Technical Memorandum
Draft Baseline State for Sediment in Taranaki Rivers

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Purpose

The purpose of this memorandum is to provide an assessment of the baseline state of suspended fine sediment in rivers and deposited fine sediment in wadeable rivers as a measure of ecosystem health, as required by the National Policy Statement for Freshwater Management 2020 (NPS-FM).

Overview of Suspended and Deposited Fine Sediment

Sediment is mineral or organic matter that is transported by water, air or ice and is the result of erosive processes. The magnitude of erosion is a function of climate, vegetation, soil type and topography. Sediment delivery to aquatic systems can be viewed as a function of the interactions between natural environmental variability, and land management decisions that affect land cover and land use.

In aquatic systems, excess fine sediment (i.e. more than would usually result from natural processes in an unmodified catchment) can have adverse effects on water quality and freshwater ecosystems, by making water turbid and stream beds muddy. This can result in the alteration of ecological communities and lead to the loss of sensitive fish and macroinvertebrate species. In the presence of elevated nitrogen levels, the release of phosphorus from suspended and deposited sediment can trigger algal blooms in rivers and lakes. Additionally, excessive sediment can reduce the water's suitability for human uses, such as drinking and swimming.

Fine sediment is primarily comprised of fine inorganic particles of clay and silt with a grain size of less than 2 mm in diameter. Sediment is introduced to waterways via erosion and runoff, or directly via discharges. Waterways appear muddy as a result of fine sediment and particulate organic matter suspended in the water column. Fine sediment will eventually settle out, forming layers of fine sand, silt, and clay covering river and stream beds. Once deposited, fine sediment can fill up the small spaces between rocks and make habitat unsuitable for fish and macroinvertebrates to live in.

Sediment and the National Objectives Framework

The NPS-FM sets out requirements for Councils and communities to maintain or improve freshwater (where it is degraded). It includes a National Objectives Framework (NOF) that specifies nationally applicable standards for particular freshwater parameters (referred to as 'attributes') for both rivers and lakes. The NOF includes two attributes for sediment:

- *suspended fine sediment* (in all rivers, measured as visual clarity, or as turbidity converted to visual clarity) and;
- *deposited fine sediment* (in wadeable and naturally hard-bottomed rivers, measured as the percentage of the stream-bed area covered with deposited fine sediment).

Attribute bands serve as a basis for objective setting as part of the NOF process. The NOF has set categorical attribute states for suspended fine sediment and deposited fine sediment into four bands, from band A (good) to band D (poor). The attribute band is determined using the numeric attribute value determined by either monitored or modelled data compared against the numeric ranges associated with each attribute band grade.

The NPS-FM includes attribute band tables for both suspended fine sediment and deposited fine sediment attributes as set out in Table 1 and Table 2. The sediment class of a given river segment dictates the attribute value ranges defining the band grade. Sediment classes are determined by the climate, topography, and geology classification (as defined in the River Environment Classification; REC[1]) of upstream segments predominately contributing flow to a given segment. To determine the attribute band for visual clarity and deposited sediment at a monitoring site or river segment the RECv2 digital stream network was used to identify the sediment class at that location.

Table 1: NOF Attribute – Suspended fine sediment. Source: MfE, 2020.

Value (and component)	Ecosystem health (Water quality)			
Freshwater body type	Rivers			
Attribute unit	Visual clarity (metres)			
Attribute band and description	**Numeric attribute states by suspended sediment class**			
	Median			
	1	2	3	4
A Minimal impact of suspended sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.	≥1.78	≥0.93	≥2.95	≥1.38
B Low to moderate impact of suspended sediment on instream biota. Abundance of sensitive fish species may be reduced.	<1.78 and ≥1.55	<0.93 and ≥0.76	<2.95 and ≥2.57	<1.38 and ≥1.17
C Moderate to high impact of suspended sediment on instream biota. Sensitive fish species may be lost.	<1.55 and >1.34	<0.76 and >0.61	<2.57 and >2.22	<1.17 and >0.98
National bottom line	**1.34**	**0.61**	**2.22**	**<0.98**
D High impact of suspended sediment on instream biota. Ecological communities are significantly altered and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.	<1.34	<0.61	<2.22	<0.98
Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years. Councils may monitor turbidity and convert the measures to visual clarity. *See* Appendix 2C Tables 23 and 26 for the definition of suspended sediment classes and their composition.				

[1] https://niwa.co.nz/freshwater/management-tools/river-environment-classification-0

Value (and component)	Ecosystem health (Water quality)
Freshwater body type	Rivers
Attribute unit	Visual clarity (metres)
Attribute band and description	**Numeric attribute states by suspended sediment class**
The following are examples of **naturally occurring processes** relevant for suspended sediment: • naturally highly coloured brown-water streams • glacial flour affected streams and rivers • selected lake-fed REC classes (particularly warm climate classes) where low visual clarity may reflect autochthonous phytoplankton production.	

Table 2: NOF Attribute – Deposited fine sediment. Source: MfE, 2020.

Value (and component)	Ecosystem health (Physical habitat)			
Freshwater body type	Wadeable rivers			
Attribute unit	% fine sediment cover			
Attribute band and description	**Numeric attribute states by deposited sediment class**			
	Median			
	1	2	3	4
A Minimal impact of deposited fine sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.	≤7	≤10	≤9	≤13
B Low to moderate impact of deposited fine sediment on instream biota. Abundance of sensitive macroinvertebrate species may be reduced	>7 and ≤14	>10 and ≤19	>9 and ≤18	>13 and ≤19
C Moderate to high impact of deposited fine sediment on instream biota. Sensitive macroinvertebrate species may be lost.	>14 and <21	>19 and <29	>18 and <27	>19 and <27
National bottom line	**21**	**29**	**27**	**27**
D High impact of deposited fine sediment on instream biota. Ecological communities are significantly altered and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.	>21	>29	>27	>27
The indicator score is percentage cover of the streambed in a run habitat determined by the instream visual method, SAM2 as defined in p. 17-20 of Clapcott JE, Young RG, Harding JS., Matthaei CD, Quinn JM. and Death RG. 2011. Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Cawthron Institute: Nelson, New Zealand. (see clause 1.8) Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years. *See* Tables 24 and 26 in Appendix 2C for deposited sediment classes and their composition. This attribute does not apply in river environment classes shown in Table 25 in Appendix 2C, or where clause 3.25 requires freshwater habitat monitoring.				

To determine the numeric attribute value for suspended fine sediment in streams and rivers, visual clarity is typically measured manually in situ, using a horizontal black disc or a clarity tube following the procedures set out in the National Environmental Monitoring Standard for Discrete Water Quality (NEMS, 2019). Council's may also monitor turbidity and convert measures to visual clarity.

The grading of deposited fine sediment cover applies to wadeable (and naturally hard-bottomed) rivers and streams. The stream assessment method 2 (SAM2) is an in-stream visual assessment of the surface area of the streambed covered with fine sediment used for measuring the deposited sediment metric.

Monitoring of sediment in the Taranaki region

Suspended fine sediment

Suspended fine sediment is monitored with black disc visual clarity at 42 sites in the Taranaki region as part of a range of TRC water quality monitoring programmes, carried out for state of the environment (SoE), consent monitoring and investigative purposes. Of these sites, 22 are routinely monitored on a monthly basis, regardless of weather and flow conditions as part of the TRC's SoE monitoring programme. The monitoring record for most of these sites extends back to the 2004-2005 monitoring period. These 22 sites have been used to inform the setting of suspended fine sediment baseline states.

