Memo

From	**Murray Hicks, Ude Shankar**
To	Stephen Fragaszy
CC	Paul Franklin
Date	21 February 2020
Subject	Sediment load reduction load reduction to meet visual clarity bottom lines
File path *(right click to update)*	*O:\MFE19502\Working\Reporting\Sediment load reduction to meet visual clarity bottom lines memo - Feb 2020.docx*

Introduction

An updated set of C/D band thresholds for median clarity, defined for a 4-class CTG/SSC classification (Table 1) and mapped onto REC_DNv2, was provided by NIWA on 17 February 2020. These thresholds are henceforth labelled the "Feb2020" thresholds.

This memo:

- assesses which river segments have median clarity exceeding these Feb2020 thresholds;
- estimates the relative reduction in mean annual up-catchment suspended sediment load required to achieve the Feb2020 thresholds;
- compares these clarity-based results with those obtained by Hicks et al. (2019) using turbidity C/D band thresholds developed for a 12-class CTG/SSC classification - referred to here as the "Mar2019" thresholds [1]; and
- summarises the derivation of "pour-point" catchments associated with the new, clarity-based reductions in sediment load.

A summary of the main findings comparing the Feb2020 and Mar2019 thresholds can be found at the end of this memo.

Table 1: C/D band thresholds for median visual clarity for Level 4 suspended sediment classification, issued February 2020. Source: Doug Booker, NIWA Christchurch 17/2/2020.

Class	Visual clarity threshold (m)
1	1.34
2	0.61
3	2.22
4	0.98

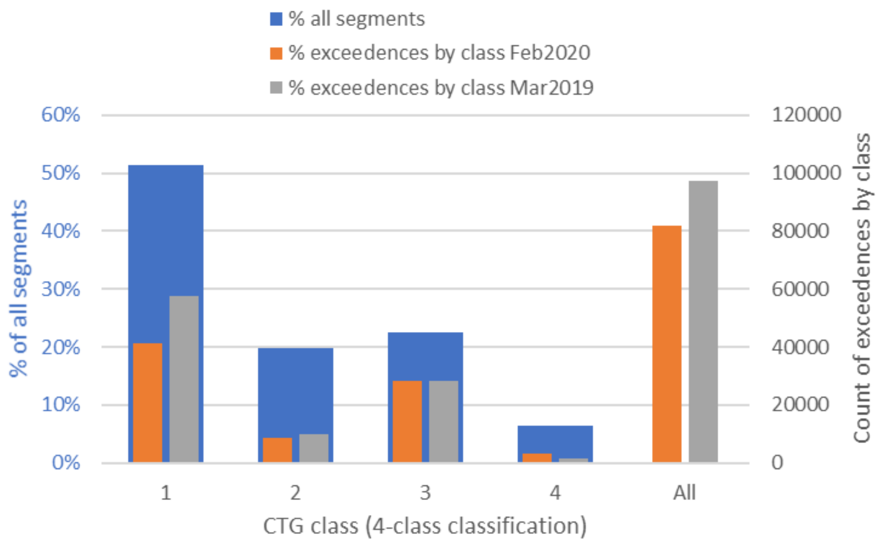
[1] Note that two previous sets of results were reported in Hicks et al. (2019). The first, reported in Section 3.4 of that report, used a set of thresholds developed for a 12-class CTG/SSC classification in March 2019. Appendix C of that report provided an alternative set of results using a more "relaxed" set of C/D band thresholds developed in May 2019. The comparisons made in this memo only concern the results from Section 3.4 based on the earlier, March 2019 set of thresholds.

Which river segments exceed the Feb2020 C/D band thresholds for clarity?

Threshold-exceeding river segments around the country were identified by comparing the provided threshold median values (Table 1) with the median clarity values predicted by the model developed in Section 3.3 of Hicks et al. (2019).

13.8% of all New Zealand river segments had median clarity values exceeding the Feb2020 clarity threshold values. In comparison, 16.4% of all New Zealand river segments had median turbidity values exceeding the Mar2019 turbidity threshold values – a relative difference of 16%.

