Minimum flow recommendations for the Wellington region

Technical report to support the Proposed Natural Resources Plan

Mike Thompson
Environmental Science Department

For more information, contact the Greater Wellington Regional Council:

Wellington
PO Box 11646

T 04 384 5708
F 04 385 6960
www.gw.govt.nz

Masterton
PO Box 41

T 06 378 2484
F 06 378 2146
www.gw.govt.nz

GW/ESCI-T-15/85
ISBN: 978-1-927217-80-1 (online)

July 2015

www.gw.govt.nz
info@gw.govt.nz

Report prepared by:	Thompson M	Senior Environmental Scientist - Hydrology	
Report reviewed by:	Boyens N	Team Leader - Hydrology	
Report approved for release by:	G Sevicke-Jones	Manager, Environmental Science	**Date**: July 2015

The report may be cited as:

Thompson M. 2015. *Minimum flow recommendations for the Wellington region: Technical report to support the Proposed Natural Resources Plan.* Greater Wellington Regional Council, Publication No. GW/ESCI-T-15/85, Wellington.

Executive summary

Minimum flows are flow thresholds in rivers and streams that are used to restrict and suspend consented water abstraction during dry spells. They are an important tool for ensuring that instream values are not unacceptably compromised by consumptive water use.

Greater Wellington Regional Council (GWRC) is intending to notify its proposed Natural Resources Plan (pNRP) in July 2015. This report makes a number of recommendations in support of the pNRP that relate to minimum flows for rivers and stream in the Wellington region.

The primary recommendations of this report are:

- To apply numerical limits (ie, in litres per second) to 17 identified rivers and streams where there is (a) significant water use, (b) sufficient information available to define appropriate thresholds and (c) a means by which to actively monitor compliance with minimum flows. The numerical thresholds for 14 of the 17 waterways are the same as listed in GWRC's existing Regional Freshwater Plan policies while the remaining three are new (ie, in catchments where no current minimum flow policy exists)

- For all rivers and streams outside of catchments covered by numerical thresholds (corresponding generally to the three whaitua areas of the Kapiti Coast, Wellington Harbour/Hutt Valley and Ruamahanga), to apply a default minimum flow limit equating to 90% of the seven day naturalised mean annual low flow at the point of abstraction

Minimum flows are recommended in this report as 'interim' in recognition that the Wellington region is only part way into a limit-setting process. In line with the progressive implementation programme set out in the National Policy Statement for Freshwater Management, it is intended that interim provisions are refined into agreed limits over coming years. The process to enable this will involve a combination of continued technical and policy assessment and community consultation, including input from whaitua (catchment) committees.

The overall consequences of water use are determined not just by minimum flow policies but also the associated allocation policies. Therefore, the refinement of interim minimum flows will need to occur alongside fuller consideration of water allocation options.

Contents

1. Introduction

This report presents results to date from a review of the minimum flows for rivers and streams in the Wellington region. These flows are set to maintain identified river and stream values. The review has been undertaken in support of the development of Greater Wellington Regional Council's (GWRC) second generation regional plan. Methods and rationale for the review are described and recommendations for minimum flows are provided.

This report is an updated version of a report with the same title that was issued when the draft Natural Resources Plan was notified in September 2014 (Thompson 2014b). This current report contains some minor revisions and corrections and replaces the earlier version.

The allocation of water is not dealt with in any detail in this report. A companion report (Thompson & Mzila 2015) discusses water allocation recommendations.

1.1 Definition of terms

Table 1.1: Definition of terms and phrases commonly used in this report

Term or phrase	Definition in the context of this report
Instream flow requirements	The flows that are required to sustain all identified instream values associated with a waterway including ecological, aesthetic, recreational, cultural and traditional values.
Low flow	The reduction in river flow usually experienced during the summer. In some catchments, naturally low base flows are further exacerbated by abstractions or diversions. The mean annual low flow (MALF) is the average of the lowest flows from each year of record and is the index most commonly referred to in this report when describing low flows.
Minimum flow	The flow that GWRC aims to maintain under low flow conditions. The minimum flow is used as a trigger to limit (and often suspend) abstraction. The flow in a river or stream may naturally drop below the minimum flow following the restriction / suspension of consented abstractions.
IFIM	Instream Flow Incremental Methodology. A decision support framework for helping determine environmental flow and allocation solutions. Habitat-based assessments are often a key part of IFIM.
1d MALF-N	The naturalised mean annual low flow with a duration of one day.
7d MALF-N	The naturalised mean annual low flow with a duration of seven days.
Core allocation	The total amount of water that may be allocated to resource consent holders from a river or stream during normal to low flow conditions (permitted activity takes and higher flow 'supplementary' takes are additional to core allocation).

1.2 Existing plan provisions

The existing (and operative) Regional Freshwater Plan (RFP, WRC 1999) establishes:

- Minimum flows for 16 of the most "used" rivers, or river reaches, in the region; and

- Allocation limits for 22 waterways (including all 16 with minimum flow provisions)

Historically GWRC has established minimum flows using a combination of historical flow methods, regionalised habitat methods and hydraulic habitat modelling (Table 1.2).

Table 1.2: Summary of approaches taken to defining minimum flows for rivers in the existing RFP (including those incorporated as plan changes since 1997)

River or stream	Approach to defining minimum flow
Tauherenikau, Waiohine, Waingawa	Historical flow methods (based on the 1-in-5 year low flow)
Kopuaranga	Flow required to achieve a 150 mm depth in the river at its confluence with the Ruamahanga River for the migration of trout
Ruamahanga (upper and lower), Waipoua	Consideration of habitat survey data, allocation status and baseline water quantity and quality data (documented in water allocation plans prepared between 1996 and 2001)
Mangatarere (upper and lower)	Consideration of habitat survey data, allocation status, baseline water quantity and quality data and public consultation (documented in water allocation plans prepared and revised between 2003 and 2007)
Otaki, Waikanae, Hutt (upper and lower) and Wainuiomata (lower)	Instream habitat assessments
Wainuiomata (upper)	Flow required to achieve minimum flow in the lower reaches
Waitohu, Mangaone, Orongorongo	Based on 60% of the 1-in-20 year low flow

1.3 Need for review

An internal review in 2007 found that the minimum flows for some of the rivers in the RFP were derived based on limited information and had not been tested with more up to date data and information to ensure they were set at an appropriate level to protect instream values (Keenan 2009a).

Allocation of water from some of our major rivers is at, or nearly at, the limits specified in the RFP (Keenan et al. 2012). These limits are exceeded in many cases once streamflow depletion from hydraulically-connected groundwater abstractions is factored in. As allocation levels increase, so too does the potential for the magnitude and duration of low flows to be exacerbated. The impact of allocation depends on both the size of the allocation ‘block’ and the minimum flows that dictate when abstraction ceases. While this report focuses on minimum flows, allocation levels are also being reviewed by Greater Wellington (see Thompson & Mzila 2015).

For context, thirty nine rivers and streams in the region have consented abstractions but no minimum flow in the existing RFP. While many more rivers and streams have unconsented and/or permitted activity abstractions (eg, for domestic or stock watering purposes), these abstractions are not subject to minimum flow rules.

1.4 Wider context of water management in the Wellington region

This report should be read in the context of the past (RFP, Wellington Regional Council (WRC) 1999a) and future management of fresh water in the Wellington region and nationally. Management of water in the immediate future will be through GWRC's regional plan that is under development – the proposed Natural Resources Plan (pNRP). The pNRP being prepared will include region-wide provisions when it is notified in July 2015. Over time, with input from in five management areas already identified in the region, variations/changes will be recommended from 2016 to 2022 that would refine region-wide provisions to include catchment specific provisions. This process will include refinement of minimum flows, taking fuller account of allocation provisions. There is also a longer timeframe that must be considered. The National Policy Statement on Freshwater Management (MfE 2014) includes a set of provisions that must be given effect to in full by 2030.

2. Guiding principles

This section sets out the guiding principles and advice behind GWRC's approach to reviewing minimum flows. These include legislated national policy and best practice technical guidance. There is also a discussion about the limitations of the approach taken, particularly with respect to gaps in information needed to make fully informed decisions about flow requirements.

2.1 Regional Policy Statement

The Regional Policy Statement (RPS) for the Wellington region (GWRC 2013a) became operative in April 2013 and sets the blueprint for subsequent plan-making. Objective 12 of the RPS states that:

> *The quantity and quality of fresh water:*
>
> *(a) meets the range of uses and values for which water is required;*
>
> *(b) safeguards the life supporting capacity of water bodies; and*
>
> *(c) meets the reasonably foreseeable needs of future generations.*

The RPS also states that:

> *A regional plan contains policies, rules and/or methods that:*
>
> *(a) require, as a minimum, that water quality, flows and water levels are managed for the purpose of maintaining or enhancing aquatic ecosystem health; and*
>
> *(b) manage water bodies for other identified purposes.*

2.2 Central government policy and guidance

In July 2014, the National Policy Statement on Freshwater Management (NPS-FM) was gazetted by the government. Objective B1 of the NPS-FM relates to safeguarding ecosystems by…

> *…every regional council making or changing regional plans to the extent needed to ensure the plans establish freshwater objectives and set environmental flows and/or levels for all bodies of fresh water in its region (except ponds and naturally ephemeral water bodies)….*
>
> [Policy B1]

The NPS-FM states that environmental flows for rivers and streams must be interpreted to include an allocation limit and a minimum flow.

With respect to technical guidance from central government, two sets of documents are particularly relevant to the GWRC review of minimum flows:

1. Flow Guidelines for Instream Values (Ministry for the Environment 1998)

2. A proposed National Environmental Standard (NES) on ecological flows and water levels (Ministry for the Environment 2008) and its technical

support document titled *Draft guidelines for the selection of methods to determine ecological flows and water levels* (Beca 2008)

These two documents summarise both traditional and more emergent methods for flow setting. While detail about the methods is not repeated here, one of the key points is that best practice application can vary from a quick rule-of-thumb assessment to detailed studies undertaken over several years. The Ministry for the Environment (2008) and Beca (2008) suggest that the level of effort and investigation should reflect the instream values and extent of demand (or hydrological alteration); their summary of the range of investigation methods that should be considered is reproduced in Appendix 1. A key point with respect to the GWRC appproach described in this report is that, while there is no universally accepted method for all rivers and streams, the few case studies that have been carried out to examine the ecological response to flow changes indicate that the response is usually consistent with instream habitat predictions (Jowett et al. 2008).

The proposed NES on ecological flows (Ministry for the Environment 2008) also makes some suggestions about criteria that could be used to set 'interim' (ie, default) limits for those rivers and streams that do not already have limits specified within regional plans and that are unlikely to undergo site-specific investigation. These limits are listed later in this report (Section 3.6.2).

While the proposed NES, or a variation of the original proposal, has not yet (as at June 2014) progressed to legislation, the advice within it is the result of deliberations by a consortium of New Zealand experts and is therefore considered to be an important guide for GWRC. It is understood that the suggested limits were formulated with drier parts of the country in mind (ie, east coasts of both islands where base flow recessions are longer and more severe) and may therefore be conservative in many other areas. However, adoption of conservative criteria, in the absence of more specific information, is consistent with the precautionary principles under which GWRC develops resource management policy.

2.3 Approaches to minimum flow setting in other regions in NZ

Lew (2006) summarised the approaches other regional authorities in New Zealand take in establishing minimum flows and allocation limits. These are summarised in Appendix 2 (Table A2.1) and have been updated by the author of this report based on an informal email survey of council staff in September 2012.

Not all councils set minimum flows in their regional plans and those that do employ a range of methods. Generally, both minimum flows and water allocation limits are most commonly expressed as a proportion of either mean annual low flow (MALF) or the 1-in-5 year low flow (Q5). Where either abstraction demand or instream values are particularly high for individual rivers, most councils set a site-specific minimum flow on the basis of more in-depth investigation and typically employ instream habitat assessments and hydraulic modelling to do this.

2.4 A technical framework for GWRC

Watts (2006) produced an internal council working document titled *Framework for instream flow assessment in the Wellington region*. The primary aim of this document was to establish a transparent process for conducting instream flow assessments and provide some guidance on selection of assessment methods.

The major principles and/or recommendations of the framework were based on a compilation of best practice at the time:

1. To ensure that the depth of investigation was commensurate with the level of demand and instream values (with three levels being specified, from desktop historic flow analysis to at-site survey and investigation).

2. That, where instream management objectives relate to protecting aquatic habitat quality, the following investigation methods should be applied:

    a) Generalised habitat modelling as described by Jowett and Hayes (2004) (where demand and instream values are moderate to low)

    b) **R**iver **Hy**draulic **Hab**itat **Sim**ulation (RHYHABSIM), to model habitat availability for trout, native fish and aquatic macroinvertebrates (where demand and instream values are moderate to high)

    c) **W**ater **A**llocation **I**mpacts **o**n **R**iver **A**ttributes (WAIORA), to model the effects of flow on temperature, dissolved oxygen and ammonia

2.5 Consultation and peer review

The framework document (Watts 2006) was circulated among staff from the Wellington Fish and Game Council, Department of Conservation, Cawthron Institute, Environmental Management Associates and several regional councils and comment received from many of these agencies. While there was not agreement on all points, it was recommended that GWRC continue to use the framework until a widely-accepted alternative was available (Watts 2006). The framework document led to the establishment of an Instream Flows Programme within council.

Beyond consultation on the initial framework document, interaction with external stakeholders has been on a case by case basis. Generally, regional officers of the Department of Conservation and Fish and Game Council – as primary interested parties – have been invited to site walkovers and been given the opportunity to comment on draft flow assessment reports. Iwi consultation has involved specific discussions on identified values as well as review of material adopted from previous consultation, depending on the level of investigation. The same applies to consultation with other community groups (eg, recreational boat clubs).

2.6 Limitations

Minimum flows are being recommended as ‘interim’ in recognition that the Wellington region is only part way into a limit-setting process. In line with the progressive implementation programme set out in the NPS-FM, it is intended that interim provisions are refined into agreed limits over coming years. The process to enable this will involve a combination of continued technical and policy assessment and community consultation, including input from whaitua[1] committees.

In their most complete form, water quantity limits (minimum flows and allocation limits) will represent a point of agreement between interested parties (including the wider community) after full consideration of in-stream and out-of-stream objectives and values, and the necessary trade-offs between these values, has been made. In the meantime, interim provisions are largely focussed on the maintenance of ecological values and the avoidance of long term decline in water resources; both of which are considered fundamental aspects of sustainable freshwater management under the Resource Management Act (RMA).

It is acknowledged therefore that the proposed minimum flows are not, in many cases, the product of balancing all values that might be of interest to the relevant communities.

2.6.1 Balancing instream and out of stream values

Out-of-stream use (eg, for public water supply or irrigation) has not been explicitly considered yet in the setting of minimum flows. While some assessment of the security of supply that arises from the recommended provisions has been completed (see Section 6.2.2) there has been no attempt to balance water user security of supply requirements with the flow requirements identified for the maintenance of instream values. It is important that out of stream requirements are considered during the refinement of interim minimum flows. Such an exercise may not be straight forward as perceptions about the acceptability of impacts under different security of supply scenarios will differ between individuals and community groups.