Deposited fine sediment

Deposited sediment measurements have been collected monthly at 12 SoE periphyton sites. Up until June 2023, deposited sediment measurements were only collected following the rapid habitat assessment (RHA) procedure. The RHA procedure assigns a score to an estimated percentage cover of deposited fine sediment for the entire reach being assessed, and does not require underwater viewing. The SAM2, which is set as the acceptable procedure for deposited fine sediment monitoring in the NPS-FM, differs from the RHA in that it requires underwater visual assessments at 20 underwater points along the reach (four locations across five transects if possible).

Baseline states for sediment

The NPS-FM requires all regional councils to identify baseline states for all attributes described in Appendix 2A and 2B of the NPS-FM within each Freshwater Management Unit (FMU). When compared against national bottom lines and the relevant objectives for an FMU, baselines provide the reference point from which councils must either maintain or improve an attribute, which in turn will contribute toward achieving freshwater objectives for each compulsory and non-compulsory value. Waterbodies must not be allowed to degrade, or remain below an identified baseline state unless that state is determined to be naturally occurring.

Under Clause 1.4 of the NPS-FM, the baseline state, in relation to an attribute, is the best state out of the following:

a) the state of the attribute on the date it is first identified by a regional council under Clause 3.10(1)(b) or (c);

b) the state of the attribute on the date on which a regional council set a freshwater objective for the attribute under the National Policy Statement for Freshwater Management 2014 (as amended in 2017);

c) the state of the attribute on 7 September 2017.

The Council has not previously set freshwater objectives under the NPS-FM 2014 (amended 2017) for sediment, so the state of these attributes under 1.4 (b) could not be calculated, and was excluded from identification of baseline. Therefore, the best state out of Clause 1.4 (a) and (c) was used to identify the baseline states for each of the sediment attributes.

Under Clause 1.6 of the NPS-FM, local authorities must use the best information available at the time (and if practicable, using complete and robust data) to give effect to the NPS-FM. In the absence of complete and robust data, the best information available should be use which may include modelling, partial data, and local knowledge, and preferably use sources that provide the greatest level of certainty (or take all practicable steps necessary to reduce uncertainty).

Under the NPS-FM, both sediment attributes are associated with the Ecosystem Health value, which is a compulsory value within the NOF (NPS-FM, Appendix 1A). Suspended fine sediment is included in the NOF as an Appendix 2A attribute, requiring limits to be set. The deposited sediment attribute is included as an Appendix 2B attribute, requiring the development of an action plan. It is necessary for baseline states to be identified by TRC for the Taranaki region to ensure that target attribute states are set at a level that either achieve or exceed the best baseline state for that attribute and (at a minimum) achieve the relevant national bottom line. It is noted that in some cases, achieving the national bottom line may be challenging for sediment attributes in areas where natural sources of sediment are significant contributors to overall sediment load. This will need to be taken into account when setting target attribute states.

The remainder of this memo summarises the monitoring and work carried out by TRC to identify baseline states for sediment attributes in the region's rivers.

Criteria for identifying site-based baseline states

Draft baseline states for both suspended fine sediment and deposited sediment have been identified for individual monitoring sites.

When determining the attribute state for both sediment attributes, the NPS-FM states that *'baselines are based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions'* and *'[the] record length for grading a site based on 5 years'*. The NPS-FM adds that the absence of high-quality data is not a justification for delaying or deferring planning measures and actions, and modelling can provide information in the absence of complete and scientifically robust data.

Suspended fine sediment monitoring requirements include monthly measurement of visual clarity, irrespective of weather and flow conditions. The record length for grading a site is based on a minimum of five years of data. Complete datasets used to set draft baseline states for monitoring sites have been defined by TRC to include sites with monthly monitored data for 90% of months in a 5-year period (n=54) (Larned et al., 2018). In the absence of a complete dataset, partial datasets of <54 data points have also been used. Of the 22 sites that are assessed here for visual clarity baseline state, 17 achieved the 90% threshold for a full dataset (n=54), and five monitoring sites had between 20 and 51 data points.

Baselines for deposited sediment were identified using RHA data collected monthly at 12 SoE periphyton sites. Deposited sediment monitoring using the RHA procedure was initiated between December 2016 and November 2018, and therefore none of the sites have enough data points to achieve the 90% full dataset threshold. Additionally, the RHA procedure differs from the SAM2 method which is set out as the acceptable procedure for deposited fine sediment monitoring in the NPS-FM.

We acknowledge and emphasise that the baseline values used to assign attribute bands at the deposited sediment monitoring sites may not be the appropriate use of this data as it does not follow the procedure specified in the NPS-FM. However, the NPS-FM states that 'local authorities must use the best information available at the time', and that 'a local authority must not delay making decisions solely because of uncertainty about the quality or quantity of the information available'. Therefore we present the findings as the best option for establishing site-based baseline states.

Site-based baseline states for sediments

Draft baseline states for 22 suspended fine sediment monitoring sites and 12 deposited fine sediment monitoring sites are presented in Figure 1, Table 3, Table 4 and Figure 2. Further details are provided in Appendix 1.

The site-based baseline assessment has assigned 13 out of 22 monitoring sites into band A for suspended fine sediment (Table 3 and Figure 1). One site is graded in band C, and the remaining eight sites are graded in band D; below the national bottom line. Except for Southern Hill Country, every FMU with more than one monitoring site has sites that are graded at both ends of the attribute table (band A and band D); highlighting the variability in state across these FMUs. Southern Hill Country only has two monitoring sites, and both are graded in band D. Northern Hill Country only has one monitoring site, which is graded in band A, while there are no monitoring sites in the Coastal Terraces included in this assessment.

