Method of prioritising sub-catchments

Addendum to the memo to the Technical Leaders Group (29th March 2016; Doc#4065913)

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This addendum presents the method used to prioritise the HRWO sub-catchments for staged development of property plans. The sub-catchments were ranked according to the amount of change in current contaminant yields (i.e., load normalised by area) required to meet the water quality objectives proposed by the Collaborative Stakeholder Group for the following attributes:

- Total nitrogen (TN) - the annual median concentrations meet or are beloweither 0.16 or 0.35 g/m^3 depending on location, within the main-stem of the Waikato River.
- Total phosphorus (TP) – the annual median concentration meet or are below 0.02 g/m^3 within the main-stem of the Waikato River.
- *E. coli* - the annual 95th percentile concentration meet or are below 260 or 540 cfu/100 ml depending on location.
- Clarity – the annual median visual clarity meet or are above either 1.0, 1.6 or 3.0 metres depending on location.

The current state of water quality for each sub-catchment[1] was evaluated using data collected for State of Environment (SOE) reporting that was supplied by WRC. The sub-catchments were ranked separately for each attribute with total suspended solids (TSS) used as a proxy for clarity following the relationship between TSS and clarity determined for the HRWO sub-catchments by Yalden and Elliot (2015). The ranks were then combined to identify the sub-catchments with the greatest overall contaminant losses.

The prioritisation method was similar for all the contaminants and hinges on the assumption that for each sub-catchment, the current state for each water quality attribute is directly proportional to the calculated mean annual load of the relevant contaminant. It was also assumed that the modelled loads have a linear relationship with the water quality attributes such that the percentage change in each attribute needed to reach the targets above is also the required percentage change in loads.

The method followed these steps:

1. Determine the current instream loads for each sub-catchment.
   Nutrient and *E. coli* loads were estimated using NIWA models that were developed for the HRWO (Semadeni-Davies et al., 2015b; Semadeni-Davies et al., 2015a). The instream loads calculated by these models includes the contributions from upstream catchments and point sources as well as the diffuse source loads generated by

[1] There are exceptions where no SOE data are available, and the concentrations for these sub-catchments were taken from concentration models developed for the HRWO.

different land covers including pastoral and horticultural land uses. Sediment loads were estimated by Landcare Research using the New Zealand Empirical Erosion Model (Palmer et al., 2013). The instream sediment load for each sub-catchment consists of the upstream load and the total load contributed by all sources in the sub-catchment.

2. Determine the load contribution from diffuse sources in each catchment.
   This step sequentially removed:
   - Incoming loads from upstream catchments;
   - Loads from any point sources found in each sub-catchment, including from geothermal sources. These point source loads were taken directly from the HRWO input data under the CSG-provided assumption that these would not change over the course of the plan change period.

   For sub-catchments that contain a large lake or hydro-dam, losses due to reservoir attenuation (taken from the model inputs) were calculated and added back to the instream load during this step to obtain the total load contribution from all sources.

3. For each sub-catchment, the loads from diffuse sources within the sub-catchment were further separated into loads generated by pastoral or horticultural land uses and loads from other land uses. Like point sources, it was assumed that the latter are not included in any management measures and represent 'unmanageable load'.
4. Loads generated by pastoral and horticultural land uses in the nutrient models are subject to catchment attenuation between the source and the stream network (Semadeni-Davies et al., 2015b). Attenuation determined as part of nutrient modelling were used to back-calculate the losses from these sources. The losses were added to the nutrient loads reaching the stream from these sources to obtain the total load generated by pastoral and horticultural land uses.
   Note that there are two sets of attenuation for TN, these are the current or *apparent* attenuation that was calibrated as part of modelling, and the "load to come" or *ultimate* attenuation estimated by the HRWO expert panel. This step used the apparent attenuation to determine the current generated load. Please refer to Semadeni-Davies et al. (2015b) for details.
5. The percentage difference between the observed state and the desired state for each attribute was calculated. If the observed state for a sub-catchment did not meet the desired state, this percentage difference was used to adjust the corresponding modelled instream load to calculate the load limit for the sub-catchment. Note that this step used the load-to-come concentration for TN, that is, the instream concentration calculated from the load-to-come load modelled using the ultimate attenuation.
6. Steps 2 to 4 were repeated using the adjusted instream load to determine the generated loads that would be required to meet the bottom-line with the exception that calculation for TN used the ultimate catchment attenuation rather than the apparent attenuation to model sub-catchment loads. For nutrients and *E. coli*, the

reduction in loads were calculated for pastoral and horticultural diffuse sources. For sediment, the reduction in loads were calculated for the sub-catchment as a whole.

