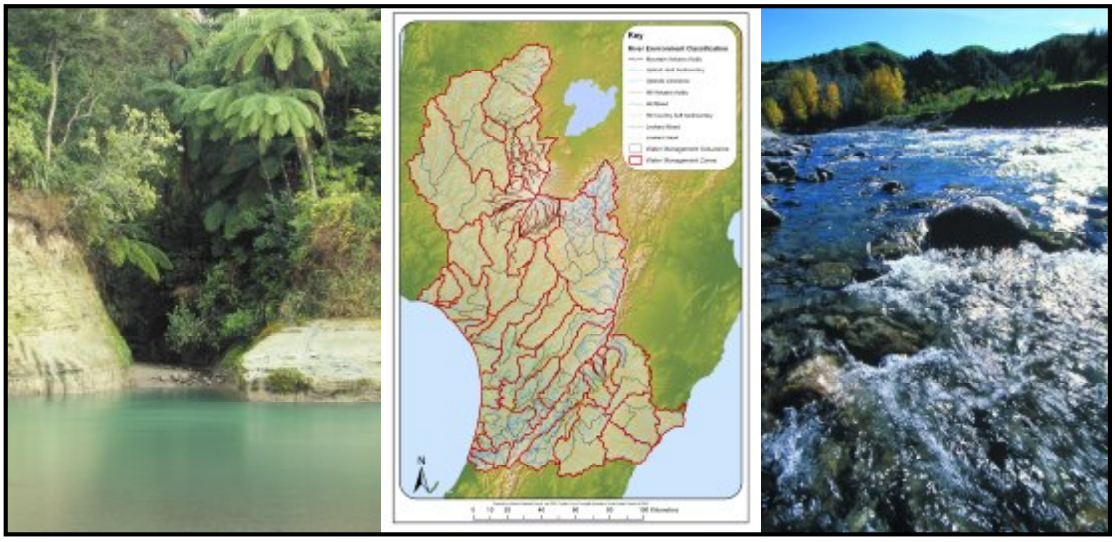
River Classification of the Manawatu-Wanganui Region to Support the Definition of the Life-Supporting Capacity Value:

Technical Report to Support Policy Development



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River Classification of the Manawatu-Wanganui Region to Support the Definition of the Life-Supporting Capacity Value: Technical Report to Support Policy Development

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May 2007

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EXECUTIVE SUMMARY

This report is part of a suite of technical reports to support the development of the water and catchment management regime proposed by Horizon's new Regional Plan, the One Plan.

A key goal for this regime will be to ensure the values our regional community places on our rivers and lakes are maintained or improved. Twenty three waterbody values, applying to all or parts of the Region's rivers and lakes, have been identified in a separate report (Ausseil and Clark, 2007). These values will be identified in the One Plan and translated into water and catchment management policies, including water quality standards.

The Life-Supporting Capacity recognises that waterbodies should support healthy aquatic ecosystems. As per the Resource Management Act 1991 (RMA) Section 5 (Purpose and Principles), the ability to support life should be safeguarded in all natural aquatic ecosystems, and it is recommended the One Plan recognises the Life-Supporting Capacity value in all natural rivers and lakes of the Region.

The Region's waterbodies are naturally very diverse, and "one size fits all" policy objectives and tools would not adequately recognise and protect such diversity.

A river classification exercise was undertaken, with the aim of defining a number of broad ecosystem types, to support the definition of the Life-Supporting Capacity value.

Eight river ecosystem types (classes) were defined using a modified version of the River Environment Classification (REC), based on a combination of the elevation of the source of flow and the geology underlying the catchment. Two other categories, comprising respectively the freshwater lakes and the coastal waters, have also been defined separately from this process.

The Life-Supporting Capacity, recommended for inclusion in the One Plan, uses these 10 aquatic ecosystem classes. It is expected this will allow a better match between the policy objectives and tools, including water quality standards, by tailoring management to the natural characteristics of different freshwater systems in the Manawatu-Wanganui Region.

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1 Context and Goals

As part of the development of its new Regional Plan (the One Plan), Horizons Regional Council (Horizons) is developing a new framework for the management of the Region's water resource[1]. A key step in the process is to identify the values associated with the Region's rivers and lakes.

These values will be identified in the One Plan and translated into water and catchment management policies, including water quality standards.

The capacity of lakes and rivers to support life (Life-Supporting Capacity, or LSC) is one of these values. Maintaining this value has been identified as central to the community's aspirations and is consistent with the purpose of the RMA. It is expected the One Plan will recognise the Life-Supporting Capacity value in all natural water bodies of the Region, as recommended in Ausseil and Clark (2007).

Rivers and streams, and the aquatic communities they support, are highly variable across the Region: a stream flowing on Mt Ruapehu's slopes is naturally very different from a stream flowing in the Manawatu lowland plains.

To allow the LSC value to account for this natural variability, a river ecosystem classification was developed, to define a number of river "types" or classes within which biological and physical characteristics are expected to be relatively uniform.

This report summarises the methodology used to define river classes in the Manawatu-Wanganui Region.

The Region contains a number of significant lakes, mostly located in the coastal area. Relatively little data is available about these lakes, and no classification tool is currently available. For these reasons, we are not in a position to confidently propose a lake classification.

2 Methodology

2.1 Potential River Classification Tools

2.1.1 The River Environment Classification (REC)

The REC is a river classification tool developed by NIWA for the Ministry for the Environment (MfE), and documented in detail in Snelder *et al*. (2002).

The REC is a GIS[2] based framework containing 6 controlling factors, or layers of information (eg. climate, geology, source of flow, and land cover) associated with unitary catchments and river reaches (Table 1). Each information layer provides a classification based on the parameter considered. By combining the classifications from different layers, the user can define more detailed classes.

[1] The reader is invited to refer to the associated "values" report (Ausseil and Clark, 2007) that describes in some detail the recommended approach for the new water management framework.

[2] Geographical Information System.

The REC's 6 layers of information contain between 3 and 9 categories each, providing a potential of more than 27,000 combined river classes. Consequently, the REC user faces the challenge to select and use only the layers that are directly relevant to the goal of the classification undertaken, to restrict the number of river classes to a workable number.

Table 1: The River Environment Classification (REC) information layers, number of categories per layer, and examples of categories relevant to the Manawatu-Wanganui Region.

Layer	Categories per layer	
	Number	**Examples (relevant to the Region)**
Climate	6	• Warm-Wet • Warm-Dry • Cool-Extremely Wet • Cool-Wet
Source of Flow	8	• Mountain • Hill • Low Elevation • Lake
Geology	7	• Alluvium • Hard Sedimentary • Soft Sedimentary • Volcanic Acidic
Land Cover	9	• Indigenous Forest • Scrub • Exotic Forest • Pastoral • Tussock
Network Position	3	• Low Order • Middle Order • High Order
Valley Landform	3	• Low Gradient • Medium Gradient • High Gradient

2.1.2 Land Environments New Zealand (LENZ)

LENZ is a GIS-based ecosystem classification tool developed by Landcare Research (Leathwick *et al.*, 2003). As for REC, it uses different layers of information and allows the user to combine them to obtain an ecosystem classification. The focus of LENZ is primarily to provide a classification framework for terrestrial ecosystems, such as forest, shrubland and tussockland. The aquatic component of the ecosystems is not accounted for in LENZ. For this reason, we concluded that LENZ does not suit the purpose of the river classification required.

