Freshwater Science and Technical Advisory Group:

Paper compilation for 24 January

Paper Author	Various	Classification	**Confidential**

Meeting date	24 January 2019	Agenda item (number)	1, 2, 3, 4, 6, 7

Contents:

Background reading not in compilation - please see portal:

Agenda Item	Title
5	National Objectives Framework – Temperature, Dissolved Oxygen & pH, proposed thresholds for discussion
5	Dissolved Oxygen data collation and preliminary analysis.
7	Sediment – technical appendix on classification systems

Science and Technical Advisory Group Meeting

Agenda

Dates and Location: Thursday 24 January 2019 9.30am-4.00pm, Room 1C (Ahumairangi), Ministry for the Environment, 23 Kate Sheppard Place, Thorndon.

STAG Members present: Adam Canning, Bryce Cooper, Chris Daughney, Clive Howard-Williams, Bev Clarkson, Graham Sevicke-Jones, Jon Roygard, Ken Taylor, Mike Joy, Russell Death, Joanne Clapcott, Ra Smith, Tanira Kingi, Mahina-a-rangi Baker

Apologies: Marc Schallenberg, Jenny Webster-Brown, Ian Hawes, Dan Hikuroa

Items:

	9.00 am	*Coffee and tea*	(30 mins)
1.	9.30 am	Previous meeting minutes and actions arising, apologies, conflict of interest (Ken Taylor) Work programme update, Maintain and Improve subgroup (Lucy Bolton, Jo Burton)	(45 mins)
2.	10.15am	Confirmation of plan for February discussion on nutrients (Ken Taylor)	(15 mins)
3.	10.30 am	Ecological flows and levels (Kirsten Forsyth)	(30 mins)
4.	11 am	Threatened Species value (Kirsten Forsyth)	(30 mins)
5.	11.30 am	Dissolved oxygen (Jen Price)	(30 mins)
	12 pm	*Lunch*	(30 mins)
6.	12.30 pm	At-Risk Catchments update (Oscar Montes de Oca Munguia)	(30 mins)
7.	1 pm	Sediment (Stephen Fragaszy)	(30 mins)
8.	1.30 pm	Ecosystem Health: definition, prioritising metrics (Carl Howarth)	(1.5 hours)
	3 pm	*Afternoon tea*	(10 mins)
	3.10 pm	Item 8 continued	(50 mins)
	4.00 pm	*Meeting close*	

Papers distributed:

Agenda item (number)	Paper title	Classification - confidential yes/no?
1	Science and Technical Advisory Group Meeting Minutes – 29 November 2018	Yes
2	No paper	-
3	Ecological Flow and Levels	Yes
4	Threatened Species Value	Yes
5	Dissolved oxygen	Yes
6	No paper	-
	Sediment – discussion paper on classification systems	Yes
7	Sediment – technical appendix on classification systems (see portal)	Yes
8	Ecosystem Health definition	Yes
8	Ecosystem Health: prioritisation of metrics	Yes

Science and Technical Advisory Group Meeting

Minutes

Dates and Location: Thursday 29 November 10am-4.30pm, Room 1A (Matairangi), Ministry for the Environment, 23 Kate Sheppard Place, Thorndon.

STAG Members present: Bryce Cooper, Chris Daughney, Clive Howard-Williams, Bev Clarkson, Graham Sevicke-Jones, Ian Hawes, Jon Roygard, Ken Taylor, Marc Schallenberg, Mike Joy, Russell Death, Joanne Clapcott, Ra Smith, Tanira Kingi, Mahina-a-rangi Baker, Jenny Webster-Brown (in the afternoon, by phone), Adam Canning (by Skype). **MfE staff:** Jen Price, Oscar Montes de Oca Munguia, Isaac Bain, Vicki Addison, Dan Elder, Helli Ward, Nik Andic, Jo Burton, Lucy Bolton, Carl Howarth.

Apologies: Dan Hikuroa, Jamie Ataria

Additional papers tabled at meeting:

1. Adam Canning – comments on periphyton note
2. Lucy Bolton – timetable of advisory group agendas and topics
3. Kirsten Forsyth – flow statistics

Items:

9. Previous meeting minutes and actions arising, Terms of Reference, apologies, conflict of interest (Ken Taylor)

Ken outlined the agenda and mentioned time constraints; this means that some topics will be discussed only briefly at this session with a more detailed discussion to come. For example, today will include a brief discussion on nitrate to scope future discussions.

Marc gave the Group a briefing on the Freshwater Leaders Group meeting. Issues discussed:

- 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.
- At Risk catchments: the best approach was discussed – working in key catchments or nationally.
- Presentations about wetlands, high risk activities, good management practice
- Minutes will be shared on the web portal; all documents can be viewed by all three groups.

Mahina-a-rangi and Tanira gave an outline of the proceedings of the Kahui Wai Māori meeting. Topics discussed included work being undertaken in respect of the National Policy Statement for Freshwater Management (NPS-FM) and the proposed National Environment Standard (NES) as part of the Essential Freshwater work programme. Also discussed were At-Risk Catchments, the Three Waters review, and land use regulation and good farming practice.
There was discussion on the importance of considering social and economic contexts. The position of Māori is that biophysical and social aspects should be considered together and all factors taken into account.

Ken indicated that the level of detail in the minutes is appropriate and helpful. The Group gave feedback and comments on the draft minutes from 18 and 19 October, and these were incorporated.

In the minutes of the discussion of the Ecosystem Health Framework on 19 October, an additional caveat was added to group's statement, that the methods of defining reference conditions still need to be resolved. Russell Death requested that a related report be circulated among the group.

Actions:	**To be completed by:**
Circulate a copy of: Boothroyd I.K.G., Harding J.S. & Death R.G. (2002) Guide to the Selection of Reference Sites for Environmental Monitoring of New Zealand Rivers and Streams. (Ed M.F.T. Environment), p. 32. Ministry for the Environment, Wellington.	Completed – on portal

1. A) Indicative work programme, milestones, timing of meetings, topics for discussion (Lucy Bolton)

Lucy presented the indicative timetable for the advisory group network with timing of decisions by ministers, and outlined the plan for the joint Advisory Group meeting on 7 December.

It was noted that the Group needs to have enough time to consider proposals and provide feedback.

Discussion points included:

- Why isn't phosphorus also being discussed along with nitrate? The group discussed this and agreed this should be a discussion about nutrients.
- How will the discussion at the workshop on the 7th December proceed around allocation, in relation to Maori rights and interests? It was mentioned that there is work being done on this topic at the moment. It is important to consider and acknowledge the genealogical relationship between tangata whenua and the land. Ken reminded the group of their responsibility to keep Māori rights and interests in their minds – this will be an important discussion on 7 December.

10.50am *Adam Canning joined the meeting by Skype.*

10. State and trends (Ton Snelder)

Ton gave a presentation on state and trends in NZ freshwaters, based on Land Air Water Aotearoa (LAWA) data. Topics included:

- A description of the river monitoring site network
- An analysis of the state of river water quality across New Zealand
- Trends (including some new statistical approaches to trend analyses)
- Cautions about the way trend results are interpreted

Discussion points:

- In relation to the declining trends in Macroinvertebrate Community Index (MCI) in natural catchments, the trend analysis uses "dominant" land cover – could this potentially mask patterns if for example, there was a small amount of intensive land use in an otherwise natural catchment? Ton replied that he has checked for the existence of such confounding patterns, but as yet hasn't been able to draw any inferences in this regard..
- The rates of change in natural systems are important, and need to be understood when comparing results to reference state.

- Periphyton can take up nitrogen from the water column and can therefore influence water quality results, which can affect the conclusions drawn when variables are examined in isolation.
- The time period over which a trend is calculated can influence its direction due to underlying climatic influences.
- Communities might place more value on exceedances and the frequency of high magnitude events rather than median conditions, e.g. how many times can I not swim in my river?
- Trends can signal requirements for further intervention.

11.30am *MfE staff Oscar and Dan left.*

11. Maintaining/improving water quality (Carl Howarth)

Carl presented a paper on how the issue of maintaining and improving water quality is dealt with in the National Policy Statement for Freshwater Management (NPS-FM), and outlined options to better manage the "bands test" for Appendix 2 attributes.

