minimal or insufficient data for this group.

Impacts (relates to the level of effect from the exposure): Insignificant = below all effects thresholds; Minor =chronic sensitivity threshold for the most sensitive species exceeded occasionally; Moderate = chronic sensitivity threshold for most sensitive species exceeded under average conditions; Major = value approaches acute sensitivity threshold.

See Table 3-1 for numeric values for protection levels for Grading and Surveillance.

[2] Based on 37-64d early life-stage (ELS) rainbow trout exposure (eggs, alevin, fry life-stages). Includes ELS data for New Zealand strain of rainbow trout.

[3] Most sensitive species. Not present in Hawke's Bay, but resident in Lake Pearson, Canterbury.

12. *Comment on whether nitrate concentrations present a barrier to migratory fish. Comment on whether there is a pathway for nitrate to affect trout eggs or hatching rates*.

The presence of elevated nitrate concentrations would not be expected to result in a barrier to migration. As the difference between chronic and acute nitrate guidelines is substantial (Figure A-1; acute guideline 20 mg NO_3-N /L, most sensitive acute species, *Deleatidium* sp. LC_{50} 54.9 mg NO_3-N /L; [11]), there is a low potential for acute effects following short-term exposure. Elevated nitrate concentrations would not be expected to cause a behavioural avoidance response with migratory fish species.

Eggs are generally resilient to exposure to many chemicals because of the presence of a selectively permeable membrane. Data for rainbow trout included results from early life-stage (ELS) tests for eggs, alevin and fry, and therefore incorporated the sensitivity of eggs. Sensitivity data for the New Zealand strain of rainbow trout in moderate hardness water showed a NOEC value of 99 mg NO_3-N /L [6] and was included in the derivation. This value is markedly higher than all guideline values and indicates that ELS of rainbow trout will be protected. These data were incorporated into the revised guideline derivation and the site-specific sensitivity data appropriate for soft- to moderate hardness waters (Appendix A).

4 Glossary of abbreviations and terms

ANZECC	Australian and New Zealand Environment and Conservation Council.
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand.
CAS	Chemical Abstracts Service.
Chronic toxicity	Lingering or continuing for a long time; often for periods from several weeks to years. Can be used to define either the exposure of an aquatic species or its response to an exposure (effect). Chronic exposure typically includes a biological response of relatively slow progress and long continuance, often affecting a life stage.
EC_{50} (median effective concentration)	The concentration of material in water that is estimated to be effective in producing some lethal or growth response in 50% of the test organisms. The EC_{50} is usually expressed as a time-dependent value (e.g., 24 hour or 96 hour LC_{50}).
Endpoint	Measured attainment response, typically applied to ecotoxicity or management goals.
Guideline (water quality)	Numerical concentration limit or narrative statement recommended to support and maintain a designated water use.
Hardness	Hard water is water that has high mineral content. Water hardness is generally determined by the concentration of the common cations calcium and magnesium and expressed as equivalent calcium carbonate ($CaCO_3$).
LC_{50}	median lethal concentration.
LOEC (Lowest observed effect concentration)	The lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms as compared with the controls.
$NaNO_3$	Sodium nitrate.
NO_3	Nitrate.
NO_3-N	Nitrate-nitrogen.
NO[A]EL	No observed [adverse] effects level.
NOEC (No observed effect concentration)	The highest concentration of a toxicant at which no statistically significant effect is observable, compared to the controls; the statistical significance is measured at the 95% confidence level.
Species	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
Standard (water quality)	An objective that is recognised in enforceable environmental control laws of a level of government.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Toxicity test	The means by which the toxicity of a chemical is determined. A toxicity test is used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical).
Trigger value (TV)	These are the concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should 'trigger' some action, either further ecosystem specific investigations or implementation of management/remedial actions.
Water quality criteria	Scientific data evaluated to derive the recommended quality of water for various uses.

5 References

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[3] Hickey CW, Martin ML. 2009. A review of nitrate toxicity to freshwater aquatic species. Technical Report No. R09/57. Environment Canterbury, Christchurch.