2.1.3 Freshwater Environments of New Zealand (FWENZ)

FWENZ is another GIS-based classification tool developed by the Department of Conservation, in association with NIWA and Landcare Research, for the Ministry for the Environment. It uses environmental variables, such as climate and catchment land use, to predict the distribution and composition of aquatic communities.

At the time of undertaking this river classification, FWENZ was not fully developed, and still very much a research tool. Further development and

testing was required before FWENZ could directly be applied to resource management decision-making.

2.1.4 Selected tool

The REC framework was selected as the most appropriate, currently available, tool to define the different river types in the Manawatu-Wanganui Region.

2.2 Application of the REC Framework to this River Classification

2.2.1 Information layer selection

The relevance of the REC's six GIS information layers to determining the river types of the Manawatu-Wanganui Region was assessed as summarised in Table 2.

Because this work was undertaken to support policy development, it was decided the number of river classes should not be too high, ideally in the order of 10 different classes.

Research on New Zealand rivers has shown geology and flow variability (related to source of flow) to be key drivers of water quality and biota (Biggs, 1995; Snelder *et al*., 2005; Biggs *et al*., 1990). Thus, the geology and source of flow layers were considered very relevant for this exercise.

Two of the other layers (landcover and network position) were considered not relevant to this exercise, and the information and conclusions provided by another two (climate and valley landform) were, in the specific context of the Manawatu-Wanganui Region, vastly redundant with the Source of Flow layer.

Selecting only the two most relevant layers was also consistent with the goal of defining a maximum of 10 river categories.

Table 2: REC information layers selected for the river classification, and reasons for the selection.

Layer	Selected for classification?	Reasons
Climate	No	Climate was considered very relevant to the goals of this river classification. However, rainfall in the Manawatu Region is directly related with the topography, causing widespread redundancy with the "Source of Flow layer.
Source of Flow	Yes	Very relevant to the stream/river type.
Geology	Yes	Catchment geology is the main determinant of river bed substrate and some physico chemical (eg. clarity, pH) characteristics of the water. These in turn greatly influence aquatic habitat types and communities composition.
Land Cover	No	Not considered relevant to a classification of natural characteristics, as it gives an indication of the level of modification and pressure but is not an indicator of natural characteristics of the streams.
Network Position	No	Not relevant for a classification by water management zone (see Section 3.1)
Valley Landform	No	Redundancy with source of flow in the Region

2.2.2 Limitations of the original REC for river classification in the Horizons Region, and proposed modifications

The original REC geology and source of flow layers were carefully tested to assess their suitability for this river classification exercise. As detailed below, a number of changes to the original layers were made to:

- better suit the purpose of this classification, or
- correct some errors in the original model's data, or
- provide a better fit with the natural characteristics of the Region.

2.2.2.1 Geology layer

- The original REC geology layer was developed from the "toprock" geology category provided by the New Zealand Land Resource Inventory (LRI), except when the LRI toprock category was loess, alluvium or peat, in which case the LRI "baserock" category was used (Snelder *et al*., 2004). This approach recognises the fact that the catchment toprock is the key determinant of river bed and river bank type, except when this toprock is a relatively thin layer of easily eroded material. To a large extent, we agree with this approach, but also consider all easily erodible soils, eg. pumice soils, should be treated the same way. Whilst this approach offers the advantage of resulting in only one geology classification, it has some limitations. One could argue that the toprock is a major determinant in local stream bed and stream bank morphology, which in turn determines the instream and riparian physical habitat. The approach taken for this work was to undertake two separate classifications, using baserock and toprock information. The information from these two separate classifications was then collated for the river classification by water management zone (Section 3.2).

- When first trialled, the original geology layer output classified a large number (about a quarter) of stream reaches within the Horizons Region as "miscellaneous". When referring to the REC User Guide (Snelder *et al*., 2004), the "miscellaneous" class includes infrequent soil types, such as peat and urban soils. However, when compared with the LRI data, the "miscellaneous" seemed to correspond to the location of sandstone toprock
- . The raw REC data was obtained from Ton Snelder. After further investigation, it appeared that a large number of rock types, particularly within the "soft sedimentary" class, of the original REC data had been mislabelled (Figure 1). The LRI data was used to check and, where necessary, re-label all geology types and produce two information layers based on the LRI toprock and baserock information.

- The REC incorporates the LRI geology types into seven categories, to "broadly describe the rock types present in the catchment of each network section" (Snelder *et al.* 2004). We strongly agree with this approach as it is the only pragmatic way to limit the number of classes. However, we considered some geology types, such as limestone or windblown sand, should not be amalgamated with others, as they lead to very particular stream/river types. Table 3 summarises details how the LRI geology categories have been clumped to define the modified REC geology classes used in this classification exercise.

Table 3: Modified geology classification (abbreviations as per LRI).

Category	LRI Category
Alluvium	Al, Gr
Hard Sedimentary	Gw
Limestone	Li
Loess	Lo
Peat	Pt
Soft Sedimentary	Us, Mm, Mb, Mj, Me, Sm, Sb, Cg, Ar, Ac, Mx
Volcanic Acidic	Ng, Mo, Tp, Ta, Vo, Kt, La
Wind Blown	Wb