Discussion points:

- The lake attributes allow for a large shift in state within bands. For example, the phytoplankton "A" band encompasses oligotrophic to mesotrophic conditions.
- The group agreed with Carl's statement that a decline within a band "might constitute a material (i.e. more than minor or significant) decline in ecosystem health, for at least some existing attributes".
- The NPS-FM states that "this national policy statement allows some variability in terms of freshwater quality, as long as the overall freshwater quality is maintained within a freshwater management unit". This definition was decided on by Cabinet.
- The group was asked to identify the most problematic bands. Responses included:
    - All of them
    - The "A" band for lakes is a very wide band that would permit deterioration in some of our most pristine lakes
    - Nitrate toxicity; bands go from affecting 5% to 20% of species
    - *E. coli*
- If a single site was used as the unit of measurement, comparison against a band would be more straightforward.
- Rates of change at sites of interest could be compared to natural rates of change at reference sites if this information was available.
- It would be appropriate to use measures that are not as variable over time and are more accurate.
- "Maintain or improve" is most useful for defining future-focussed planning objectives.

The group considered Options A and B presented by Carl: Option A: Maintain precise attribute state, remove the bands test, or Option B: Reassess the problematic bands and adjust them accordingly. Discussion included:

- Introducing more bands would cause more issues. A paper recently written by Graham McBride of NIWA provides a statistical approach for defining maintenance of water quality (it is currently under review and will be published soon).
- Ken summarised that the group did not appear to be advocating strongly for more bands.
- The use of bands is separate from the use of trends.
- Natural rates of change, variability and "noise" in the data need to be understood.
- Bands are a useful tool for setting community objectives and communicating to the public and councils; however they can cause some detail to be lost.

- For communities, "maintaining" water quality often means "not getting worse". It's difficult to talk about single variables with the community; a more holistic/ecosystem health based approach is needed, and the overall picture needs to be communicated.
- Ken summarised that the message from the group was that we need to integrate attributes to have more resonance with the community.
- Te Mana o te Wai is an important concept to consider here, as tangata whenua may hold a different view. For example, decline within a band is not acceptable to Ngāti Kahungunu ki Wairarapa.
- Ken commented that this view was consistent with that expressed by the group members. He summarised that the general message from the group was that the issue can't be addressed solely by disaggregating bands.
- Worked examples would be helpful in considering this issue.
- More bands could be useful in conjunction with a statistical measure to define "maintain".
- Could narratives be used to define bands more precisely? More detail could be provided within bands, e.g. A1, A2, A3, with accompanying explanations.
- An advantage of the current bands is that they are easy to understand, but they are only part of the bigger picture.
- The current approach is that attributes come into the conversation with communities after a discussion on the state of the waterbody. Then, the bands are used as a tool for defining state – they do not steer the conversation.
- Options discussed included to have an increased number of bands for some variables recognising that there could be a reduction, (say 3 bands) for others.
- Ken's summary of the discussion (provided afterwards): The main purpose of the option to include more bands would be facilitating communication, not defining state.

Actions:	**To be completed by:**
Provide a worked example of the situations outlined in the paper.	Carl

12.10pm *Ra Smith left.*

12. Sediment (Stephen Fragaszy)

Stephen presented a paper seeking advice on two themes:

1. Sediment attribute components – metrics and exceedance criteria for potential attributes
2. Policy principles to guide bottom-line attribute development

Proposed environmental classification systems for the attributes and the exceptions criteria will be discussed at a later meeting. Stephen mentioned that the proposed attribute tables for suspended and deposited sediment from the Stage 2 report will change due to current ongoing work.

The group considered the question: Does the evidence in the reports support the decision to base attributes on rolling medium-term (~2 years) measures of central tendency? Discussion points:

- A worked example would be useful to help the group consider whether to support the decision to base attributes on rolling medium-term (~2 years) measures of central tendency.
- Important considerations would be how to sample monthly when conditions are sometimes unsuitable, and how to use continuous monitoring results (if available), as the information gained from continuous monitoring (e.g. for suspended sediment via turbidity measurements) is far more detailed and comprehensive than a monthly grab sample.

- Can a macroinvertebrate measure such as %EPT (Ephemeroptera, Plecoptera, Trichoptera[1]) be used? Recently developed macroinvertebrate indicators can be used that are more specific to the effects of sediment than the existing metrics such as %EPT. These could be used to demonstrate an ecological response to increased sediment but will not be used to define new attributes. These can be calculated from standard MCI sampling results and do not require the collection of separate samples.
- Isn't the impact greatest when the sediment is first deposited? This question has been explored by looking into results from the Quorer method. Quorer results are correlated with measures of deposited sediment on the surface, which are much more widely used.
- It would be useful to check how continuous suspended sediment data compares to monthly sampling, across several rivers.
- Yearly sediment loads can be used to allocate limits on land use in a relatively straightforward way; this is more complicated for variables such as clarity. The previous sediment study built an analytical framework linking annual sediment load to environmental state variables in attribute tables. It would be helpful to see a worked example of the analytical framework.
- Narrative effects of suspended sediment are explained in the narrative sections of the attribute tables in terms of effects on fish and macroinvertebrates. These are based more on habitat, rather than toxicity effects. The thresholds for the proposed bands were formulated by gathering all sediment and ecological information, then using landscape gradients to examine responses to changes in sediment. The resulting gradients were used to define the A, B, C and D bands.
- Could deposited sediment be used on its own rather than having attributes for both? Attribute tables have been formulated for both suspended and deposited sediment. It was pointed out that models were more robust for suspended sediment, suspended sediment can be more widely measured, and turbidity also affects swimmability and therefore has additional value as an attribute.
- The attribute tables are based on 2-year rolling medians based on a rule of thumb and also on analysis of deposited sediment data. It was pointed out that a 2-year median may cause the median to jump around, and that a 2-year median may be problematic if there was an extreme event.
- Ken's summary was that there is more analysis and justification needed on the 2-year time period for the attribute tables.
- More work is needed on time series data of water clarity in lakes.

The group examined the question: Suspended sediment: What is your opinion on the attribute indicators chosen and the possibility of their interconversion? Discussion points:

- This is practical, there was agreement among the group on this.
- Other factors can affect clarity in addition to suspended sediment, the relationship is river specific. There are exceptions in the attribute tables, e.g. for glacial-fed rivers and tannin staining.

The group examined the question: Deposited sediment: What is your opinion on the attribute indicator and monitoring method? Discussion points:

- Measuring deposited sediment throughout the year will be difficult, which may lead to a data availability issue. It would be helpful to have guidance on how to deal with limited samples, e.g., if entering the water was not practical or unsafe it could be possible to use bankside measures of deposited sediment and correlate these with other measures.

[1] The percentage of the sensitive groups mayflies, stoneflies, and caddisflies in the sample.

Additional discussion:

- Bands will be determined by the deviation from the reference state. There is a linear relationship between pressures and state – it comes down to how much deviation is acceptable.
- What is the process for combining attributes? We need to have a discussion about this.
- The attributes measure certain effects of sediment, but what about the resulting changes in geomorphology? Geomorphology is addressed through the classification system which takes climate, topography and geography into account.

Actions:	**To be completed by:**
Provide a worked example to help the group consider whether to support the decision to base attributes on rolling medium-term (~2 years) measures of central tendency.	Stephen
Comparison of how continuous suspended sediment data compare to monthly sampling, across several rivers.	Stephen
Worked example of the analytical framework relating annual sediment load to environmental state variables in attribute tables	Stephen
Provide more information or analysis on the 2-year period for medians	Stephen

1.20pm *Jenny Webster-Brown joined the meeting by phone.*

The group considered "Policy principles for development of NPS-FM ecosystem health attribute bottom lines". Discussion points included:

- Principle 3 needs to be altered to account for cultural differences in the way ecological health is described. Te Mana o te Wai allows for the relationship between humans and water; people can be part of a healthy and functioning ecosystem. Managing in the complete absence of human intervention is not consistent with this concept. This could be captured by changing the wording, e.g. change "free from alterations resulting from human activity" to "free from adverse impacts".
- Te Mana o te Wai encompasses the relationship between people and water and includes the requirement to maintain and restore mauri. A commonly referenced value is mahinga kai, but the relationship between humans and water is not just about food gathering. Rather, food is a connector between people and the land.
- Scientific targets sometimes do not match community aspirations and ideas relating to water quality, and may not adequately define the mauri of the water. For example, Lake Rotorua has a Trophic Level Index target of 4, corresponding to the equivalent water quality measured in the 1960s. But communities that live near the lake have a different understanding of what water quality was in the 1960s, and therefore have a different understanding of lake health.
- Ken summarised that it is key to have provision for, and meaningful recognition of, Te Mana o te Wai in the Principles.
- Bottom lines need to be measurable and related to the purpose or outcomes being sought.
- Researchers need to make clear which option they have chosen under (4): "*Base bottom lines on the least acceptable state of ecosystem health and/or the state prior to irreversible degradation occurring (the former is a normative and subjective judgment, the latter, given adequate information, is not)*".
- The interventions we want to trigger need to inform where bottom lines are set. In terms of risk management, Māori may not be interested in the effects or threshold approach but an approach can be more informed by kaupapa, where you would need to intervene any time

the objectives are not being met. A less technocratic way of defining risk would help with community buy in.
- Stephen commented that both natural state and ecological effects can be taken into account when formulating bottom lines. The key purpose for bottom lines is a regulatory back stop, essentially informing communities "you can't aim for water quality to be worse than this"
- Communities also hold values that aren't communicated in attributes.