2.6.2 Judging 'acceptable' levels of change (habitat retention)

One of the main recurring objectives of minimum flow setting (under the GWRC approach) is determination of the flow requirements to maintain instream habitat quality. This ultimately requires some judgement about how much habitat should be retained (or conceded) for a given species, a judgement that relies upon an understanding of the value and flow demands of that species. While there is plenty of literature on general flow demands for fish, the value that should be attributed (to guide decision making on habitat retention) is a much more subjective area. One way to reduce subjectivity is to compare the abundance of a species in one river with other rivers and grade overall value and habitat retention choices accordingly. This approach works well where trout management is a primary objective (and has been adopted by GWRC) because there is a relative abundance of population and 'angling days' data with which to make meaningful comparisons between rivers. Furthermore, trout objectives lend themselves more to this relative grading of value because

[1] 'Whaitua' is a term used to describe a catchment committee process that is being established in the Wellington region. Five whaitua are proposed, covering each of the Ruamahanga River catchment (as at June 2014, this whaitua process is underway), the eastern Wairarapa hill country, the Hutt River and Wellington Harbour catchment, Porirua Harbour catchment and the Kapiti Coast. The whaitua will develop a set of recommendations that may supercede many of the regional plan provisions, including interim minimum flow and water allocation limits.

anglers have the option of visiting rivers where trout requirements have been well catered for. However determining the value of native fish species based on river to river comparisons is not so appealing, partly because there is generally very little information on native fish abundance, but also because the notion of offering more or less habitat retention when dealing solely with intrinsic indigenous ecological value is more fraught.

3. Methodology – minimum flow review

This section describes in more detail the key elements of the technical framework previously introduced. It summarises the methods used to review and derive catchment-specific minimum flows, as well as the rationale for the application of regional 'rules of thumb' and default criteria.

3.1 Reviewing and establishing management objectives

As with many aspects of the instream flows work, the level of rigour applied reviewing and establishing management objectives was a function of the value and priority of the waterway under investigation. High value, high use waterways (eg, the Ruamahanga River, Papawai Stream) have been the subject of 'issues' reports, where management objectives and flow setting methods have been established through specific consultation with interested parties. Objectives and flow setting methods for waterways with lower values, or that are under lower abstraction stress, have been established with less consultation, usually making use of information on instream values and uses that is already available (eg, from historical consent applications, previous river management plans and consultations).

The RPS (GWRC 2013a) also sets out general management objectives for many of the more significant rivers and streams in the region. Objectives include managing for significant amenity and recreational value (including angling) and significant indigenous ecosystems. Both river specific (ie, from investigation) and general RPS management objectives are listed for each waterway in Appendix 3.

3.2 Prioritisation of rivers and streams

To help allocate resources for instream flow investigations, the 56 rivers and streams in the region with consented abstraction[2] were prioritised for attention. Prioritisation involved ranking the waterways according to identified instream values (and the degree of risk to these from abstraction) as well as the amount of abstractive pressure. A full description of the ranking process is provided by Watts (2007b) and the 30 top ranked waterways are summarised in Table 3.1, along with a note as to whether a minimum flow for each waterway is listed in the existing RFP.

[2] This number excludes some small tributary streams whose consented allocation is counted as part of a parent catchment.

Table 3.1: Prioritisation of rivers and streams in the Wellington region (from which there is consented abstraction) by combining instream value and abstractive demand scores (listed from highest to lowest). Reproduced from Watts (2007b). The top ranked 30 waterways are shown out of 56 with consented abstraction

River / Stream	'Risk' score (demand + values combined score) (/10)	Minimum flow in existing RFP?	Continuous flow recorder?
Hutt River – upper reach	9.0	Yes	Yes
Ruamahanga River – lower reach	9.0	Yes	Yes
Waingawa River	9.0	Yes	Yes
Hutt River – lower reach	8.6	Yes	Yes
Ruamahanga River – upper reach	8.2	Yes	Yes
Mangatarere Stream	7.6	Yes (upper and lower)	Yes (3 sites)
Waipoua River	7.6	Yes	Yes
Papawai Stream	7.3	No	Yes
Waiohine River	7.1	Yes	Yes
Kopuaranga River	6.5	Yes	Yes
Wainuiomata River – upper reach	6.5	Yes	Yes
Parkvale Stream	6.3	No	Yes
Tauherenikau River	6.1	Yes	Yes
Waikanae River	6.1	Yes	Yes
Otukura Stream	6.0	No	Yes
Waitohu Stream	5.9	Yes	Yes
Booths Creek	5.7	No	No
Stonestead (Dock) Creek	5.6	No	No
Tauweru River	5.6	No	Yes
Waimanu (Rahui) Stream	5.6	No	No
Orongorongo River	5.5	Yes	Yes
Akatarawa River	5.4	No	Yes
Otaki River	5.4	Yes	Yes
Abbots Creek	5.2	No	No
Mangaone Stream	5.2	Yes	Yes
Huangarua River	5.1	No	No

3.3 Selecting flow sites and statistics

3.3.1 Choice of minimum flow management sites

Management sites are the points in each catchment where minimum flow rules are applied in accordance with at-site measured flow rates. In the existing RFP, most of the listed rivers have one management site and associated minimum flow value. Some rivers, particularly those with significant tributary input or bulk water abstraction (eg, Hutt, Ruamahanga, Wainuiomata) have two management sites, each with an associated minimum flow value. One waterway – the Mangatarere Stream – has a single management site but two minimum flows (designed so that abstractions in the more vulnerable upper catchment are regulated earlier in a flow recession than those in the lower catchment).

For the pNRP it is recommended that all existing RFP management sites are retained. However, new sites should also be added, making use of the existing recorder network where appropriate to reflect additional minimum flow recommendations. Figure 3.1 shows the location of continuous flow recorders in the Wellington region that are rated to accurately measure low flows and are on rivers and streams that have water allocated via resource consent. There are 40 sites representing 30 rivers and streams, largely overlapping with the top 30 ranked waterways mentioned in the previous section.

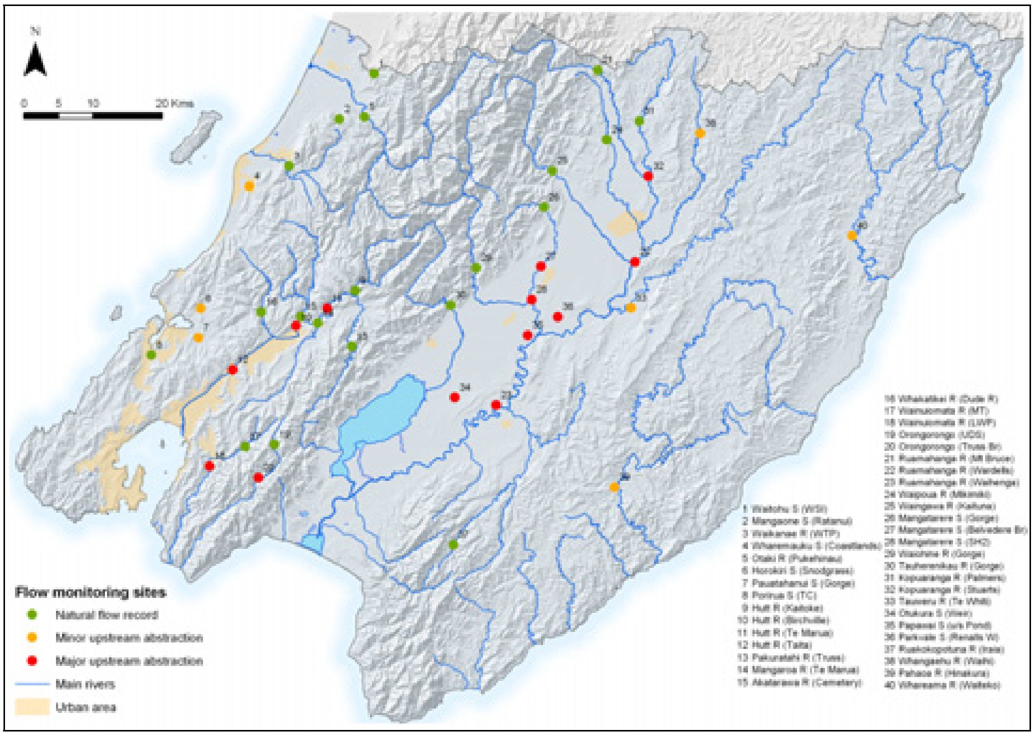


Figure 3.1: Location of continuous flow recorders in the Wellington region that are rated for low flows on allocated rivers or streams. Degree of upstream flow alteration (from abstraction and diversion) is shown

3.3.2 Choice of reference flow statistics

GWRC has opted to use the mean annual low flow (MALF – see definition in Table 1.1) as the primary low flow statistic for benchmarking minimum flows. The choice of MALF is partly related to a desire to maintain consistency over time (MALF has been used as a flow management statistic by GWRC in the past) but mainly because it has been shown to be ecologically relevant in New Zealand rivers and streams. Jowett (1990, 1992) found that instream habitat for adult brown trout at MALF was correlated with adult brown trout abundance in New Zealand rivers. Furthermore, the return period of MALF, which is usually about 1.8 years on average for most rivers in the Wellington region, is indicative of the low flows likely to be experienced by trout –and therefore sets a lower limit to physical space likely to be available to them – before they begin making a reproductive contribution to the population (Hay 2010a). It seems reasonable that the MALF should be similarly relevant to native fish species that also have generation cycles longer than a year.

The use of MALF as a reference statistic for both minimum flows and setting of core allocation is common in other regions in New Zealand (see Appendix 2, Table A2.1) and supported by Beca (2008) in their technical assessments for the proposed National Environmental Standard on ecological flows.

(a) 1-day (1d) or 7-day (7d) duration MALF?

In early (ie, pre-2000) water resource and instream flow assessments by GWRC (and its predecessor agencies), no reference to the duration of MALF was made. It is possible that both the 1d and 7d MALF were used over the years although the extent of any such inconsistency is unknown (and given the similarity in 1d and 7d figures, reassessment of historical flow data does not typically reveal which statistic was used).

In more recent years (since about 2000), GWRC has favoured use of the 1d MALF for deriving minimum flows. While less conventional than using 7d MALF, use of the 1d MALF is not unprecedented in New Zealand; Horizons Regional Council recently adopted this statistic for use in the allocation framework in their One Plan on the basis that, as a council, they manage water allocation on a daily time scale (according to maximum daily rate of take) and that rivers in the Horizons region “change on a daily basis” (Roygard 2010).

A primary argument for adopting 7d MALF is that this statistic is a more robust indicator of low flows (less prone to spikes in data than 1d MALF). Recommendations in the proposed NES on ecological flows are based on 7d MALF and this statistic has also recently been used by GWRC in groundwater investigation and stream flow depletion studies in the Wairarapa (eg, Hughes & Gyopari 2011). A key point to note is that since 7d MALF is always higher than 1d MALF it leads to a more conservative minimum flow. However, if core allocation is also determined as a proportion of 7d MALF then more water is made available than if 1d MALF were to be used.

In practical terms, the difference between using 1d MALF and 7d MALF for flow setting is thought unlikely to lead to demonstrably different outcomes for either instream values or water users[3]. It is recommended that default minimum flows in the dNRP are based on 7d MALF and, where practicable, any future catchment-specific studies should opt for 7d MALF as the basis for minimum flow recommendations. However, minimum flows that have already been recently derived from 1d MALF should be retained in the dNRP.

(b) Naturalised or measured MALF?

Naturalised MALF (MALF-N) has been used in recent GWRC investigations to benchmark minimum flow requirements. This has been done by ‘correcting’ MALF in survey reaches by adding back in an estimate of abstracted flow. The corrected flow has then been related back to the catchment recorder site to obtain the management point minimum flow. It appears to have been uncommon in earlier Wellington Regional Council assessments (eg, pre-2000) for flows to be naturalised and *measured* MALF (MALF-M) was often used as the reference statistic.

3 Thompson (2011f) provides a more detailed comparison of 1d MALF and 7d MALF.

While naturalising MALF is considered to represent a more meaningful flow baseline for resource management, MALF-N is typically a less precise number than MALF-M. This is mainly because of assumptions required about the level of abstraction occurring during low flow conditions (in the absence of time series abstraction data). It is also very difficult to naturalise for groundwater abstraction or the ‘returns’ associated with irrigation runoff and water race discharges. Notwithstanding these uncertainties, the overriding argument for using MALF-N is that it helps avoid the situation of successive flow assessments using incrementally lower MALF values as abstraction increases over time.

It is anticipated that, over time, all management flows (including minimum flows) for rivers and streams in the region will be based on standardised assessments of MALF-N; the accuracy of naturalised estimates should improve as abstraction metering increases. More detail on how flow statistics in this report have been naturalised is provided in the introduction to Appendix 3.

From this point on in the report all references to MALF will indicate whether it is the naturalised or measured value being discussed.

3.4 Site-specific investigations

For those rivers and streams recognised as having relatively high value and/or a high level of abstractive demand, site-specific investigations have been undertaken using the guiding framework and methods set out earlier.

Consistent results have been obtained in the application of IFIM and generalised habitat modelling methods for several rivers allowing us to propose revisions to existing minimum flow criteria. Results from these studies have also improved our ability to predict habitat changes that might occur in rivers and streams that have not / cannot be directly investigated (see next section on regionalised approach). Results from the application of dissolved oxygen models have been more variable. In some cases (eg, the Papawai Stream investigation, Keenan 2009c) robust relationships between field-measured dissolved oxygen and flow have been found and used as a basis for reviewing the minimum flow. However, a GWRC commissioned study on several Wairarapa streams (Young & Doehring 2010) showed that the relationship between measured dissolved oxygen and flow varies widely between streams and concluded that for groundwater-fed streams it is difficult to predict changes in dissolved oxygen in response to changes in flow.

3.5 A regionalised approach to flow setting

In 2010, GWRC commissioned the Cawthron Institute to provide advice on instream flow setting options. As part of this assessment, Hay (2010a) compared the outputs of historic RHYHABSIM data with those from generalised models for the same Wellington rivers and streams and found very good agreement.

Based on this analysis, Hay (2010a) suggested that the generalised models are well suited for application to minimum flow setting in the Wellington region, at least on rivers and streams with a similar channel form to those in the test dataset (ie, mainly the larger, gravel-bed rivers with U-shaped channels).

Hay (2010a) also assessed the relationship between trout habitat retention flows determined through full habitat modelling techniques (ie, RHYHABSIM) and 1d MALF-N for rivers in the Wellington region and found that a strong linear relationship exists; ie, a minimum flow set at 87% of MALF-N is likely to be very similar to one set by habitat modelling to retain 90% of the adult brown trout habitat available at MALF-N[4]. While the relationship does not appear to hold for the largest river in the region – the Ruamahanga River with MALF-N higher than 5 m^3/s – it does provide a compelling basis for establishing rules of thumb and default limits for rivers and streams in the region with more moderate flows and established trout values (and that have not been subject to more in depth investigation).

3.6 Application of default minimum flow criteria

The developmental work and investigations described in the previous sections can be used to derive default minimum flow criteria for application to rivers and streams in the absence of detailed site-specific information.