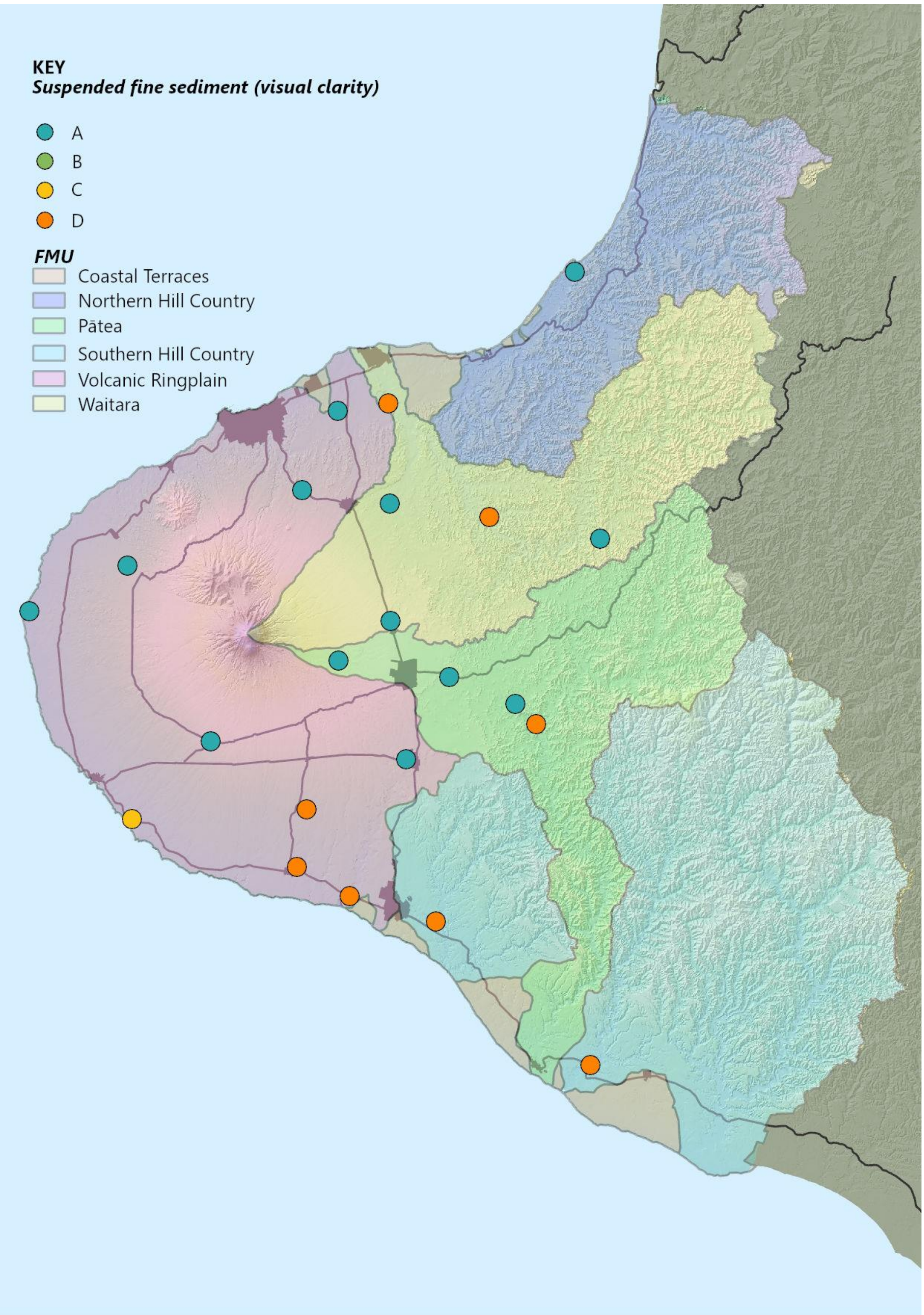

Figure 1: *Site-based baseline state for suspended fine sediment*

Table 3: Site-based baseline state for suspended fine sediment

Freshwater Management Unit	Site name	Site code	Median visual clarity when first identified	Median visual clarity at 7 September 2017	NOF attribute band
Southern Hill Country	Tawhiti Stream at Duffy's water level recorder	TWH000435	0.68	Insufficient data	D
	Whenuakura River at Nicholson Road	WNR000450	0.32	Insufficient data	D
Pātea	Mangaehu River at Raupuha Road bridge	MGH000950	0.84	0.91	D
	Makuri Stream 30 m D/S of Raupuha Road	MKR000495	1.39	Insufficient data	A
	Pātea River at Barclay Road bridge	PAT000200	4.26	4.42	A
	Pātea River at Skinner Road bridge	PAT000360	1.93	1.80	A
Volcanic Ringplain	Kapoaiaia Stream at Cape Egmont	KPA000950	1.91	Insufficient data	A
	Mangaoraka Stream at Corbett Road	MRK000420	2.13	1.75	A
	Punehu Stream at Wiremu Road	PNH000200	1.89	1.69	A
	Punehu Stream at State Highway 45	PNH000900	1.46	1.51	C
	Hangahatua (Stony) River at Mangatete Road	STY000300	4.45	2.7	A
	Waingongoro River at Eltham Road bridge	WGG000500	1.84	1.64	A
	Waingongoro River at State Highway 45	WGG000900	1.06	1.32	D
	Waiwhakaiho River at State Highway 3	WKH000500	3.18	3.11	A
	Waiokura Stream at Skeet Road	WKR000500	0.63	Insufficient data	D
	Waiokura Stream at Manaia Golf Course	WKR000700	0.57	0.60	D
Waitara	Manganui River U/S of State Highway 3 (NRWQN)	MGN000195	3.85	Insufficient data	A
	Maketawa Stream at Tarata Road	MKW000300	2.65	2.39	A
	Matau Stream U/S of confluence with unnamed tributary	MTA000068	1.54	N/A	A
	Waitara River adjacent to Autawa Road	WTR000540	0.38	Insufficient data	D
	Waitara River at Bertrand Road (NRWQN)	WTR000800	0.46	N/A	D
Northern Hill Country	Waikaramarama Stream at Waikaramarama Road	WMR000100	1.29	Insufficient data	A

In FMUs with limited monitoring sites, it is unlikely that these results properly reflect the broader state of suspended fine sediments. This is particularly exhibited in the Northern Hill Country FMU with its single monitoring site graded in band A while the Southern Hill Country has two sites graded in band D, despite these FMUs both sharing landscape characteristics and land uses that contribute to high sediment erosion potential. Results from the remaining FMUs (Pātea, Volcanic Ringplain and Waitara) demonstrate the importance of having a greater number of monitoring sites in order to capture the state of suspended fine sediments across these large areas with diverse landscapes and land uses. Although FMU representativeness may be limited by monitoring site coverage, these site-based baseline states provide an accurate assessment of state at specified locations which can then be used to compare change against into the future. The merits and limitations of site-based baseline states, and alternative approaches, are discussed later in this memorandum.

The site-based baseline assessment for deposited fine sediment has assigned seven out of 12 sites into band A, one site into band B, two sites into band C and two sites into band D; below the national bottom line (Table 4 and Figure 2). The same considerations regarding monitoring site coverage apply to deposited fine sediment, with only one site in each of the Southern Hill Country, Pātea and Northern Hill Country FMUs. This is discussed in more detail, later in the memorandum.

Table 4: Site-based baseline assessment for deposited fine sediment

FMU	Site Name	Site Code	Deposited sediment class	RHA equivalent streambed cover (%)	NOF band
Southern Hill Country	Tawhiti Stream at Duffy's water level recorder	TWH000435	2	30	D
Pātea	Makuri Stream at Raupuha Road	MKR000495	3	15	B
Volcanic Ringplain	Kapoaiaia Stream at Cape Egmont	KPA000950	2	10	A
	Punehu Stream at Wiremu Road	PNH000200	2	10	A
	Punehu Stream at State Highway 45	PNH000900	2	10	A
	Hangahatua (Stony) River at Mangatete Road	STY000300	2	30	D
	Waingongoro River at Eltham Road	WGG000500	2	10	A
	Waiwhakaiho River at Egmont Village	WKH000500	2	10	A
Waitara	Manganui River u/s of State Highway 3	MGN000195	2	5	A
	Maketawa Stream at Tarata Road	MKW000300	2	5	A
	Matau Stream at Matau Road	MTA000068	2	20	C
Northern Hill Country	Waikaramarama Stream at Waikaramarama Road	WMR000100	3	20	C