These exceedances associated with the Feb2020 clarity and Mar2019 turbidity thresholds are shown broken-down by suspended sediment class (within the 4-class classification) in Figure 1. Note that the original 12-class CTG classification used in Hicks et al. (2019) has been mapped onto the 4-class classification for this purpose.



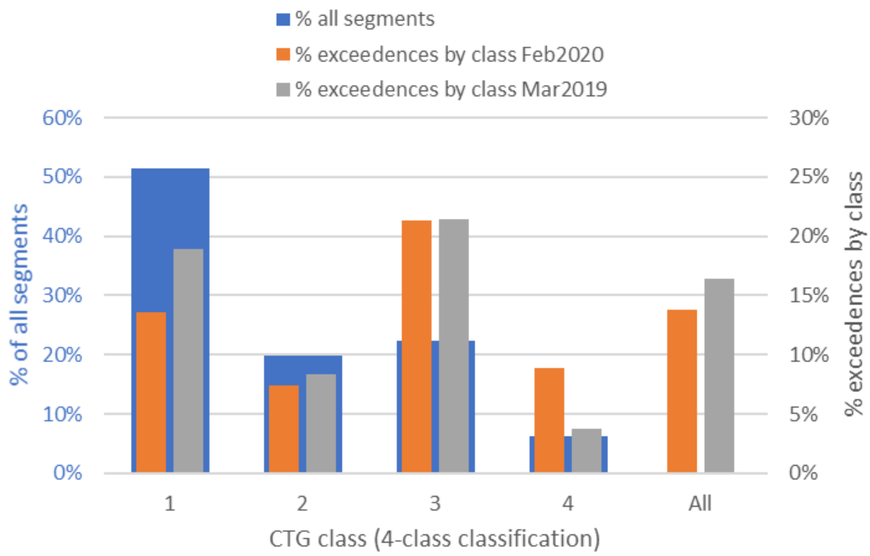


Figure 1: Count (top plot) and proportion (bottom plot) of stream segments in each CTG/SSC class (4-class classification) exceeding Feb2020 clarity thresholds and Mar2019 turbidity thresholds. In both plots, the underlying blue bars show the distribution by SSC class for all segments.

Considering first the Feb2020 clarity-based results (orange bars), Class 1 has the highest number of segments exceeding the threshold (followed by Class 3, then 2, then 4), mainly because Class 1 has the most segments nationally (blue bars). However, Class 3 has the highest proportion of its segments exceeding the threshold (21.4%, lower plot), with Class 2 showing the lowest proportion (7.4%).

The Mar2019 turbidity-based exceedance results (grey bars) show a reasonably similar distribution by segment count and proportion to the Feb2020 clarity-based distribution. The main count difference occurs in Class 1, where the Mar2019 exceedance proportions were 40% compared with 30% in Feb2020. While the Feb2020 Class 4 exceedance proportions were twice those from Mar2019, the overall impact of this is low by virtue of Class 4 having the least segments nationally.

The exceedances associated with the Feb2020 clarity and Mar2019 turbidity thresholds are shown broken-down by dominant land cover in Figure 2.

Note from Figure 2:

- The threshold exceedance counts for both Feb2020 and Mar2019 are dominated by pasture land cover (because pasture is the dominant land cover nationally).
- Within the pasture land cover, the exceedance proportions are very similar whether using the Feb2020 thresholds (25.6%) or Mar2019 thresholds (25.9%).
- The exceedance count and exceedance proportion distributions are reasonably aligned across most of the other land covers. The main exception is bare ground, where 6.3% of segments exceeded the Feb2020 thresholds but 35.6 exceeded the Mar2019 thresholds. The impact of this overall is muted by bare ground only affecting 6% of segments.

