Memo

From	**Rick Stoffels, Paul Franklin, Doug Booker**
To	Stephen Fragaszy
Date	13 March 2020
Subject	Contract 23184: Task 4 – Check of deposited fine sediment reference states against all available SoE data

1 Background

Franklin et al. (2019) presented deposited fine sediment reference states for streams throughout New Zealand's river network. These reference states were estimates of the levels of deposited fine sediment within a stream that we can expect on the average, assuming minimal urban, agricultural and forestry development upstream. Reference states for deposited fine sediment were estimated using a model-based approach, following Dodds and Oakes (2004).

Deposited fine sediment reference states were estimated for streams within different 'sediment classes' of the New Zealand river network. The sediment classes group streams that have similar sediment supply and retention characteristics. The rationale and method underpinning the assignment of New Zealand's streams to sediment classes—the Sediment State Classification (SSC)—is presented in Appendix D of Franklin et al. (2019). The deposited SSC groups streams at four hierarchical levels of spatial aggregation (Aggregation Levels 1-4). Aggregation Level 1 is the coarsest level of aggregation, comprising only two classes nationwide, while Aggregation Levels 2, 3 and 4 comprise 4, 8 and 12 classes respectively. Deposited fine sediment reference states were estimated for all classes at each level of aggregation. These reference states formed the basis of deriving proposed fine sediment attribute band thresholds within the National Objectives Framework (NOF).

The data used to estimate the reference states within Franklin et al. (2019) came from the New Zealand Freshwater Fish Database (NZFFD). These data are streamside visual estimates of the proportion of stream bed comprised of deposited fine sediment (< 2mm grain size). These visual estimates are a subjective metric and are not made using a standard protocol or apparatus. As such, the NZFFD sediment data are not characterised by high precision or accuracy. The NZFFD contains few sites where observations have been made at different times. These data therefore represent many one-off observations rather than a set of at-site median values. However, an advantage of the NZFFD sediment data is its high spatial coverage of the New Zealand river network; many data were available within all classes at all levels of spatial aggregation.

An alternative source of data for estimating deposited fine sediment reference states is the State of the Environment (SoE) data collected by regional councils. Estimates of deposited fine sediment cover within the SoE data set are less subjective than those within the NZFFD (yielding higher accuracy) because they are made using various standard protocols (yielding higher precision). SoE data often contain replicate observations through time for each site. These data can therefore be used to calculate a set of site medians. A disadvantage of the SoE data is that it is monitored at few stations nationwide, so provides poor coverage of the New Zealand river network.

The brief from the Ministry for Environment (MfE) to NIWA was to develop reference states—and resultant management band thresholds—for the entire river network of New Zealand. Accordingly, Franklin et al. (2019) chose to use the NZFFD data, whose spatial coverage was far more extensive than that of the SoE data. Further, Franklin et al. (2019) anticipated that, despite the low accuracy of individual measurements within the NZFFD, precise estimates of reference state may still be made given the very large number of measurements within the NZFFD (following the Law of Large Numbers), under a critical assumption:

- that the NZFFD estimates of deposited fine sediment are not biased relative to the chosen method of assessment by regional councils against the NOF.

Following the release of the draft NOF fine sediment thresholds, regional councils compared the proposed fine sediment reference estimates of Franklin et al. (2019) to observed data obtained using the Sediment Assessment Method 2 (SAM2). Regional councils suggested that the proposed reference estimates were consistently higher than their observations. If this were true, the proposed deposited sediment thresholds presented by Franklin et al. (2019) would not be sufficiently protective of the life supporting capacity of streams; they would permit too much degradation of New Zealand's streams. Further, since completion of Franklin et al. (2019) more SoE data has been made available for analysis.

2 Objectives

In light of the observations of regional councils and the availability of more SoE data, the overarching objectives of the present analysis was to test the critical assumption stated above. The specific requirements and objectives of the current analysis were:

- collate all available SoE deposited fine sediment data and within each SSC class,
- at each level of aggregation compare and contrast:
  - all SAM1 and SAM2 estimates of deposited fine sediment with the draft reference states presented in Franklin et al. (2019); and
  - the SAM1 and SAM2 estimates of deposited fine sediment taken from reference sites only with the draft reference states presented in Franklin et al. (2019).