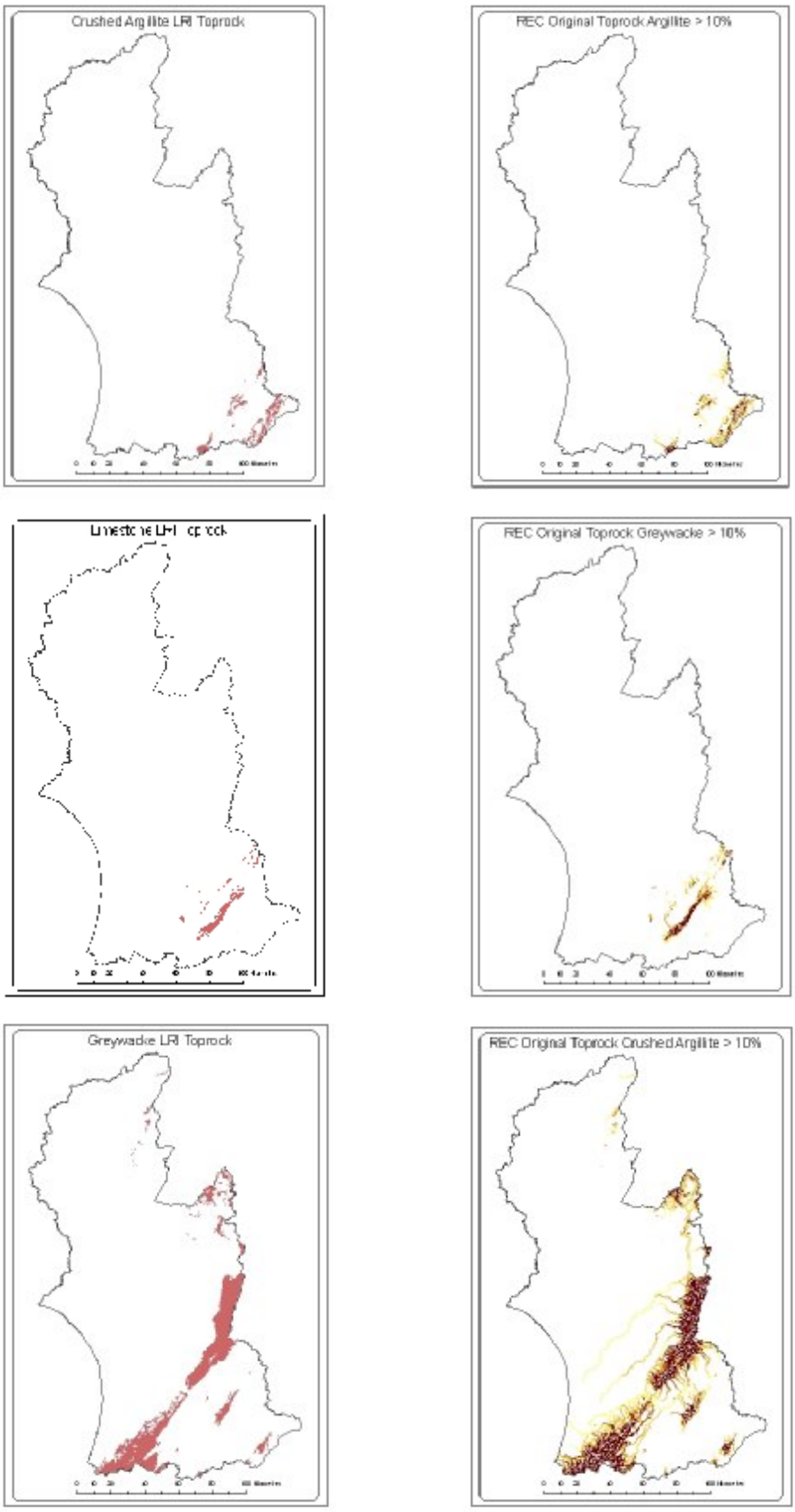


Figure 1: Examples of comparison between the REC geology layer's raw data and the LRI toprock information.

2.2.2.2 Source of flow layer

The original REC "source of flow" (SoF) layer defines 8 categories. It provides an estimate of the dominant source of flow, based on the distribution of rainfall within the upstream catchment, and an estimate of the influence of lakes (Snelder *et al.*, 2004). As summarised in Table 4, only three categories were considered relevant to both the natural characteristics of the Manawatu-Wanganui Region and the purpose of the river classification undertaken. The three SoF categories retained describe the elevation of the dominant source of flow for each river reach.

Table 4: REC source of flow categories selected for the river classification, and reasons for the selection.

Category	Selected for classification?	Reasons
Glacial-mountain	No	Absent from the Region.
Mountain	Yes	Very relevant to the stream/river type.
Hill	Yes	
Low Elevation	Yes	
Lake	No	Only two streams in the Horowhenua plains. Were merged with lowland category.
Spring	No	Extremely little information available – renders this category too inconsistent to use.
Wetland	No	
Regulated	No	Not relevant to the natural characteristics of the rivers.

The original REC used the following cut-offs: 400 m and 1000 m to separate the Lowland/Hill/Mountain categories. While 1000 m was considered an appropriate threshold between Mountain and hill categories, 400 m was considered too high to appropriately differentiate the lowland streams from the hill country streams in the Manawatu-Wanganui Region. For example, the original REC classifies most of the Upper Manawatu catchment as lowland streams and rivers. This was considered inappropriate as these streams and rivers definitely have hill country characteristics. In the Manawatu-Wanganui Region, the true lowland streams take source, and flow, within the Manawatu and Rangitikei plains, and their source of dominant flow is usually under 200 m of elevation. The 200 m cut off was found to provide a better fit to the Region's characteristics and therefore adopted (Table 5).

Table 5: Category and elevation thresholds for the source of flow classification.

Category	Elevation Band
Mountain	>1000 m
Hill	200 m – 1000 m
Lowland	< 200 m

3 River Environment Classification for the Manawatu-Wanganui Region

3.1 River Classification by River Reach

3.1.1 Geology layer

Eight categories were defined based on the rock and soil characteristics and their recognised influences on the river substrate and water quality (Table 3). Each REC unitary reach was then classified according to the dominant (highest percentage) geology within the associated catchment.

An exception occurred for the soft sedimentary where a 40% threshold was used instead of the 25% threshold of the original REC. Thus, if any reach had 40% or more soft sedimentary it was classified as a soft sedimentary geology over any dominant geology. Because of the natural geology of the Region, a very large number of stream reaches have more than 25% soft sedimentary geology in their associated catchment. The change for the 40% threshold allowed a better discrimination between the streams moderately and heavily influenced by soft sedimentary geology.

Two classifications were done, relating to the LRI toprock and baserock information.

3.1.2 Source of flow layer

Three categories were defined, based on the elevation of the source of dominant flow. The thresholds used are summarised in Table 5.

3.1.3 Combined geology/source of flow classification

The combined geology/source of flow classification produces a theoretical maximum of 24 classes. Of these, 6 are not represented in the Region, and another 6 represent less than 1% of the Region's river reaches. The remaining 12 classes represent between 2 and 47.1% of the river reaches in the Region (**Error! Reference source not found.**).

In a context of regional resource management policy, it was considered that 18 river classes would be too many, and 5 to 10 categories was a more manageable number. Hence, some classes obtained with the first classification step were grouped, as summarised in Table 7.

The results of the toprock and baserock classifications are presented in Map 1 and Map 2.