It is recommended that these default criteria are based on the protection of aquatic habitat at low flows. This is because we have been able to demonstrate general relationships between flow requirements for habitat protection and MALF-N. So far, studies of dissolved oxygen and water temperature fluctuations with flow have been too inconclusive, even within a subset of spring-fed streams, to consider using as a basis for region-wide minimum flow criteria. Likewise, there is not yet the density of good information on other flow-related instream values to consider establishing generalised relationships.

Defining flow criteria for habitat protection requires consideration of two factors: the level of habitat retention desired and the flow characteristics of the river or stream.

3.6.1 Level of habitat maintenance

Determining the appropriate level of habitat maintenance is not an exact science. This is largely because the current state of knowledge on the effects of low flow is insufficient to predict with certainty how much instream values will change with a percentage flow reduction (Hay 2010a). However, there is published expert advice to help guide the process, including suggested significance ranking of critical values and minimum levels of habitat retention by Jowett and Hayes (2004) (see Table 3.2). While the percentages in Table 3.2 are thought to be conservative (Jowett & Hayes 2004; Hay 2010a) – and denote clear boundaries where, in reality, very fuzzy boundaries exist – the key point is that a habitat retention level of, say, 90% of that available at MALF-N will generally maintain existing fish populations, whereas retention levels of 50% of that available at MALF-N *might* result in a negative impact.

[4] An equally strong relationship was found when using alternative habitat retention criteria of 70% of MALF.

Table 3.2: Significance ranking (from highest of 1 to lowest of 5) of critical values and levels of habitat retention in relation to habitat available at MALF (from Jowett & Hayes 2004)

Critical value	Fishery quality	Significance ranking	Habitat retention (%)
Large adult trout – perennial fishery	High	1	90
Diadromous galaxiid	High	1	90
Non-diadromous galaxiid	–	2	80
Trout spawning / juvenile rearing	High	3	70
Large adult trout – perennial fishery	Low	3	70
Diadromous galaxiid	Low	3	70
Trout spawning / juvenile rearing	Low	5	60
Bullies, eg, upland, common, bluegill	–	5	60

3.6.2 Proposed default minimum flows

The suggested minimum flow rules given in the proposed NES on ecological flows (MfE 2008) are:

- *For rivers and streams with mean flows less than or equal to 5 m^3/s, a minimum flow of 90% of the mean annual low flow (MALF)*[5] *as calculated by the regional council.*

- *For rivers and streams with mean flows greater than 5 m^3/s, a minimum flow of 80% of MALF as calculated by the regional council.*

To date, GWRC has adopted habitat retention criteria for specific instream flow investigations that are consistent with these rules, which in turn, broadly reflect the more conservative range of criteria in Table 3.2. For a regional default rule it is therefore suggested that the MfE (2008) criteria are adopted. It is noted however that there are no rivers with a mean flow exceeding 5 m^3/s in the Wellington region for which a case-specific minimum flow has not already been determined (so the second of the two rules is effectively redundant as a default).

3.6.3 River and stream size / flow rate

Consideration has been given to taking stream size/flow rate into account when setting default minimum flows. In paricular, whether small streams (eg, 7d MALF-N of less than 100 L/s) should be afforded additional levels of habitat maintenance. By way of example, Horizons Regional Council adopts a default minimum flow value of 95% of 1d MALF-N for their smallest waterways. However there are no established criteria in the Wellington region for setting minimum flows on the basis of flow rate and no clear evidence that small streams warrant special attention. In practice there is little material difference between thresholds of 90%, 95% and 100% of MALF-N as they all describe a proportion of total flow that is typically less than the error in most flow measurements. In the absence of better information, and in the interests of

[5] Although the proposed NES is not explicit, their definition of MALF is presumed to be the 'natural' 7 day MALF.

retaining a simple approach that is consistent with national guidelines, it is recommended that no alternative default provision be assigned to small streams.

3.6.4 Variability in annual minimum flows

One of the potential drawbacks of using MALF-N as a universal index for minimum flow provisions is that the **mean** of annual low flows does not always adequately represent the **variability** in annual minimum flows. For example, a catchment with highly variable annual minimum flows may have the same MALF as a catchment with less variable annual minimums. In this example, when applying the recommended default minimum flow of 90% of MALF-N, both catchments would receive the same minimum flow but the former catchment *may* have an ecosystem that is more tolerant of extreme low flows.

Differences in annual low flow variability between catchments can be compared using the coefficient of variance[6]. This comparison is made in Figure 3.2 for rivers and streams in the region with suitable flow record. Of the 29 flow records included, all but four had CoVs constrained within the range 0.2 to 0.5; smaller streams tended to be towards the top end of this range for this main cluster. Three of the four CoVs that were significantly higher than the main cluster were for rivers in the eastern Wairarapa that experience a relatively wide range of annual minimums, while the other 'outlier' was for a small stream (the Taupo Stream) on the west coast north of Porirua Harbour.

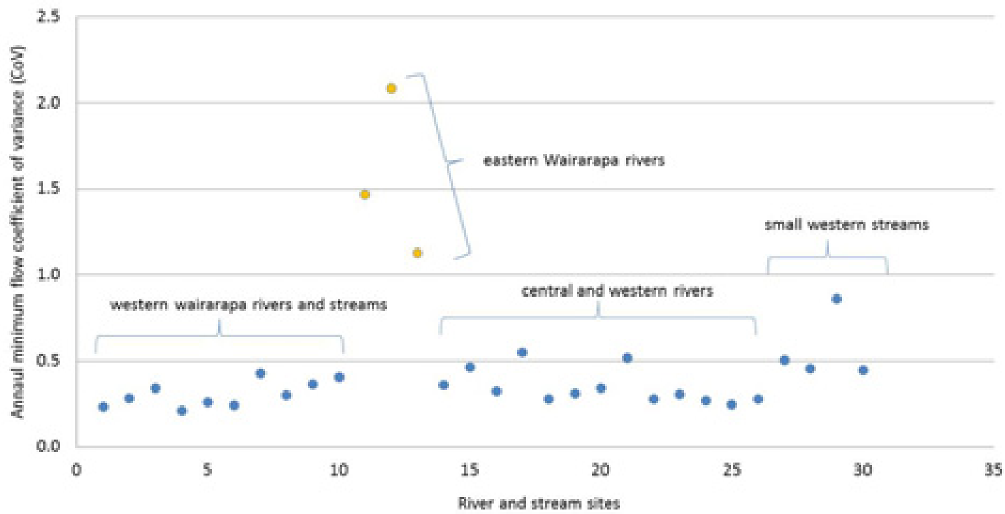


Figure 3.2: Coefficient of Variance (CoV – see footnote 6) of annual minimum flows for a range of river and streams in the Wellington region. The orange coloured markers emphasise rivers that exhibit a significantly higher range of low flow variability than the main cluster

The dataset in Figure 3.2 is biased towards larger river systems (as these are more closely monitored) so it is inappropriate to draw strong conclusions about the extent of low flow variability across the region. Nevertheless, the analysis

[6] The coefficient of variance (CoV) in this case is the standard deviation of the annual minimum low flows divided by the mean of the annual low flows and provides a normalised index of low flow variability; low CoV indicates low variability between years in the minimum flow and high CoV indicates a high variability.

indicates some spatial uniformity in patterns low flow variability. This in turn provides confidence that default minimum flow setting based on MALF is likely to be reasonable in most circumstances. The analysis does also highlight that, in general terms, the application of a default minimum flow based on MALF is likely to be less appropriate for catchments in some parts of the region, particularly in the east. The most pragmatic way to deal with this apparent imbalance is to retain the simple default rule but allow some flexibility in the planning framework to recognise new catchment-specific information that justifies a more appropriate alternative minimum flow.

4. Recommended minimum flows

4.1 Numerical minimum flows for high priority rivers and streams

This section summarises recommended minimum flows for rivers and streams in the region with existing significant consented abstraction and sufficient flow data available to derive MALF with confidence (and therefore a numerical minimum flow). Summary information is listed in Table 4.1 and fuller details for each river or stream, including relevant flow statistics, monitoring site information and catchment-specific reference material, are provided in Appendix 3. Rivers and streams in Table 4.1 are grouped by sub-region and then listed generally from north to south. They are also shown in Figure 4.1.

Generally, the recommendations in Table 4.1 are to either:

- **Retain the existing minimum flow**; either because the minimum flow is a relatively recent addition to the RFP, no catchment-specific review has yet been conducted (this may be because no information exists to show an urgent review is required) or, if a review has been conducted, it showed the existing minimum flow is appropriate
- **Introduce a new minimum flow (where previously there was not one);** where a river or stream is not listed in the existing RFP but new information has enabled a prospective minimum flow to be derived

In the case of three waterways (the Waiohine and Otaki rivers and the Mangaone Stream), technical review in recent years has provided a good case for increasing the existing minimum flows (see specific discussion of these sites in Appendix 3). However, consultation on these changes with stakeholders during the 'Discussion Document' phase of the Regional Plan development (August 2013 to June 2014)[7] has led to the GWRC decision to refrain from recommending the changes at this stage. This decision reflects a desire to work any changes through the more comprehensive catchment committee process where additional instream and out-of-stream values will be considered.

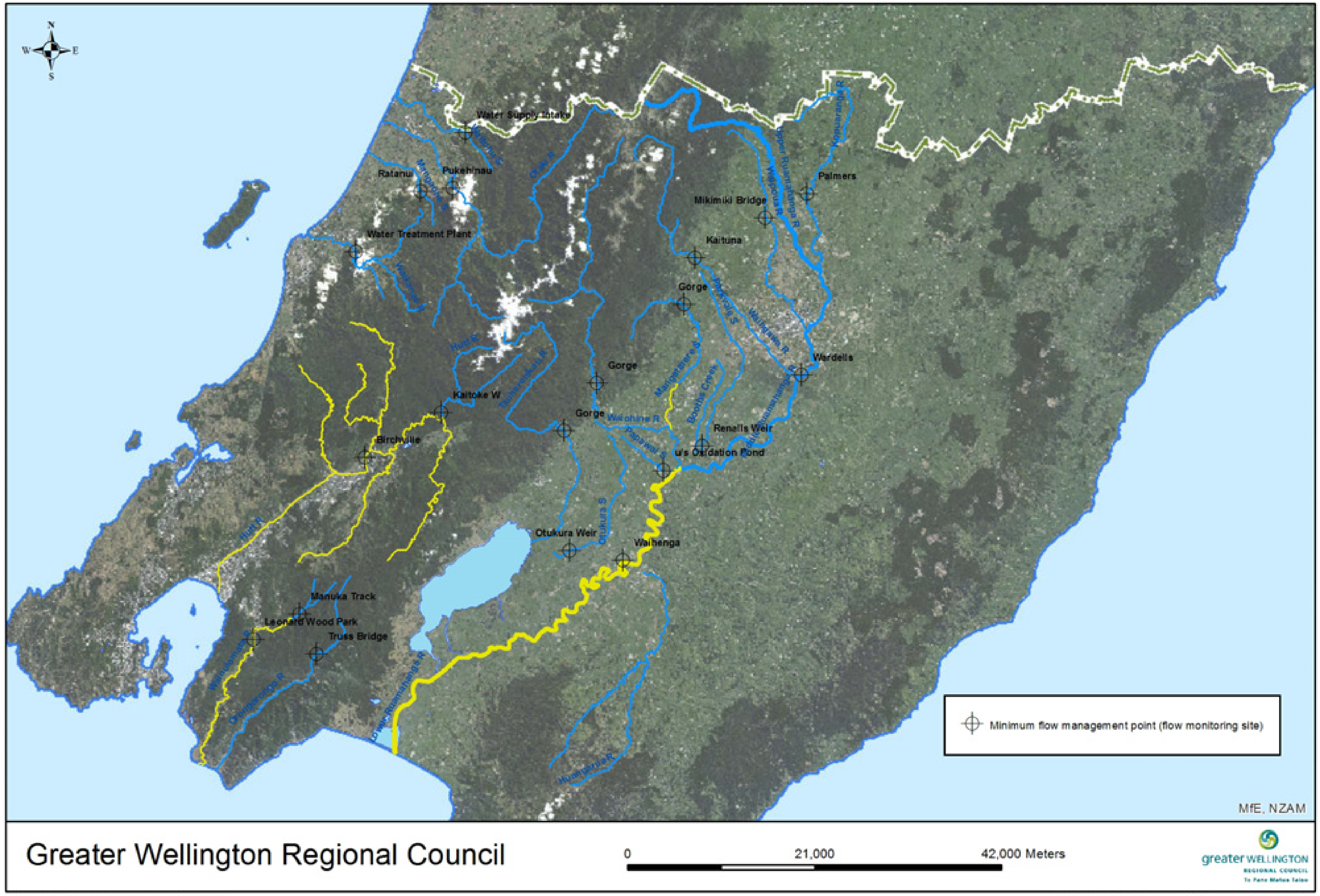
All of the rivers and streams in Table 4.1 and Figure 4.1 have at least one continuous flow recorder in their catchments that can be used for monitoring and managing minimum flows.

[7] See GWRC (2013b) – Greater Wellington Regional Plan: Working document for discussion. This document set out early proposals for plan provisions, including recommended minimum flows, and was used as the basis for stakeholder consultation before the draft Regional Plan was finalised.

Table 4.1: Existing and new recommended numerical minimum flows for the rivers and streams in the Wellington region. Waterways are grouped by sub-region and listed primarily from north to south. Green shading denotes no change in minimum flow and yellow shading denotes a new minimum flow where previously there was not one listed for that waterway

Note: the minimum flows for each listed waterway apply to all upstream tributaries of that waterway, unless the tributary is also listed.

Sub-region	River (or reach)	Existing minimum flow (L/s)	New minimum flow (L/s)
Wairarapa	Kopuaranga River	270	270
	Waipoua River	250	250
	Waingawa River	1,100	1,100
	Upper Ruamahanga River	2,400	2,400
	Parkvale Stream	None	100
	Mangatarere Stream	240 [upper], 200 [lower]	240 [upper], 200 [lower]
	Waiohine River	2,350	2,350
	Papawai Stream	None	180
	Middle Ruamahanga River	8,500	8,500
	Otukura Stream	None	95
	Tauherenikau River	1,100	1,100
	Lower Ruamahanga River	8,500	8,500
Hutt Valley	Hutt River – Upper reach	600	600
	Hutt River – Lower reach	1,200	1,200
	Wainuiomata – Upper reach	100	100
	Wainuiomata – Lower reach	300	300
	Orongorongo River	100	100
Kapiti Coast	Waitohu Stream	140	140
	Otaki River	2,550	2,550
	Mangaone Stream	22	22
	Waikanae River	750	750
All other rivers		No provisions	Default 90% of MALF



Topographic and Cadastral data is copyright LINZ

Regional Orthophotography Copyright : GWRC / NZAM 2010

Figure 4.1: Rivers (and river reaches) to which the numerical minimum flows listed in Table 4.1 apply. Where there are the two minimum flows specified for a single river or stream the reaches to which the minimum flows apply are colour coded blue (upper reach) and yellow (lower reach). The main stem of the Ruamahanga River is shown as a thicker line to highlight it among the tributary rivers and streams. Flow recorder sites used to monitor minimum flows for each river and reach are shown as black cross-hairs

4.2 Default minimum flows for 'other' rivers and streams in the region

For rivers and streams that are not listed in Table 4.1 (ie, those with minor or no current consented abstraction and/or insufficient data with which to determine and monitor a minimum flow), the recommended default minimum flow presented earlier in Section 3.6.2 should be adopted:

Minimum flow = 90% of 7d MALF-N at the point of abstraction

In practice, in order for the default rules to be applied an estimate of 7d MALF-N is required. Where GWRC has little or no information on flow for a specific river or stream, resource consent applicants will need to undertake sufficient work to derive an estimate. To assist, it is recommended GWRC prepare best practice guidance material for low flow estimation in support of consent applications.