The SAM2 protocol involves instream visual estimates of fine sediment coverage in runs using an underwater viewer. At least 20 readings are made to assess fine sediment deposited within a reach (Clapcott et al. 2011). The SAM1 protocol involves rapid bankside visual assessments of fine sediment coverage in riffles, runs and pools within a reach (Clapcott et al. 2011), and was included in the present analysis as it should in theory yield estimates comparable with those in the NZFFD. Hereafter, the SAM1 and SAM2 data are collectively referred to as "the assessment data".

3 Method

We prepared boxplots of the assessment data obtained within each SSC class at all levels of aggregation to determine the direction (above or below Franklin et al.'s estimates?) and magnitude (by how much?) of any bias in the proposed reference estimates. For each of the objectives we prepared boxplots using:

a) raw, pooled individual observations within classes and;

b) median values within sites, calculated across different sampling events within each site.

For (a) the boxplot statistics are estimated across samples taken on individual dates within sites, and so all sampling dates within sites are assumed to be independent. For (b) a site had to be associated with at least five samples through time to qualify for calculation of a median (Table 1).The proposed attributes are based on site medians, so the analysis based on medians presented in (b) provides a better comparison with the proposed attribute. However, given numerous sites had 4 or less individual observations, we have included (a) because the data comprising it cover more of the river network. Ideally, site medians would be calculated across more than five individual observations, but increasing the critical sample number beyond five would have resulted in too few sites being included in the analysis.

SAM1 assessments have been taken from riffles, runs and pools by councils, so we prepared SAM1 boxplots by those habitat types; we did not obtain a habitat-length-weighted average SAM1 value for each site.

All SoE data were joined to the River Environment Classification (REC) so that we could define reference sites. Following the protocol of Franklin et al. (2019), a monitoring site was considered a reference site if the upstream catchment was characterised by > 90% native vegetation, < 5% exotic vegetation and 0% urban development.

Table 1. The number of sites containing 5 or more observations, or less than 5 observations for each assessment methods utilised by regional councils.

Regional Council	Assessment method/ habitat	N (5 or more observations)	N (less than 5 observations)
Canterbury	SAM2	114	10
Hawkes Bay	SAM2	31	10
Horizons	SAM2	95	0
Nelson	SAM2	25	0
Northland	SAM1_pool	0	75
Northland	SAM1_riffle	0	75
Northland	SAM1_run	0	74
Otago	SAM1_pool	4	13
Otago	SAM1_riffle	16	11
Otago	SAM1_run	21	11
Southland	SAM2	32	1
Tasman	SAM1_run	25	0
Wellington	SAM2	26	0

4 Results

4.1 SAM1 and SAM2 data from all monitoring sites

Within all classes, at all levels of spatial aggregation, SAM2 measurements were consistently lower than the proposed reference state estimates (Figure 1). In many cases even the 75th percentile of all SAM2 estimates within a class were significantly lower than reference estimates (under the reference 95% confidence intervals) (Figure 1). The magnitudes of difference between SAM2 medians and proposed reference states were great; sometimes exceeding ca. 50% deposited fine sediment coverage (e.g. class 2.1 (Agg. Level 2; Class 1); Figure 1).

Medians of all the SAM1 assessments (regardless of site) were also generally well below the proposed reference states (Figure 1). In some classes the SAM1 medians from pools were either comparable or greater than the proposed reference estimates (e.g. Agg. Level 3, Classes 6 and 8; Figure 1). In one class (Agg. Level 3 Class 5 and Agg. Level 4 Class 8), SAM1 medians from runs exceeded the proposed reference state, but those assessments comprised only two individual sampling events (Figure 1).

A total of 445 SAM2 observations (from 4 sites in total; see Figure 2) were from one, or several REC climate-topography-geology classes that could not be classified (see Franklin et al. 2019).