1.50pm *Stephen left.*

13. Wetlands (Helli Ward)

Helli's wetlands paper was discussed. It was pointed out that we are starting from the premise of halting wetland loss and decline of all wetlands, not just those that are regionally significant.

Noted that the Biodiversity Collaborative Group (BCG) has also provided wetland policies in the draft NPS Indigenous Biodiversity (NPS-IB) and officials are working closely to work out how and where policies fit and ensure there are no gaps.

Wetland Identification and Delineation

The wetland identification and delineation process provided by the BCG for the NPS- IB was discussed. Having a nationally consistent approach to delineating a wetland would remove an avenue for appeal.

- Bev talked about the process and where it came from based on a method developed by the United States Army Corps of Engineers.
- Talked about the tension between translating technical processes into a form suitable for policy and the iterative experience with the Periphyton note.
- STAG generally agreed with the concept but it was noted that some of the process was incorrectly written.

Action: Helli to supply Bev with word version of the process for comment, and continue to work together to refine it.

Water level changes

Discussed the Draft NES Ecological Flows 2008 provisions for wetland water level.

- It was confirmed that the indicative change in median levels were in relation to reference condition but unclear what time frame the median was in relation to.
- The table of methods signals to councils the amount of effort required to investigate water levels in wetlands depending on the degree of hydrological alteration and significance of the wetland and their management.

Setbacks

Setbacks for activities around wetlands were discussed.

- It was generally agreed that these were a good idea indicating a clear management zone. They signal social change of what is acceptable around these water bodies but needs to be backed up with education etc.
- It was agreed that a one size fits all wetlands approach for all wetlands was acceptable (i.e. certain setback for certain activity for all wetland types).

- There was a concern that setbacks could inhibit temporary activities that were intended for the good of the wetland and care would be needed to avoid restoration etc. in the wording of this.

Wetland size

Wetland size in regulation and national maps was discussed. Currently national maps identify wetlands to approximately >0.5 – 1 ha. Smaller wetlands collectively make up a significant amount and can fly under the planning radar.

- There was a general acceptance that a stipulation of size would be good to capture small wetlands but there was nervousness around a strict one size fits all to regulations.
- Could use a stipulated size and include provisions based on rarity or significance.
- It was noted that Sentinel 1 satellite has a resolution of 10x10m.

National Targets/ Wetland condition Index

National targets for increasing wetland aerial extent were discussed.

- It was noted that this recommendation was based on the idea behind national targets for swimming.
- There was an acceptance from the group that increasing wetlands was a good idea but we need to think through the best way to achieve this.
- In the first instance the priority is to protect the wetlands we have got and then improve area.
- Discussion on aspirational goals, which could include a central government-led programme with multiple outcomes (i.e. climate change, flood mitigation, sediment). The Billion Trees programme is an example of such a programme.

The wetland condition index (WCI) was briefly discussed.

- Several components have recently been updated and the WCI is also currently under review at council level to achieve better scoring consistency
- It was noted that wetland extent has a strong correlation with condition and the observed over expected attribute for wetland area based on historic extent could be a good proxy.
- A strength of the wetland condition index is that it indicates where management and restoration are needed.

Action: Helli to look into wetland extent attribute.

Actions:	**To be completed by:**
Helli to supply Bev with word version of the process for comment, and continue to work together to refine it.	Helli
Helli to look into wetland extent attribute.	Helli

14. Updates/shorter sessions: indicators of health from a Māori perspective, nitrate, copper and zinc, dissolved oxygen

Note: flows and dissolved oxygen were scheduled but not discussed due to time constraints

Indicators of health from a Māori perspective

Jo outlined that work is under way on this topic and MfE will report back to the group when the work is progressed further.

Mahina-a-rangi outlined the common measures of health from Māori perspective. Those that typically overlap with Western science include:

- measures of habitat and fish life
- measures relating to ecotoxicology
- other measures such as *E. coli*, algae, temperature and sediment, viewed in terms of their effect on mahinga kai.

Other types of measures include:

- economies of food sovereignty, and considerations of how communities rely on water for food
- catchment decision making and who influences this
- emotional and social wellbeing of communities and connectivity (there is a lot of information in Pakeha science relating to connectivity in the recreational fishing literature).

Tanira spoke about factors that should be considered in relation to data collection, such as who does the data collection, and how does it connect to policy making? Mātauranga Māori is a source of information that is often held closely to communities and is not standardised across the country.

Health in its widest sense includes an examination of how decisions are influenced. If this was considered, it would lead to a broader set of objectives including social matters.

Incorporation of cultural and historical information can lead to a better outcome; resources are required to achieve this. Consideration is needed of the mechanisms to support true engagement and involvement, rather than "consultation".

Discussion points:

- How does the Cultural Health Index fit in this discussion? This index can be adapted to different communities. Cultural health indices are currently used in an ad-hoc way, but need to be embedded in policy to function like state of the environment monitoring. The policy would need to allow for local differences in who does the monitoring, and what is monitored.
- Ken noted that it was not the role of the group to consider the details around indicators of health from a Māori perspective as this would be done by Māori. But it is useful for scientists to signal willingness to work in an integrated way and to provide for Te Ao Māori in their thinking..
- It is key to provide the right frameworks to integrate a wider perspective of health while maintaining the integrity of the different systems.

3.09pm *Tanira Kingi left.*

Nitrate

Addendum to nitrogen paper provided by MfE: the 2014 publication "*A guide to attributes in appendix 2 of the National Policy Statement for Freshwater Management 2014*" also contains detail on the periphyton attribute for rivers, including how the attribute is defined, using the attribute to set freshwater objectives, defining management actions to achieve freshwater objectives, and sampling and statistical considerations.

Clive Howard-Williams outlined the processes set out in the 2018 MfE report "*A draft technical guide to the Periphyton Attribute Note*". The approach takes into account that there are many influences on periphyton, not just dissolved inorganic nitrogen and dissolved reactive phosphorus. The current NPS-FM requires councils to take downstream receiving environments into account as well. The

draft technical guide also has a process for converting loads to amounts of algae in lakes and periphyton in estuaries. Phosphorus can also influence periphyton growth and there is a need to deal with both nitrogen and phosphorus in our discussions.

Discussion points:

- Some members of the group would like to see attribute tables in the National Objectives Framework for the trophic state effects of nitrogen and phosphorus in rivers. Such tables have been put forward by Fish & Game in their amended NPS-FM. The numbers in the tables relate back to Russell Death's work and Russell would be happy to present to the group on how these were derived.
- Adam has provided a commentary on "A draft technical guide to the Periphyton Attribute Note" for the members to consider for the next meeting.
- Nitrate can fluctuate diurnally, particularly where there is a lot of periphyton which presents a challenge for monitoring. Environment Southland is testing probes for measuring nitrate. Continuous data can be useful for determining how many spot measurements are needed.
- There is a need to give attention to nitrogen in groundwater as this influences concentration in groundwater-fed streams. Groundwater also requires ecosystem health attributes as there are none at the moment.
- There are two separate issues to discuss: 1) what is the relationship between nutrients and periphyton, and 2) how do we achieve nutrient objectives in catchments?
- The Attribute Tables in Appendix 2 of the NPS separate out those associated with Ecosystem health from Human Health. Then under Ecosystem Heath attributes are separated by trophic state and toxicity, e.g. if you look at the attribute tables for (say) lake phytoplankton or periphyton you will see the attribute name includes the words 'Trophic state' .
- Trophic state wasn't really an end point, it was recognition that this is one component of ecosystem health (as is the presence of toxic compounds). We now need to look more broadly than just trophic state and toxicity.