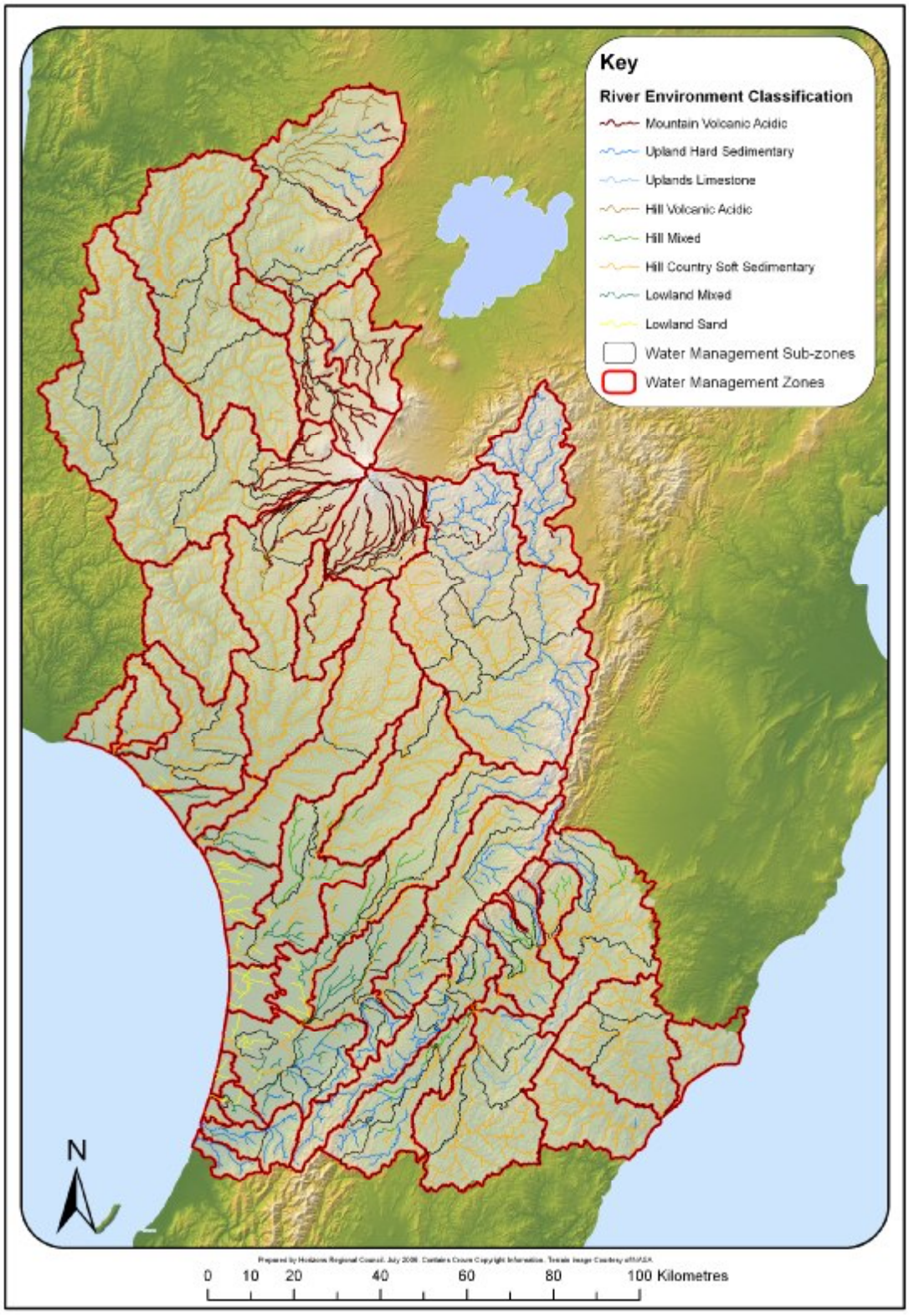
Table 6: Source of flow/geology classification and regional percentage.

Category (Source of flow/geology)	Percentage of reaches
Hill Alluvium	<1
Hill Hard Sedimentary	5
Hill Limestone	<
Hill Loess	5
Hill Peat	0
Hill Soft Sedimentary	47
Hill Volcanic Acidic	12
Hill Wind Blown	0
Lowland Alluvium	2
Lowland Hard Sedimentary	<1
Lowland Limestone	0
Lowland Loess	4
Lowland Peat	<1
Lowland Soft Sedimentary	3
Lowland Volcanic Acidic	<1
Lowland Wind Blown	3
Mountain Alluvium	<1
Mountain Hard Sedimentary	4
Mountain Limestone	0
Mountain Loess	<1
Mountain Peat	<1
Mountain Soft Sedimentary	2
Mountain Volcanic Acidic	13
Mountain Wind Blown	0

Table 7: Proposed river environment classes for the Manawatu-Wanganui Region.

Category (Source of flow/geology)	Percentage of reaches	Proposed classes	Reason
Mountain Volcanic Acidic (MVA)	13	MVA (Mountain Volcanic Acidic)	A category on its own, representing a significant percentage of streams around the Central Plateau area.
Hill Volcanic Acidic (HVA)	12	HVA (Hill Volcanic Acidic)	Only a very small number of streams in the LVA class, and geographically adjacent to HVA.
Lowland Volcanic Acidic (LVA)	<1		
Mountain Hard Sedimentary (MHS)	4	UHS (Upland Hard Sedimentary)	MHS and HHS are part of a continuum along the same streams. These streams are usually short, and two categories are not justified, as they would not describe significantly different streams.
Hill Hard Sedimentary (HHS)	5		
Lowland Hard Sedimentary (LHS)	<1		LHS contains only a very low number of short stream sections and are geographically adjacent to UHS.
Hill Limestone (HLi)	1	UL (Upland Limestone)	Only a very small percentage of regional reaches in these categories, but the limestone-based streams are particular enough to justify a class. The LLi category represent only a few reaches that are geographically adjacent to the HLi category.
Lowland Limestone (LLi)	<0.05		
Mountain Soft Sedimentary (MSS)	2	HCSS (Hill Country Soft Sedimentary)	Only a very small number of streams in the MSS and LSS classes, and geographically adjacent to HSS.
Hill Soft Sedimentary (HSS)	47		
Lowland Soft Sedimentary (LSS)	3		
Hill Alluvium	<1	HM Hill Mixed	HM and HL tend to occur in the same areas, and to be mixed within adjacent stream reaches.
Hill Loess	5		
Lowland Alluvium	2	LM Lowland Mixed	LA and M and HL tend to occur in the same areas, and to be mixed within adjacent stream reaches. It was considered a single class would better represent this stream type. LP and LU represent only a very small number of stream reaches, and does not constitute a significant part of any catchment.
Lowland Loess	4		
Lowland Peat	<1		
Lowland Unconsolidated	<1		
Lowland Wind Blown	3	LS Lowland Sand	A class on its own, representing most coastal streams in the Horowhenua, Manawatu and Rangitikei plains.
Mountain Alluvium	<1	N/A	Not considered significant in the Manawatu-Wanganui Region.
Mountain Loess	<1		
Mountain Peat	<1		

Map 1: River classification for the Manawatu-Wanganui Region based on the combined source of flow/geology toprock information layers.



Map 2: River classification for the Manawatu-Wanganui Region based on the combined source of flow/geology baserock information layers.

3.2 River Classification by Water Management Zone

Horizons has defined 44 water management zones (WMZ) and 117 water management subzones (WMsZ) as the spatial framework for its proposed new water management regime. These zones and subzones correspond to catchments or subcatchments, and are described in McArthur *et al*. (2007).

Major geology or elevation changes were part of the considerations when the WMZ were defined. However, other considerations, such as location and intensity of the pressures on the water resource (eg. water abstractions, discharges to water, and intensive land-use), and the existence of water quality and river flow information, were also part of the decision-making process. For this reason, the delineation of the water management zones and subzones does not always correspond to the limits between river classes. Moreover, most management zones contain several river classes.