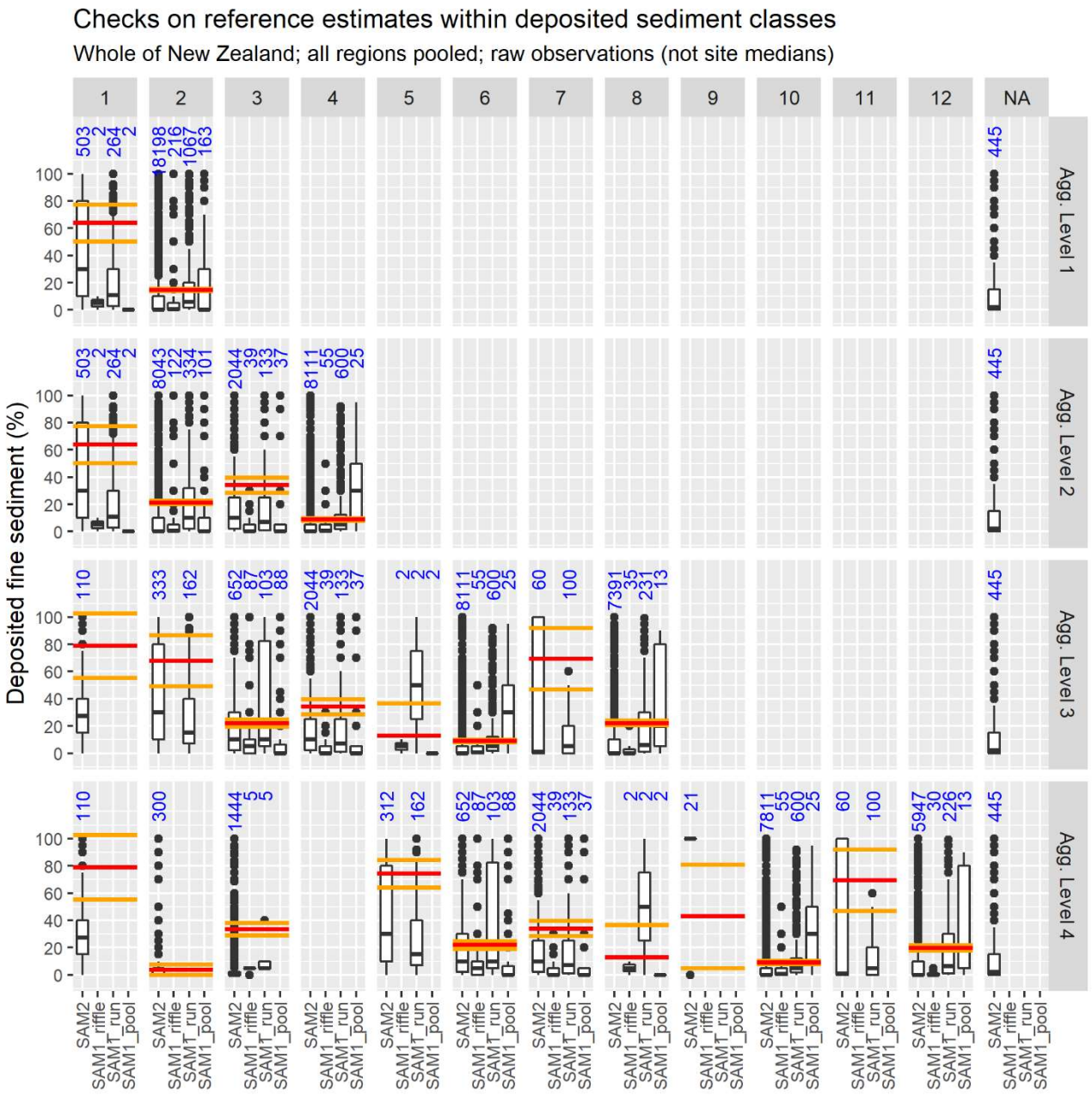

Figure 1. Boxplots of SoE assessments of deposited fine sediment within each SSC class (columns) at four levels of spatial aggregation (rows). *Raw individual observations* from four SoE assessments are presented: SAM2 instream visual assessments, and SAM1 bankside visual assessments in three habitat types: riffles, runs and pools. Horizontal red and orange lines present the estimated reference states and confidence intervals, respectively. Lower and upper hinges of boxes define the 25th and 75th percentiles of the data, respectively. The horizontal line in the middle of the box defines the median. The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are called "outlying" points and are plotted individually. The *number of individual observations* comprising each box are presented in blue.

Boxplots of SAM site medians were characterised by smaller interquartile ranges (IQRs) and less outliers (Figure 2). Many sites within the SoE dataset contained less than five observations so had to be excluded from the analysis (Table 1). This resulted in insufficient data to characterise SAM assessments within certain classes at Aggregation Levels 3 and 4 (Figure 2). Nevertheless, the overall conclusion is the same as that reached using all individual observations from all sites: the proposed reference states estimated using NZFFD are all higher than SAM assessments.