Actions:	**To be completed by:**
Circulate "A draft technical guide to the Periphyton Attribute Note" and Adam Canning's comments on it	Completed – on portal
Arrange half-day discussion on nutrients for next meeting	MfE

3.50pm *Russell Death left.*

Copper and zinc

Nik presented a paper with questions. Discussion points included:

- There are other contaminants of concern, e.g. aluminium, arsenic. We need to understand better the range of contaminants affecting urban and rural areas.
- Mahinga kai values may be affected by a range of contaminants.

4pm *End of meeting*

Papers distributed at 29 November meeting:

Agenda item (number)	Paper title	Classification - confidential yes/no?
1	STAG Meeting Minutes – 18 & 19 October	No
2	No paper	-
3	Setting planning objectives to 'maintain' water quality. What constitutes 'maintain' at a site?	Yes
4	Sediment discussion document	Yes
5	Wetlands	Yes
6	A summary of attributes relating to nitrogen	Yes
6	Update on package to address copper and zinc	Yes
6	A summary of attribute development to date: dissolved oxygen	Yes
1, 3, 4, 5, 6	Paper compilation	See above

Possible use of an attribute table to set objectives for flow regimes in rivers

Summary of the problems

Rivers: Setting appropriate flow regimes in rivers to safeguard ecosystem health is technically difficult and often controversial

The National Policy Statement for Freshwater Management has confusing direction for setting objectives and limits for water quantity

Context

The National Policy Statement for Freshwater Management directs councils to set freshwater objectives using the applicable attributes in Appendix 2.

Councils are setting freshwater objectives for water quality using those attributes (for example periphyton), and then setting limits on resource use (for example nitrogen and phosphorus) to achieve those objectives.

In terms of river flows, councils are setting limits on resource use by setting river flow restriction regimes and allocation limits. The combination of allocation limits and restriction regimes in rivers allow people to take water while preventing a rapid decline in flow up to and past the point at which the area of sufficient suitable habitat diminishes. The limits are generally designed to retain a proportion of the historic flows or flow variability, or retain habitat.

It is not clear whether councils are setting the limits to achieve a specific objective for habitat or flow variability. This means that the physical habitat and hydrological regime requirements of the aquatic ecosystem are not necessarily what is driving the flow restriction regimes and water allocation limits.

This could be resolved by adding an attribute table for physical habitat and hydrological regime requirements to the National Policy Statement for Freshwater Management.

The objectives set using this attribute table will direct choices councils make for the minimum flows and allocation limits set in the regional plan. The limits may include a set of cut off thresholds at various flows, with the restrictions stepping up as the flow decreases to the minimum flow.

Policy CB1 of the NPSFM requires councils to monitor progress towards the achievement of freshwater objectives. If objectives are set in accordance with an attribute table in the NPSFM, councils would be better placed to assess how their water quantity limits (the allocation limit, the minimum flow and the intermediate restriction thresholds) are achieving ecosystem health objectives.

VERY ROUGH FIRST CUT of possible attribute table for setting water quantity objectives in rivers

Value	Ecosystem health
Water body	Rivers
Attribute	Habitat as affected by [human induced] flow variations
A	There is an abundance and diversity of habitat types to support the species assemblage that would expected without the adverse impacts of water abstraction or diversion. There is a variety of flows needed to influence channel morphology and bed movement. The flow regime provides for all ecosystem processes.
B	There is some reduced habitat but of short duration. Effects of abstractions or diversions can be mitigated (for example by shading or flow augmentation). There is a variety of flows needed to influence substrate movement. The flow regime provides for all ecosystem processes.
C	There is some reduced habitat of long duration, but still sufficient habitat to support the species populations. Variety of habitat is reduced.
D	Available habitat is likely to decrease even without continued abstractions or diversions. The remaining habitat cannot sustain populations long-term. This is the threshold where abstractions and diversions must cease to allow for natural decline without loss of life-supporting capacity.
E	There is no connectivity with other water bodies. Indigenous species are stressed by high temperatures and low dissolved oxygen in the water. There is insufficient food and space for the species that have lived there.

The descriptions above follow a similar approach to the narrative attribute states in the final columns of the water quality attributes. The A state describes a largely unmodified river system (such as would be found on Stewart Island). The E state describes an unacceptable state. Hydrologically modified catchments, such as the Waikato, might be somewhere in the middle.

The use of an attribute table is being considered in terms of its recognition of Te Mana o te Wai

- In terms of the first principle of Te Mana o te Wai – the first share of the water goes to the river.
- Te Mana o te Wai recognises the values of Mana Atua: mauri, wairua, natural character, mana, life-supporting, ecology, biodiversity and native fish. These values are not subordinate to other values.
- Te Mana o te Wai recognises the values of Mana Tangata: ceremonial, drinking, transportation, economic, recreation and food gathering.

Questions for the Science and Technical Advisory Group

1. Do the draft narrative descriptions above make sense from a biophysical aquatic ecosystem perspective? How could they be improved?
2. Would it be useful and defensible to specify thresholds in the B and C state as departures from the A state (the C state still provides for ecological function)?
3. Could the various states be measured using stream habitat assessments and hydrology?

Adding a new value "Threatened Species"

Context

Three-quarters of New Zealand's native freshwater fish species are threatened or declining. The widespread migratory species, such as koaro and inanga, appear to be declining in both abundance and distribution. While some fish populations persist in poor habitat, many species require particular habitat conditions. Thus, managing a water management unit to particular attribute states to achieve ecosystem health will not necessarily provide for the needs of a fish population that may be threatened in that unit.

A value of "threatened species" would mean that the council must consider managing for that value where those species are present (or should be present). A possible description is:

Threatened species – specified areas in the freshwater management unit support a population of indigenous freshwater species that are threatened or in decline nationally. The aquatic habitat, water quality, and flows or water levels in the freshwater management unit provide the necessary requirements for the identified species.

Questions for the Science and Technical Advisory Group

1. What is the group's view of managing specific areas within a freshwater management unit for specific habitat needs?
2. Would the draft value description help councils set objectives?
3. What information, data and monitoring would be needed for councils to apply this value?

A summary of attribute development to date: dissolved oxygen

Dissolved oxygen in the National Policy Statement for Freshwater Management

Oxygen is essential for almost all forms of life for respiration. Reduced dissolved oxygen levels (hypoxia) can impair the growth and/or reproduction of aquatic organisms and very low or zero dissolved oxygen levels (anoxia) will kill organisms (Davies-Colley et al. 2013). Consequently, the dissolved oxygen concentration of water is critical to stream ecosystem health (Davies-Colley et al. 2013).

There are three key processes affecting dissolved oxygen concentrations: 1) oxygen production associated with photosynthesis of algae and other plants; 2) oxygen uptake associated with respiration of all river life including plants, algae, fish, invertebrates and microbes; and 3)oxygen diffusion through the water surface.

The measurement of dissolved oxygen is complicated by the fact that concentrations vary widely on a 24-hour cycle, often peaking in the late afternoon due to photosynthesis, and reaching a minimum in the early hours of the morning due to respiration. Dissolved oxygen is therefore best characterised by continuous measurements, using loggers that are deployed in the waterbody of interest for a period of several days or weeks. Loggers are expensive and require specialist training to deploy and maintain, generally limiting their use to sites of particular interest or need, for example, for assessing effects of water takes or discharges. State of the Environment monitoring more often uses spot measurements of dissolved oxygen. Because different sites are measured at different times of the day, it is not straightforward to use spot measurements to gain an overall picture, measure trends over time, or compare between sites (but see description of study by Depree et al. (2016) below, for potential methods to address this).

In early June 2013 during the development phase of the NOF, NIWA prepared a report (Davies-Colley et al. 2013) to inform the inclusion of attributes in the NOF (including dissolved oxygen). The report specifically presented discussion on:

a) The drivers of dissolved oxygen in water
b) Where low dissolved oxygen most commonly occurs
c) Dissolved oxygen tolerances by organisms
d) Approaches to defining dissolved oxygen thresholds and bottom lines
e) Dissolved oxygen criteria and NOF limits for temperature, including narrative band descriptions and tentative numeric band boundaries

The information presented in Davies-Colley et al. 2013 only provided sufficient information to justify inclusion of a dissolved oxygen attribute in the NOF below point source discharges (Table 1). The difficulties associated with defining an attribute for dissolved oxygen for diffuse sources were not satisfactorily resolved when the 2014 NPS-FM was released. It was envisaged that the remaining information gaps would be addressed at a later date (see details under “Details of the proposed research” below.