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[6] Hickey CW, Thompson KA, Albert A, Martin ML. 2013. Chronic sensitivity of juvenile inanga (*Galaxias maculatus*) and early life-stage rainbow trout (*Oncorhynchus mykiss*) to nitrate. HBR13207; HAM2013-012. NIWA report for Hawke's Bay Regional Council.

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Appendix A Summary data for nitrate guideline derivation

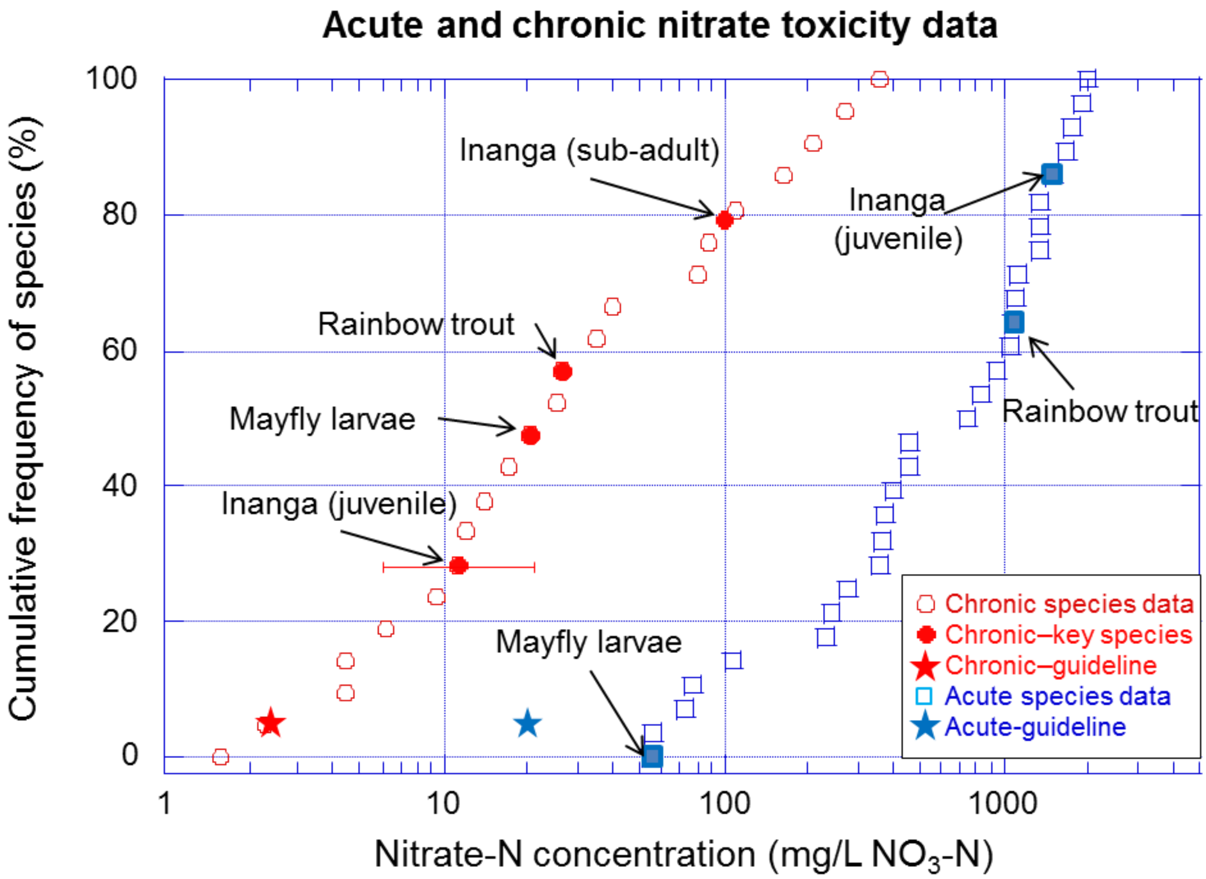

Figure A-1: Species sensitivity distribution for acute and chronic nitrate-N exposure. Chronic NOEC data from Table A-1 with NOEC 95th percentile guideline shown. Juvenile inanga data range shown for tests at two hardness concentrations. Acute survival data and guideline from Hickey (2013) [11].

Table A-1: Summary of chronic species sensitivity data used for nitrate-N guideline derivation.