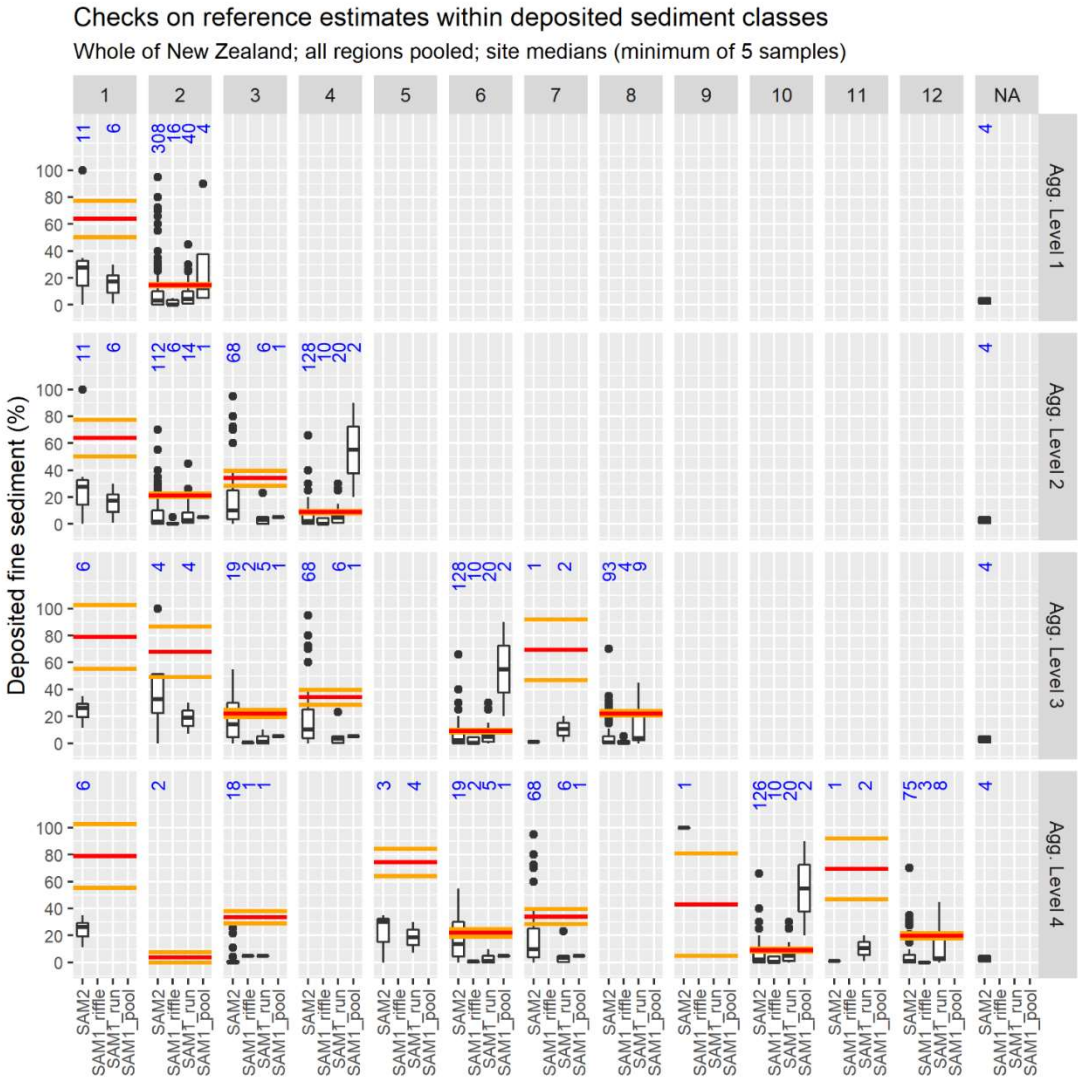

Figure 2. Boxplots of SoE assessments of deposited fine sediment within each SSC class (columns) at four levels of spatial aggregation (rows). *Site medians* from four SoE assessments are presented: SAM2 instream visual assessments, and SAM1 bankside visual assessments in three habitat types: riffles, runs and pools. Horizontal red and orange lines present the estimated reference states and confidence intervals, respectively. Lower and upper hinges of boxes define the 25th and 75th percentiles of the data, respectively. The horizontal line in the middle of the box defines the median. The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are called "outlying" points and are plotted individually. The *number of sites* comprising each box are presented in blue.