For the sake of clarity and workability in a resource management context, it was considered the water management subzones were the smallest practicable management unit. It was therefore decided to define only one river class per water management subzone (WMsZ).

For each WMsZ individually, the source of flow and geology mixes in the zone itself and, where applicable, within the catchment above, were considered and used to make a final decision for the classification by WMsZ.

In many WMsZ a river class was found to be heavily dominant. In these cases, the decision was straight forward and the WMsZ was classified according to the original river class (eg. hill soft sedimentary (HSS), upland hard sedimentary (UHS), upland volcanic acidic (UVA), and lowland sand (LS)).

A number of other zones had no dominant river classes, particularly in areas where alluvium (eg. gravel) or loess have been deposited over sedimentary rocks (eg. greywacke or mudstone). A typical example of this is the Upper Manawatu catchment, where the geology varies widely both horizontally (across the landscape) and vertically (toprock *vs* baserock) within a given management zone or subzone (Map 1 and Map 2). Two classes were created to account for this mixed geology context; hill mixed (HM) and lowland mixed (LM).

The upland volcanic mixed (UVM) class was defined to describe catchments with soft sedimentary rocks underlying “tender” ash or pumice.

Details, including a set of “rules” leading to the final classification by zone, are provided in Appendix One. Table 8 summarises the final 8 Life-Supporting Capacity river classes and provides typical examples, while Map 3 shows the final classification.

4 Conclusion

Eight river classes were defined, representing 8 major freshwater riverine environment types in the Manawatu-Wanganui Region. These will be complemented by two additional classes for the lakes and coastal environments.

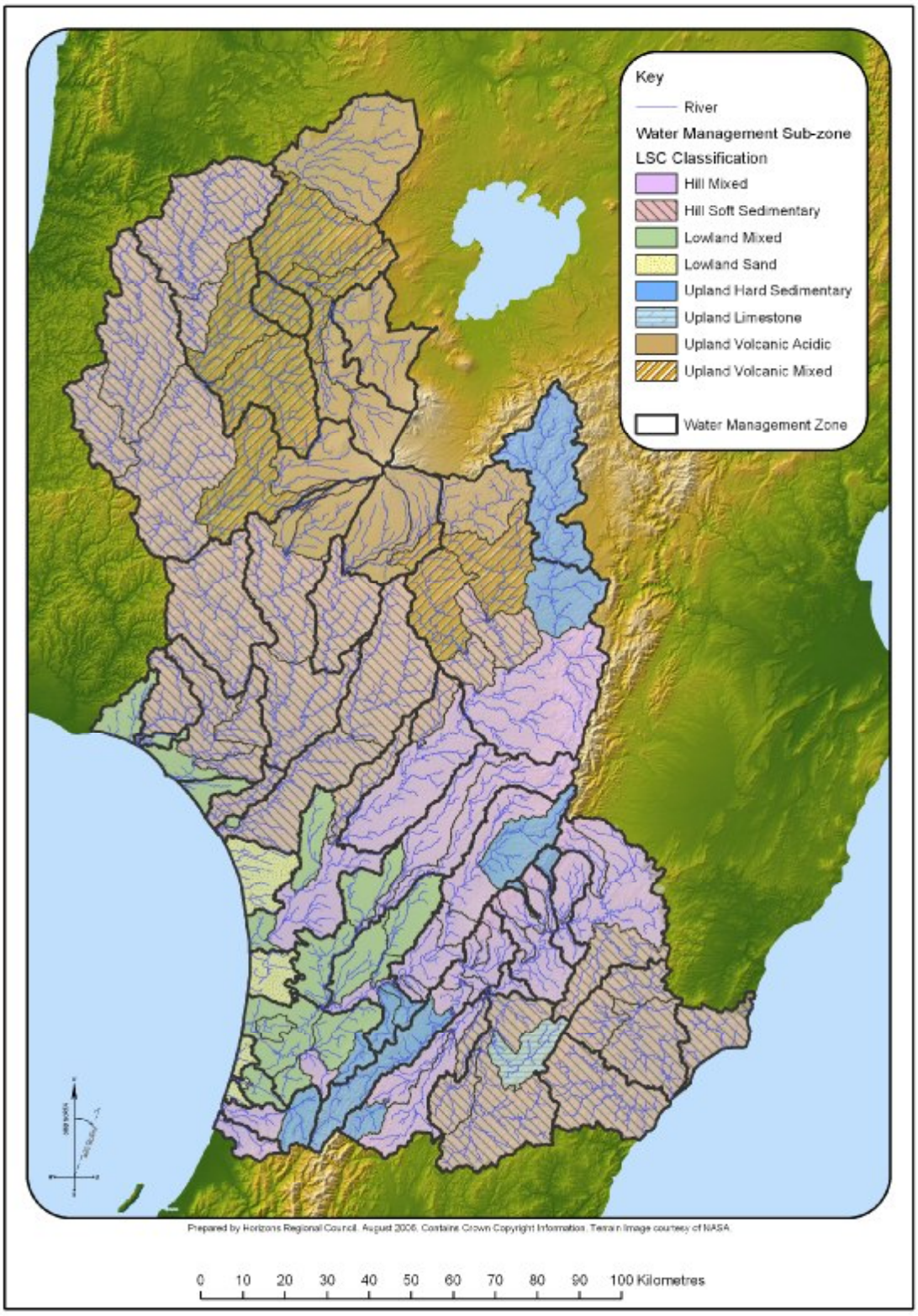
A classification exercise can be as detailed or as broad as required; the key challenge being to strike the right balance between an overly detailed classification, resulting in an unworkable number of classes, and too broad a classification, where classes are too heterogeneous to be meaningful.

The river classification exercise presented in this report was constrained by its policy development context, where 10 classes was considered a maximum workable number. The water management zones and subzones developed for the One Plan also provided the spatial framework, thus defining the scale at which the classification had to be relevant.

Whilst it is recognised there is an inevitable level of heterogeneity inside a given zone, and between zones classified under the same class, we believe this classification provides a pragmatic, science-based framework for developing relevant and realistic water management policies for each river and stream in the Region.

Table 8: Description and typical examples of water management subzone classes.