Table 1. Dissolved oxygen attribute for rivers below point sources.

Attribute State	Numeric Attribute State	
	7-day mean minimum (1 Nov-30 April)	**1-day minimum (1 Nov-30 April)**
A	≥8.0	≥7.5
B	≥7.0 and <8.0	≥5.0 and <7.5
C	≥5.0 and <7.0	≥4.0 and <5.0
National Bottom Line	5.0	4.0

The following statement from the NOF Reference Group minutes (19/3/2014) sums up the decision to include a dissolved oxygen attribute in the NOF below point source discharges:

> *"The group recognised that the inclusion of a point source dissolved oxygen attribute was more about making a start, and there was a desire to keep it.*
>
> *Guidance should recognise that the attribute is not quite there for all sources yet, and there was a desire to eventually include a diffuse source attribute.*
>
> *The group noted that in any case the inclusion of the point source attribute now, means councils will do something about continuous monitoring, and that this would inform management interventions."*

What is the current state of dissolved oxygen?

In mid-2015 the Ministry for the Environment commissioned NIWA to determine whether there was dissolved oxygen data of sufficient quality, quantity and representativeness to assess the current state of the attribute on a national scale (Depree et al. 2016). The report assessed continuous dissolved oxygen data recorded at 368 sites (Figure 1), and also compared spot dissolved oxygen data from 799 sites with the 7-day average minimum dissolved oxygen attribute bands proposed in Davies-Colley et al. (2013). The report indicates that potentially 15% of streams may be below the national bottom line.

Depree et al. (2016) concluded that:

- Spot data had good spatial and temporal coverage.
- Continuously logged data was collected for general monitoring purposes as well as for specific projects, which means that it may not be representative on a regional or national scale.
- a reasonable picture of current state at the national scale may be attained when using rule-of-thumb techniques to align continuous data with the more widespread spot data.
- The quality and quantity of dissolved oxygen data may therefore be sufficient to allow the current state to be assessed at the national scale (data were requested from regional councils and research institutions in 2015).

The continuous and spot measurements were compared to the NOF bands in different ways. Spot data were evaluated against the NOF 1-day and 7-day average minimum dissolved oxygen attributes. For spot measurements, the C and D bands were combined into one "at risk" classification due to the tendency of spot data to be above the daily minimum. The continuous data were evaluated against the NOF 1-day and 7-day bands.

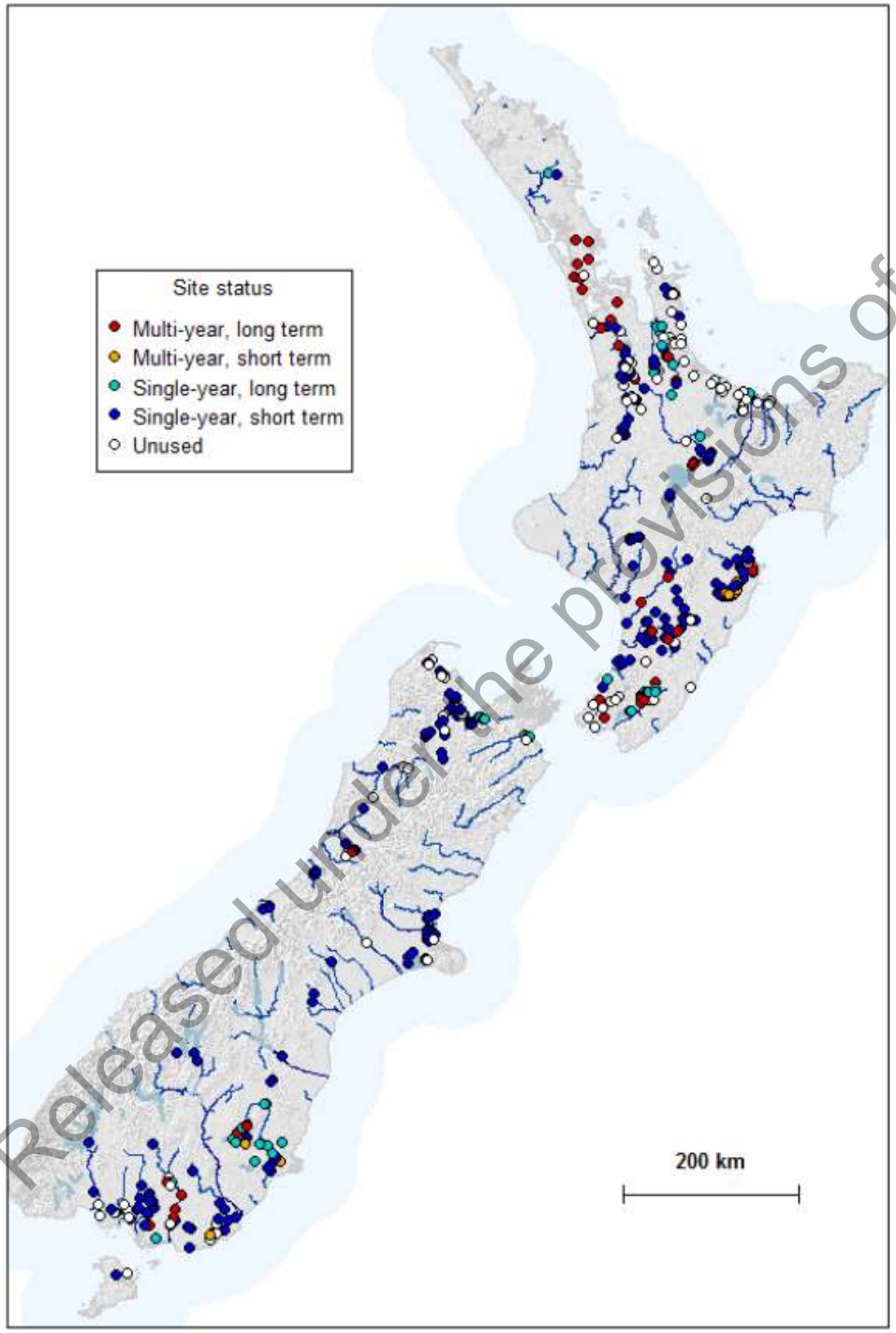

Figure 1. Geographical distribution of continuous dissolved oxygen monitoring data sets (sites) collated in the dissolved oxygen database. (Depree et al. 2016)

Based on the analysis of Depree et al. (2016), approximately 15% of streams may be below the NOF 1-day minimum bottom line that currently applies below point source discharges. Dissolved oxygen showed a similar pattern to other water quality indicators; spot and continuous measurements of dissolved oxygen were highest in streams and rivers with natural land cover, followed by exotic forest, pasture, and urban, in order of declining water quality. Temporal trends were not assessed.

The report recommended that "guidance be provided for characterising the dissolved oxygen state of streams for a given season, and also longer-term for multi-year/seasonal dissolved oxygen records. In addition, some consideration may need to be given for having different dissolved oxygen criteria for different stream types."

Following the study of Depree et al. (2016), a request for proposal was put out for further data collation and analysis to inform the inclusion of an instream temperature attribute in the NOF.

Details of the proposed research

The objectives of this proposed project were to develop a dissolved oxygen attribute as detailed in stages 1 and 2 below. The work was planned to collate sufficient technical detail to support inclusion of a dissolved oxygen attribute for diffuse and point sources in a future iteration of the NOF.

Stage 1 - Quantify the influence of critical drivers

The objective of Stage 1 was to assess the relative importance of the critical drivers influencing the dissolved oxygen regime. Whilst there are numerous drivers, emphasis should be placed on those that are deemed critical.

Information on the critical drivers of depleted dissolved oxygen should be collated and a conceptual model of the relationship between drivers presented. The relative importance of these critical drivers should then be examined and presented. This could be in the form of a Bayesian network type approach or similar.