4.2 SAM1 and SAM2 data from reference sites

Very few reference sites were available nationwide (a total of 13; Table 2), and reference sites were only available in a subset of SSC classes (Figure 3; Figure 4)—SSC classes containing river segments that characterise cool mountain streams with naturally low sediment supply and retention regimes. As such, we were only able to compare SAM1 and SAM2 data from reference sites with proposed reference states that were already quite low (Figure 3; Figure 4).

Table 2. The number of reference sites available within each regional council

Regional Council	N Reference Sites (5 or more observations)	N Reference Sites (less than 5 observations)
Canterbury	0	0
Hawkes Bay	2	0
Horizons	3	0
Nelson	1	0
Northland	0	9
Otago	0	0
Southland	1	0
Tasman	3	0
Wellington	3	0

Although classes containing references sites also contained the lowest proposed reference states, the proposed reference states obtained using NZFFD data were consistently higher than SAM1 and SAM2 estimates. This was true irrespective of whether we analysed raw, individual observations (Figure 3) or site medians (Figure 4). Even in these classes characterised by low to very low sediment supply and retention, the degree of bias imposed by using the NZFFD data was high. Using reference site medians, SAM1 and SAM2 indicated that reference states should generally be lower than 10% coverage of deposited fine sediment. By contrast, the proposed reference states of Franklin et al. (2019) may be as high as 20% in the same classes (twice the coverage of deposited fine sediment; Figure 4).