Group	Common name	Scientific name	Life Stage	Duration (d)	Effect	Temp (°C)	Hardness of exposure water (mg/L as $CaCO_3$)	NOEC (mg/L NO_3^--N)	TEC (mg/L NO_3^--N)	Rank	Cum %
Fish	**Lake trout**	***Salvelinus namaycush***	**Embryo-Alevin-I**	**146d**	**DVP, GRO**	**7.5**	**10-16**	**1.6**	**3.2**	1	0
Fish	**Chinook salmon**	***Oncorhynchus tshawytscha***	**Fry**	**30d**	**MOR**	**10**	**8-10**	**2.3**	**3.2**	2	5
Fish	Lahontan cutthroat trout	*Salmo clarki*	Fry	30d	MOR	13	6-9	4.5	5.9	3	10
Fish	Coho salmon	*Oncorhynchus kisutch*	Fry	30d	MOR	10	8-10	>4.5	>4.5	4	14
Fish	Lake whitefish	*Coregonus clupeaformis*	Embryo-Alevin-Fry	126d	DVP	7.5	10-16	6.25	12.5	5	19
Amphibian	American Toad	*Bufo americanus*	Egg	23d	HAT	5-10	ND	>9.3	>9.3	6	24
Fish	**Inanga**	***Galaxias maculatus***	**Juveniles**	**40d**	**GRO**	**15**	**40**	**11.2***	**46.5***	7	29
Amphibian	Pacific treefrog	*Pseudacris regilla*	Tadpoles	10d	GRO	22	75	12.0	19.0	8	33
Invertebrate	Freshwater crayfish	*Astacus astacus*	NR	7d	MOR	15	ND	>14.0	14.0	9	38
Invertebrate	**Water flea**	***Ceriodaphnia dubia***	**Neonate**	**7d**	**REP**	**25**	**44-172**	**17.1***	**31.1***	10	43
Invertebrate	**Mayfly**	***Deleatidium* sp**	**Larvae**	**20d**	**MOR**	**15**	**40**	**20.3**	**35.0**	11	48
Invertebrate	Florida apple snail	*Pomacea paludosa*	Juveniles	14d	MOR	21-24	ND	25.3*	29.0*	12	52
Fish	**Rainbow trout**	***Oncorhynchus mykiss***	**Embryo-Alevin-Fry**	**30d**	**DVP, GRO**	**10**	**8-310**	**26.3***	**56.7***	13	57
Invertebrate	Freshwater prawn	*Macrobrachium rosenbergii*	Juveniles	21d	GRO	28	ND	35.0	62.0	14	62
Amphibian	African clawed frog	*Xenopus laevis*	Embryo	10d	GRO	22	21-24	40.4	58.5	15	67
Invertebrate	Midge	*Chironomus dilutus*	Larvae	10d	GRO	23	46-172	80.0*	113*	16	71
Invertebrate	Crustacean	*Hyalella azteca*	Juveniles	10d	GRO	23	46-310	88.1*	136*	17	76
Fish	**Inanga**	***Galaxias maculatus***	**Sub-adults**	**31d**	**MOR**	**15**	**40**	**>103**	**>103**	[a]	
Fish	Fathead minnows	*Pimephales promelas*	Embryos and larvae	11d	MOR, GRO	25	12-230	111*	159*	18	81
Amphibian	Red-eared frog	*Rana aurora*	Embryo	10d	GRO	15	26	162	195	19	86
Algae	**Green algae**	***Pseudokirchneriella subcapitata***	**Exponential**	**3d**	**GRO**	**24**	**10**	**206**	**289**	20	90
Fish	Topeka shiner	*Notropis topeka*	Juveniles	30d	GRO	24.5	210-230	268	361	21	95
Invertebrate	Water flea	*Daphnia magna*	Neonates	7d	REP	25	156-172	358	507	22	100

[a] Sub-adult inanga data not used in guideline derivation as juvenile growth a more sensitive endpoint; * indicates geometric mean of data from multiple studies or measurements over a range of hardness values.

Notes: Bold highlight indicates species resident in New Zealand. Table 4-1 from Hickey (2013) [11].

Abbreviations: NOEC = no observed effect concentration; LOEC = lowest observed effect concentration DVP = development; GRO = growth (length or weight); MOR = mortality; HAT = hatching; REP = reproduction.