WMZ class	Source of flow	Geology	Typical river type	Examples
Lowland Sand (LS)	Lowland	Windblown sand dominant.	Western coastal streams. A large proportion of these streams flow either into or out of coastal lakes.	West coast zones.
Lowland Mixed (LM)	Lowland	No dominant geology, generally a mix of sand, loess, alluvium and soft sedimentary.	Medium to slow flowing streams/rivers. Bed material a mix of gravel and soft sediments.	Mangaone Stream, lower Manawatu and lower Rangitikei.
Hill Mixed (HM)	Predominantly Hill	Hill country zones with no dominant geology class. Geology is generally a mix of alluvium, SS, HS and loess.	Typically rivers with a gravel/cobble bed, receiving base flow from the Tararua or Ruahine Ranges, but also influenced by soft sedimentary geology, impacting on water clarity/bed siltation.	Upper and middle Manawatu, Pohangina, Mangatainoka, Middle Rangitikei and some tributaries.
Upland Hard Sedimentary (UHS)	Predominantly Hill with some Mountain	Predominantly greywacke.	Typically streams flowing from the Tararua and Ruahine Ranges.	Tamaki, Turitea, Kahuterawa, Mangahao, upper zones of the Rangitikei, Mangatainoka, Pohangina and Oroua.
Upland Limestone (UL)	Hill	Predominantly limestone.	Streams flowing off the Puketoi Range.	Makuri River
Upland Volcanic Acidic (UVA)	Predominantly Mountain with some Hill	Volcanic acidic soils (ash, pumice) over mostly hard sedimentary (greywacke) or hard volcanic rocks (ignimbrite, lavas).	Rivers flowing off the Ruapehu – Tongariro area, Kaimanawa and Hauhungaroa Ranges. Typically cold, clear, fast flowing rivers on rock/boulder/cobble bed.	Upper zones of: Moawhango, Whangaehu, Mangawhero, Manganui o Te Ao, Whanganui, Whakapapa and Ongarue.
Upland Volcanic Mixed (UVM)	Predominantly Hill with some Mountain	Volcanic acidic soils (ash, pumice) over mostly soft sedimentary (sandstones, mudstones).	Rivers flowing off the Central Plateau area. Often transitions zones between UVA and HSS zones.	Upper Hautapu, lower Manganui o Te Ao, lower Ongarue, Retaruke, and Whanganui to the confluence with the Retaruke.
Hill Soft Sedimentary (HSS)	Hill	Predominantly soft sedimentary (refer to Table 3)	Zones dominated by soft sedimentary geology.	East coast rivers, Tiraumea, Turakina, middle and lower Whangaehu, and middle and lower Whanganui and tributaries.



Map 3: Water management subzone classification by river ecosystem type.

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Appendix One

Source of flow and geology classes in each water management zone, and in the catchment above each zone (including the zone itself). The numbers are given in percentage of total number of individual stream reaches within the unit considered.

Note: Where the zone is located at the upstream end of the catchment, the river classification in the "whole catchment above the zone" and in the "subzone" itself are the same. In these cases, the numbers in the table below are given for the management zone only.

Key:

- Geology categories: SS: Soft Sedimentary; HS: Hard Sedimentary; Li: Limestone; Lo: Loess; Wb: Windblown Sand; VA: Volcanic Acidic; Pt: Peat; Al: Alluvium
- SoF (Source of Flow) categories: M: Mountain; H: Hill; L: Lowland.
- LSC (Life-Supporting Capacity) Classes: UVA: Upland Volcanic Acidic; UVM: Upland Volcanic Mixed; UHS: Upland Hard Sedimentary; HM: Hill Mixed; ULi: Upland Limestone; HSS: Hill Soft Sedimentary; LM: Lowland Mixed, LS: Lowland Sand.

Management zone	Zone code	Sub-zone	Geology classification in whole catchment above zone																Geology classification in water management zone/sub-zone														SOF	Geol	LSC class
			Toprock								Baserock								Toprock								Baserock									
			SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al			
Upper Manawatu	Mana_1a	Upper Manawatu	56	9	8	20				6	63	9	8					19	58	3	5	27				7	67	3	5					25	H	M	HM
	Mana_1b	Mangatewainui																	16	36		39				9	33	36						31	H	M	HM
	Mana_1c	Mangatoro																	69	10	17					4	69	10	17					4	H	SS	HSS
Weber – Tamaki	Mana_2a	Weber – Tamaki	52	9	7	23				8	62	9	7					21	62	11	9	4				13	63	11	9					17	H	M	HM
	Mana_2b	Mangatera																	18	7		55				17	51	7						38	H	M	HM
Upper Tamaki	Mana_3	Upper Tamaki																		82		11			1	6	6	83						11	H	HS	UHS
Upper Kumeti	Mana_4	Upper Kumeti																		60		8			2	30	4	62						34	H	HS	UHS
Tamaki – Hopelands	Mana_5a	Tamaki - Hopelands	42	15	6	23				14	53	12	6					28	50	14	4	7				26	55	14	4					27	H	M	HM
	Mana_5b	Lower Tamaki		54		26			1	19	12	55						33		34		36			2	28	16	36						48	H	M	HM
	Mana_5c	Lower Kumeti		39		24			1	36	1	21						78		34		36			2	28		5						94	H	M	HM
	Mana_5d	Oruakeretaki																		35		32				34	3	35						62	H	M	HM
	Mana_5e	Raparapawai																	13	21		49				17	28	21						51	H	M	HM
Hopelands – Tiraumea	Mana_6	Hopelands – Tiraumea	43	14	5	22				15	54	12	6					28	64		2	1				32	66		2					32	H	M	HM
Tiraumea	Mana_7a	Upper Tiraumea	77	2	11				11		77	2	11					11	87	1	1					10	87	1	1					10	H	SS	HSS
	Mana_7b	Lower Tiraumea	75	3	10				12		75	3	10					12	65	11	5	2				17	67	11	5					17	H	SS	HSS
	Mana_7c	Mangaone River																	86	2						12	86	2						12	H	SS	HSS
	Mana_7d	Makuri																	42	4	44					10	42	4	44					10	H	Li	ULi
Mangatainoka	Mana_8a	Upper Mangatainoka																	9	81		1				9	9	81						10	H	M	UHS
	Mana_8b	Middle Mangatainoka	27	31		14				27	32	31						37	20	16		9				56	22	16						62	H	M	HM
	Mana_8c	Lower Mangatainoka	34	25	1	12				28	38	25	1					36	15		4	9				65	21		4					68	H	M	HM