Stage 2 – Identify potential management actions available to meet dissolved oxygen objectives

The objective of Stage 2 was to identify management actions which could be implemented to meet dissolved oxygen objectives. It was planned that information on management actions should be collated and a conceptual model of the relationship between management actions and critical drivers should be presented.

The ability of management actions to meet dissolved oxygen objectives should be explored in some detail. Exploration should include analysis of how management actions could be implemented to enhance waterways from degraded to less degraded dissolved oxygen attribute band states, with consideration given to different settings across New Zealand.

What other monitoring data are available?

In addition to the regional council monitoring data collated by Depree et al. (2016), several studies have been carried out monitoring the effects of mechanical desilting, aquatic vegetation removal on dissolved oxygen, using continuous monitoring.

Summary

The attribute for dissolved oxygen currently only applies below point sources. The attribute was not applied to all waterbodies due to information gaps in 1) the national state of dissolved oxygen, 2)

the relative importance of the critical drivers influencing the dissolved oxygen regime, and 3) management actions which could be implemented to meet dissolved oxygen objectives. The gap in knowledge in point 1) above has been addressed, but the second two points have not.

Questions:

1. Do we have enough dissolved oxygen data for the dissolved oxygen attribute to be applied more widely, e.g. by removing "below point sources"?
    a. If there is insufficient data, what additional data would be needed?
    b. If not as an attribute, can dissolved oxygen be incorporated in the NPS-FM in another way? Could dissolved oxygen be included as a monitoring requirement, for example?

2. Do you see this as a priority for continued work?

References

Davies-Colley, R., Franklin, P., Wilcock, R., Clearwater, S., Hickey, C. (2013) National Objectives Framework – Temperature, Dissolved Oxygen & pH, proposed thresholds for discussion. *NIWA Client Report HAM2013-056.* https://www.mfe.govt.nz/sites/default/files/national-objective-framework-temperature-dissolved-oxygen-ph.pdf

Depree, C., Unwin, M., Young, R. (2016) Dissolved Oxygen data collation and preliminary analysis. *NIWA Client Report HAM2016-008.* https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/dissolved-oxygen-data-collation.pdf

Revised sediment attribute classification systems

Context

Revision of the environmental classification systems for both suspended and deposited sediment attributes is a major component of the ongoing attribute development work. This paper summarises the new approach and findings and discusses briefly how the proposed system would incorporate ecological response information to structure the final proposed bottom lines (and potentially bands). We seek your feedback on the approach taken and findings to support the proposed classification systems as well as their practicality for implementation in NPS planning and limit-setting processes.

We emphasise that this is a working document that is part of an ongoing research project. It is not to be circulated beyond the STAG, it has not been reviewed internally by NIWA, and it does not yet present the visual clarity reference estimates.

Environmental classification systems approach

The analysis had two primary objectives:

1. Develop "sediment state classification" (SSC) systems for New Zealand rivers
2. Determine reference states for deposited fine and suspended sediment environmental state variables (ESVs; proportion of streambed coverage with sediment <2mm; clarity, turbidy) across segments

The researchers used the following principles to guide the approach with the intention of developing frameworks that are meaningful and achievable for NOF attributes in that they reflect real differences in reference in-stream sediment characteristics and the ecological response to them:

- Balance between generality (simplicity) and sensitivity to changes in sediment status.
- Build on existing river classification systems
- Based on drivers of sediment supply and retention and also observed sediment indicators
- Use a spatial scale reflecting changes in geomorphology and climatology

The analysis produced two sets of SSCs (for deposited and suspended sediment) that group streams by their REC climate, topography, and geology (CTG) variables, which are the primary controls on sediment supply and retention. The researchers did this through the following steps:

Step 1 – class definition: Characterise each CTG class as a vector defining the frequency distribution of indicator values within that CTG class; if there are insufficient data in initial CTG classes, aggregate in a logical fashion until the frequency distribution of the ESV can be defined in each CTG class;

Step 2 – hierarchical clustering: Based on the frequency distribution of ESV values within each CTG class, use multivariate analysis to determine the dissimilarity of ESV frequency distributions among classes, such that we may aggregate CTG classes into sediment classes based on the similarity of their ESV distributions.

Step 3 – estimate reference state and conduct cluster analyses: Within each sediment class, estimate the ESV reference states, determine which level of aggregation provides the most parsimonious description of reference states for each ESV, and map the spatial distribution of sediment classes, hence reference states, to all river reaches of the New Zealand river network.

Environmental classification systems results

Step 1: This step included two sub-steps and had the following results

Step	Process	Resultant classes/clusters
Pre-aggregation of potential CTG classes **(See Table AX.1)**	Combine CTG variables according to sediment supply and retention characteristics	210 potential classes reduced to 64, of which 54 actually exist in the river network. For example, there may not be cold-dry (C), lowland (T) volcanic (G) classes in the network).
Test resultant CTG classes **(See Figures AX.2, AX.3, and Table AX.2)**	Test classes – must have n>20 samples in that class. A sample for deposited sediment is a NZ Freshwater Fish Database reach and for turbidity is a State of the Environment monitoring site.	Sufficient data to include 34 CTG classes for deposited sediment and 18 CTG classes for turbidity

Step 2: The researchers produced hierarchical clusters for suspended and deposited sediment classes at the level of 50%, 30%, 20%, and 15% dissimilarity. This resulted in 4 SSCs for deposited sediment (one at each level of dissimilarity) and 4 SSCs for suspended sediment. For both deposited and suspended sediment this resulted in SSCs that consist of 2, 4, 8, and 12 "clusters" of CTG classes. **(See Figures AX. 4 and 5 for the levels of CTG aggregation and AX.6 and 7 for the ESV frequency distributions for each cluster; See Tables AX.3 for class membership)**

Step 3: To produce and test sediment reference states for each of the clusters, the researchers undertook the following process:

1. Test the parsimoniousness of four models that describe ESV reference states as a function of land cover/uses that represent human disturbances.
2. Compare and contrast the above model estimates of ESV reference states with observed ESV data to produce several key statistics related to reference, minimally disturbed, and all sites.
3. Generate plots showing the "bias" in reference state when moving between aggregation clusters

Outputs for deposited sediment

The most complex model – that incorporating factors for pasture, urbanisation and forestry – proved the most parsimoniousness in all cases for deposited sediment. Reference states for in-stream deposited sediment cover within the clusters ranges from 0.01% fine cover to 0.79% fine cover. An individual cluster, depending on the level of aggregation and class composition, can represent between 92.9% of the REC network to 0.03%. Less than 2% of the river network was unclassified. At all levels of aggregation there was generally good agreement between model-based reference estimates and observed reference and minimally disturbed site data.

(See Table AX. 4 for produced cluster reference states and % coverage; see Figure AX.11 for their mapped areas. See Figure AX.8 for the reference state model fit, Figure AX.9 for data checks, and Figure AX.10 for reference state bias when moving amongst cluster aggregation levels)

Outputs for suspended sediment

At the lowest level of aggregation (2 clusters), the most complex model was most parsimonious, and for the higher levels of dissimilarity, the simplest model, which only reflected pasture cover, was the most parsimonious. Median reference state estimates for turbidity from the various clusters determined by the most parsimonious model ranged between less than 1 NTU and approximately 5 NTU. An individual cluster, depending on the level of aggregation and class composition, can represent between 56.8% of the REC network to 1.4%. At lesser levels of aggregation, several clusters did not have reference sites, though most had a good range of heavy pasture values for regression purposes. With the cluster definitions applied, approximately 13% of the river network was unclassified.

(See Table AX.6 for produced cluster reference states and % coverage; See Figure AX.14 for their mapped areas. See Figure AX.12 for the reference state model fit, Figure AX.13 for data checks, and Figure AX.14 for reference state bias when moving amongst cluster aggregation levels)

Next steps for the research effort:

The following constitute some of the analytical next steps to complete the attribute development work:

1. Complete all ecological response analyses to populate the weight of evidence framework.
2. Incorporate ecological response information into the classification systems at the various aggregation levels (2/4/8/12 clusters).
3. Examine where overlaps in ecological response/protection levels exist across hierarchical groupings.
4. Examine the "bias" in ecological response/protection levels that exists when using various hierarchical groupings and/or aggregating classes.
5. Information from points 1-4 will support the choice of which hierarchical groupings to propose.