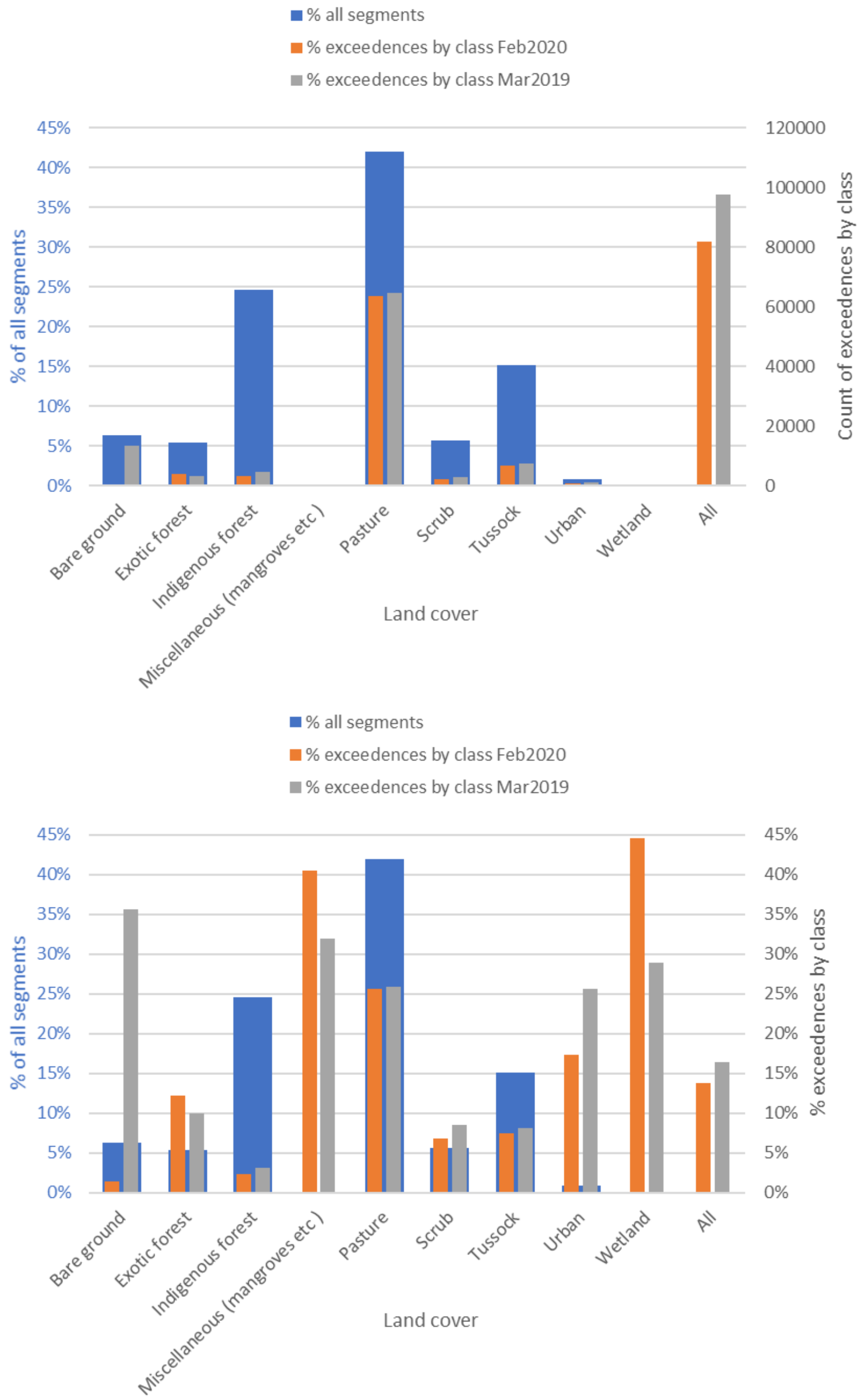


Figure 2: Count (top plot) and proportion (bottom plot) of stream segments in land cover classes exceeding Feb2020 clarity thresholds and Mar2019 turbidity thresholds. In both plots, the blue bars show the distribution by land cover for all segments. Where no blue bars show, that land cover's proportion is too small to register.