Management zone	Zone code	Sub-zone	Geology classification in whole catchment above zone																Geology classification in water management zone/sub-zone												SOF	Geol	LSC class
			Toprock								Baserock								Toprock								Baserock							
			SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al			
	Mana_8d	Makakahi																	38	23		21				16	46	23						31	H	M	HM
	Mana_8e	Mangaramarama																	86		2	1				10	87		2					10	H	SS	HSS
Upper Gorge	Mana_9a	Upper Gorge	45	18	5	15				17	52	17	5					25	11	22	1	29				38	19	26	1	3				51	H	M	HM
	Mana_9b	Mangapapa																	14	35		29				21	29	35		13				22	H	M	HM
	Mana_9c	Mangaatua	24	19	1	30				25	39	19	1	6				34	26	16	1	30				25	41	16	1	4				37	H	M	HM
	Mana_9d	Upper Mangahao																	4	69		10				17	8	70						22	H	HS	UHS
	Mana_9e	Lower Mangahao	5	60		17					14	61						25	14	13		51				22	46	15						40	H	M	HM
Middle Manawatu	Mana_10a	Middle Manawatu	41	21	4	15				17	50	21	4	2				23	12	12		46				23	18	21		30				23	H	M	HM
	Mana_10b	Upper Pohangina																	27	65		1			2	4	27	67						5	H	HS	UHS
	Mana_10c	Middle Pohangina	48	38		6			1	7	50	39		1				10	66	16		9				9	69	16		1				14	H	M	HM
	Mana_10d	Lower Pohangina	48	36		5			1	9	49	37		1				12	43	22		5				27	44	24		1				29	H	M	HM
	Mana_10e	Aokautere																	33	12		36				19	37	36		9				19	H	M	HM
Lower Manawatu	Mana_11a	Lower Manawatu[3]	37	20	4	18				20	46	20	4	3				26				15				77	2			13				77	H	M	HM
	Mana_11b	Turitea																	5	54		33				7	9	70		13				7	H	HS	UHS
	Mana_11c	Kahuterawa																	1	56		32				11	9	64		15				11	H	HS	UHS
	Mana_11d	Upper Mangaone Stream																				85				15	39			36				25	L	M	LM
	Mana_11e	Lower Mangaone[4] Stream				74				14	33			32				23				5				11				5				11	L	M	LM
	Mana_11f	Main Drain																								99								99	L	M	LM
Oroua	Mana_12a	Upper Oroua	38	15		33				15	44	15		7				34	35	26		25				14	40	26		9				25	H	M	HM
	Mana_12b	Middle Oroua[5]	30	11		41				16	40	11		14				34								88								88	H	M	HM
	Mana_12c	Lower Oroua	25	9		37	8			20	33	9		15	9			34				21	45			34	3			16	47			34	L	M	LM
	Mana_12d	Kiwitea																	42			43				15	48			5				47	H	M	HM
	Mana_12e	Makino																	5			76				15	27			43				26	L	M	LM
Coastal Manawatu	Mana_13a	Coastal Manawatu	32	18	3	21	4		1	21	40	18	3	6	4			27	1			5	56		10	28	3			3	56		10	28	L	M	LM
	Mana_13b	Upper Tokomaru																		80		18				2		94		4				1	H	HS	UHS
	Mana_13c	Lower Tokomaru		29		35			6	30	8	35		21			6	30	1	11		41			8	40	12	13		27				40	L	M	LM
	Mana_13d	Mangaore																	6	43		23				25	7	48		17				25	H	M	HM
	Mana_13e	Kopaturoa[6]																	5	21		61			2	10	27	22		37			2	10	L	M	LM

[3] 8% of toprock for the Lower Manawatu Catchment is classified as "other".

[4] 83% of baserock and toprock is classified as "other". This is mostly due to the presence of Palmerston North city in the sub-zone. No LRI information is available under developed urban areas.

[5] 12% of baserock and toprock classified as "other", mostly due to the presence of Feilding township within the sub-zone.

[6] 9% of toprock is recognised as "other", partly due to the presence of Foxton township within the subzone.

Management zone	Zone code	Sub-zone	Geology classification in whole catchment above zone																Geology classification in water management zone/sub-zone												SOF	Geol	LSC class
			Toprock								Baserock								Toprock								Baserock							
			SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al			
	Mana_13f	Foxton Loop																					67			24					67			24	L	M	LM
Upper Rangitikei	Rang_1	Upper Rangitikei																		26				74			9	84				6			M	HS	UHS
Middle Rangitikei	Rang_2a	Middle Rangitikei	15	19				65		1	32	59				9		1	44	5				49		2	76	8				14		2	M	HS	UHS
	Rang_2b	Pukeokahu – Mangaweka	34	16		1		47		3	47	39				10		3	51	35		3		4		8	55	35				1		9	M	M	HM
	Rang_2c	Upper Moawhango																		6				94			1	61				38			M	VA	UVA
	Rang_2d	Middle Moawhango	10	3				87			34	40				26			19	1				80			62	22				15			H	VM	UVM
	Rang_2e	Lower Moawhango	27	2				70		1	50	30				19		1	77					21		2	97					1		2	H	SS	HSS
	Rang_2f	Upper Hautapu																	39					58	2	1	90					7	2	1	M	VM	UVM
	Rang_2g	Lower Hautapu	53					44	1	1	92					5	1	1	93					2		1	95							1	H	SS	HSS
Lower Rangitikei	Rang_3a	Lower Rangitikei	38	13		6		39		4	51	31		1		8		7	49			38				11	64			6				28	H	M	HM
	Rang_3b	Makohine																	93			1		2		5	94							6	H	SS	HSS
Coastal Rangitikei	Rang_4a	Coastal Rangitikei	34	11		13	1	33		7	47	26		6	2	7		11	1			50	15			31	17			30	15			35	H	M	HM
	Rang_4b	Tidal Rangitikei	34	11		13	2	32		7	47	26		6	2	7		11						66		34					66			34	L	M	LM
	Rang_4c	Porewa																	61			17				21	62			9				29	H	SS	HSS
	Rang_4d	Tutaenui																				80	6			9	10			68	6			11	L	M	LM
Upper Whanganui	Whai_1	Upper Whanganui																	1	1				98			34	7				59			M	VA	UVA
Cherry Grove	Whai_2a	Cherry Grove	3	1				95			34	9				57								94		4	55					39		4	M	VM	UVM
	Whai_2b	Upper Whakapapa																	1					99			2					98			M	VA	UVA
	Whai_2c	Lower Whakapapa	2	1				97			10	7				83			4	4				91		1	18	24				57		1	M	VA	UVA
	Whai_2d	Piopiotea																	1					98	1		18					82			H	VA	UVA
	Whai_2e	Pungapunga																	1	6				93			63	15				22			H	VM	UVM
	Whai_2f	Upper Ongarue																	1	1				98			10	19				70			H	VA	UVA
	Whai_2g	Lower Ongarue	5	1				93			36	13				51			11	2				87			70	5				24			H	VM	UVM
Te Maire	Whai_3	Te Maire	4	1				94			36	8				55		1	12					86		2	72					25		3	H	VM	UVM
Middle Whanganui	Whai_4a	Middle Whanganui	26	1				71		2	59	5				34		2	45					54		1	95					2		3	H	VM	UVM
	Whai_4b	Upper Ohura																	74					20		6	88					6		6	H	SS	HSS
	Whai_4c	Lower Ohura	74					19		6	88					6		6	76					15		9	86					5		9	H	SS	HSS
	Whai_4d	Retaruke																	36					62		1	90					8		1	H	VM	UVM
Pipiriki	Whai_5a	Pipiriki	45					53		2	69	3				26		2	94					6			99					1			H	SS	HSS
	Whai_5b	Tangarakau																	81					15		4	92					4		4	H	SS	HSS
	Whai_5c	Whangamomona																	80					17		3	97							3	H	SS	HSS
	Whai_5d	Upper Manganui O Te Ao																	12					88			78							22	M	VA	UVA
	Whai_5e	Lower Manganui O Te Ao	50					50			62					37			74					25			89					11			M	VM	UVM