Ecological response information consists of multiple lines of evidence and incorporates the findings used in the Draft Stage 2 Attribute report available on the portal and new analyses that are still underway. In brief, the lines of evidence describe, for both fish and macroinvertebrates, a range of ecological indicators in relation to sediment ESVs. The indicators include absolute abundance, general community composition, stressor-specific community composition, presence/absence and other indicators such as impact initiation/cessation thresholds from literature. Methods used include quantile regression, global linear models, global linear mixed models, random forest models, boosted regression tree models as well as information from literature that encompasses other methods. Results are either global or spatially differentiated depending on the specific method.

Questions

- Do you think the method for developing the SSC clusters is appropriate given the attribute development objectives and the available evidence to inform the approach?
- Do you think the findings provide a defensible platform for classifying attribute bottom lines and potentially bands?
- From a practical perspective as a scientist/researcher, would FMU-level planning and limit-setting processes differ significantly if there are up to 12 attributes each for deposited and suspended sediment compared to, say, 2 or 4 each?

Minor amendments to the value description of Ecosystem Health in Appendix 1

STAG Jan 2019

Context

Ecosystem health is one value in the NPS-FM.

The two Compulsory Values in the NPS-FM, applying in all freshwaters everywhere

Councils must set objectives and limits for the value of Ecosystem Health in each freshwater management unit in their region.

Appendix 1 describes the value. The role of this description is to guide councils in choosing what attributes to manage (Policy CA2).

We are investigating minor changes to the description of ecosystem health in the NPS-FM, in order to clarify how resilience contributes to a healthy ecosystem, and see if further changes are required to clarify what needs to be managed.

The current description is:

> *Ecosystem health – The freshwater management unit supports a healthy ecosystem appropriate to that freshwater body type (river, lake, wetland, or aquifer).*
>
> *In a healthy freshwater ecosystem ecological processes are maintained, there is a range and diversity of indigenous flora and fauna, and there is resilience to change.*
>
> *Matters to take into account for a healthy freshwater ecosystem include the management of adverse effects on flora and fauna of contaminants, changes in freshwater chemistry, excessive nutrients, algal blooms, high sediment levels, high temperatures, low oxygen, invasive species, and changes in flow regime. Other matters to take into account include the essential habitat needs of flora and fauna and the connections between water bodies.*

Resilient to change?

Being resilient to change can be interpreted as applying to a degraded ecosystem that is resilient to being improved.

Questions:

What advice does the STAG have to improve this wording? One suggestion is replacing ‘change’ with ‘stress’ or ‘anthropogenic stress’.

Is the rest of the description clear?

Is it clear what biophysical matters need to be managed?

Can we improve the definition by aligning it more clearly with the components of the Ecosystem Health Framework?

Prioritising ecosystem health metrics

STAG 24 January 2019

Background

In its first meeting, the STAG supported the Assessment Framework for Freshwater Ecosystem Health and its five components (below). Underpinning the framework is that there is no redundancy among components, and the components apply to all types of freshwater (river, lake, wetland, groundwater, estuaries).

1. **Aquatic life** – the indigenous biodiversity of freshwaters including invertebrates, aquatic plants, microbes, fish and water birds.
2. **Water quality** – this includes the physical and chemical measures of the water (e.g. temperature, dissolved oxygen, pH) and the level of specific pollutants (e.g. nutrients, heavy metals).
3. **Water quantity** – the quantity, timing and variability in water flows and levels.
4. **Habitat** – this includes the form and extent of habitat, connectivity (how well species can move from one habitat patch to another), the substrate and riparian vegetative cover.
5. **Ecological processes** – the extent to which ecosystems retain their natural function, resilience and capacity to deliver a range of benefits, biogeochemical processes and the interactions between organisms.

The five components can be represented by metrics for each freshwater type.

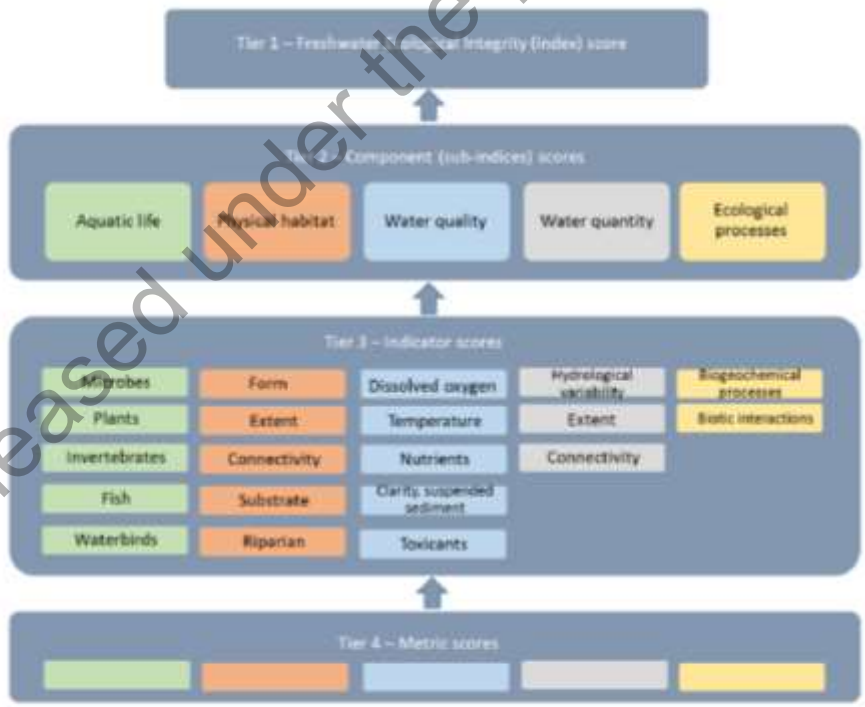

Figure 7. A tiered framework to assess freshwater ecological integrity (biophysical ecosystem health).

Problems

The NPS-FM focusses effort on the management of water quality and quantity, and less on the other three components of ecosystem health (aquatic life, habitat and ecological processes). The range of the current compulsory ecosystem health Appendix 2 attributes is narrow, related to nutrient enrichment.

Questions

Of all the possible indicators that could be used to provide national direction to Councils for managing ecosystem health, which are highest priority to be developed first?

To help consider this question, a list of indicators is provided in **Appendix A**. There's space to add any indicators that are missing.

We're asking the STAG to give advice on prioritising these indicators (or others) for future work, and to provide an explanation why the indicators are a priority.

To assist there are some criteria you could consider:

> **Urgency (magnitude of associated problem)** – Consider in the context of the biophysical ecosystem health issue being addressed. Consider if the issue being addressed by the metric is:
>
> • Irreversible
>
> • Cumulative
>
> • Large in scale or pervasive [e.g. nationally, or affects a number of regions]
>
> • Increasing in scale and/or distribution, especially if it is accelerating
>
> • Able to tip a system over a threshold into another (worse) state
>
> The more questions answered with a 'yes', the more reason to consider whether the issue associated with the metric is currently being managed adequately. Collectively the criteria indicate 'urgency' when considered in terms of magnitude and timeframe. This criteria also relates to using a precautionary approach in cases of uncertainty (e.g. certainty of relationship to stressors). To date, the Parliamentary Commissioner for the Environment has used these criteria to identify nutrients, sedimentation and longfin eel communities as important freshwater ecological issues.
>
> **Representativeness** – are the five ecosystem health components represented by metrics? Doing so will also ensure we have a range of stressors and responses.

Appendix B illustrates how metrics fit within indicator groups. Also included is an assessment of suitability. Suitability includes sensitivity and science sufficiency – how suitable is the metric for managing human pressure? This is based on being sensitive to stressors and certainty of the relationship; as well as ease of measurement, based on current knowledge and technology. Less suitable metrics will need more validation and method development.