What load reduction is required to achieve the Feb2020 C/D band thresholds for clarity?

Sediment load reduction factors for visual clarity (R_c) across all 593545 segments of the REC_DNv2 digital network were estimated as detailed in Section 3.4.3 of Hicks et al. (2019). Note that $R_c = (L - L_{ct})/L$, where L is the actual sediment load and L_{ct} is the target sediment load that just meets the clarity threshold.

As in Hicks et al. (2019), the calculated R_c values were grouped into 5 classes:

- $0<R_c<0.2$
- $0.2<R_c<0.4$
- $0.4<R_c<0.6$
- $0.6<R_c<0.8$, and
- $0.8<R_c<1$.

Figure 3 (left column) shows the distributions of the R_c classes by stream order, SSC class, region, and land cover. These are compared (right column) with the equivalent distributions of R_t classes derived using the Mar2019 turbidity-based thresholds (as in Figure 3-15 of Hicks et al. 2019). Key points are:

- **By stream order**: Order 1-7 segments have similar R-class distributions for both sets of thresholds, with Orders 1-5 dominated by relatively low R-values (< 0.4) in both cases. Order 8 segments with the Feb2020 thresholds have more higher R-values (R>0.4), notably concentrated in the 0.6-0.8 range compared with the Mar2019 thresholds.
- **By SSC class (4-class classification)**: The R-class distributions are reasonably similar for both sets of thresholds, with all SSC classes having mainly low R-values (< 0.4) and with SSC class 4 having almost all low values.
- **By region**: With the Feb2020 thresholds, low R-values (< 0.4) dominate (i.e. have >50% R-values) in most regions except for Auckland. Stewart Island and Waikato having 49% of R-values > 0.4 - the Stewart Island result is unexpected, given its largely pristine character, and appears to have occurred because most if its stream segments fall into SSC-class 3 or 4 which have the more rigorous clarity thresholds (2.2 m and 1.38 m) while the clarity prediction model is predicting lower clarities there[2]. In comparison, with the Mar2019 turbidity-based thresholds, low R-values prevail except for Auckland and Waikato (but not Stewart Island).
- **By land cover**: The R-class distributions are broadly similar for both sets of thresholds. The main difference is with bare ground, which has 30% R-values > 0.4 with the Feb2020 thresholds but only 6% RI-values > 0.4 with the Mar2019. It is of note (see earlier comments around Figure 2) that the Feb2020 thresholds provide much fewer exceedances in bare ground catchments than do the Mar2019 thresholds; also, bare ground dominates the catchments of only a relatively small proportion (6%) of the country's stream segments.
- **Overall**: The breakdowns of R-classes by stream order, SSC class, region, and land cover are all reasonably similar whether using the Feb2020 clarity-based thresholds or the Mar2019

[2] This matters little in the "big picture" since Stewart Island lies predominantly in the DoC Conservation Estate, which has been excluded from interest by MFE.

thresholds. Notable differences only appear for Order 8 segments, regions (e.g. Stewart Island) with a high proportion of segments subject to the most rigorous clarity threshold, and segments with upstream catchments dominated by bare ground (which represent 6% of all segments nationally).