Appendix B Hawke's Bay Water Management Zones

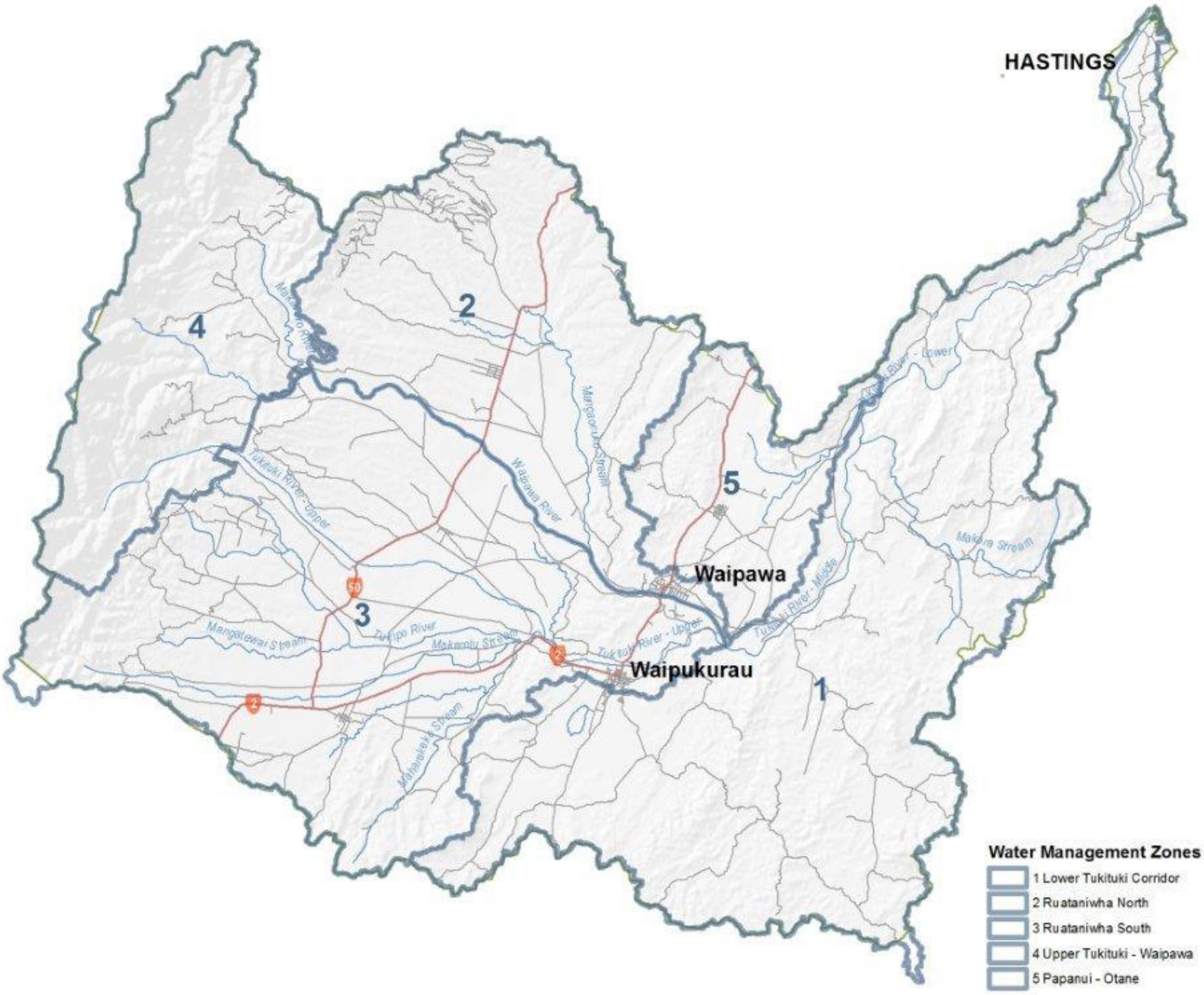

Figure B-1: Tukituki Water Management Zones. (A. Uytendaal, Hawke's Bay Regional Council, pers. com.).