In some cases it may be appropriate for a default rule to be superseded by a more in-depth flow investigation (eg, for a particularly large take and/or when instream values are considered likely to be high or low flow characteristics are considered to be particularly atypical). Determinations about the level of any investigation required should be consistent with approaches taken to date by GWRC and be guided by advice we have received – particularly that of Hay (2010a) who provides advice on river and stream classification in the Wellington region and a tiered approach to instream flow assessment and minimum flow setting.

4.3 Comparing recommendations across the region

Figure 4.2 shows the recommended minimum flows in Table 4.1 as a percentage of 7d MALF-N. Minimum flows range from about 40% to 140% of 7d MALF-N with the lowest proportion of flow set aside for bulk public water supply rivers (the Hutt, Wainuiomata). The highest recommended minimum flow (as a proportion of 7d MALF-N) is for the Mangatarere Stream and reflects the significant abstractive and water quality pressures on this waterway. Generally, the highest minimum flows (as a proportion of 7d MALF-N) are recommended for the smaller rivers and streams (shaded light blue in Figure 4.2).

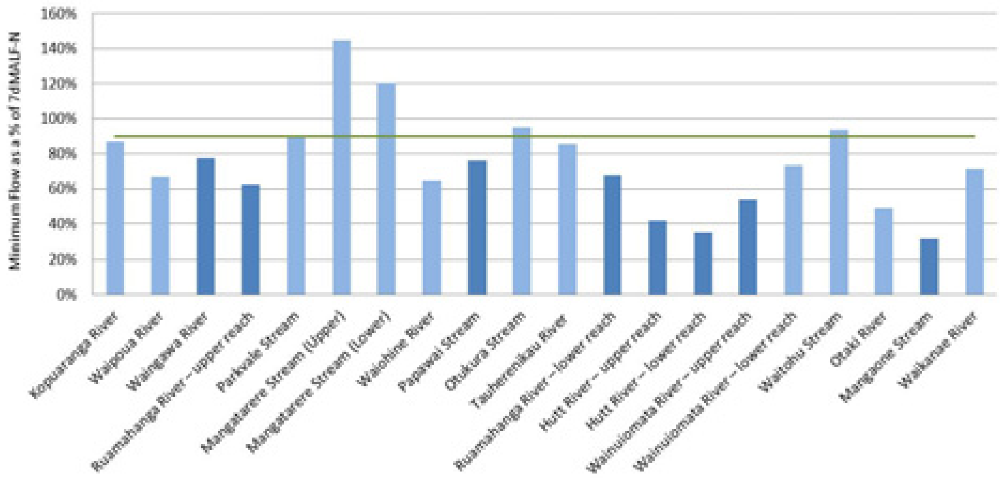


Figure 4.2: Recommended <u>numerical</u> minimum flows as a percentage of 7d MALF-N (at the relevant flow management site) – listed in the same order as in Table 4.1. 'Large' rivers (ie, with mean flow >5 m^3/s) are shaded dark blue and 'small' rivers (ie, with mean flow <5 m^3/s) are shaded light blue. The recommended default minimum flow of 90% 7dMALF-N is shown as the horizontal green line

5. Implementing and monitoring minimum flows

Taking the approach of the existing RFP (WRC 1999a), the general intent of minimum flows is that all non-essential abstractions are under full suspension by the time the specified threshold (or equivalent downstream flow) is reached. Abstractions include riparian 'hydraulically connected' groundwater takes as set out in the frameworks for integrated groundwater-surface water management (eg, Hughes & Gyopari 2014). Achieving this intent is only possible if there are clear criteria around abstraction reductions (ie, step-downs) as flow recedes towards the minimum flow and an effective compliance monitoring framework is in place. It is also worth considering whether minimum flow rules and policies should only become operative once a certain allocation pressure is reached in a catchment. These potential implementation issues are discussed in more detail in the following sections.

5.1 Step-down flows

Currently, step-down criteria are specified in the RFP for most non-water supply catchments and consents, but not all (eg, Kopuaranga River). Step-downs are required primarily because many of the GWRC flow monitoring sites (at which the minimum flow is specified) are upstream of where abstractions occur. Without step-downs, there would be periods during flow recession when abstraction is potentially causing an unanticipated (and possibly unacceptable) level of alteration to the low flow regime further down the catchment. Step-downs ensure that abstraction is appropriately scaled back prior to the minimum flow being reached. The scale of step-down, as a proportion of total core allocation, varies between rivers and streams in the region, but generally step-downs begin to be enforced once a flow equal to the minimum flow plus consented abstraction is reached.

It is important to note that in some catchments where public and stock water supply are important uses (eg, Waingawa, Waiohine and Tauherenikau rivers), non-essential abstractions are currently required to cease some way above the minimum flow. This is to ensure sufficient headroom exists to sustain the essential abstractions that cannot be significantly reduced by step-down restrictions.

It is recommended that GWRC continue to exercise step-down rules. It is appropriate that the detail of the step-down rule continue to be tailored to the catchment where it is being applied. The higher the consented allocation is, the more stringent the step-down rule should be.

5.2 Minimum flow exclusions based on allocation pressure

Some catchments in the Wellington region have (as at June 2014) only minor abstractive pressure. In such catchments, the effect of abstraction, even at very low flows, is likely to be indiscernible and the merit of applying minimum flow restrictions, therefore, questionable. While it is necessary to introduce default minimum flow limits in these catchments to protect against potential future growth in abstraction, it may be appropriate that these minimum flows only become operable once a certain abstraction threshold has been exceeded. For example, a total catchment allocation equivalent to $\geq$ 20% of 7d MALF-N may be a suitable threshold as it represents a degree of flow alteration that is both discernible (using conventional flow measurement techniques that are typically accurate to ± 8%) and potentially having an impact.

5.3 Monitoring requirements

The benefit of having minimum flow limits in place is significantly diminished if they are not effectively monitored and enforced. While the management sites referred to in Section 3.3.1 are appropriate for triggering flow restrictions they are generally not suitable for monitoring the *impact* of abstractions and general success or otherwise of minimum flow policies. As shown in Figure 3.1, and discussed in the Section 3.3.1, most management sites are relatively high in the catchment, and measure natural flows upstream of the majority of water abstractions.

Given the spatial and temporal variability in flow regimes, and the constraints on network reconfiguration[8], fully representative monitoring of minimum flow policies in the region is unrealistic. Instead, it is recommended that monitoring makes use of existing continuous flow recorders where they are located in lower river reaches, supplemented by rotational summer spot flow gauging programmes focussed on representative reaches and bottom-of-catchment locations. Historical concurrent gauging information – most recently summarised in Keenan (2009b) – can also be used to target reaches of interest in many rivers and streams.

The difficulties associated with establishing and maintaining permanent flow recorder sites in downstream river reaches is another good reason to rely on step-down policies to manage abstractive drawdown.

[8] Not just financial or resource based but also physical constraints; many lower river reaches do not present any suitable locations for establishing permanent flow monitoring sites.

6. Future refinement of minimum flows

As stated in Section 1, it is intended that the minimum flow recommendations in this report will form the basis for proposed interim limits in the dNRP. Subsequent refinements will focus on weighing the recommended interim flows against other factors such as water user requirements and broader community values.

6.1 Revisiting management objectives

A likely area of interest for the whaitua zone committees is the management objectives defined for major rivers and streams in the region. At present there is a mix of catchment-specific objectives formed during flow investigations and more general objectives formed during community consultation and documented in the RPS (GWRC 2013a). These have been used to guide the minimum flow recommendations (see tables in Appendix 3 for listed objectives for each river with a recommended numerical minimum flow).

As discussed in Section 2.6, a number of value-laden judgements are required in moving from a management objective to a minimum flow recommendation, including determination of the relative importance of instream characteristics and the level of protection these characteristics merit. It may be appropriate to revisit some judgements and test against broader community interests, including a detailed consideration of out of stream water uses. Possible methodological refinements in this area are discussed later in Section 6.3.

6.2 Incorporating other values in the review of minimum flows

6.2.1 Tangata whenua values

In 2010 GWRC commissioned Caleb Royal from Ohau Plants Ltd to compile a report of tangata whenua flow-related values for the following 14 rivers and streams in the Wairarapa: Waingawa River, Tauherenikau River, Waipoua River, Parkvale Stream, Huangarua River, Ruamahanga River – upper reach, Papawai Stream, Kopuaranga River, Booths Creek, Stonestead (Dock) Creek, Tauweru River, Abbots Creek, Makahakaha Stream and Makoura Stream. Royal (2012) made minimum flow recommendations for each of the rivers and streams, some of which are in close agreement with flow recommendations for the same waterways by GWRC and others that are quite different. A subsequent briefing paper (Thompson et al. 2012) provides further context to both the GWRC and Royal (2012) approaches to minimum flow review to help with interpretation of the respective recommendations. A key point is that many of the recommendations of Royal (2012) are based on perceptions of flow requirements and the associated qualitative assessments require further refinement and validation.

This report does not attempt to integrate the minimum flow recommendations of Royal (2012) with those made by GWRC. It is envisaged that any such integration will be considered along with other unaddressed values during the ongoing limit-setting process, and the Ruamahanga whaitua process in particular.

6.2.2 Considering out-of-stream uses

Overall consequences for environmental values and water users depend not just on minimum flows but also the associated allocation policies. It is anticipated that the recommended minimum flows for some catchments may require refinement in the future based, as stated above, on more detailed consideration of catchment management objectives but also the combined consequences of flow and allocation policies. Franklin et al. (2012) note that there are multiple ways (ie, combinations of minimum flow and allocation rules) to satisfy management objectives. The eventual decision about limits will reflect the relative importance of values assessed and decisions may vary between catchments or management zones.

(a) Reliability of supply

Reliability of supply for water users (ie, the proportion of time that water is available to be abstracted) is determined by a combination of the natural flow regime (and how many days a river naturally spends below MALF), the minimum flow policy (which is in turn often dictated by levels of habitat retention that are selected) and level of core allocation that is set. Figure 6.1 shows the variability between catchments in reliability of supply during the irrigation season (November to April inclusive) under the minimum flows recommended in this report. The general pattern is one of high reliability (>95%) for abstractions from the Tararua Range-fed rivers with relatively well-supported base flows and lower reliability (80–90%) for abstractions from smaller foothill and spring-fed catchments.[9]

If there was a desire to improve the security of supply for water users (eg, to achieve at least 90% security across the region) there would clearly be a need to reduce minimum flows in some areas.

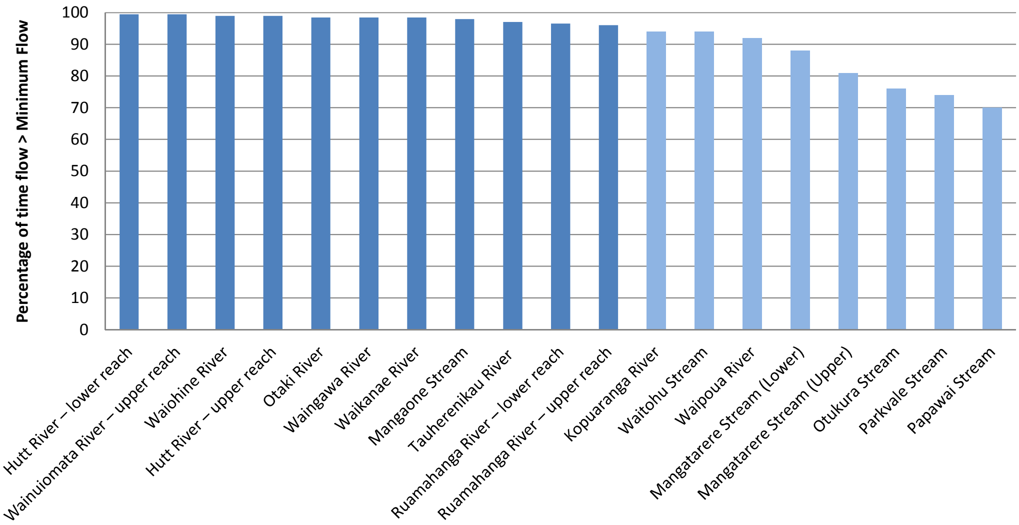


Figure 6.1: Percentage of time during the irrigation season (Nov–Apr inclusive) that flows are above the recommended minimum flow thresholds (listed in Table 4.1). Rivers are ranked from highest reliability (left) to lowest reliability (right) and colour coded according to the predominant source of flow (dark blue are predominantly Tararua Range-fed rivers while the light blue are rivers or streams that originate in the foothills or are spring-fed)

[9] Note that Figure 6.1 indicates the amount of time that **no** water would be available to users. However, since abstractions are required to reduce according to stepdown criteria as the minimum flow is approached, the amount of time that **full** allocation is not available would be higher than indicated in the graph.

(b) Core allocation

GWRC has not yet gone through a process of determining allocation limits based on a balance of in-stream and out-of-stream (ie, security of supply) values. Such a process is not science-driven but requires coordinated community and water user input to determine the acceptability of trade-offs. As an interim measure it is proposed that surface water (and directly connected groundwater) allocation limits be based on default values that are aimed at maintaining ecological values.[10] The chosen values and the rationale behind them is described in Thompson and Mzila (2015).

6.3 On-going technical reviews

Environmental flow setting is an on-going process for GWRC. There are several high use, high value waterways in the region that have not yet been the subject of a specific and thorough minimum flow review since original provisions were set in the existing RFP (eg, the Hutt River, the Waipoua River). A rolling schedule of technical reviews will continue as part of the ongoing technical and policy work programme of GWRC. The outcomes of such reviews could be proposed as plan changes (if considered urgent) or held over for the next full plan review.

It is important that GWRC continues to refine its flow setting methodology over time to maintain best practice. While it is not within the scope of this report to discuss in detail what refinements might be needed, a key area is likely to encompass the process by which instream values and desired levels of habitat retention are determined. There remain some differing views among experts about how concepts such as the overall ‘value’ of a river, or a particular species within that river, should be defined. For example, should a native fish species with a ‘highly threatened and declining’ status be considered of higher value than a non-threatened species, irrespective of their relative abundance in a given river?

A key point, upon which there *is* wide agreement, is that robust assessments depend on good information about the longitudinal distribution of species and instream values within river systems as well as between systems. Unfortunately there is generally very little such information on native fish abundance in Wellington rivers. Future flow assessments should consider the merits of including study-specific fish monitoring data rather than relying on historic database information.