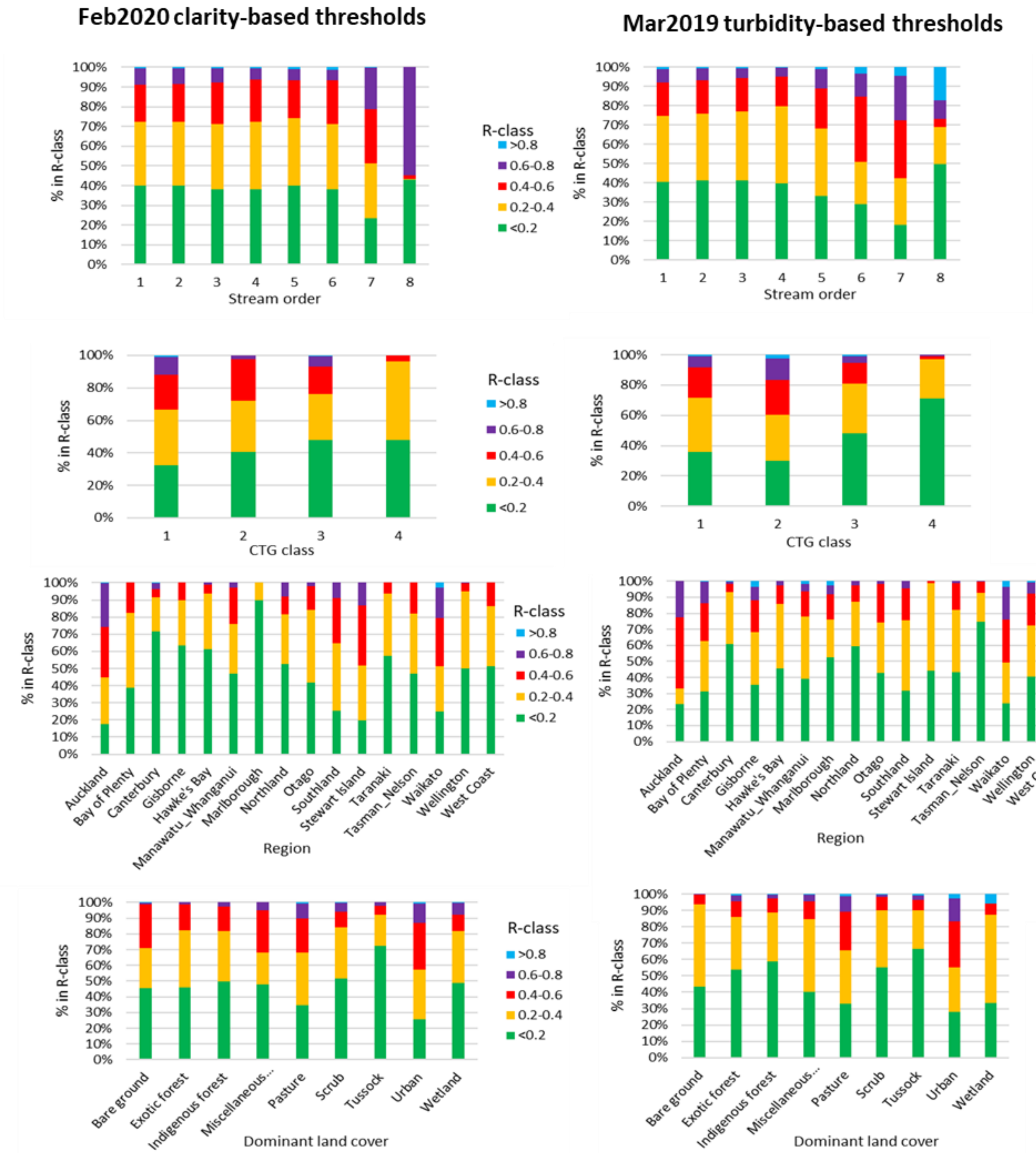


Figure 3: R_c**-class breakdowns by stream order, CTG/SSC class, region, and land cover for Feb2020 clarity-based thresholds and Mar2019 turbidity-based thresholds.**

Comparison with R results using observed data

The left plot on Figure 4 compares the R-class distribution of segments where R_c has been calculated with observed median clarity data (that were used to develop the clarity predictive model) and off the matching predicted median clarity values, as well as the distribution from all predicted segments nationally. Comparing the predicted and observed bars provides an indication of how sensitive the R-class results are to uncertainty in the national model used to predict clarity. Comparing the predictions for the observed dataset with the predictions for all segments gives an indication of the national representativeness of the observed dataset.