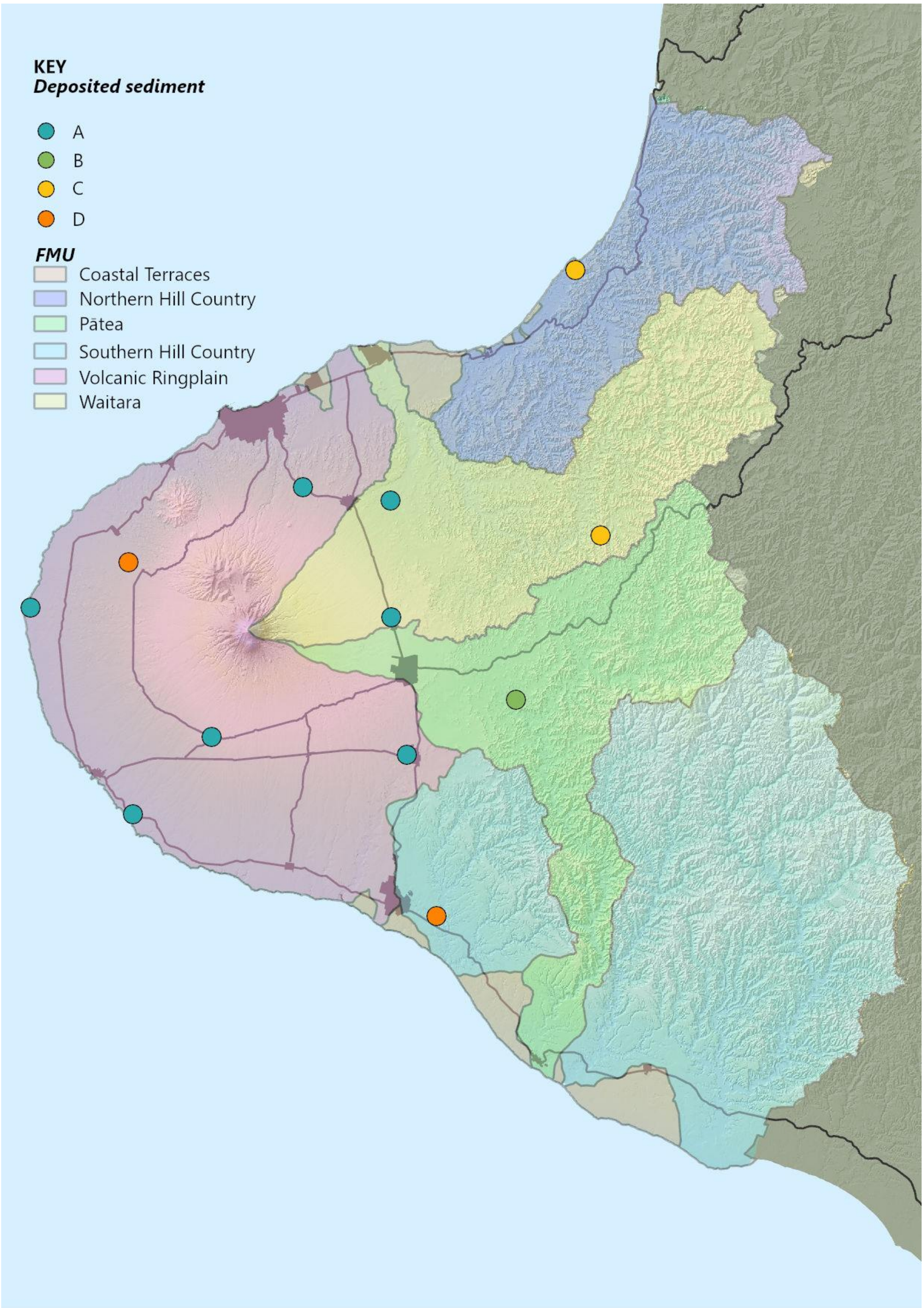

Figure 2: Site-based baseline assessment for deposited fine sediment

Baseline period and temporal state variability

This baseline assessment has been carried out using data that demonstrates the best state, out of the baseline periods defined in the NPS-FM. The council has not previously set freshwater objectives for sediment attributes, and therefore we reported our results according to sub-clause 1.4 (a) and (c), while sub-clause 1.4(b) is not applicable.

For suspended fine sediment, the best state was identified out of the earliest five years of monitoring data, and the five years of data prior to September 2017, as shown in Table 3 and Appendix 1. For deposited fine sediment, there was no data available prior to September 2017, and as such, the baseline period identified for this attribute is the earliest five years of monitoring data. Further details are presented in Appendix 1.

Clause 3.10(4) of the NPS-FM states that "attribute states and baseline states may be expressed in a way that accounts for natural variability and sampling error". Acknowledging the natural variability of attribute states informs target attribute state (TAS) setting and long-term vision/objectives development at a site-specific level. This section discusses the uncertainty associated with setting site-specific baseline states that originates from the natural variability of water quality and outlines the steps TRC is taking to address the uncertainty.

Site-specific water quality attribute states derived from monthly monitored data are potentially uncertain (Snelder and Kerr, 2020). Potential uncertainty is largely due to the changing nature of short-term flow regimes and linked to how contaminants such as sediments are transported, concentrated, and diluted by hydrological flow paths and instream processes (Cassidy et al. 2018). A discrete monthly sampling regime (monthly collection of separate water samples) is only able to provide a snapshot of the "true" water quality state over the assessment period and consequently does not capture data that is fully representative of temporal variability.

Additionally, variability in the five year flow regime produces another source of uncertainty in attribute state assessments. This uncertainty is associated with the fact that the flow regime at a monitoring site for any five year assessment period is unlikely to be a perfect representation of the long-term flow regime. The flow regime can be expected to vary significantly across assessment periods. Therefore, the attribute state assessments can also be expected to vary over time in response to changes in flow (Snelder and Kerr, 2020).

Despite the aforementioned uncertainties associated with deriving baseline attribute states from monitored data, the site-specific numeric and NOF attribute states derived from complete data records are still considered the best estimates of the water quality state (Snelder and Kerr, 2020). However, it has been recommended that the attribute states derived from monitored data should be interpreted as the "best information at the time". Further, it is acknowledged that the uncertainty associated with the assessment is not an adequate reason to delay giving effect to the NPS-FM (Snelder and Kerr, 2020).

If there is a long-term data record (as is the case for many river sites), it is useful to assess whether the selected 5-year period is representative of the overall data set. If it is, then the data can be used to make meaningful conclusions about the state of the river. However, if the data is naturally variable over time, then the 5-year period may not be representative, and the selected baseline may be arbitrary. A rolling state evaluation of the visual clarity attribute NOF bands has been performed to assess the temporal variations for all 5-year periods from 1 July 1993 to 31 December 2017 at monitoring sites where long-term data records were available (Fraser, 2022). Results of the assessment show that temporal variability in attribute grades is common, but the magnitude of change is generally limited (Figure 3).