[10] The proposed limits are for core allocation amounts to equate to 30% of MALF for rivers with a mean flow of less than 5 m^3/s and 50% of MALF for rivers with a mean flow of greater than 5 m^3/s. These limits are consistent with those recommended by Ministry for the Environment (2008) and Beca (2008).

7. Summary

This report has made a number of recommendations for the dNRP that relate to minimum flows for rivers and stream in the Wellington region.

The primary recommendations are:

- To apply numerical limits (ie, in litres per second) to 17 identified rivers and streams where there is (a) significant water use, (b) sufficient information available to define appropriate thresholds and (c) a means by which to actively monitor compliance with minimum flows. The numerical thresholds for 14 of the 17 waterways are the same as listed in the existing RFP policies while the remaining five are new (ie, in catchments where no current minimum flow policy)

- For all rivers and streams outside of catchments covered by numerical thresholds, to apply a default minimum flow limit equating to 90% of the mean annual low flow at the point of abstraction

- To consider both the numerical and default limits described above as **interim** in the dNRP in recognition of the process being undertaken by catchment committees to refine and agree on longer term limits. Particular attention should be given to the Waiohine River, Otaki River and Mangaone Stream during this process in light of scientific review to date that suggests increasing the minimum flows for these waterways is justified

Other specific recommendations include:

- To use the 7d MALF-N in all applications of the default minimum flow

- To continue to exercise stepdown restrictions in a manner that ensures minimum flows (or the equivalent natural flows downstream) are not breached by non-essential abstractions. Some discretion will be needed to ensure each stepdown regime is appropriate to the target catchment

- For GWRC to conduct sufficient flow monitoring in ungauged catchments with existing consent holders to characterise mean annual low flow conditions

- To require new consent applicants in ungauged catchments to furnish sufficient information with an application to estimate mean annual low flow (and therefore apply the default minimum flow)

- To retain sufficient planning flexibility to apply an alternative minimum flow (to the default) if it can be justified

- For GWRC to continue to review minimum flows to ensure provisions are adequate. Priority should be given to the Hutt, Wainuiomata, Waingawa and Waipoua rivers in coming years

References

Beca 2008. *Draft guidelines for the selection of methods to determine ecological flows and water levels.* Report prepared for Ministry for the Environment, Wellington.

Franklin P, Snelder T, Diettrich, J and Booker D. 2012. *Default water allocation limits for selected catchments in the Canterbury region*. NIWA Client Report No. HAM2012-113, prepared for Environment Canterbury, Christchurch.

Gordon M. 2012. *Hydrological statistics for surface water monitoring sites in the Wellington region – 2012 summary.* Unpublished internal report, Document#723259, Greater Wellington Regional Council, Wellington.

Greater Wellington Regional Council. 2003. *Draft water allocation plan for the Mangatarere catchment*. Unpublished internal report, Greater Wellington Regional Council, Wellington.

Greater Wellington Regional Council. 2007. *Water allocation plan for the Mangatarere catchment (including changes from proposed Plan Change 2).* Unpublished internal report, Greater Wellington Regional Council, Wellington.

Greater Wellington Regional Council. 2013a. *Regional Policy Statement for the Wellington region*. Greater Wellington Regional Council, Publication No. GW/EP-G-13/23, Wellington.

Greater Wellington Regional Council. 2013b. *Regional Plan: Working document for discussion*. Greater Wellington Regional Council, August 2013 (unpublished).

Hay J. 2007. *Review of "Hutt instream flow assessment – proposed investigations".* Unpublished letter of advice prepared by Joe Hay of the Cawthron Institute for Greater Wellington Regional Council, Wellington.

Hay J. 2008. *Instream flow assessment for the lower Ruamahanga River*. Cawthron Institute, Publication No. 1403, prepared for Greater Wellington Regional Council, Wellington.

Hay J. 2010a. *Instream flow assessment options for Greater Wellington Regional Council.* Cawthron Institute, Publication No. 1770, prepared for Greater Wellington Regional Council, Wellington.

Hay J. 2010b. *Minimum flow advice for the Waikanae River.* Unpublished letter of advice, Document #879601, Cawthron Institute, prepared for Greater Wellington Regional Council, Wellington.

Hay J. 2011. *Review of instream habitat modelling for the Wainuiomata River.* Unpublished letter of advice, Document #1090794, Cawthron Institute, prepared for Greater Wellington Regional Council, Wellington.

Harkness M. 2003. *Instream habitat assessment for the Wainuiomata River*. Unpublished internal report, Wellington Regional Council, Wellington.

Hudson H. 2010. *Assessment of potential effects on instream habitat with reduced flows in the Hutt River at Kaitoke.* Assessment of Environment Effects (AEE) prepared by Environmental Management Associates Ltd for Greater Wellington Regional Council Water Supply Department, Wellington.

Hughes B and Gyopari M. 2011. *Wairarapa Valley groundwater resource investigation: Proposed framework for conjunctive water management.* Greater Wellington Regional Council, Publication No. GW/EMI-T-11/53, Wellington.

Hughes B and Gyopari M. 2014. *Wairarapa Valley groundwater resource investigation: Framework for conjunctive water management.* Greater Wellington Regional Council, Publication No. GW/EMI-T-14/94, Wellington.

Jowett I. 1990. Factors related to the distribution of and abundance of brown and rainbow trout in New Zealand clear-water rivers. *New Zealand Journal of Marine and Freshwater Research 24: 429–440*.

Jowett I. 1992. Models of the abundance of large brown trout in New Zealand rivers. *North American Journal of Fisheries Management* 12: 417–432.

Jowett I. 1993. *Minimum flow assessments for instream habitat in Wellington rivers.* NZ Freshwater Miscellaneous Report No. 63, National Institute of Water and Atmospheric Research, Christchurch.

Jowett I and Hayes J. 2004. *Review of methods for setting water quantity conditions in the Environment Southland draft Regional Water Plan.* NIWA Client Report: HAM2004-018, prepared by NIWA for Environment Southland, Invercargill.

Jowett I, Richardson J and Bonnett M. 2005. Relationship between flow regime and fish abundances in a gravel bed river, New Zealand. *Journal of Fish Biology* 66:1–18.

Keenan L. 2009a. *Review of minimum flows for Wairarapa rivers.* Internal staff report to Greater Wellington Regional Council Regulatory Committee, 21 October 2009. Report No. 09.502, Wellington.

Keenan L. 2009b. *Mean annual low flow statistics for rivers and streams in the Wellington region.* Unpublished internal report, Document #715651, Greater Wellington Regional Council, Wellington.

Keenan L. 2009c. *Instream flow assessment for Papawai Stream.* Greater Wellington Regional Council, Publication No. GW/EMI-G-09/332, Wellington.

Keenan L. 2009d. *Waiohine River instream values and minimum flow assessment.* Greater Wellington Regional Council, Publication No. GW/EMI-G-09/276, Wellington.

Keenan L, Thompson M and Mzila D 2012. *Freshwater allocation and availability in the Wellington region: state and trends*. Greater Wellington Regional Council, Publication No. GW/EMI-T-12/141, Wellington.

Ministry for the Environment 1998. *Flow guidelines for instream values*. Two volumes. Ministry for the Environment, Wellington.

Ministry for the Environment 2008. *Proposed National Environmental Standard on ecological flows and water levels.* Discussion Document. Ministry for the Environment Publication No. ME 868, Wellington.

Ministry for the Environment. 2014. *National Policy Statement for Freshwater Management 2014.* Publication No. ME1155, Ministry for the Environment, Wellington.

Morgan M. 1998. *Taueru River low flow monitoring and B. Patrick irrigation take.* Unpublished internal report, Wellington Regional Council (Wairarapa Division), Masterton.

Royal C. 2012. *Cultural values for Wairarapa waterways report.* Prepared by Ohau Plants Ltd (Caleb Royal) for Greater Wellington Regional Council, Wellington.

Roygard J. 2010. *Proposed One Plan – Section 42A report.* Submitted to the Hearings Panel on behalf of Horizons Regional Council, Palmerston North.

Suren A and Jowett I. 2006. Effects of floods versus low flows on invertebrates in a New Zealand gravel-bed river. *Freshwater Biology* 51: 2,207–2,227.

Thompson M. 2011a. *Otaki River instream values and minimum flow assessment.* Greater Wellington Regional Council, Publication No. GW/EMI-T-11/133, Wellington.

Thompson M. 2011b. *Minimum flow for the Waingawa River: Desktop review.* Unpublished internal filenote, Document #953580, Greater Wellington Regional Council, Wellington.

Thompson M. 2011c. *Taueru River flow review: Background for Patrick consent renewal.* Unpublished internal filenote, Document #903937, Greater Wellington Regional Council, Wellington.

Thompson M. 2011e. *Low flow assessment for Kapiti Golf Course water take from Wharemauku Stream: Consent WGN110160.* Unpublished internal memo, Document #885341, Greater Wellington Regional Council, Wellington.

Thompson M. 2011f. *Comparison of minimum flow setting using 1-day and 7-day MALF for two rivers in the Wellington region.* Unpublished internal report, Document #938883, Greater Wellington Regional Council, Wellington.

Thompson M. 2012a. *Tauherenikau River instream values and minimum flow assessment.* Unpublished technical report (Document #799709), Greater Wellington Regional Council, Wellington.

Thompson M. 2012b. *Booths Creek low flow hydrology: Technical advice to assist with review of abstraction consents.* Unpublished internal memo, Greater Wellington Regional Council, Document #970604, Wellington.

Thompson M. 2012c. *Waikanae River – background issues report to inform Minimum flow discussions.* Unpublished internal memo, Greater Wellington Regional Council, Document #894438, Wellington.

Thompson M. 2014a. *Naturalising low flows in the Ruamahanga River.* Unpublished technical report, WGN_DOCS#1425509. Greater Wellington Regional Council, Wellington.

Thompson M. 2014b. *Minimum flow recommendations for the Wellington region: Technical report to support the draft Natural Resources Plan.* Greater Wellington Regional Council, Publication No. GW/ESCI-T-14/62, Wellington.

Thompson M and Mzila D. 2015. *Water allocation recommendations for the Wellington region: Technical report to support the proposed Natural Resources Plan.* Greater Wellington Regional Council, Publication No. GW/ESCI-T-15/84, Wellington.

Thompson M, Grace M and Royal C. 2012. *Assessing river and stream flow requirements; a discussion of the findings from tangata whenua and GWRC led approaches to assessing flow requirements.* Paper prepared jointly by Greater Wellington and Caleb Royal to assist in Regional Plan review process, unpublished, Document #1066722, Wellington.

Wairarapa Catchment Board. 1988. *Water resources survey and water allocation plan for the Waingawa water resource region 1988.* Unpublished internal report, Wairarapa Catchment Board, Wellington.

Watts L. 2003. *Instream habitat assessment for the Waikanae River.* Unpublished internal report, Wellington Regional Council, Wellington.

Watts L. 2006. *Framework for instream flow assessment in the Wellington region.* Unpublished internal report, Wellington Regional Council, Wellington.

Watts L. 2007a. *Instream flow assessment for Otukura Stream and Battersea Drain: Stage 1 – Instream flow issues report.* Greater Wellington Regional Council, Publication No. GW/EMI-T-07/55, Wellington.

Watts L. 2007b. *Review of Greater Wellington's priorities for instream flow assessment.* Unpublished internal report, Document #472053, Greater Wellington Regional Council, Wellington.

Watts L. 2008. *Instream flow assessment for Otukura Stream: Stage 2 – Instream flow requirements.* Greater Wellington Regional Council, Publication No. GW/EMI-T-08/70, Wellington.

Watts L and Perrie A. 2007. *Lower Ruamahanga River instream flow assessment: Stage 1 – Instream flow issues report.* Greater Wellington Regional Council, Publication No. GW/EMI-G-07/135, Wellington.

Wellington Regional Council. 1999a. *Regional Freshwater Plan for the Wellington region.* Wellington Regional Council, Publication No. WRC/RP-G-99/31, Wellington.

Wellington Regional Council. 1999b. *Kopuaranga River catchment water allocation plan.* Unpublished draft internal report, Wellington Regional Council, Wellington.

Wellington Regional Council. 2000. *Water allocation plan – upper Ruamahanga River (May 2000).* Unpublished internal report, Wellington Regional Council, Wellington.

Wellington Regional Council. 2001. *Waipoua River catchment water allocation plan.* Unpublished draft internal report, Wellington Regional Council, Wellington.

Wilson S. 2006. *Low-flow hydrology of the Hutt catchment.* Greater Wellington Regional Council, technical report (Document #329214), Wellington.

Young R and Doehring K. 2010. *Relationship between low flow and dissolved oxygen in selected rivers and streams in the Wairarapa: Preliminary findings from 2009/10 summer monitoring.* Cawthron Institute, Publication No. 1865, prepared for Greater Wellington Regional Council, Wellington.

Acknowledgements

An early version of this report was reviewed by Ian Jowett (Jowett Consulting Ltd) and Joe Hay (Cawthron Institute). Both are thanked for their helpful comments.

Appendix 1: Methods for assessing ecological flows

Table A.1: Methods used in the assessment of ecological flow requirements for degrees of hydrological alteration and significance of instream values (adapted from Table A4.3 in MfE (2008))

<table>
<tr><th rowspan="2">Degree of hydrological alteration</th><th colspan="3">Significance of instream values</th></tr>
<tr><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td>Low</td><td>Historical flow method
Expert panel</td><td>Historical flow method
Expert panel</td><td>Generalised habitat models
1D hydraulic habitat model
Connectivity/fish passage
Flow duration analysis</td></tr>
<tr><td>Medium</td><td>Historical flow method
Expert panel
Generalised habitat models</td><td>Generalised habitat models
1D hydraulic habitat model
Connectivity/fish passage</td><td>1D hydraulic habitat model
2D hydraulic habitat model
Dissolved oxygen model
Temperature models
Suspended sediment
Fish bioenergetics model
Groundwater model
Seston flux
Connectivity/fish passage
Flow variability analysis</td></tr>
<tr><td>High</td><td>Generalised habitat models
1D hydraulic habitat model
Connectivity/fish passage
Periphyton biomass model</td><td>Entrainment model
1D hydraulic habitat model
2D hydraulic habitat model
Bank stability
Dissolved oxygen model
Temperature models
Suspended sediment
Fish bioenergetics model
Inundation modelling
Groundwater model
Seston flux
Connectivity/fish passage
Periphyton biomass model</td><td>Entrainment model
1D hydraulic habitat model
2D hydraulic habitat model
Bank stability
Dissolved oxygen model
Temperature models
Suspended sediment
Fish bioenergetics model
Inundation modelling
Groundwater model
Seston flux
Connectivity/fish passage
Periphyton biomass model
Flow variability analysis</td></tr>
</table>

Appendix 2: Other regional approaches to minimum flow setting

Table A2.1: Approaches taken to setting minimum flows in regional councils around New Zealand. The table reproduces material from Appendix 2 in the proposed National Environmental Standard on Ecological Flows and Water Levels (MfE 2008) but text in italics is revised by the author of this report based on updated information sought from council staff in September 2012

Note: Most councils have not made it clear whether the flow statistics being referred to are naturalised or not; no assumptions are made in the following table and descriptions of statistics and units are reproduced as provided

Regional Council	Method
Northland Regional Council *(Operative plan)*	Design minimum flow is set at MALF for streams with MALF < 300 L/s. Otherwise, it is set at Q5 unless the water body has a high ecological value; then MALF becomes the design minimum flow. Flow correlation method used to estimate design minimum flow (Q5) in catchments with no long-term record. In all instances, lower minimum flows can be set if the adverse effects of the take can be demonstrated to be avoided.
Auckland Regional Council (Proposed plan)	Regional plan provides for the setting of minimum flows in high-use rivers and streams. No minimum flows are scheduled in the regional plan. However, ARC uses key documents to set minimum flow requirements: *Flow guidelines for instream values* (MfE 1998) and *Guidelines for setting stream flow regimes in the Auckland Region* – draft (ARC 2000). The plan also uses the WAIORA (Water Allocation Impacts on River Abstraction) modelling tool to identify the effect of actions to meet its objectives.
Environment Waikato *(Operative allocation variation)*	*Policy 2 (Abbr): Determine minimum flows following detailed habitat and river studies. Where such studies have not been undertaken, the minimum flow shall be set at 90% of the one in five year 7d low flow (Q5) for streams with a mean flow greater than 5 cumecs and 95% of the Q5 for streams with a mean flow less than 5 cumecs. One function of the minimum flow is to determine when water take restrictions commence.*
Bay of Plenty Regional Council *(Operative plan)*	*Minimum flows are determined through IFIM and RHYHABSIM[1] to protect specific ecological values.* *The plan also uses Flow guidelines for instream values (MfE 1998) for other values.* *Otherwise, the default instream minimum flow requirement is 90% of the Q5 seven-day low flow.*
Gisborne District Council *(Operative plan)*	*Minimum flows are set based on a minimum level at a river gauging site in the northern areas that are irrigated. When the level drops, monitoring begins.*
Taranaki Regional Council (Operative plan)	Default minimum flow will provide two-thirds of the habitat at MALF. It is a guideline only – flow will go under or over it, depending on the values and community. This method was found to be the most robust method for the region and is based on scientific work.