The observed dataset has 575 segments. Of these, 176 (30.6%) exceeded the Feb2020 clarity thresholds (i.e. R_c >0), while in the matching predicted dataset 171 (29.7%) exceeded these thresholds – a close agreement. The matching predicted and observed distributions were reasonably similar across the R-classes, which provides reassurance around the model predictions. Compared with the observed dataset, the full predicted dataset had relatively more segments with low R-values (R>0.2) and relatively fewer segments with high R-values (R>0.6).

The right plot on Figure 4 shows the equivalent results using the Mar2019 turbidity-based thresholds (as reported by Hicks et al. 2019). In that case, the observed dataset contained 847 segments (of which 570 segments overlapped with those in the observed clarity dataset). Of these, 31.2% exceeded the Mar2019 turbidity thresholds (i.e., R_t >0), while in the matching predicted dataset 30.4% exceeded the thresholds. These Mar2019 exceedance percentiles are very similar (within 1%) to those based on the Feb2020 clarity-based thresholds.

The distribution by R-class using the Mar2019 thresholds is similar to that for the Feb2020 thresholds – with no change in the rankings of each R-class. The main difference is that the Feb2020 results from the observed data show relatively fewer segments in the higher R-classes (R>0.6) balanced by slightly more in the lower R-classes (R<0.4).

The concordance between observed and predicted results is marginally better overall for the Mar2019 turbidity-based results (e.g. compare 0.4-0.6, 0.6-0.8 classes), but this may simply reflect the greater number of segments in the observed turbidity dataset.

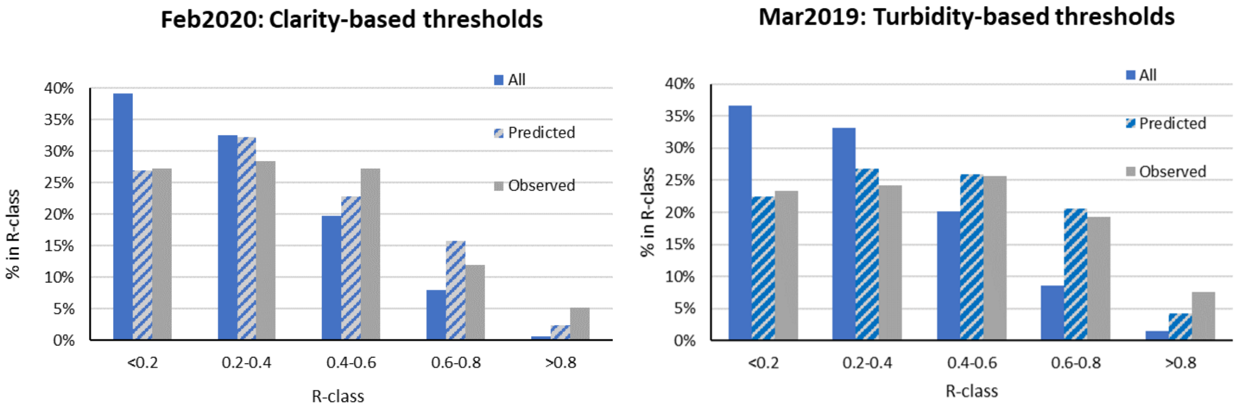


Figure 4: Distribution of segments with R>0 using Feb2020 clarity-based thresholds (left) and Mar2019 turbidity-based thresholds (right). Results shown for all predicted segment nationally, segments with R calculated off observed clarity/turbidity data, and matching segments with R calculated off predicted clarity/turbidity. Right plot is Figure 3-16 from Hicks et al. (2019).

Pour-point catchments

As in Section 3.4.7 of Hicks et al. (2019), pour-point catchments (defined as those parts of a coast-draining catchment upstream from the first segment where a $R_c > 0$ value was encountered) were mapped for the Feb2020 set of clarity thresholds.

MFE have identified that they wish to focus on catchments outside the DoC Conservation Estate (which have dominantly natural land cover) and outside urban areas. To facilitate this, the % area of each pour-point catchment that lies inside either of these two exclusion areas was determined by intersecting the pour-point catchment boundaries with a national layer combining the DoC Estate and urban land cover (as mapped on the LCDB-4 land cover database). This % was recorded as a field in the pour-point catchment attribute table, and can be used in ArcGIS to filter-out catchments lying significantly within these exclusion areas. For example, filtering with a threshold of 100% will remove catchments with areas completely within the DoC Estate or with urban land cover but will keep catchments 99% in the DoC Estate or urban.