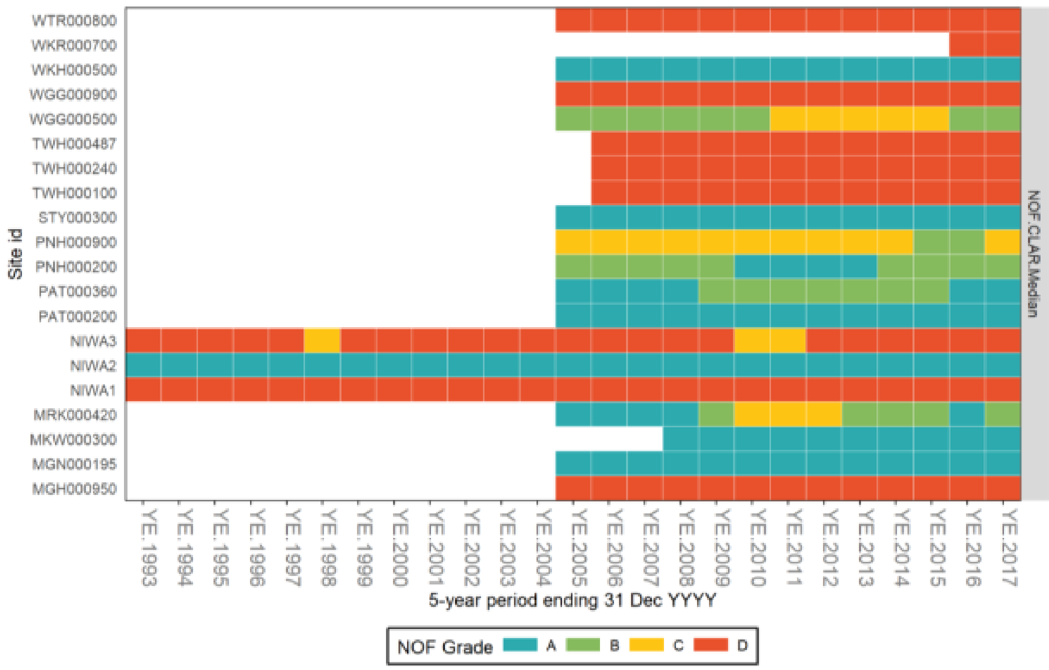

Figure 3: Five year rolling state assessment from Fraser (2022).

In the rolling state assessment carried out by Fraser (2022), six sites show changes in attribute grades over the entire data set, although these shifts mostly occur up and down between two consecutive grades (e.g. from B to C and back to B), which is not unexpected, given that the numeric values that inform the grading can often sit close to the boundary between two grades. At one site (MRK000420), more than two grades were recorded over the entire data range. Overall, the 5-year baseline periods that have been selected for this baseline assessment appear to be appropriate, and are not undermined by temporal variability in the datasets.

Due to the short monitoring record that exists for deposited sediment (less than five years for most sites), it is not possible to assess temporal variability in this data. As such, less confidence can be assigned to the baseline grades, as it is not possible to say how representative the baseline period is of 'typical' state.

Freshwater Management Unit (FMU) coverage and representativeness

An overarching requirement of the NOF framework is for councils to identify Freshwater Management Units (FMU). The NPS-FM 2020 requires monitoring to be undertaken at sites that are representative of each FMU and a monitoring plan that identifies at least one representative site in each FMU for monitoring progress against freshwater objectives (NPS-FM 2020, Clause 3.8(4)).

Representativeness refers to the comparative distribution of monitoring sites and rivers across an area. Multiple sites across an FMU may be required to ensure acceptable representativeness as it has been proposed that the location of sites should reflect the geophysical complexity and variability of the landscape in the FMU. Additional considerations for proper representativeness requires:

a) data from all waterbody/landscape classes; and

b) the number of sites in each physiographic class and the total area of land in that class to be proportional (MfE, 2017).

Additionally, land-use intensity and soil types should be taken into account when considering monitoring site representativeness as these characteristics may vary across an FMU (MfE, 2017).

The Bay of Plenty Regional Council (BoPRC) assessed representativeness of their Natural Environment Regional Monitoring Network (NERMN) programme based on 'landuse', 'biophysical', 'size', and 'temporal' classifications for their water quality monitoring sites in each FMU (Suren, et al., 2022). Another potential procedure for determining representativeness is described in 'Recommendations for new sites to improve representativeness in the New Zealand river environmental monitoring network' published by NIWA (Larned and Unwin, 2012). The NIWA study created a REC reference land cover class termed Natural (N) by pooling the land cover categories Bare, Indigenous Forests, Tussock, and Scrub. The Natural category was used for comparisons with the impacted land cover categories Pastoral (P), Urban (U) and Exotic Forest (EF). Representativeness in the BoPRC and NIWA assessments were calculated as the ratio of the % of sites in each class being sampled to the % of waterway length (Snelder and Scarsbrook, 2005).

Suspended fine sediment

An assessment of the representativeness of the 22 suspended fine sediment baseline sites was undertaken (Table 5). To perform this analysis we identified the ratio of the percentage of monitoring sites within each land cover class to the percentage of waterway length by land cover class, pooling 'natural' land cover categories following the procedure described in the NIWA report for each FMU (Larned and Unwin, 2012). Following the assessment by the BoPRC, appropriate representativeness occurred when the ratio was between 0.7 and 1.3, under-representativeness at <0.7, and over-representativeness >1.3 (Suren, et al., 2022).

Table 5: Representativeness of 22 suspended fine sediment monitoring sites assessed by land cover and separated by FMU

	Stream length (km)				Number of monitoring sites in each land cover class				Representativeness ratio			
Land cover	N	EF	P	U	N	EF	P	U	N	EF	P	U
Southern Hill Country	1,918	17	1,687	15	0	0	2	0	0.00	0.00	2.16	0.00
Coastal Terraces	0	0	339	32	0	0	0	0	-	-	0.00	0.00
Pātea	576	48	1,284	25	1	0	3	0	0.84	0.00	1.13	0.00
Volcanic Ringplain	777	0	3,579	73	2	0	8	0	1.14	-	0.99	0.00
Waitara	572	6	1,578	10	1	0	4	0	0.76	0.00	1.10	0.00
Northern Hill Country	944	1	449	0	0	0	1	0	0.00	0.00	3.10	-

The approach used here is strictly an example of an assessment of the representativeness of the monitoring sites in the region and is by no means a complete analysis. Still, based on the NPS-FM requirement that each FMU must have at least one representative monitoring site, the absence of any monitoring sites in the Coastal Terraces FMU is something that needs to be addressed. Although there are a number of under-represented land cover types shown in red in the table, it is important to note that land cover types are not evenly proportioned within each FMU (as is shown with stream length in Table 5). Therefore, attention should be set on improving monitoring coverage for land cover types which account for a significant proportion of the FMU. Ideally, there should be proportionality between the stream length classification found in an FMU and the monitoring sites in those stream classifications. However, there are significant financial and resourcing constraints associated with monitoring, and although monitoring network representativeness can be optimised, there are limitations to the coverage that can be feasibly achieved with conventional monitoring. Monitoring network design and development is outside the scope of this document but will be considered as part of the TRC's overall freshwater implementation programme.

Deposited fine sediment

The same method for assessing monitoring site representativeness was applied to the deposited fine sediment monitoring network (Table 6). As with suspended fine sediment, there is a notable lack of any monitoring in the Coastal Terraces FMUs. Furthermore, each FMU is devoid of monitoring coverage in at least one land cover type, though in many cases these land covers comprise a very small proportion of the overall stream network.