Regional Council	Method
Manawatu Wanganui (Horizons) Regional Council *(Operative plan)*	*Decisions made on a case-by-case basis, considering habitat requirements, instream values and hydrological characteristics. It is an integrated approach, using IFIM and taking into account overriding policies such as Water Conservation Orders and level of assessment / quality of information available.* *Minimum flows are based on MALF according to the following criteria:* • *For 1d MALF<0.460 m^3/s, Minimum flow = 95% of 1d MALF* • *For 1d MALF 0.460 to 3.70 m^3/s, Minimum flow = 85% of 1d MALF* • *For 1d MALF>3.70 m^3/s, Minimum flow = 80% of 1d MALF*
Hawke's Bay Regional Council *(Operative plan)*	*The criteria for setting minimum flows in Hawke's Bay are based on the following:* *(a) Identified or estimated habitat requirements for a range of species which currently exist in the river* *(b) The need to maintain water quality at low flows* *(c) The need to meet recreational requirements* *(d) Maori cultural and spiritual values* *(e) The application of consistent methodology when setting and reviewing minimum flows* *(f) The need to adequately provide for the recharge of groundwater.* *Minimum flows in the current operative Regional Resource Management Plan have been established through a range of methods which include instream habitat modelling, statistical and expert panel approaches. Minimum flows are established either on a case by case basis or through future catchment specific plan changes.* *Minimum flows apply to both direct surface water abstractions and stream depleting groundwater abstractions.*
Marlborough District Council *(Operative plans - both plans currently in review stage)*	*Wairau Awatere Plan – no specific methods for setting SFRs, but plan policies include reasons and considerations when setting SFRs.* *SFRs have been set for the three major rivers in the plan area, which collectively account for about 80% of surface water takes within this area.* *Marlborough Sounds Plan* *SFR is to be the 10 year, 7 day low flow*
Nelson City Council *(Operative plan)*	*Default surface water allocation limits but no minimum flow criteria*
Tasman District Council *(Operative plan)*	*The Plan is to have regard to Flow guidelines for instream values (MfE 1998) when establishing minimum flow regimes.* *Integrated surface and groundwater models are used where required to establish links, and modified IFIM methods are used for surface water triggers. Minimum flows and triggers for rationing of water takes are specified for high-use catchments based on the previous paragraph.* *For smaller rivers where there is insufficient information or where abstractive pressures are less, the established thresholds for abstractive allocation are based on the five-year, seven-day low flow and the significance of the rivers or streams.*
West Coast Regional Council (Proposed plan)	Where more than 20% of any stream has been allocated, a minimum flow will be applied to any new consent for taking water. In the absence of detailed hydrological information, a minimum flow based on 75% of the MALF will apply. Lower minimum flows can be set if the adverse effects of the take can be demonstrated to be avoided.

Regional Council	Method
Environment Canterbury *(Operative catchment regional plans)* *(Water Conservation orders)* *(Operative plan NRRP)* *(Proposed Land and Water Regional Plan LWRP)*	*Three operative catchment regional plans. Each apply different methods to set flow and allocation (generally have included IFIM approach).* *Flow and allocation regimes included in three water conservation orders. Waitaki Regional Plan recognises allocation and minimum flow provisions of the Ahuriri WCO. NRRP recognises Rakaia WCO and is to be amended to recognise the Rangitata WCO (finalised since the NRRP was notified).* *Some flow and allocation regimes are set in the NRRP and more are being introduced into LWRP via sub-regional flow plans following specific collaborative catchment investigations and consultation. Flow requirements are determined for different values and judgement applied to establish overall water management regime including flow and allocation, transfer, storage, damming, augmentation, water users groups and other such provisions. IFIM approach used. Guided by Flow Guidelines for Instream Values (MFE 1998).* *The minimum flow used in the default situation is that which has been established in the catchment to date via the resource consent process. If there are no set minimum flows for a particular catchment then default regional rules in the LWRP apply for establishing a minimum flow and allocation block.* *Where catchments are considered to be over-allocated in the regional sections 'claw-back' measures are to be used through provisions relating to transfers, reasonable use tests, water efficiency and telemetry*
Otago Regional Council *(Operative plan)*	*Site and catchment-specific scientific approach – predominantly IFIM – for all rivers.* *Supplementary minimum flows are set to allow water harvesting at moderate to high flows.*
Environment Southland *(Proposed plan)*	The plan groups rivers using the 'Source of Flow' level in the River Environment Classification (REC). For each group of rivers, critical values are identified that are used as the basis for determining minimum flows and levels. The concept of critical values is that by providing sufficient flow to sustain the most flow-sensitive value, the other significant values will also be sustained. The Plan contains a staged management approach to surface water allocation as follows: a) where less than 10% of the mean annual low flow is allocated, the default minimum flow is the mean annual low flow and the take or diversion is a restricted discretionary activity b) where 10% to 30% of the mean annual low flow is allocated, a minimum flow derived from generalised habitat models for the critical value species applies and the take or diversion is a discretionary activity c) where greater than 30% of the mean annual low flow is allocated, a minimum flow derived from an instream habitat analysis for the critical value species applies and the take or diversion is a non-complying activity.

[1] Instream Flow Incremental Method; River Hydrologic Habitat Simulation

Appendix 3: Recommended minimum flows – site by site

The tables in this appendix summarise key flow statistics, minimum flow recommendations and reference information for each river reach listed in Table 4.1 in the main text. Rivers and streams are listed in the same order as Table 4.1, beginning with the Wairarapa.

Several variations of Mean Annual Low Flow (MALF) are provided; MALF-M is the *measured* MALF at the flow recorder site and MALF-N is an estimate of *naturalised* MALF (for the recorder site and the bottom of the catchment or critical reach where appropriate). At many recorder sites, MALF-N is equivalent to MALF-M because the recorder is upstream of any major abstractions or discharges.

Where adjustment to naturalise flow was needed, details about the derivation of MALF-N estimates, as well as key reference documents, are included in the tables in this appendix. In general, MALF-N estimates come from Keenan (2009b) and recent (post-2000) instream flow assessment reports. Methods included analysis of flow records and concurrent gauging results (focused on periods of abstraction restriction or suspension) and interpretation of riparian groundwater level records. Where possible, major inputs (eg, discharges) and abstractions (including water races) have been accounted for.

There are some important general assumptions and limitations to note with respect to the flow naturalisation methodology:

- Due to the absence of actual abstraction data, detailed time series modelling (ie, to reconstruct a 'natural' hydrograph) has not been undertaken. Rather, static blocks of abstraction and discharge have been added or subtracted from estimated MALF flows
- Abstraction adjustment has focused on direct surface water takes and only included riparian groundwater takes where a direct hydraulic connection has historically been recognised (eg, via resource consent conditions). Additional depletion of low flows (and MALF-N) occurring as a result of other groundwater takes – such as those with a lower degree of hydraulic connection and described as 'Category B' and 'Category C' areas by Hughes & Gyopari (2011, 2014) – has not been accounted for
- Permitted activity water use has not been accounted for

In broad terms, MALF-N in catchments with significant groundwater abstraction and/or permitted use is likely to be underestimated. There are also other complicating factors such as the extent to which water race and irrigation runoff returns alter low flows at minimum flow management points.

Wairarapa rivers and streams

Ruamahanga River (upper reach from headwaters to Waiohine River confluence)

Existing minimum flow	2,400 L/s (at Wardells)	
Flow data	Continuous recorder at Wardells Start of good quality low flow record: 1977	
Mean flow at Wardells	23,550 L/s (1977 to 2012 data)	
MALF-M at Wardells	2,680 L/s (1d) 3,070 L/s (7d) (1977 to 2009 data)	2,708 L/s (1d) 3,110 L/s (7d) (1977 to 2012 data)
MALF-N at Wardells	3,605 L/s (7d) Method of estimation described in Thompson (2014b)	
MALF-N at bottom of reach	8,025 L/s (7d) Method of estimation described in Thompson (2014b)	
Management objective	No reach specific (and up to date) objective for flow setting Ruamahanga River values requiring protection (as stated in Appendix 1 of the RPS) include **significant amenity and recreational value (including angling)** and **significant indigenous ecosystems**	
Recommended / revised minimum flow	**2,400 L/s at Wardells** ie, retain existing minimum flow	
Method	No change. Minimum flow was added to RFP based on historical IFIM (Jowett 1993) and more recent WAIORA modelling.	
Comments	Minimum flow is about 90% of 1d MALF-M at Wardells. However, it is only 67% of estimated 7d MALF-N at Wardells. If the 7d MALF-N estimate is reasonable this would indicate the minimum Flow is below that advocated by the NES rule of thumb (80–90% 7d MALF). Given the high demand on this river it is not appropriate to increase the minimum flow in line with a rule of thumb, but a more detailed review is warranted.	
Potential monitoring sites [bolded sites are continuous flow recorders]	Double Bridges, **Wardells,**Gladstone Double Bridges and Gladstone suggested by Royal (2012)	
References	Wellington Regional Council (2000) Royal (2012)	

Ruamahanga River (lower reach from Waiohine River confluence to Lake Wairarapa outflow confluence)

Existing minimum flow	8,500 L/s (at Waihenga)	
Flow data	Continuous recorder at Waihenga Start of good quality low flow record: 1976	
Mean flow at Waihenga	83,900 L/s (1976 to 2012 data)	
MALF-M at Waihenga	8,770 L/s (1d) 10,363 L/s (7d) (1976 to 2009 data)	8,820 L/s (1d) 10,433 L/s (7d) (1976 to 2012 data)
MALF-N at Waihenga[11]	10,810 – 11,300 L/s (1d) 12,565 – 13,100 L/s (7d)	
MALF-N at bottom of reach	12,900 L/s (1d) 15,065 L/s (7d) Estimates based on method described in Thompson (2014b)	
Management objectives	Specific objectives in the 2007 instream flow review were that: 1. There is adequate water depth for migratory fish passage and recreational boating. 2. Sufficient habitat is maintained for fish, in particular brown trout. 3. During times of low flow, water quality is suitable for contact recreation and aquatic ecosystem purposes. Ruamahanga River values requiring protection (as stated in Appendix 1 of the RPS) include **significant amenity and recreational value (including angling)** and **significant indigenous ecosystems**	
Recommended / revised minimum flow	**8,500 L/s at Waihenga** ie, retain existing minimum flow	
Method	Instream flow assessment report completed and published	
Comments	Minimum flow is about 96% of 1d MALF-M at Waihenga. However, it is only 68% of estimated 7d MALF-N at Waihenga. An IFIM study in 2007 deemed the existing minimum flow to be appropriate as it retains approximately 90% of the trout habitat at the naturalised 1d MALF.	
Potential monitoring sites [bolded sites are continuous flow recorders]	Morrisons Bush, Bentleys Beach, **Waihenga** Morrisons Bush and Bentleys Beach are popular recreational sites	
References	Watts & Perrie (2007) Hay (2008) Thompson (2011d)	

[11] Estimating naturalised MALF for the Ruamahanga River is a complicated task because of the many gains and losses from abstractions and discharges. Two attempts have been made in the recent past; the first in 2007 by Laura Keenan during the lower Ruamahanga IFIM study (WGN_DOCS#498330) and the second by Thompson (2014b). The range provided here represents the estimates gained from the two methods.