7. The differences in generated loads was normalised by area to obtain differences in generated yields required to meet the desired state. Since a large sub-catchment with the same catchment characteristics and land use will contribute a higher load than a small sub-catchment, the use of yields allows the sub-catchments to be compared and ranked.
8. The yields were then ranked for each attribute with a rank of 1 having the lowest priority. The combined ranking for each sub-catchment is the rank of the average ranking for all the attributes. For example, Waikato at Ohaaki, which has relatively clean water from Lake Taupo, had the average rank of 8 and the combined rank of 2. The worst ranked sub-catchment was Mangatu which had an average rank of 56.3 giving it a combined rank of 74.
9. The rankings were then grouped into 6 classes for mapping. The classes are as follows: Best 20%; 20-40 %; 40-60 %; 60-80 %; 80-90 %; and Worst 10% .

An example of the calculation method (Steps 1-7) is given below for TN loads for the Waikato at Ohakuri sub-catchment.

Current situation

Current observed TN annual median concentration: 0.22 g/m^3

Modelled current mean annual instream load: 1453324 kg/y

Reservoir attenuation: 0.97

Modelled upstream load contribution: 1168502 kg/y
less reservoir attenuation in Waikato at Ohakuri sub-catchment: 1133172 kg/y

Modelled load contribution from Waikato at Ohakuri subcatchment:
320153 kg/y = 1453324-1133172

Sub-catchment load contribution adjusted for reservoir attenuation: 330134

Load contribution from point and geothermal sources: 1000 kg/y

Load contribution from non-pastoral or horticultural diffuse sources: 64050 kg/y

Load contribution from pastoral and horticultural diffuse sources reaching the stream network: 265084 kg/y

Apparent catchment attenuation (calibrated): 0.35

Current generated load from pastoral and horticultural diffuse sources: 757383 kg/y

Sub-catchment area with pastoral and horticultural land use: 35840 ha

TN generated yield from pastoral and horticultural sources = 21.1 kg/ha/y

Load to come

Modelled instream load calculated using ultimate attenuation (load-to-come): 1896772 kg/y

Modelled load-to-come concentration: 0.28 g/m^3

Desired state – Scenario 1

Concentration: 0.16 g/m^3

Percentage reduction from load-to-come concentration required to meet bottom line: 42.98%

Instream load limit required to meet bottom-line concentration:
1081544 kg/y = 1896772*(1-0.4298)

Modelled upstream load contribution: 811610 kg/y
less reservoir attenuation in Waikato at Ohakuri sub-catchment: 787070 kg/y
Note that the upstream contribution is lower than for the current state as it is assumed the upstream catchments are at the bottom-line concentration

Modelled load contribution from Waikato at Ohakuri subcatchment:
294478 kg/y = 1801544-787070

Sub-catchment load contribution adjusted for reservoir attenuation: 303655 kg/m^3

Load contribution from point and geothermal sources: 1000 kg/y

Load contribution from non-pastoral or horticultural diffuse sources: 64050 kg/y

Load contribution from pastoral and horticultural diffuse sources reaching the stream network: 229423 kg/y

Ultimate catchment attenuation: 0.70

Generated load limit from pastoral and horticultural diffuse sources: 327748 kg/y

TN generated yield from pastoral and horticultural sources = 9.1 kg/ha/y

Difference in yield required (and used for ranking) – 12.0 kg/ha/y

References

Palmer, D., Dymond, J. and Basher, L. (2013) Assessing erosion in the Waipa catchment using the New Zealand Empirical Erosion Model (NZeem®), Highly Erodible Land (HEL), and SedNetNZ models, Technical Report 2013/54: 31.

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