Table 6: Representativeness of 12 deposited fine sediment monitoring sites assessed by land cover and separated by FMU

	Stream length (km)				No. DFS monitoring sites with landcover				Representativeness ratio			
Land cover	N	EF	P	U	N	EF	P	U	N	EF	P	U
Southern Hill Country	1918	17	1687	15	0	0	1	0	0.00	0.00	2.16	0.00
Coastal Terraces	0	0	339	32	0	0	0	0	-	-	0.00	0.00
Pātea	576	48	1284	25	0	0	2	0	0.00	0.00	1.51	0.00
Volcanic Ringplain	777	0	3579	73	1	0	5	0	0.95	-	1.03	0.00
Waitara	572	6	1578	10	1	0	2	0	1.26	0.00	0.92	0.00
Northern Hill Country	944	1	449	0	0	0	1	0	0.00	0.00	3.10	-

FMU-based baseline states

While sediment monitoring is carried out at representative sites in Taranaki, there are limitations as to how well the data can describe current state at the FMU scale. To help address these limitations, modelling has been used to make predictions of the baseline state for sediment at the river reach scale, across the entire Taranaki region.

Modelled data allows for an assessment of baseline states across both monitored and unmonitored waterways in the Taranaki region. Using modelled data, baseline states can be identified for each FMU, expressed as percentage waterway length in each FMU within each NOF attribute band. The site-based baseline states set using the long term SoE sites should be interpreted as site-specific and results are not necessarily indicative of the state of the overall FMU, while the modelled data and FMU-based baseline states portray patterns at a broader spatial scale and can be interpreted as applying to a section of river segments in an FMU, rather than strictly to a specific monitoring site.

The use of visual clarity and deposited sediment monitoring data alone has the potential to lead to biased conclusions given individual monitoring sites are non-random and are not entirely representative of the regional landscape and the pressures impacting on the health of the region's waterbodies. Although there is inherent uncertainty in the use of models, those presented here and described below provide the most comprehensive picture of the state of suspended and deposited fine sediment across the entire regional stream network.

Suspended fine sediment

The 'Taranaki water quality state spatial modelling' report delivers predictive spatial models of water quality state statistics for a five year period ending in 2017 (Fraser, 2022). The modelled data is based on a digital drainage network of the Taranaki region that describes a range of descriptors of the individual network segments and their upstream catchment characteristics. There are six catchment characteristics that were included in the model: geography and topography, climate, hydrology, geology, land cover, and stocking density data. Estimates of visual clarity were derived by combining monitoring site water quality statistics with predictors associated with the digital network to make predictions for unmonitored locations. The model results for visual clarity had satisfactory performance. Statistics such as median and 95th percentile values for black disc visibility (the field procedure used to measure visual clarity) were calculated for each river segment in the region.

Table 7 below shows the percentage of stream length of each FMU within each attribute band using modelling data with a map of the results presented in Figure 4.

Table 7: Percentage of stream length within each FMU with each suspended sediment attribute band based on modelled results from Fraser (2022).

Attribute band	Southern Hill Country	Coastal Terraces	Pātea	Volcanic Ringplain	Waitara	Northern Hill Country
A	64%	0%	39%	27%	54%	84%
B	11%	3%	12%	7%	12%	6%
C	10%	17%	16%	11%	7%	2%
D	16%	79%	32%	55%	27%	8%

The modelled estimates show that the majority of total stream reach across the Waitara, Southern Hill Country and Northern Hill Country FMUs fall in band A for visual clarity (54%, 64% and 84%, respectively). Whereas the majority of total stream reach in the Volcanic Ringplain and Coastal Terraces FMUs are graded within band D; below the national bottom line (55% and 79% respectively). The visual depiction of these results in Figure 4 show a clear gradient of decreasing visual clarity with distance downstream towards the coast in every FMU with indigenous forest land cover in the upper catchments, and agricultural pasture in the mid to lower catchments (see Table 6 for a summary of total stream length in different land cover classes for each FMU).

Although indigenous forest is the dominant land cover in the upper sections of the Southern Hill Country and Northern Hill Country FMUs, the proportions of stream reach graded in band A appear relatively high considering that the geology and terrain in both of these FMUs are particularly prone to high rates of sediment erosion. It should be noted that there was limited available monitoring data to calibrate the model in these areas, with data from neighbouring regions being used to help improve model performance. Improved monitoring coverage in these areas will help to provide improved understanding of suspended fine sediment concentrations in these waterways and can be used to calibrate subsequent iterations of spatial water quality models.

Deposited sediment

Spatial water quality modelling was also used to assess the baseline state for the deposited fine sediment, albeit using a separate model that was developed to make predictions at the national scale (Clapcott and Goodwin, 2017).

It should be noted that the performance of the model by Clapcott and Goodwin (2017) was poor, and that the model did not perform well at the extreme ends of environmental ranges, e.g. high altitudes. Still, the authors did find meaningful spatial patterns at the national scale. The model was able to attribute a moderate amount of the national-scale variation to land cover and natural environmental gradients at the segment scale using flexible spatial regression.

Unexplained variation in the model estimates may be due to finer scale processes that affect sediment distribution such as velocity and bed roughness, sediment quality such as organic content and particle size, or temporal variation; none of which were accounted for in the model. As such, the ability to accurately estimate reference condition was restricted by the strength of explanatory models and a lack of representative reference sites. However, examination of four different data sets used in the modelling exercise provided a body of evidence from which some inferences can be made.

The results used to assign NOF band grades for deposited sediment are based on the data recommended by the authors of the model report. However, the authors do not recommend the model output be used in isolation to inform the values, and instead find it reasonable to use the value as a basis for regional verification of exceptions to the < 20% sediment cover class. According to the data used to establish reference (baseline) values, the bulk of such exceptions appear to be located in areas that we would expect to see high sediment cover naturally due to low slope, low elevation and erodible geologies.

The model provides a predicted reference state (defined by the absence of a change in land cover due to human land use and therefore interpreted to represent the baselines state) from a boosted regression tree model trained on reference site data defined by land cover rules, and all available deposited sediment data. As with the model output from the suspended sediment attribute, the dataset used to establish the deposited sediment baseline values was reported at the REC stream segment scale. Therefore we were able to assess the percentage of stream length of each FMU within each attribute band, with results presented in Table 8 and Figure 5.

Table 8: Percentage of stream length within each FMU with each deposited sediment attribute grade based on modelled results from Clapcott and Goodwin (2017).

Attribute band	Southern Hill Country	Coastal Terraces	Pātea	Volcanic Ringplain	Waitara	Northern Hill Country
A	14%	2%	11%	39%	27%	9%
B	24%	9%	38%	24%	47%	46%
C	22%	6%	22%	13%	17%	29%
D	27%	21%	24%	20%	9%	16%
NSB	14%	62%	5%	4%	0%	0%

NSB: Naturally soft-bottomed

Results of the model show a relatively even distribution of total stream reach across the various attribute bands in each FMU, with no FMU categorised by one single band (Table 8). The percentage of total stream reach below the national bottom line (D band) ranged from 27% in the Southern Hill Country, to 9% in the Waitara Catchment. As with the visual clarity modelled estimates, deposited fine sediment state is generally best in the upper catchments, and lowest in the mid to lower catchments (Figure 5). The visual depiction in Figure 5 also highlights an area in South Taranaki that is classified as having naturally soft bottomed stream habitat. This area overlaps with the Volcanic RIngplain, Pātea, Coastal Terraces and Southern Hill Country FMUs, and is the dominant stream classification for the Coastal Terraces, comprising 62% of total stream reach. The deposited fine sediment attribute does not apply to naturally soft bottomed streams. The results of the model demonstrate the diverse conditions that contributes to a wide but relatively even distribution of deposited fine sediment state across each FMU.