Waingawa River

Existing minimum flow	1,100 L/s (at Kaituna)	
Flow data	Continuous recorder at Kaituna Start of good quality low flow record: 1976	
Mean flow at Kaituna	10,240 L/s (1976 to 2012 data)	
MALF-M at Kaituna	1,210 L/s (1d) 1,420 L/s (7d) (1976 to 2009 data)	1,216 L/s (1d) 1,427 L/s (7d) (1976 to 2012 data)
MALF-N at Kaituna	1,210 L/s (1d) 1,420 L/s (7d) Kaituna is upstream of major abstraction so MALF-N = MALF-M	
MALF-N at bottom of catchment (confluence with Ruamahanga)	1,590 L/s (1d) 1,720 L/s (7d)	
Management objectives	No reach specific (and up to date) objective for flow setting Waingawa River values requiring protection (as stated in Appendix 1 of the RPS) include **significant amenity and recreational value (including angling)** and **significant indigenous ecosystems** (but limited to macroinvertebrate communities only)	
Recommended / revised minimum flow	**1,100 L/s at Kaituna** ie, retain existing minimum flow	
Method	Field visit in February 2010 indicated undertaking a Generalised Habitat Assessment in lower reach would not be appropriate because of perched, multi-thread channels. However, earlier IFIM data for the 'Aerodrome' reach has been re-assessed according to more widely adopted habitat retention criteria.	
Comments	While the IFIM reassessment shows existing minimum flow is likely to be adequate (the existing minimum flow is essentially equivalent to 90% of 1d MALF-N and 80% of 7d MALF-N at Kaituna and therefore broadly consistent with regional default rule), this river is potentially a high priority for more sophisticated review. Note that non-essential consents are required to cease take when flow at Kaituna is 1,700 L/s to preserve allocation for water races and the MDC water supply take.	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Kaituna**, Aerodrome and/or Ruamahanga confluence	
References	Wairarapa Catchment Board 1988 Jowett (1993) Keenan (2009b) Thompson (2011b)	

Waipoua River

Existing minimum flow	250 L/s (at Mikimiki)
Flow data	Continuous recorder at Mikimiki Start of recent good quality low flow record: 2007
Mean flow at Mikimiki	3,495 L/s (2007 to 2013 data)
MALF-M at Mikimiki	310 L/s (1d) 375 L/s (7d) MALF estimates based on historical 1976 to 1997 data and Atiwhakatu correlation (Gordon 2009). Not updated in Gordon (2012)
MALF-N at Mikimiki	310 L/s (1d) 375 L/s (7d) Mikimiki is upstream of major abstraction so MALF-N = MALF-M
MALF-N at bottom of catchment (confluence with Ruamahanga)	410 L/s (1d) 490 L/s (7d)
Management objectives	No up to date specific objective for flow setting Primary objective in the 2001 water allocation plan was to manage abstractions so that the instream habitat of the Waipoua River is maintained and enhanced (with priority given to indigenous species rather than trout) Waipoua River values requiring protection (as stated in Appendix 1 of the RPS) include **significant amenity and recreational value (including angling)** and **significant indigenous ecosystems** (threatened indigenous fish)
Recommended / revised minimum flow	**250 L/s at Mikimiki** Retain existing minimum flow
Method	Minimum flow recommended through the Waipoua River Water Allocation Plan in 2001. Set on the basis of habitat and water quality studies.
Comments	The existing minimum flow is 67% of MALF-N (7d), relatively low compared with other rivers. Should be prioritised for review
Potential monitoring sites [bolded sites are continuous flow recorders]	Paierau Rd, Akura, Ruamahanga confluence
Reference documents	Wellington Regional Council (2001) Keenan (2009b)

Waiohine River

Existing minimum flow	2,300 L/s (at the Gorge)	
Flow data	Continuous recorder at the Gorge Start of good quality low flow record: 1979	
Mean flow at Gorge	24,510 L/s (1979 to 2012 data)	
MALF-M at Gorge	3,050 L/s (1d) 3,570 L/s (7d) (1979 to 2009 data)	3,095 L/s (1d) 3,612 L/s (7d) (1979 to 2012 data)
MALF-N at Gorge	3,050 L/s (1d) 3,570 L/s (7d) Gorge is upstream of major abstraction so MALF-N = MALF-M	
MALF-N at confluence with Ruamahanga	3,190 L/s (1d) 3,550 L/s (7d)	
Management objectives	Specific objectives in the 2007 instream flow review were to: 1. Maintain passage for migratory fish 2. Maintain habitat for fish Waiohine River values requiring protection (as stated in Appendix 1 of the RPS) include **significant amenity and recreational value (including angling)** and **significant indigenous ecosystems**	
Recommended / revised minimum flow	**2,765 L/s at the Gorge** [but see note in 'comments']	
Method	IFIM assessment in 2009. Based on 90% habitat retention for adult trout MALF-N (1d)	
Comments	While investigations have shown a higher minimum flow is warranted, it is recommended that the existing minimum flow of 2,300 L/s at Gorge is retained for the draft Plan as an **interim** limit. This will allow opportunity for the consequences of increasing the minimum flow (for existing users) to be fully assessed, along with other instream and out of stream values by the Ruamahanga whaitua (catchment committee)	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Gorge,** SH2 Bridge, Ruamahanga confluence	
Reference documents	Keenan (2009b) Keenan (2009d)	

Tauherenikau River

Existing minimum flow	1,100 L/s (at Gorge)	
Flow data	Continuous recorder at the Gorge Start of good quality low flow record: 1976	
Mean flow at Gorge	9,100 L/s (1976 to 2012 data)	
MALF-M at Gorge	1,110 L/s (1d) 1,290 L/s (7d) (1976 to 2009 data)	1,137 L/s (1d) 1,321 L/s (7d) (1976 to 2012 data)
MALF-N at Gorge	1,110 L/s (1d) 1,290 L/s (7d) Gorge is upstream of major abstraction so MALF-N = MALF-M	
MALF-N at river mouth	260 L/s (1d) 310 L/s (7d)	
Management objectives	Specific objectives in the draft 2013 instream flow review were to: 1. Maintain habitat for fish 2. Maintain migratory passage for fish Tauherenikau River values requiring protection (as stated in Appendix 1 of the RPS) include **significant amenity and recreational value (including angling)** and **significant indigenous ecosystems**	
Recommended / revised minimum flow	**1,100 L/s** at Gorge ie, retain existing minimum flow	
Method	Generalised Habitat Assessment survey carried out in 2010 put forward several options for minimum flow but did not make a final recommendation due to uncertainty over the level of habitat retention deemed appropriate.	
Comments	Arguably, the Tauherenikau does not warrant 90% habitat retention for trout as it ranks fairly low in the region for angling days. A similar level of retention for torrentfish may be justified (and was favoured in the report) but ultimately a fully informed judgement could not be made and decision to defer. Setting a minimum flow for torrentfish protection would see it reduced from 1,100 L/s at Gorge to about 1,000 L/s at Gorge Existing minimum flow is equal to 100% MALF-N (1d) and about 85% of MALF-N (7d). Therefore it is recommended that the existing flow be retained until it can be further deliberated.	
Potential monitoring sites [bolded sites are continuous flow recorders]	SH53	
Reference documents	Thompson (2012a)	

Mangatarere Stream (upper reach from headwaters to Belvedere Road)

Existing minimum flow	240 L/s (at the Gorge)	
Flow data	Continuous recorders at: The Gorge (start of good quality low flow record: 1999) Belvedere Rd Bridge (start of good quality low flow record: 2004)	
Mean flow at Gorge	1,780 L/s (1999 to 2012 data)	
MALF-M at Gorge	136 L/s (1d) 166 L/s (7d) (1999 to 2009 data)	144 L/s (1d) 176 L/s (7d) (1999 to 2012 data)
MALF-N at Gorge	136 L/s (1d) 166 L/s (7d) Gorge is upstream of major abstraction so MALF-N = MALF-M	
MALF-N at bottom of upper reach[12] (Belvedere Rd Bridge)	80 L/s (1d) 100 L/s (7d)	
Management objectives	Specific objective in the 2003 Draft Allocation Management Plan was: -The enhancement of water quality and maintenance of water quantity to support trout and fishing/spawning and aquatic ecosystems Mangatarere Stream values requiring protection (as stated in Appendix 1 of the RPS) include **significant indigenous ecosystems**	
Recommended / revised minimum flow	**240 L/s at the Gorge** Retain existing minimum flow	
Method	IFIM and WAIORA modelling in 2002 described in a draft allocation management plan (see reference below). Submissions from stakeholders used to refine numbers	
Comments	Data from continuous flow recorders at Belvedere Rd and SH2 and completion of a number of concurrent gaugings since water allocation plan indicate a review of minimum flows is warranted in near future. However, existing provisions considered adequate and consistent with status of river and flow setting methods.	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Gorge**, Andersons Line, **Belvedere Rd Bridge**	
Reference documents	Greater Wellington Regional Council (2003) Greater Wellington Regional Council (2007) Keenan (2009b)	

[12] Based on ratio of average flow loss between the Gorge and Belvedere Rd shown in concurrent gauging data presented in Keenan (2009b)

Mangatarere Stream (lower reach from Belvedere Road to Waiohine River confluence)

Existing minimum flow	200 L/s (at the Gorge)	
Flow data	Continuous recorders at: The Gorge (start of good quality low flow record: 1999) Belvedere Rd Bridge (start of good quality low flow record: 2004) SH2 (start of good quality low flow record: 2009)	
Mean flow at Gorge	1,780 L/s (1999 to 2012 data)	
MALF-M at Gorge	136 L/s (1d) 166 L/s (7d) (1999 to 2009 data)	144 L/s (1d) 176 L/s (7d) (1999 to 2012 data)
MALF-N at Gorge	136 L/s (1d) 166 L/s (7d) Gorge is upstream of major abstraction so MALF-N = MALF-M	
MALF-N at top of lower reach[13] (Belvedere Rd Bridge)	80 L/s (1d) 100 L/s (7d)	
MALF-N at bottom of lower reach[14] (SH2)	305 L/s (1d) 370 L/s (7d)	
Management objectives	Specific objective in the 2003 Draft Allocation Management Plan was: -The enhancement of water quality and maintenance of water quantity to support trout and fishing/spawning and aquatic ecosystems Mangatarere Stream values requiring protection (as stated in Appendix 1 of the RPS) include **significant indigenous ecosystems**	
Recommended / revised minimum flow	**200 L/s at the Gorge** Retain existing minimum flow	
Method	IFIM and WAIORA modelling in 2002 described in a draft allocation management plan (see references below). Submissions from stakeholders used to refine numbers	
Comments	Data from continuous flow recorders at Belvedere Rd and SH2 and completion of a number of concurrent gaugings since water allocation plan indicate a review of minimum flows is warranted in near future. However, existing provisions considered adequate and consistent with status of river and flow setting methods.	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Gorge**, **Belvedere Rd Bridge, SH2**	
Reference documents	Greater Wellington Regional Council (2003) Greater Wellington Regional Council (2007) Keenan (2009b)	

[13] Based on ratio of average flow loss between the Gorge and Belvedere Rd shown in concurrent gauging data presented in Keenan (2009b)
[14] Based on ratio of average flow gain between the Gorge and SH2 shown in concurrent gauging data presented in Keenan (2009b)

Kopuaranga River

Existing minimum flow	270 L/s (at Palmers Bridge)	
Flow data	Continuous recorder at Palmers Start of good quality low flow record: 1985	
Mean flow at Palmers	2,600 L/s (1985 to 2012 data)	
MALF-M at Palmers	285 L/s (1d) 310 L/s (7d) (1985 to 2009 data)	283 L/s (1d) 314 L/s (7d) (1985 to 2012 data)
MALF-N at Palmers	285 L/s (1d) 310 L/s (7d) Palmers is upstream of major abstraction so MALF-N = MALF-M	
MALF-N at confluence with Ruamahanga	570 L/s (1d) 605 L/s (7d)	
Management objectives	Specific objectives in the 1999 instream flow review were to: 1. Safeguard instream habitat (particularly trout habitat and spawning) and ecosystem and recreational values 2. Allocate water in a fair and transparent manner Kopuaranga River values requiring protection (as stated in Appendix 1 of the RPS) include **significant amenity and recreational value (fishing)**	
Recommended / revised minimum flow	**270 L/s at Palmers** ie, retain existing minimum flow	
Method	Minimum flow based on WAIORA modelling and technical assessment in 1999	
Comments	Minimum flow is approximately equal to 90% MALF-N (7d) There is currently no stepdown in allocation required (which is unusual). Flow is now also continuously recorded lower in the catchment at Stuarts.	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Palmers, Stuarts**	
Reference documents	Wellington Regional Council (1999b) Young and Doehring 2010	

Parkvale Stream

Existing minimum flow	None specified in existing RFP
Flow data	Continuous recorder at Renalls Weir Start of good quality low flow record: 2002
Mean flow at Renalls Weir	785 L/s (2002 - 2012 data)
MALF-N at Renalls Weir (= confluence with Booths Creek and Ruamahanga River)	120 L/s (1d) 140 L/s (7d) 'Naturalised' flow estimates derived from an analysis of recession curves as flow record impacted by abstraction Period of record used for MALF estimates 2002-2009
Management objectives	No specific objectives for the Parkvale Stream RPS objectives for Parkvale Stream more generally (as a tributary of the Ruamahanga River) include managing for **significant indigenous ecosystems (macroinvertebrate health)**
Recommended / revised minimum flow	**100 L/s at Renall's Weir**
Method	Existing cease take threshold on consents
Comments	Assessment of flow and DO/temperature by Cawthron in 2009/10 did not yield any critical threshold that should be reflected in the minimum flow Note: While the default regional method of 90% MALF-N (7d) provides a minimum flow of 125 L/s, existing surface water consent holders have a cease take condition of 100 L/s. It is considered appropriate to default to this (at least for interim Plan provisions) given the likely difficultly in demonstrating the material difference that 25 L/s makes.
Potential monitoring sites [bolded sites are continuous flow recorders]	**Renall's Weir**
Reference documents	Keenan (2009b) Young and Doehring (2010)

Papawai Stream

Existing minimum flow	None specified in existing RFP
Flow data	Data below is derived from a continuous recorder located above Tilsons Creek confluence (this is effectively the bottom of the catchment) Start of good quality low flow record: 2005 **Note:** this flow site is, as of June 2014, being decommissioned and relocated upstream to a culvert under Fabians Road.
Mean flow at Upstream Tilsons Creek	324 L/s (2005 to 2013 data)
MALF-N at Upstream Tilsons Creek[15]	200 L/s (1d) 210 L/s (7d) (2005–2009 data)
MALF-N at confluence with Ruamahanga	340 L/s (1d) 350 L/s (7d)
Management objectives	Specific objectives in the 2009 instream flow review were to: 1. Protect instream habitat conditions for longfin eels 2. To maintain dissolved oxygen conditions above aquatic ecosystem guidelines To ensure flows are sufficient for recreational use, particularly for swimming at the marae RPS objectives for Booths Creek more generally (as a tributary of the Ruamahanga River) include managing for **significant indigenous ecosystems (macroinvertebrate health)**
Recommended / revised minimum flow	**180 L/s** (Fabians Road culvert)
Method	IFIM instream flow assessment report completed 2009. Considered both habitat and water quality (DO and temperature) criteria. This study recommended a minimum flow of 160 L/s at the Upstream Tilsons flow monitoring site. This site is, as of June 2014, being decommissioned and relocated upstream to Fabians Rd culvert. Correlation analysis (see reference below) shows that a flow of 160 L/s at Upstream Tilsons equates to **180 L/s** at Fabians Road culvert.
Comments	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Fabians Road culvert**
Reference documents	Keenan (2009b) Keenan (2009c) WGN_DOCS#1389379 (Flow correlation analysis)

[15] No MALF-M or MALF-N (7d) was given in Keenan (2009c) for this stream. However, comments by Keenan (2009c) about likely small differences in MALF allow the estimate of MALF-N (7d) of 210 L/s to be made.