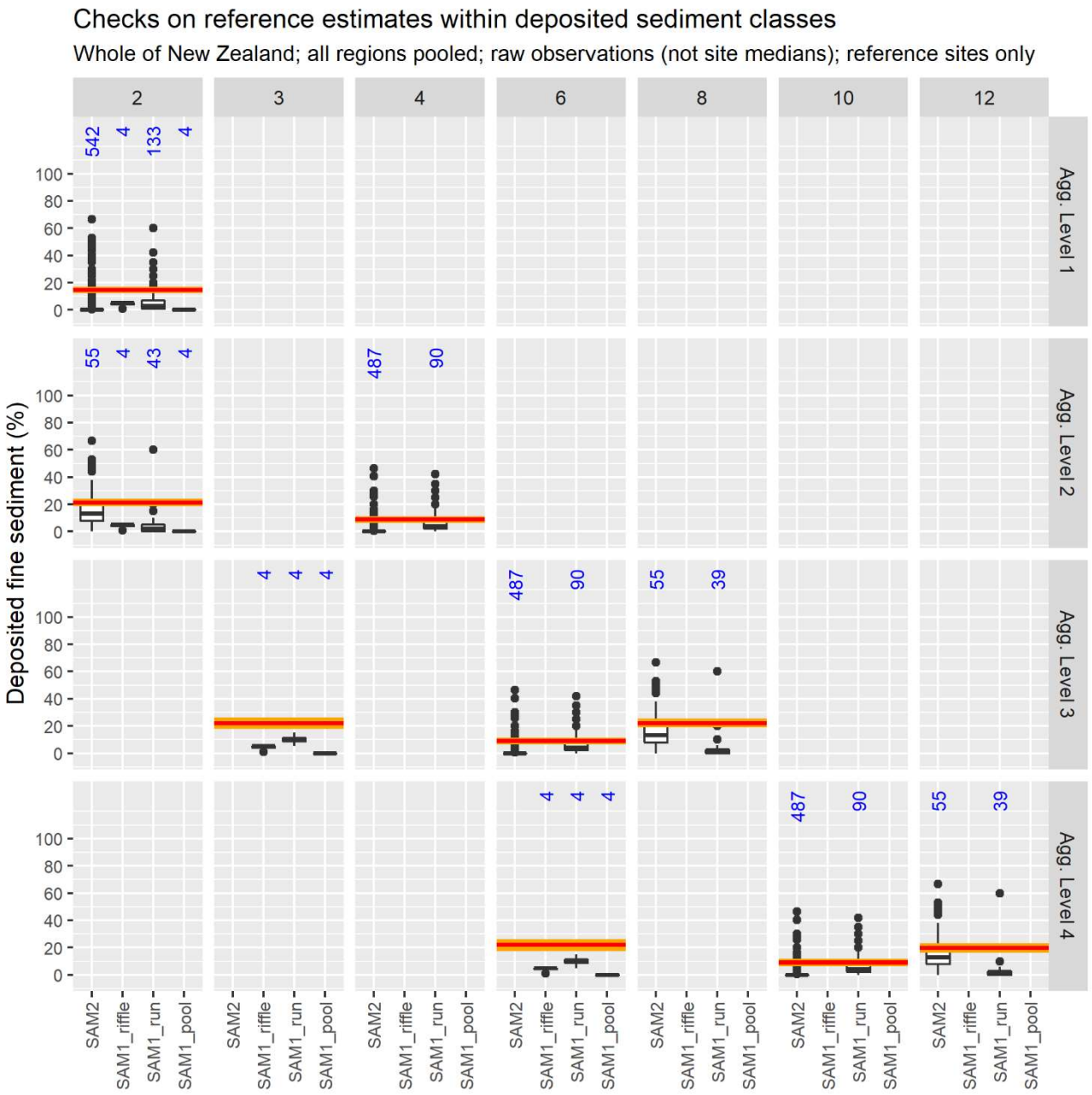

Figure 3. Boxplots of SoE assessments of deposited fine sediment within each SSC class (columns) at four levels of spatial aggregation (rows) *at reference sites only*. *Raw individual observations* from four SoE assessments are presented: SAM2 instream visual assessments, and SAM1 bankside visual assessments in three habitat types: riffles, runs and pools. Horizontal red and orange lines present the estimated reference states and confidence intervals, respectively. Lower and upper hinges of boxes define the 25th and 75th percentiles of the data, respectively. The horizontal line in the middle of the box defines the median. The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are called "outlying" points and are plotted individually. The *number of individual observations* comprising each box are presented in blue.