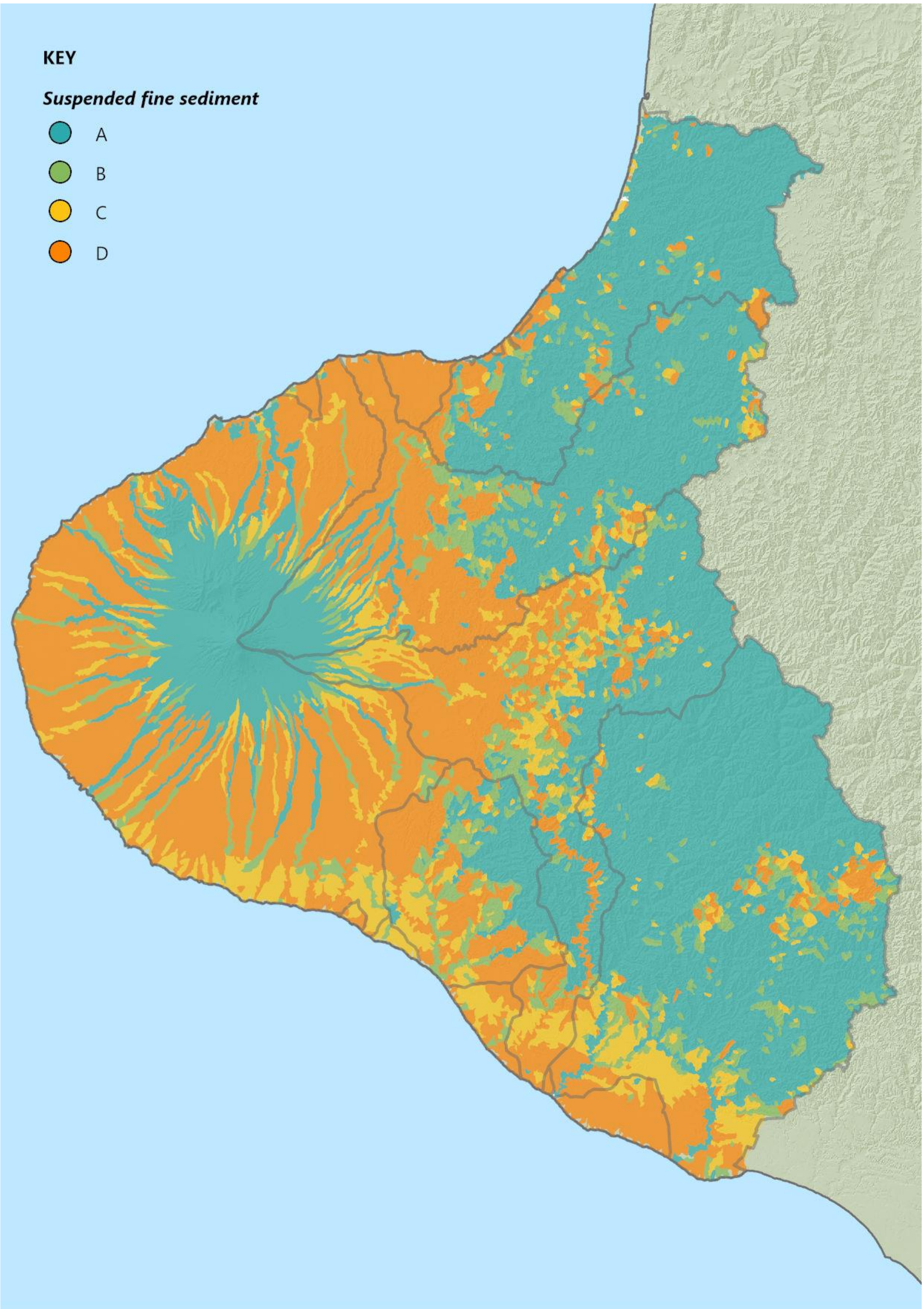

Figure 4: Map of the Taranaki region with visual clarity attribute band grades of stream segments expanded to contributing watershed.

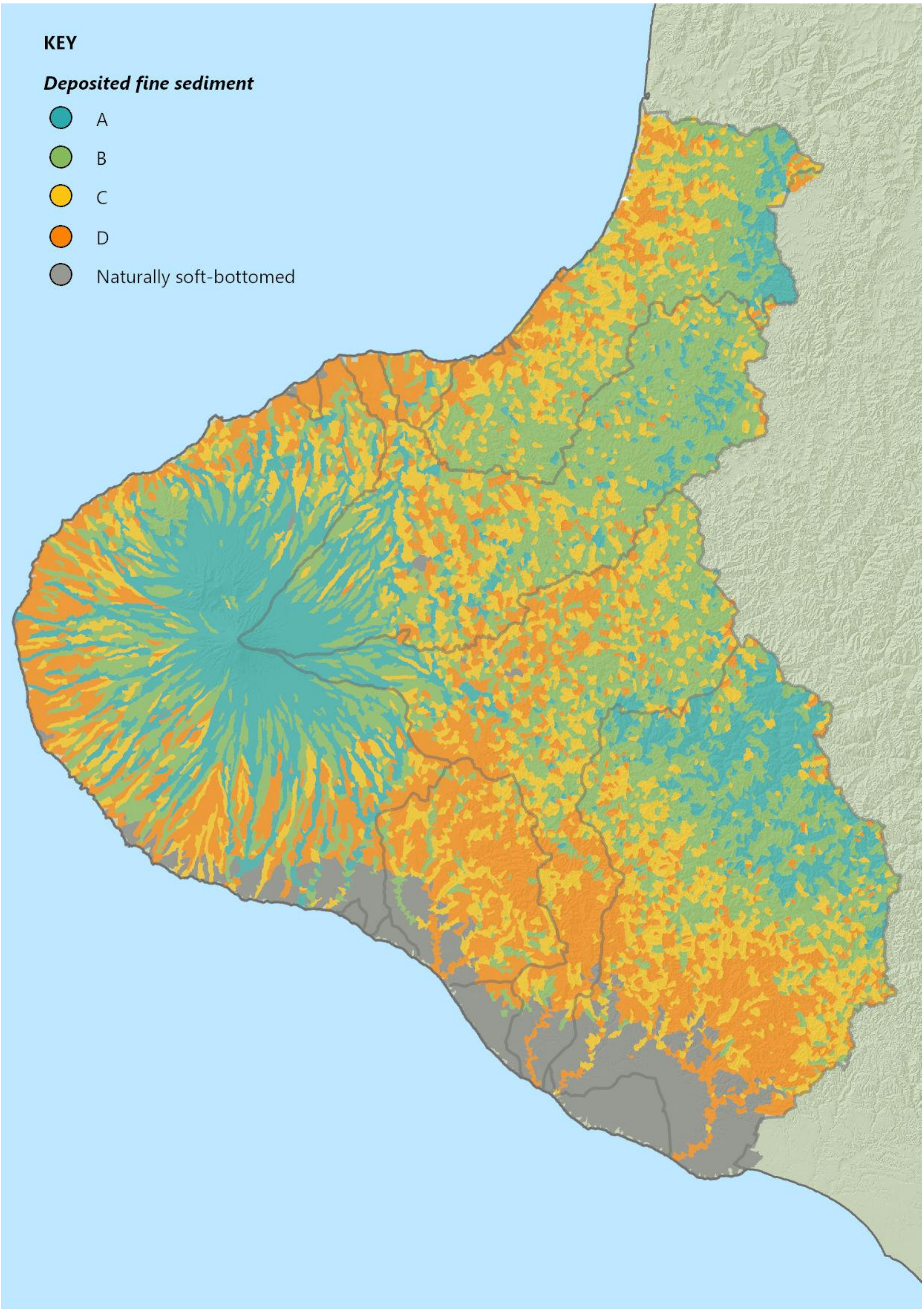

Figure 5: Map of the Taranaki region with the reference (baseline) deposited sediment attribute band grades of stream segments expanded to contributing watershed.