Otukura Stream

Existing minimum flow	Not specified in existing RFP	
Flow data	Continuous recorder at Weir (2 km upstream of Stonestead Creek) Start of good quality low flow record: 1997	
Mean flow at Weir	540 L/s (1998 to 2012 data)	
MALF-M at Weir	65 L/s (1d) 75 L/s (7d) (1997 to 2009 data)	66 L/s (1d) 80 L/s (7d) (1997 to 2012 data)
MALF-N at Weir This is essentially the bottom of the catchment	85 L/s (1d) 100 L/s (7d)	
Management objectives	Specific objective in the 2007 and 2008 instream flow review reports was: - To manage water quantity in the Otukura Stream and Battersea Drain so that the ecological values of the waterways are imporved RPS objectives for Otukura Stream more generally (as a tributary of the Ruamahanga River) include managing for **significant indigenous ecosystems**	
Recommended / revised minimum flow	**95 L/s** (at Weir)	
Method	Based on dissolved oxygen and water temperature relationships (using WAIORA modelling)	
Comments	Recommendations broadly consistent with 90% of MALF-N (7d). Existing surface water consent holders on Otukura already have the 95 L/s minimum flow condition imposed	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Weir**	
Reference documents	Watts (2007a) Watts (2008)	

Central sub-region rivers and streams

Hutt River (upper reach – upstream of the Pakuratahi River confluence)

Existing minimum flow	600 L/s (at Kaitoke Weir)
Flow data	Continuous recorders at: Kaitoke (start of good quality low flow record: 1967) Birchville (start of good quality low flow record: 1970). Both sites are operated by NIWA
Mean flow at Kaitoke Recorder	7,380 L/s (1967 to 2012 data)
MALF-M at Kaitoke Recorder	1,320 L/s (1d) 1,435 L/s (7d) Both estimates from Keenan (2009c). MALF not estimated in Gordon (2009) or Gordon (2012)
MALF-N at Kaitoke Recorder	1,320 L/s (1d) 1,435 L/s (7d) Kaitoke is upstream of the major water supply abstraction so MALF-N = MALF-M
Management objectives	No specific recent objectives although it is primary public water supply source RPS objectives for Hutt River more generally include managing for **significant amenity and recreational value (including angling and swimming)** and **significant indigenous ecosystems**
Recommended / revised minimum flow	**600 L/s at Kaitoke Weir**
Method	Retain existing minimum flow
Comments	Minimum flow provisions for the Hutt River should be reviewed once Hutt Aquifer Modelling (HAM) has been updated <u>and</u> the future water supply options for Wellington have been confirmed.
Potential monitoring sites [bolded sites are continuous flow recorders]	**Kaitoke Weir, Te Marua, Birchville, Taita,** Boulcott
Reference documents	Hay (2007), Keenan (2009b), Wilson (2006), Gordon (2012)

Hutt River (lower reach – from the Pakuratahi River confluence to the coastal marine boundary)

Existing minimum flow	1,200 L/s (at Birchville)	
Flow data	Continuous recorder at Birchville Site operated by NIWA Start of good quality low flow record: 1970	
Mean flow at Birchville Recorder	22,110 L/s (1970 to 2012 data)	
MALF-M at Birchville	2,270 L/s (1d) 2,640 L/s (7d) (1970 to 2009 data)	2,349 L/s (1d) 2,704 L/s (7d) (1970 to 2012 data)
MALF-N at Birchville	3,030 L/s (1d) From Table 19 in Wilson (2006). Estimated abstraction of 760 L/s added back in. 3,430 L/s (7d) From Wilson (2006) with estimated abstraction of 760 L/s added back in.	
MALF-N at Melling (bottom of lower reach)	4,225 L/s (7d). Based on correlation with Taita Gorge from equation in Table 26 of Wilson (2006) with further groundwater depletion effect added back in. See WGN_DOCS#1377451	
Management objectives	No specific recent objectives RPS objectives for Hutt River more generally include managing for **significant amenity and recreational value (including angling and swimming)** and **significant indigenous ecosystems**	
Recommended / revised minimum flow	**1,200 L/s at Birchville**	
Method	Retain existing minimum flow	
Comments	Minimum flow provisions for the Hutt River should be reviewed once Hutt Aquifer Modelling (HAM) has been updated and the future water supply options for Wellington have been confirmed.	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Birchville, Taita,** Boulcott	
Reference documents	Hay (2007), Keenan (2009b), Wilson (2006), Gordon (2012)	

Wainuiomata River (upper reach – between Manuka Track and the confluence with George Creek)

Existing minimum flow	100 L/s (at Manuka Track)	
Flow data	Continuous recorder at Manuka Track (upstream of the water supply intake) The upper reach is only about 2km long (from Manuka Track gauge site to the abstraction point at the George Creek confluence) Start of good quality low flow record: 1982	
Mean flow at Manuka Track Recorder	910 L/s (1982 to 2011 data)	
MALF-M at Manuka Track	174 L/s (1d) 184 L/s (7d) (1982 to 2009 data)	169 L/s (1d) 179 L/s (7d) (1982 to 2011 data)
MALF-N at Manuka Track	174 L/s (1d) 184 L/s (7d) Manuka Track is upstream of the major water supply abstraction so MALF-N = MALF-M	
Management objectives	No specific objective set out in the 2003 IFIM investigation although recognition of the trout value in the lower river was explicit. Also, it is primary public water supply source RPS objectives for Wainuiomata River more generally include managing for **significant amenity and recreational value** (including angling and swimming) and **significant indigenous ecosystems**	
Recommended / revised minimum flow	**100 L/s at Manuka Track**	
Method	Retain existing minimum flow	
Comments	Review minimum flow prior to expiry of water supply consent (2036)	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Leonard Wood Park**, Golf Club, Pencarrow/Whites Bridge	
Reference documents	Keenan (2009b)	

Wainuiomata River (lower reach – between the George Creek confluence and the coastal marine boundary)

Existing minimum flow	300 L/s (at Leonard Wood Park)	
Flow data	Continuous recorder at Leonard Wood Park (downstream of the water supply intake) Start of good quality low flow record: 1977	
Mean flow at LWP Recorder	2330 L/s (1977to 2012 data)	
MALF-M at top of reach (Leonard Wood Park)	260 L/s (1d) 295 L/s (7d) (1977 to 2009 data)	260 L/s (1d) 290 L/s (7d) (1977 to 2011 data)
MALF-N at top of reach (Leonard Wood Park)	370 L/s (1d) 410 L/s (7d) Estimated by adding back in abstraction to LWP record using mean daily abstraction data from Bulk Water Group for period 2000–2010 (see WGN_DOCS#1114646).	
MALF-N at bottom of lower reach (ie, river mouth)	585 L/s (1d) 600 L/s (7d) From Keenan (2009c)	
Management objectives	No specific objective set out in the 2003 IFIM investigation although recognition of the trout value in the lower river was explicit. RPS objectives for Wainuiomata River more generally include managing for **significant amenity and recreational value** (including angling and swimming) and **significant indigenous ecosystems**	
Recommended / revised minimum flow	**300 L/s at Leonard Wood Park**	
Method	Retain existing minimum flow	
Comments	Application of the '2/3 habitat' guideline in the original (1993) and 2003 IFIM studies questionable given approach most commonly taken these days. Joe Hay has reviewed the original IFIM reports and has some misgivings about methods. A precautionary revised interim minimum flow could be assigned using regional default rule. This would probably be around 330 L/s (as 90% of 7d MALF-N). However, the difference is not considered sufficient enough to warrant a change in the existing provisions. A better option would be to prioritise the lower river for reassessment.	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Leonard Wood Park,** Golf Club, Pencarrow/Whites Bridge	
Reference documents	Jowett (1993), Harkness (2003), Keenan (2009b), Hay (2011) WGN_DOCS#955570 – naturalised flow calculations	

Orongorongo River

Existing minimum flow	100 L/s (at Truss Bridge)
Flow data	Continuous recorder at Truss Bridge (this site is downstream of the water supply intakes and so measured low flows are significantly affected) Start of adequate low flow record: 1998
Mean flow at Truss Bridge Recorder	2,150 L/s (1998 to 2012 data). Modified by abstraction upstream
MALF-M at Truss Bridge	100 L/s (1d) 140 L/s (7d) Based on fairly limited (1998–2012) data
MALF-N at Truss Bridge	285 L/s (1d) 320 L/s (7d) 'Naturalised' estimates from synthesised records described in Keenan (2009c)
Management objectives	No specific objective although it is primary public water supply source RPS objectives for Orongorongo River more generally include managing for **significant amenity and recreational value** (including angling and swimming) and **significant indigenous ecosystems**
Recommended / revised minimum flow	**100 L/s at Truss Bridge**
Method	Retain existing minimum flow
Comments	Minimum flow for upper reach should be reviewed prior to expiry of water supply consent (2036)
Potential monitoring sites [bolded sites are continuous flow recorders]	**Truss Bridge**
Reference documents	Keenan (2009b)

Kapiti Coast rivers and streams

Waikanae River

Existing minimum flow	750 L/s at Water Treatment Plant	
Flow data	Continuous recorder at Water Treatment Plant (head of coastal plain, above the KCDC abstraction and about 6 km from mouth) Start of good quality low flow record: 1975	
Mean flow at WTP Recorder	4,820 L/s (21975 to 2012 data)	
MALF-M at WTP recorder	950 L/s (1d) 1,050 L/s (7d) (1975 to 2008 data)	955 L/s (1d) 1,050 L/s (7d) (1975 to 2012 data)
MALF-N at WTP recorder	950 L/s (1d) 1,050 L/s (7d) No major abstraction upstream of recorder so MALF-N=MALF-M	
MALF-N at bottom of catchment	770 L/s (1d) 845 L/s (7d) Based on average ratio between WTP and Mouth concurrent flow gaugings (with abstraction discounted) of 0.8 (from 4 gaugings)	
Management objectives	No specific management objective although it is a primary public water supply source RPS objectives for Waikanae River more generally include managing for **significant amenity and recreational value (including angling)** and **significant indigenous ecosystems**	
Recommended / revised minimum flow	**750 L/s at Water Treatment Plant**	
Method	Retain existing minimum flow	
Comments	Existing minimum flow is based on 2/3 habitat approach. Reassessment of the original IFIM data by Joe Hay using more contemporary criteria (90% habitat retention) showed this would result in a slightly higher minimum flow (~850 L/s). However, an issues report (Thompson 2012c) indicated that the practical benefits of increasing the minimum flow may be marginal and difficult to justify given the significant implication this would have for security on the existing town supply	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Water Treatment Plant,** Jim Cooke Park	
Reference documents	Hayes (1993) Watts (2003) Keenan (2009b) Hay (2010b) Thompson (2012c)	

Waitohu Stream

Existing minimum flow	140 L/s at Water Supply Intake	
Flow data	Continuous recorder at Water Supply Intake (head of coastal plain, upstream of abstraction and about 6 km upstream of mouth) Start of good quality low flow record: 1994	
Mean flow at WSI Recorder	850 L/s (1994 to 2012 data)	
MALF-M at recorder	140 L/s (1d) 150 L/s (7d) (1994 to 2008 data)	136 L/s (1d) 147 L/s (7d) (1994 to 2012 data)
MALF-N at recorder	140 L/s (1d) 150 L/s (7d) No major abstraction upstream of WSI recorder	
MALF-N at bottom of catchment (Golf Club)	230 L/s (1d) 250 L/s (7d) From Keenan (2009c)	
Management objectives	No specific management objective although it is a primary public water supply source RPS objectives for Waitohu Stream more generally include managing for **significant indigenous ecosystems**	
Recommended / revised minimum flow	**140 L/s at WSI**	
Method	Retain existing minimum flow	
Comments	In the absence of IFIM data the appropriate regional default method to apply would be 90% MALF-N (7d) However the difference between the existing minimum flow (140 L/s) and that under a default rule (125 L/s) is marginal, therefore recommendation is to retain the existing flow for now	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Water Supply Intake,** Taylors Road Bridge and/or Golf Club	
Reference documents	Keenan (2009b)	

Otaki River

<table>
<tr><td>Existing minimum flow</td><td colspan="2">2,550 L/s (at Pukehinau)</td></tr>
<tr><td>Flow data</td><td colspan="2">Continuous recorder at Pukehinau (head of coastal plain, about 13 km from mouth)
Joint NIWA/GWRC site
Start of good quality low flow record: 1980</td></tr>
<tr><td>Mean flow at Pukehinau Recorder</td><td colspan="2">30,400 L/s (1980 to 2012 data)</td></tr>
<tr><td>MALF-M at Pukehinau recorder</td><td>4,770 L/s (1d)
5,220 L/s (7d)
(1980–2009 data)</td><td>4,693 L/s (1d)
5,183 L/s (7d)
(1980–2012 data)</td></tr>
<tr><td>MALF-N at Pukehinau recorder</td><td colspan="2">4,770 L/s (1d)
5,220 L/s (7d)
Little abstraction above the recorder site so MALF-N=MALF-M</td></tr>
<tr><td>MALF-N at bottom of catchment (Lower Transmission Lines</td><td colspan="2">3,560 L/s (1d)
3,940 L/s (7d)
Estimated based on average difference between Pukehinau and Lower Transmission Lines low flow gauging results</td></tr>
<tr><td>Management objectives</td><td colspan="2">Specific objectives in the 2011 instream flow review were to:
1. Maintain passage for migratory fish
2. Maintain habitat for fish

RPS objectives for Otaki River more generally include managing for significant amenity and recreational value (including angling) and significant indigenous ecosystems</td></tr>
<tr><td>Recommended / revised minimum flow</td><td colspan="2">4,120 L/s at Pukehinau [but see comments below]</td></tr>
<tr><td>Method</td><td colspan="2">Generalised Habitat Assessment (Thompson 2011a)</td></tr>
<tr><td>Comments</td><td colspan="2">While investigations have shown a higher minimum flow is warranted, it is recommended that the existing minimum flow of 2,550 L/s at Pukehinau is retained for the proposed Plan as an interim limit. This will allow opportunity for the consequences of increasing the minimum flow (for existing users – the proposed increase in minimum flow is considerable (60%) with implications for security of supply) to be fully assessed, along with other instream and out of stream values during the catchment committee process. However, consideration could be given to reducing core allocation in the interim because if it is fully utilised with the existing minimum flow, a high (and possibly unacceptable) level of flow alteration would occur.</td></tr>
<tr><td>Potential monitoring sites
[bolded sites are continuous flow recorders]</td><td colspan="2">Pukehinau, SH1, Lower Transmission Lines</td></tr>
<tr><td>Reference documents</td><td colspan="2">Keenan (2009b)
Thompson (2011a)</td></tr>
</table>

Mangaone Stream

Existing minimum flow	22 L/s at Ratanui	
Flow data	Continuous recorder at Ratanui where stream emerges on to plains, about 9 km upstream from the mouth Start of good quality low flow record: 1996	
Mean flow at Ratanui Recorder	330 L/s (1996 to 2012 data)	
MALF-M at Ratanui recorder	65 L/s (1d) 70 L/s (7d) (1996 to 2008 data)	69 L/s (1d) 72 L/s (7d) (1996 to 2012 data)
MALF-N at Ratanui recorder	65 L/s (1d) 70 L/s (7d) No upstream abstraction so MALF-N = MALF-M	
MALF-N at bottom of catchment	155 L/s (1d) 165 L/s (7d)	
Management objectives	No specific management objective although it is a primary public water supply source RPS objectives for Mangaone Stream more generally include managing for **significant indigenous ecosystems**	
Recommended / revised minimum flow	**60 L/s at Ratanui [but see comments below]**	
Method	Regional default method: 90% MALF-N (7d)	
Comments	While flow data analysis has shown a higher minimum flow is warranted (the existing minimum flow has never been recorded and was based on a very limited data set when conceived), it is recommended that the existing minimum flow of 22 L/s at Ratanui is retained for the proposed Plan as an **interim** limit. This will allow opportunity for the consequences of increasing the minimum flow (for existing users – the proposed increase in minimum flow is considerable (60%) with implications for security of supply) to be fully assessed, along with other instream and out of stream values during the catchment committee process.	
Potential monitoring sites [bolded sites are continuous flow recorders]	**Ratanui,** SH1, Mouth Concurrent gaugings show SH1 is where flow is typically lowest	
Reference documents	Keenan (2009b)	