Result-files forwarded to MfE with this memo include:

- shape-files of the Feb2020 set of pour-point catchments, including their boundaries and summary statistics in an attribute table (including count and proportion of R-values > 0, average R-values, and % area within the DoC Estate / urban exclusion area)
- shape-files of all REC_DNv2 segments, with an attribute table including values of R computed off clarity (R_c).

In summary, with the Feb2020 clarity thresholds, 633 pour-point catchments were mapped, with 39 (6.1%) of these lying substantially (i.e. >90% of their area) within the DoC Estate or with urban land cover.

In comparison, with the Mar2019 turbidity thresholds, 627 pour-point catchments were mapped, with 42 (6.7%) of these lying completely within the DoC Estate or with urban land cover (as determined by Neverman et al. 2019).

Summary of comparisons between using Feb2020 clarity-based and Mar2019 turbidity-based thresholds

Considering threshold exceedances:

- 13.8% of all New Zealand river segments had median clarity values exceeding the Feb2020 clarity threshold values, compared with 16.4% having median turbidity values exceeding the Mar2019 turbidity threshold values – a relative difference of 16%.
- The Feb2020 and Mar2019 exceedance results show reasonably similar distributions by CTG class, both by segment count and proportion. The main count difference occurs in Class 1, where the Mar2019 exceedance proportions were 40% compared with 30% in Feb2020.
- The threshold exceedance counts for both Feb2020 and Mar2019 are dominated by pasture land cover, and the exceedance proportions under pasture are very similar (25.6% vs 25.9%, respectively). For other land covers, the exceedance count and exceedance proportion distributions are reasonably aligned except for bare ground, where 6.3% of segments exceeded the Feb2020 thresholds but 35.6 exceeded the Mar2019 thresholds. The overall impact of this is muted by bare ground only affecting 6% of segments.

Considering load reduction factors:

- The breakdowns of R-classes by stream order, SSC class, region, and land cover are all reasonably similar whether using the Feb2020 clarity-based thresholds or the Mar2019 thresholds. Notable differences only appear for Order 8 segments, regions (e.g. Stewart Island) with a high proportion of segments subject to the more rigorous clarity thresholds, and segments with upstream catchments dominated by bare ground (which represent 6% of all segments nationally).
- When comparing results based on observed and predicted clarity/turbidity values, the threshold exceedance percentiles are very similar (within 1%) whether determined off observed or predicted data and whether using the Feb2020 clarity thresholds or the Mar2019 turbidity thresholds. The main difference between the Feb2020 and Mar2019 analyses is that the Feb2020 results show relatively fewer segments in the higher R-classes (R>0.6) balanced by slightly more in the lower R-classes (R<0.4).
- The Feb2020 clarity-based load-reduction factors produced 633 pour-point catchments, with 39 of those more than 90% in the Doc Conservation Estate or under urban land cover. In comparison, the Mar2019 turbidity-based load-reduction factors produced 627 pour-point catchments, with 42 of those completely in the Doc Conservation Estate or under urban land cover.

References

Hicks, D.M., Haddadchi, A., Whitehead, A., Shankar, U. (2019) Sediment load reductions to meet suspended and deposited sediment thresholds. NIWA Client Report 2019100CH prepared for Ministry for the Environment, June 2019.

Neverman, A., Djanibekov, U., Soliman, T., Walsh, P., Spiekermann, R., Basher, L. (2019) Impact testing of a proposed suspended sediment attribute: identifying erosion and sediment control mitigations to meet proposed sediment attribute bottom lines and the costs and benefits of those mitigations. Manaaki Whenua – Landcare Research Contract Report LC 3574, prepared for Ministry for the Environment, August 2019.