Appendix C Hawke's Bay water hardness summary

Table C-1: Summary of water hardness (mg $CaCO_3$/L) of monitoring sites across the catchment. Monthly data collected 2004 to 2011. (A. Uytendaal, Hawke's Bay Regional Council, pers. com.).

		Winter				Summer				All Data			
Zone	Site Name	Mean	Median	25th	75th	Mean	Median	25th	75th	Mean	Median	25th	75th
1	Tukituki River at Black Bridge	78	79	72	85	75	70	66	79	76	75	67	83
1	Tukituki River at Red Bridge	79	80	72	85	72	70	65	81	75	75	67	84
1	Tukituki River at Shag Rock	55	55	51	59	56	57	54	62	56	56	52	61
1	Mangatarata Stream	117	112	90	130	130	128	119	133	122	122	106	132
2	Waipawa River at SH2	48	45	42	54	60	61	58	65	55	56	46	62
2	Mangaonuku Stream	60	61	50	67	74	75	71	77	67	71	61	75
3	Tukituki River at SH2	50	50	43	55	57	57	50	62	54	54	46	60
3	Porangahau Stream	113	99	87	130	151	150	130	169	133	130	99	159
3	Makaretu Stream at SH50	29	28	26	31	33	34	31	35	31	31	27	34
3	Tukipo River at SH50	42	42	37	47	56	54	49	60	50	48	40	56
4	Tukituki River at SH50	30	30	28	33	35	35	33	37	33	33	29	35
4	Waipawa River at SH50	36	36	34	38	39	40	37	41	38	38	35	40

Appendix D Protection levels

This section provides a background to the site-specific nitrate-N guideline values developed for the range of management classes.

The ANZECC [1] numeric guideline protection levels are inherently precautionary and use no observed effect concentration (NOEC) data for sub-lethal chronic (long-term) effects measures (e.g., growth reproduction) for the derivation procedures, which in many cases are likely to be result in more conservative guideline values compared with the sensitivity of field monitoring approaches (e.g., reduced species diversity).

The ANZECC (2000) guidelines use a statistical approach and a risk-based methodology to determine numeric protection guidelines which are applicable to the narrative guidelines in the New Zealand Resource Management Act [13]. The use of the 99% protection guideline values was recommended for waters to be protected from 'adverse effects' [14]. This would correspond to pristine environmental with high conservation values and an 'Excellent' management classification.

For receiving waters requiring protection from 'significant adverse effects', the statistical approach can be used to vary the level of protection according to the values to be protected. The ANZECC (2000) descriptor: 'slightly disturbed systems' would correspond to this class and would be compared with a 95% protection guideline value. This equates to environments which are subject to a range of disturbances from human activities, but with minor human effects. This would correspond to a 'Very good' management classification.

A management classification of 'Good' would equate to environments which have naturally seasonally elevated concentrations of nitrate for significant periods of the year. The ANZECC (2000) descriptor: 'moderately disturbed systems' would correspond to this class and monitoring data would be compared with a 90% protection value.

A management classification of 'Fair' would equate to environments which are measurably degraded and which have seasonally elevated nitrate concentrations for significant periods of the year. The ANZECC (2000) descriptor: 'highly disturbed systems' would correspond to this class and monitoring data would be compared with an 80% protection value.

The site-specific nitrate guidelines based on NOECs would be compared with annual median nitrate concentrations measured in the receiving environments. The NOEC-based guideline values are termed 'Grading values' in Table 3-1.

Seasonal variation in nitrate concentration in streams is often significant, with elevated concentrations occurring for 1 to 3 month periods, requiring some additional consideration of protective guidelines for species protection during these exposure periods. The statistical approach may also be used to derive guideline values based on the threshold effect concentration (TEC) values for each species to provide a protective threshold for elevated concentrations. Environment Canada uses the TEC values to derive their water quality guidelines and have recently published guidelines for nitrate in marine and freshwaters [4]. The TEC value is calculated as the geometric mean of the NOEC and the lowest observed effect concentration (LOEC) value for all species. As such, the TEC value is a concentration lower than the lowest statistically significant effect concentration.

The site-specific guidelines based on TEC values would be compared with the annual 95th percentile nitrate concentrations measured in the receiving environments. The TEC-based guideline values are termed 'Surveillance values' in Table 3-1.