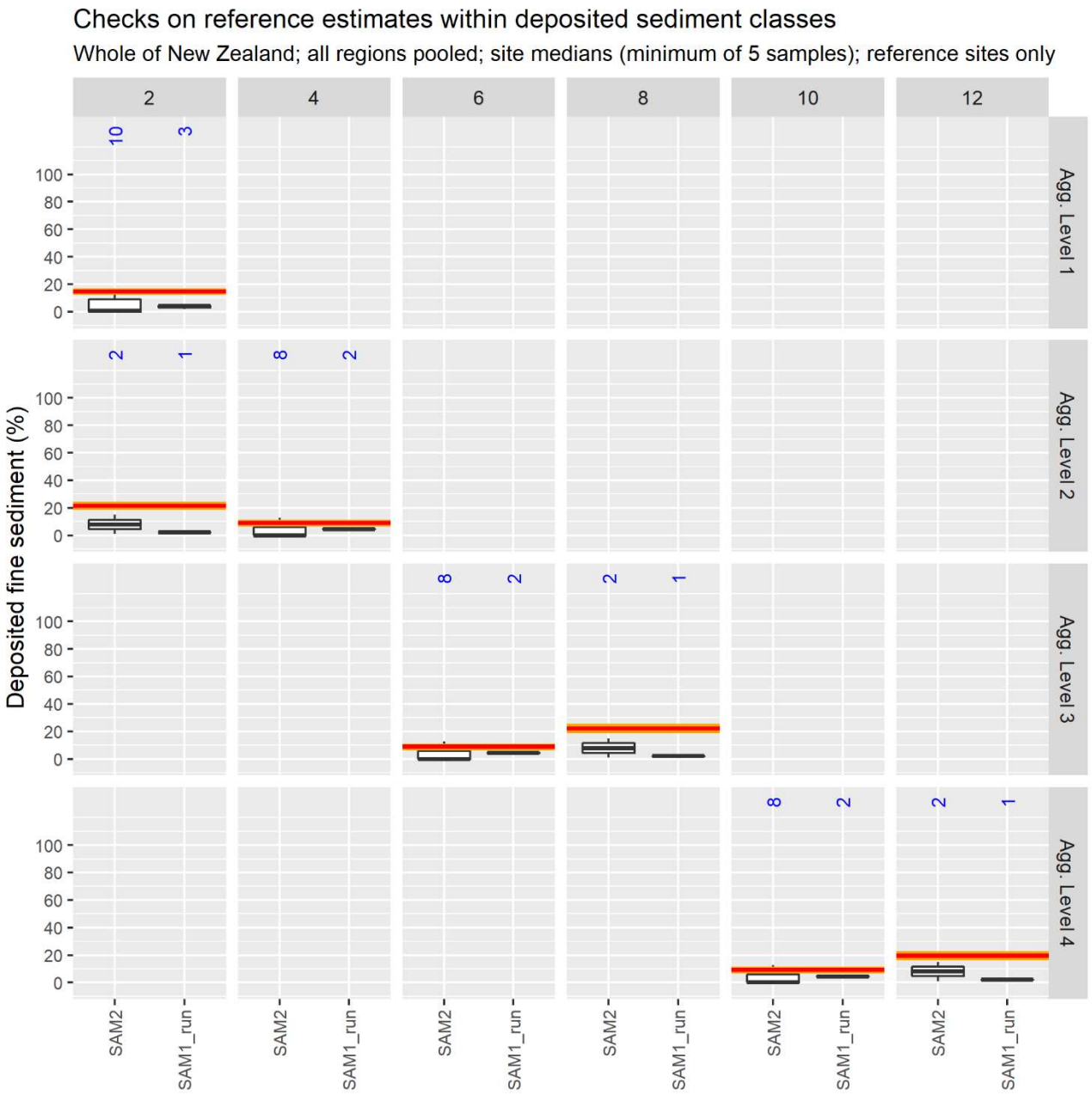

Figure 4. Boxplots of SoE assessments of deposited fine sediment within each SSC class (columns) at four levels of spatial aggregation (rows) *at reference sites only*. *Site medians* from four SoE assessments are presented: SAM2 instream visual assessments, and SAM1 bankside visual assessments in three habitat types: riffles, runs and pools. Horizontal red and orange lines present the estimated reference states and confidence intervals, respectively. Lower and upper hinges of boxes define the 25th and 75th percentiles of the data, respectively. The horizontal line in the middle of the box defines the median. The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are called "outlying" points and are plotted individually. The *number of individual observations* comprising each box are presented in blue.

5 Conclusions and recommendations

The conclusions from this analysis are straightforward:

- The critical assumption made by Franklin et al. (2019) when estimating reference states was false. The NZFFD estimates of deposited fine sediment are biased relative to the SAM1 and SAM2 methods of assessment.
- The proposed deposited fine sediment reference states in Franklin et al. (2019) are higher than deposited fine sediment observations made using SAM1 and SAM2 protocols, irrespective of whether those SAM1 and SAM2 observations are made in reference sites or not.
- The biases in the proposed reference states are present in all classes at all levels of aggregation.
- In most cases, the differences between the proposed reference states and the SAM1 and SAM2 estimates are great, indicating that the proposed reference states will not be sufficiently protective of the life supporting capacity of New Zealand's streams.

In light of these conclusions we recommend:

- In light of the most recent SoE data that has come to hand we recommend re-estimating deposited fine sediment reference states using the SAM2 data.
- This reanalysis needs to utilise a similar approach to the one developed by Franklin et al. (2019), but needs to be adapted to the lower quantity of data available within the SoE (cf. NZFFD). This will involve redeveloping certain routines in the algorithm laid out in Appendix D of Franklin et al. (2019).
- NIWA now has sufficient SoE data to revise the estimates of reference states for deposited fine sediment. The revised reference state values are likely to address and satisfy the concerns raised by external referees. The new reference state estimates would be based on the same methodology proposed for assessment of deposited fine sediment state against the NOF.
- NIWA would be pleased to develop a proposal to adapt the approach of Franklin et al. (2019) to the SoE data so that new deposited fine sediment attribute thresholds may be developed.

6 References

Clapcott, J. E., R. G. Young, H. J. S., C. D. Matthei, J. M. Quinn, and R. G. Death. 2011. Sediment Assessment Methods: Protocols and Guidelines for Assessing the Effects of Deposited Fine Sediment on Instream Values.

Dodds, W. K., and R. M. Oakes. 2004. A technique for establishing reference nutrient concentrations across watersheds affected by humans. Limnology and Oceanography: Methods **2**:333-341.

Franklin, P., R. Stoffels, J. Clapcott, D. Booker, A. Wagenhoff, and C. Hickey. 2019. Deriving potential fine sediment attribute thresholds for the National Objectives Framework. NIWA Report to the Ministry for Environment.