Appendix A: Ecosystem Health indicators

	Ecosystem Health				
	Aquatic life	**Physical habitat**	**Water quality**	**Water quantity**	**Ecological processes**
Rivers	Microbes Plants (e.g. periphyton, macrophytes, phytoplankton) Invertebrates Fish Waterbirds	Form Extent Connectivity (e.g. floodplain, fish passage) Substrate Riparian	Dissolved oxygen Temperature Nutrients Clarity, suspended sediment Toxicants (e.g. ammonia, nitrate, metals)	Hydrological variability Extent Connectivity (e.g. floodplain, groundwater)	Biogeochemical processes Biotic interactions
Lakes	Microbes Plants (e.g. periphyton, macrophytes, phytoplankton) Invertebrates Fish Waterbirds	Form Extent Connectivity Substrate Riparian	Dissolved oxygen Temperature Nutrients Clarity, suspended sediment Toxicants (e.g. ammonia, nitrate, metals)	Hydrological variability Extent Connectivity (e.g. floodplain, groundwater)	Biogeochemical processes Biotic interactions
Wetlands	Microbes Plants Invertebrates Fish Waterbirds	Form Extent Connectivity Substrate Riparian	Dissolved oxygen Temperature Nutrients Clarity, suspended sediment Toxicants (e.g. ammonia, nitrate, metals)	Hydrological variability Extent Connectivity (e.g. floodplain, groundwater)	Biogeochemical processes Biotic interactions
Groundwater	Microbes Invertebrates	Form Extent Connectivity Substrate / Geology	Dissolved oxygen Temperature Nutrients Clarity, suspended sediment Toxicants (e.g. ammonia, nitrate, metals)	Hydrological variability Extent Connectivity	Biogeochemical processes Biotic interactions

Appendix B: Component metrics, methods, and example prioritisation in terms of *suitability*

(adapted from Clapcott et al. 2018[2]. Criteria adapted from Schallenberg et al. 2011)

Metrics for the five ecosystem health components were graded from Poor (1) to Good (3) for a number of criteria, based on expert opinion. The higher the rating, the more suitable the indicator is as an assessment tool, based on current knowledge and technology. Conversely, the lower the score, the greater the need for more validation and method development. The criteria used were:

Sensitivity to human impact	1 = None, 3 = Yes, strong evidence for direct relationship
Standard methods available:	1 = no, 2 = in part, 3 = yes
Current use	1 = rare, 3 = common
Ease of sampling and analysis	1 = difficult, 3 = easy
Reference calibrated	1= unknown, 3 = well known
Spatial and temporal scale of measure	1= site/spot, 2 = reach/seasonal, 3 = (sub) catchment/continuous
Spatial/Temporal scale of impact:	1=site/day, 2=reach/week-month, 3= (sub)catchment/annual

<u>Aquatic Life</u> (* = common regional council metrics)

Indicator	Sensitivity	Standard methods	Current use	Ease of sampling	Reference calibrated	Scale of measure	Scale of impact	Total
Waterbirds								
Taxa richness	1	1	1	1	1	1	1	7
Abundance	2	1	1	1	2	1	1	9
Native fish								
Taxa richness	1	3	2	1	1	2	3	13
Fish IBI	2	2	2	1	2	2	3	14
O/E fish species	1	2	1	1	2	2	3	12
Pest species	1	2	1	1	3	2	3	13
Invertebrates								
Taxa richness	1	3	3	2	1	1	2	13
MCI*	3	3	3	2	2	1	2	16
%EPT*	3	3	3	2	2	1	2	16
O/E species	2	2	1	2	3	1	3	14
Invertebrate IBI	3	3	1	1	2	1	2	13
SHMAK MCI	2	3	2	3	2	1	2	15
Macrophytes								
% cover	2	3	1	3	1	1	1	12
% native	2	3	1	3	3	1	2	15
MCC	2	3	1	3	1	1	1	12
Periphyton								
% cover*	2	3	3	3	1	1	2	15
Biomass (chl-*a*)*	2	3	3	2	2	1	2	15
% filamentous*	1	3	3	3	2	1	2	15
% cyanobacteria	1	2	1	3	1	1	2	11
SHMAK % cover	1	3	1	3	1	1	2	12
Microbes								
O/E species	1	1	1	3	2	1	1	10
BCI	2	1	1	3	1	1	1	10

IBI = Index of Biotic Integrity, O/E = observed to expected ratio, MCI = Macroinvertebrate Community Index, SHMAK = Stream Health Monitoring and Assessment Kit, MCC = Macrophyte Channel Clogginess, BCI = Bacteria Community Index.

[2] http://www.mfe.govt.nz/publications/fresh-water/freshwater-biophysical-ecosystem-health-framework

Water Quality (* = common regional council metrics)

Indicator	Sensitivity	Standard methods	Current use	Ease of sampling	Reference calibrated	Scale of measure	Scale of impact	Total
*Dissolved oxygen**								
Minimum DOɬ	2	3	2	2	1	2	2	12
Spot measure	2	2	3	3	1	1	2	13
*Temperature**								
Maximum	2	2	1	2	1	2	1	9
CRI	2	2	1	2	1	2	1	10
Spot measure	1	2	3	3	1	1	1	12
*pH**	1	2	3	3	1	1	2	13
*Susp.sediment**								
Clarity	2	2	3	3	2	1	2	15
Turbidity	2	2	3	3	1	1	2	14
Sediment load^	2	1	1	1	2	3	3	10
*Nutrients**								
Total N and P	3	3	3	3	2	1	3	18
Dissolved P	3	3	3	3	2	1	3	18
Nutrient loads^	2	1	1	2	2	3	3	11
Toxicants								
Ammonia toxicity	3	3	3	3	3	1	1	17
Nitrate toxicity	3	3	3	1	3	1	1	15
Metals	3	3	1	2	3	1	1	14

DO = dissolved oxygen, ɬ = only below discharges, CRI = Cox-Rutherford Index, ^Nutrients and sediment loads can be calculated from flow-weighted measurements or predicted using farm- or catchment-scale models, e.g. OVERSEER™ (Ledgard et al. 1999), CLUES (Woods et al. 2006).

Water Quantity (* = common regional council metrics)

Indicator	Sensitivity	Standard methods	Current use	Ease of sampling	Reference calibrated	Scale of measure	Scale of impact	Total
Extent								
Wetted area	1	2	1	3	2	1	1	10
Velocity	1	2	2	3	1	2	1	12
Depth	1	2	2	3	1	1	1	11
Hydrological variability								
Mean*	1	3	2	1	2	2	3	13
MALF*	2	3	2	1	2	2	3	14
Variability	2	3	1	1	2	2	3	13
Flood frequency	2	3	1	1	2	2	3	13
Flood magnitude	2	3	1	1	2	2	3	13
Connectivity								
Floodplain	2	1	1	1	1	2	3	11
Groundwater	1	1	1	1	1	2	3	10

MALF = Mean annual low flow.

Physical habitat (* = common regional council metrics)

Indicator	Sensitivity	Standard methods	Current use	Ease of sampling	Reference calibrated	Scale of measure	Scale of impact	Total
Substrate								
% fine sediment*	2	3	2	3	2	2	3	17
Substrate stability	1	2	1	3	1	1	2	11
Interstitial space	2	1	1	3	1	1	2	11
Organic matter	1	1	1	3	1	1	1	9
Extent								
WUA	2	2	2	1	2	2	2	12
Residual pool depth	2	2	1	2	1	2	2	12
RHA*	1	3	2	3	2	1	2	14
Form								
Bank stability	2	1	1	3	1	1	1	10
Sinuosity	2	1	1	1	1	2	3	11
Gradient	1	2	1	3	1	2	2	12
Connectivity								
Floodplain connect	2	1	1	2	2	2	3	13
Riparian								
SHAP Naturalness	2	2	1	2	2	1	1	11
Shade*	2	3	2	3	2	1	1	14

RHA = Rapid Habitat Assessment, WUA = Weighted Usable Area (taxa specific), SHAP = Stream Habitat Assessment Protocols.

Ecosystem processes (* = common regional council metrics)

Indicator	Sensitivity	Standard methods	Current use	Ease of sampling	Reference calibrated	Scale of measure	Scale of impact	Total
Biotic interactions								
Connectance	1	1	1	1	1	1	2	8
Rel. ascendency	1	1	1	1	1	1	2	8
Path length	1	1	1	1	1	1	2	8
Parasitism	1	1	1	1	1	1	1	7
Biogeochemical processes								
GPP	3	2	1	2	2	2	2	14
ER	2	2	1	2	2	2	2	13
Cotton strip assay*	3	3	1	3	1	1	1	13
OM processing	2	1	1	1	1	1	1	8
OM	2	2	1	2	1	1	2	11
Delta15N	2	2	1	1	1	1	1	9
Algal bioassay	2	2	1	2	1	1	1	10
Denitrification	1	1	1	1	1	1	2	8

GPP = gross primary productivity, ER = ecosystem respiration, OM = organic matter retention, Delta15N = the ratio of two stable isotopes of N (15N:14N) in primary producers or consumers.