Management zone	Zone code	Sub-zone	Geology classification in whole catchment above zone																Geology classification in water management zone/sub-zone												SOF	Geol	LSC class
			Toprock								Baserock								Toprock								Baserock							
			SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al			
Paetawa	Whai_6	Paetawa	49					49		2	72	3				24		2	90					9			98								H	SS	HSS
Lower Whanganui	Whai_7a	Lower Whanganui	51					46		2	93	3				3			81			6		4		7	82			5		3		7	H	SS	HSS
	Whai_7b	Coastal Whanganui[7]	51			1		45		2	72	3		1		22		2	17			15	38	1		1	17			15	38	1		1	L	M	LM
	Whai_7c	Upokongaro																	93			1		1		4	95			1				4	H	SS	HSS
	Whai_7d	Matarawa																	73			13				10	73			13				10	H	SS	HSS
Upper Whangaehu	Whau_1a	Upper Whangaehu	1					98			15					83		1	1					98	1		15					84			M	VA	UVA
	Whau_1b	Waitangi																	4					95			56					43			M	VM	UVM
	Whau_1c	Tokiahuru																						99		1	3					93		3	M	VA	UVA
Middle Whangaehu	Whau_2a	Middle Whangaehu	33					66		1	45					54		1	75					24		1	90					9		1	M	SS	HSS
Lower Whangaehu	Whau_3a	Lower Whangaehu	44					39		3	64					33		3	89			1		1		9	90			1				9	H	SS	HSS
	Whau_3b	Upper Makotuku																						100			1					99			M	VA	UVA
	Whau_3c	Lower Makotuku	4					94		1	12					86		1	6					91		1	16					81		1	M	VA	UVA
	Whau_3d	Upper Mangawhero	6					91		3	32					66		1	6					89		4	41					56		2	M	VA	UVA
	Whau_3e	Lower Mangawhero	47					51		2	69					29		2	73					25		2	93					4		2	H	SS	HSS
Coastal Whangaehu	Whau_4	Coastal Whangaehu	44			1	1	37		4	62			1	1	31		5	36			9	21			34	36			9	21			34	H	SS	HSS
Turakina	Tura_1a	Upper Turakina																	88					8		4	96							3	H	SS	HSS
	Tura_1b	Lower Turakina	75			11	1	4		7	83			7	1			8	60			25	3			12	68			15	3			14	H	SS	HSS
	Tura_1c	Ratana																	4			73	23				4			73	23				L	M	LM
Ohau	Ohau_1a	Upper Ohau																		87		9				4		93		3				4	H	HS	UHS
	Ohau_1b	Lower Ohau	1	58		15	5		2	18	1	63		8	5		3	19	3	23		23	12		4	34	3	27		15	12		6	36	H	M	HM
Owahanga	Owha_1	Owahanga																	85	6						8	85	6						8	H	SS	HSS
East Coast	East_1	East Coast																	95				1			4	95				1			4	H	SS	HSS
Akitio	Akit_1a	Upper Akitio																	96		3						96		3						H	SS	HSS
	Akit_1b	Lower Akitio	90	3	1					6	90	5						6	88	6						6	88	6						6	H	SS	HSS
	Akit_1c	Waihi																									87		3					9	H	SS	HSS
Northern Coastal	West_1	Northern Coastal																	40			33	13	13		1	41			33	13	12		1	L	M	LM
Kai-Iwi	West_2	Kai-Iwi																	75			15		6		4	77			15		3		4	H	SS	HSS
Mowhanau	West_3	Mowhanau																	38			57				5	38			53		4		5	L	M	LM
Kaitoke Lakes	West_4	Kaitoke Lakes																	20			30	46	1		2	22			30	46			2	L	M	LM
S. Whanganui Lakes	West_5	Southern Whanganui Lakes																				9	90			1				6	90			1	L	S	LS
N. Manawatu Lakes	West_6	Northern Manawatu Lakes																					100								100				L	S	LS

[7] 23% of toprock and 14% baserock is classified as "other".

Management zone	Zone code	Sub-zone	Geology classification in whole catchment above zone																Geology classification in water management zone/sub-zone												SOF	Geol	LSC class
			Toprock								Baserock								Toprock								Baserock							
			SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al	SS	HS	Li	Lo	Wb	VA	Pt	Al			
Waitarere	West_7	Waitarere																					97		1						97				L	S	LS
Lake Papaitonga	West_8	Lake Papaitonga																	11			3	69		15		11			3	69		15		L	S	LS
Waikawa	West_9	Waikawa																		51		15	12		7	16	6	53		3	12		7	18	H	M	HM
Lake Horowhenua	Hoki_1a	Lake Horowhenua[8]																	4	2		23	28		7	16	4	2		23	28		7	16	L	M	LM
	Hoki_1b	Hokio Stream[9]	4	2		21	35		7	15	4	2		21	35		7	15					96								96				L	S	LS

Rules for the water management zone classification:

1. When both top- and baserock river classifications in the catchment above the zone were dominated by one geology class (≥ 60%), the zone was classified according to the river classification (eg. HS – Hard Sedimentary, SS – Soft Sedimentary, VA – Volcanic Acidic), with the exception of rule 2 below.
2. When the river classification in the catchment above the zone was dominated by volcanic acidic toprock (VA ≥ 70%) and soft sedimentary baserock (SS ≥ 50%), the zone was classified UVM (Upland Volcanic Mixed).
3. When both top and baserock river classification in the catchment above the zone were dominated by either or both loess and alluvium (Lo + Al ≥ 70%), the zone was classified "mixed" (either Hill Mixed – HM or Lowland Mixed – LM).
4. The Manawatu from Weber Road to Tamaki zone (Mana_2a) is classified HM for consistency with the zones immediately upstream (Mana_1) and downstream (Mana_5)
5. When the toprock river classification in the catchment above the zone was dominated by volcanic acidic rocks (VA ≥ 70%) and the baserock was dominated by either volcanic acidic rocks (VA ≥ 70%) or a mix of volcanic acidic and hard sedimentary (VA + HS ≥ 70%), the zone was classified VA), with the exception of rule 6 below.
6. In the Upper Rangitikei zones (Rang_1 and Rang_2b), the tephra (VA) mantle deposited over greywacke (HS) rocks is very thin. The greywacke has by far the strongest influence over the Upper Rangitikei's hydrogeology and bed sediment type, and the Upper Rangitikei would best be classified as Upland Hard Sedimentary- UHS (Dr. Barry Biggs, *pers. comm.*).
7. The Makuri River's hydrogeology and bed sediment type is strongly influenced by the presence of limestone. A specific WMZ class was created: ULi (Upland Limestone).
8. When no geology clearly dominated the river classification in the catchment above the zone, and/or none of the rules above applied, the zones were classified "mixed" (either Hill Mixed – HM or Lowland Mixed – LM).
9. Foxton Loop catchment is dominated by WB (Windblown Sand). However, the Loop is an old meander of the Manawatu River, still fed by river water at both ends. For this reason, it has received the same classification as the coastal Manawatu sub-zone: LM.

[8] 13% toprock other and 5% water
[9] 3% toprock other

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