Recommendations

Draft baseline states have been calculated for both monitoring sites and the stream network, to provide the best known state for the deposited and suspended fine sediment attributes as an indicator of ecosystem health across each FMU.

Consideration should be given towards setting target attribute states at broader spatial scales (e.g. at catchment or FMU scale) in addition to specified monitoring sites, given the available spatial modelling information. This approach recognises that environmental outcomes are intended to be achieved for all waterbodies rather than only at a select few monitoring sites. Target attribute states will need to be set at a level that (at a minimum) achieves the baseline state, or exceeds the baseline state where this is necessary to achieve improvement.

To support the target setting process, possible actions and mitigations that are available to promote the maintenance and improvement of freshwater in relation to suspended and deposited fine sediment must be identified and assessed. This work is currently underway, with Manaaki Whenua Landcare Research (MWLR) having developed a regional model using SedNet to assess the impact of a range of scenarios on suspended fine sediment concentrations in Taranaki rivers and streams. The existing mitigations that are already being investigated include the completion of the riparian fencing and planting programme, and full implementation of TRC hill country farm plans. The effects of climate change on soil erosion have also been simulated, and the relative contributions of sediment from natural and non-natural land cover areas have been estimated. Further mitigation strategies are also being considered. Assessing a broad range of possible mitigation actions for improving water quality will help to inform the target setting process by providing an indication of what can realistically be achieved under different scenarios.

Finally, additional river monitoring sites will need to be established for both suspended fine sediment and deposited fine sediment in order to achieve monitoring coverage in all FMUs, and appropriate representativeness across the region.

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Appendix 1

Table 1: Date ranges and number of samples in the record analysed for suspended fine sediment site-based baseline setting

Freshwater Management Unit	Site Code	Record from earliest sampling date				Record ending September 2017			
		Date start	Date ending	Number of samples	Data source	Date start	Date ending	Number of samples	Data source
Southern Hill Country	TWH000435	19/10/2017	15/09/2022	48	TRC	No data			
	WNR000450	10/03/2016	11/02/2021	57	TRC	10/03/2016	7/09/2017	18	TRC
Pātea	MGH000950	23/06/1995	10/05/2000	60	TRC	12/9/2012	9/8/2017	60	TRC
	MKR000495	14/11/2018	14/12/2022	36	TRC	14/11/2018	7/09/2017	10	TRC
	PAT000200	13/07/1995	14/06/2000	60	TRC	10/10/2012	13/09/2017	60	TRC
	PAT000360	13/07/1995	14/06/2000	60	TRC	10/10/2012	13/09/2017	60	TRC
Volcanic Ringplain	KPA000950	12/07/2017	14/12/2022	51	TRC	No data			
	MRK000420	23/06/1995	10/05/2000	60	TRC	12/9/2012	9/8/2017	60	TRC
	PNH000200	13/07/1995	14/06/2000	60	TRC	12/9/2012	9/8/2017	60	TRC
	PNH000900	13/07/1995	14/06/2000	60	TRC	12/9/2012	9/8/2017	60	TRC
	STY000300	23/06/1995	10/05/2000	60	TRC	12/9/2012	9/8/2017	60	TRC
	WGG000500	13/07/1995	14/06/2000	60	TRC	12/9/2012	9/8/2017	60	TRC
	WGG000900	8/7/1998	9/6/2003	60	TRC	10/10/2012	13/09/2017	60	TRC
	WKH000500	13/07/1995	14/06/2000	60	TRC	12/9/2012	9/8/2017	60	TRC
	WKR000500	12/08/2021	07/03/2023	20	TRC	No data			
	WKR000700	13/6/2011	1/6/2016	60	TRC	09/08/2012	07/08/2017	60	TRC
Waitara	MGN000195	26/01/1989	11/01/1994	60	NIWA	10/10/2012	7/09/2017	6	TRC
	MKW000300	09/07/2003	11/06/2008	60	TRC	12/9/2012	9/8/2017	60	TRC
	MTA000068	14/06/2017	17/05/2022	55	TRC	14/06/2017	13/09/2017	1	TRC
	WTR000540	10/03/2016	11/02/2021	59	TRC	10/03/2016	7/09/2017	18	TRC
	WTR000800	26/01/1989	11/01/1994	60	NIWA	No data			
Northern Hill Country	WMR000100	14/06/2017	17/05/2022	51	TRC	14/06/2017	7/09/2017	1	TRC

Table 2: Date ranges and number of samples in record analysed for deposited fine sediment site-based baseline setting

<table>
<tr><th rowspan="2">Freshwater Management Unit</th><th rowspan="2">Site Code</th><th colspan="4">Record from earliest sampling date</th><th colspan="4">Record ending September 2017</th></tr>
<tr><th>Date start</th><th>Date ending</th><th>Number of samples</th><th>Data source</th><th>Date start</th><th>Date ending</th><th>Number of samples</th><th>Data source</th></tr>
<tr><td>Southern Hill Country</td><td>TWH000435</td><td>19/10/2017</td><td>11/11/2021</td><td>40</td><td>TRC</td><td colspan="4" rowspan="12">No data</td></tr>
<tr><td>Pātea</td><td>MKR000495</td><td>14/11/2018</td><td>11/11/2021</td><td>32</td><td>TRC</td></tr>
<tr><td rowspan="6">Volcanic Ringplain</td><td>KPA000950</td><td>31/10/2017</td><td>10/11/2021</td><td>48</td><td>TRC</td></tr>
<tr><td>PNH000200</td><td>19/10/2017</td><td>11/11/2021</td><td>51</td><td>TRC</td></tr>
<tr><td>PNH000900</td><td>12/10/2017</td><td>11/11/2021</td><td>51</td><td>TRC</td></tr>
<tr><td>STY000300</td><td>30/10/2017</td><td>10/11/2021</td><td>41</td><td>TRC</td></tr>
<tr><td>WGG000500</td><td>12/10/2017</td><td>11/11/2021</td><td>45</td><td>TRC</td></tr>
<tr><td>WKH000500</td><td>25/10/2017</td><td>10/11/2021</td><td>44</td><td>TRC</td></tr>
<tr><td rowspan="3">Waitara</td><td>MGN000195</td><td>22/12/2016</td><td>19/10/2021</td><td>47</td><td>TRC</td></tr>
<tr><td>MKW000300</td><td>30/01/2017</td><td>10/11/2021</td><td>47</td><td>TRC</td></tr>
<tr><td>MTA000068</td><td>14/11/2017</td><td>16/11/2021</td><td>44</td><td>TRC</td></tr>
<tr><td>Northern Hill Country</td><td>WMR000100</td><td>14/11/2017</td><td>16/11/2021</td><td>43</td><td>TRC</td></tr>
</table>